REASSESSMENT OF SITE COEFFICIENTS AND NEAR-FAULT FACTORS FOR BUILDING CODE PROVISIONS

Program Element: II

98-HQ-GR-1010


Walt Silva
Robert Darragh
Nicholas Gregor

Pacific Engineering and Analysis
311 Pomona Avenue
El Cerrito, CA 94530
(510) 528-2821, 2135 (fax)
Email: pacific@crl.com

Geoff Martin
22 Crestwind Drive
Rancho Palos Verdes, CA 90275
Los Angeles, CA 90089
(310)541-8847,8812 (fax)
Email:geomar@mizar.usc.edu

Norm Abrahamson
152 Dracena Avenue
Piedmond, CA  94611
(510) 428-9823, 9824 (fax)
Email:naa3@earthlink.com

Charles Kircher
Charles Kircher & Associates
444 Castro Street, Suite 433
Mountain View, CA 94041
(650) 968-3939, 0960 (fax)
Email: cakircher@aol.com.

## ABSTRACT

Site amplification factors are developed for the NEHRP site Categories considering ranges in profile depth, uncertainties and variabilities in dynamic material properties, as well as both western and eastern United States (WUS and CEUS) crustal conditions. Equivalent-linear analyses are used and comparisons are made to results using a fully nonlinear analysis procedure. The results suggest that sufficient conservatism exists in the NEHRP soft site Category E amplification factors and that the hard rock factors, NEHRP Category A, reflect appropriate amplification. However, NEHRP Category C amplification may be unconservative for most cases while NEHRP Category D amplification may not have sufficient conservatism, being unconservative for some cases.

Evaluation of the 1997 UBC design spectra with spectra computed from recorded motions showed design spectral levels conservatively above median estimates for Seismic Source Zone 4, Fault Types A, B, and C, and all site conditions. For Seismic Source Zone 3, the 1997 UBC design spectra were generally above the median + 1$\sigma$ estimates from the recorded motions for all site conditions.

For an evaluation of the 2,000 IBC design spectra, residuals between five frequently used empirical attenuation relations for western United States crustal sources and available recorded motions were computed. In general the relations predict the recorded motions acceptably well. The major exceptions occurring at low-frequency ($\leq$ 2 Hz) and for earthquakes with magnitude greater than 7 and most noticeably in the 10 km to 35 km distance range.

## ACKNOWLEDGMENTS

We are indebted to Professor Ellen Rathje of the University of Texas at Austin for the Turkey earthquake data as well as site condition information. Our gratitude and thanks as well to the Seismology Center of the Central Weather Bureau of Taiwan for making the CD ROM of the Chi-Chi ground motion data available in a very timely manner. We also thanks Dr. W.Y. Chien of the Central Weather Bureau of Taiwan for the recording site information and Dr. S.J. Chiou of Geomatrix for Chi-Chi earthquake source-to-site distances. Dr. Ping Qui performed the nonlinear site response calculations. We are grateful for her expertise and proficiency.

Research supported by the U.S. Geological Survey (USGS), Department of the Interior, under USGS award number 98-HQ-GR-1010. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

**TABLE OF CONTENTS**

**LIST OF TABLES**

## LIST OF FIGURES

76 Fault type A: **M** GE 7.0, NEHRP Class D.

77 Fault type A: **M** GE 7.0, NEHRP Class D.

78 Fault type B: **M** 6.50 to 6.99, NEHRP Class D.

79 Fault type B: **M** 6.50 to 6.99, NEHRP Class D.

80 Fault type C: **M** 5.75 to 6.49, NEHRP Class D.

81 Fault type C: **M** 5.75 to 6.49, NEHRP Class D.

82 Residuals (natural log) of 5% damped response spectra between average horizontal component recorded motions and median expected motions for five WUS rock site empirical attenuation relations: AS, Abrahamson and Silva; BAO Boore and others; CAMP, Campbell; IMI, Idriss; SAO, Sadigh and others. Earthquakes with **M** = 7 or larger, frequencies of 5 Hz and greater.

83 Residuals (natural log) of 5% damped response spectra between average horizontal component recorded motions and median expected motions for five WUS rock site empirical attenuation relations: AS, Abrahamson and Silva; BAO Boore and others; CAMP, Campbell; IMI, Idriss; SAO, Sadigh and others. Earthquakes with **M** = 7 or larger, frequencies below 5 Hz.

84 Residuals (natural log) of 5% damped response spectra between average horizontal component recorded motions and median expected motions for five WUS rock site empirical attenuation relations: AS, Abrahamson and Silva; BAO Boore and others; CAMP, Campbell; IMI, Idriss; SAO, Sadigh and others. Earthquakes with **M** = 6.75 or larger, frequencies of 5 Hz and greater.

85 Residuals (natural log) of 5% damped response spectra between average horizontal component recorded motions and median expected motions for five WUS rock site empirical attenuation relations: AS, Abrahamson and Silva; BAO Boore and others; CAMP, Campbell; IMI, Idriss; SAO, Sadigh and others. Earthquakes with **M** = 6.75 or larger, frequencies below 5 Hz.

86 Residuals (natural log) of 5% damped response spectra between average horizontal component recorded motions and median expected motions for five WUS rock site empirical attenuation relations: AS, Abrahamson and Silva; BAO Boore and others; CAMP, Campbell; IMI, Idriss; SAO, Sadigh and others. Earthquakes with **M** between 6 and 7, frequencies of 5 Hz and greater.

87 Residuals (natural log) of 5% damped response spectra between average horizontal component recorded motions and median expected motions for five WUS rock site empirical attenuation relations: AS, Abrahamson and Silva; BAO Boore and others;

CAMP, Campbell; IMI, Idriss; SAO, Sadigh and others. Earthquakes with **M** between 6 and 7, frequencies below 5 Hz.

88 Residuals (natural log) of 5% damped response spectra between average horizontal component recorded motions and median expected motions for five WUS rock site empirical attenuation relations: AS, Abrahamson and Silva; BAO Boore and others; CAMP, Campbell; IMI, Idriss; SAO, Sadigh and others. Earthquakes with **M** between 5 and 6, frequencies of 5 Hz and greater.

89 Residuals (natural log) of 5% damped response spectra between average horizontal component recorded motions and median expected motions for five WUS rock site empirical attenuation relations: AS, Abrahamson and Silva; BAO Boore and others; CAMP, Campbell; IMI, Idriss; SAO, Sadigh and others. Earthquakes with **M** between 5 and 6, frequencies below 5 Hz.

# 1.0 INTRODUCTION

NEHRP (1994, 1997) site categories are based on the average shear-wave velocity over the top 30m, an approach suggested by Roger Borcherdt (Martin, 1994). Since site amplification (change in amplitude in passing from deeper and faster materials to shallower and slower materials) in general depends on profile stiffness, site categories based on shear-wave velocity represents a physically based binning scheme which should reflect statistically stable differences in expected levels of ground motions, assuming the same level of input motions at some depth. The adopted depth of 30m is not based on any assumption regarding frequency range (wavelength) of interest but is simply an expedient dictated by average depths of boreholes at soil sites. An assumed limitation of the 30m depth is the frequency range which the top 30m of a site is likely to influence through amplification, effects of a velocity gradient or deamplification due to material damping as well as wave scattering. If one simply uses a depth range of one quarter wavelength, a 30m depth is limited to high frequencies, except for very soft profiles.

However, the issue is not at all this simple. Because these exists a strong vertical correlation in velocity (EPRI, 1993; Silva et al., 1997), the average velocity over the top 30m is representative, on average, of depths far exceeding 30m. In other words, profiles which start out stiff tend to remain stiff and with a steeper gradient than soft profiles. The average velocity over the top 30m captures enough of the profile velocity gradient to provide a binning criterion which results in stable differences in amplification for wavelengths which far exceed 30m. As long as the categories are separated enough such that within category profile variation is sufficiently smaller than mean or average category properties, the categories should provide stable and meaningful differences in expected ground motions.

However, because too few recording sites have been properly characterized to be assigned NEHRP categories, a clear and stable distinction in ground motions between the NEHRP categories has not been unambiguously demonstrated.

For a site categorization scheme based solely on profile stiffness, there are two other potentially significant issues: effects of profile depth as well as material nonlinearities.

Profile depth, or depth to very stiff conditions, can have large effects on strong ground motions (EPRI 1993; Marek et al., 1998; Kimball and Costantino, 1999). Profiles (except very soft soils) with depths in the 100 to 200 ft range are not expected to have significant amplification (5% damped response spectra) at low frequency (< 1 Hz) while very deep profiles (≥ 300 ft) may have large amplification (≥ 2) at low frequency. Additionally, we may expect the degree of nonlinear effects to impact very deep profiles to a larger degree than shallow (≤ 200 ft) profiles (EPRI, 1993; Silva et al., 1999b). To assess the impacts of profile depth on the NEHRP amplification factors, comparisons of amplification factors will be made for NEHRP category profiles assuming average depths to very stiff conditions from about 100 ft to 1,000 ft (section 4).

The other potentially important issue not directly addressed in a stiffness based site binning scheme is nonlinear material properties. Although one may believe that stiffer materials are "more linear", than soft materials, the converse is actually true. For a given level of cyclic shear-strain, generally exceeding about $10^{-2}$ % (Dobry et al., 1982), the reduction in shear modulus and increase in material damping for rock exceeds that of some clays as well as peat soils. Profile stiffness may then not capture trends in dynamic material nonlinear properties. Higher plasticity clays do not necessarily have a higher initial stiffness and gravels, which tend to be stiffer than sands, are also generally more nonlinear. A recent analysis of strong ground motions in northern and southern California found quantifiable differences in nonlinear soil properties for the two regions. San Francisco Bay area soils tended to be more nonlinear than Los Angeles area soils (Silva et al., 1999b) and the soil sites studied in both regions would have the same NEHRP classification. Surficial geology in terms of age (holocene verses pleistocene) as well as average stiffness may provide a more robust and easier to implement site categorization scheme.

## 2.0 SUMMARY OF CODE PROVISIONS

### 2.1 Site Factors

Recent code provisions for the seismic design of buildings (1994 and 1997 NEHRP, 1997 UBC) have adopted new site response coefficients based on acceleration response spectra amplification factors (with respect to rock) for 0.3 and 1.0 second periods, and a new procedure for site classification into six categories. The recommendations leading to these provisions, were developed from a consensus proposal arising from a 1992 Site Response Workshop in Los Angeles, attended by 65 invited geoscientists, geotechnical engineers, and structural engineers. Papers presented at the workshop which led to the consensus proposal are available in the Workshop Proceedings (Martin, 1994). Preliminary reports on the new site categories or related discussion are described by Borcherdt (1994b), Crouse and McGuire (1996), Martin and Dobry (1994), Rinne (1994), Seed et al. (1994a), and Silva and Toro (1998).

The new site classification is primarily based on the representative average shear wave velocity over the top 30 m (100 ft) of soil as shown in Table 1. The methodology for constructing response spectra is based on modified USGS mapped 5% damped acceleration spectral ordinates at 0.3 and 1.0 seconds ($A_a$ and $A_v$) for rock (assumed Class B) as shown in Figure 6. The anchor spectrum for rock is modified by site coefficients $F_a$ (applicable to short period motion in the range 0.1 – 0.5 seconds) and $F_v$ (applicable to longer period motion in the range 0.4 – 2.0 seconds). The factors $F_a$ and $F_v$ are a function of $A_a$ and $A_v$, respectively, and of site classification, as shown in Table 3.

The site profile categories, the use of a 30 m characteristic depth and the values of $F_a$ and $F_v$ recommended as a result at the 1992 Workshop, were based on results derived from both empirical studies of recorded motions and numerical site response analyses. The empirical results included studies at the 1989 Loma Prieta Earthquake data and other events as described by Borcherdt (1994a), Borcherdt and Glassmoyer (1992), and Joyner et al. (1994). As these earthquakes were characterized by low rock accelerations (about 0.1 g), values of site coefficients recommended for higher levels of ground motion, were based on numerical one dimensional site response analytical analyses after calibration with the empirical data (Seed et al. 1994b, Dobry et al. 1994). While fractile levels were not quantified, the site factors were intended to reflect a degree of conservatism and are considered to represent amplification more consistent with $+ 1\sigma$ levels, rather than median estimates. We note that the use of a 30 m characteristic depth was also motivated by the practical need to use depths where geotechnical data could reasonably be expected from geotechnical site investigations.

### 2.2 Near Source Factors

The 1997 UBC (ICBO, 1997) reflects two significant changes to the design criteria that increase earthquake forces for the design of structures. For sites located near active sources, a set of near-source factors was developed to accommodate recent observations of large near-source motions which exceed the 1994 UBC design spectra. Near-source motions have been a concern of the SEAOC Seismology Committee for some time (Mathieson et al., 1984) and the strong motion data from the 1994 **M** 6.7 Northridge and 1995 **M** 6.9 Kobe earthquakes provided the motivation for incorporating the near-source factors. Additionally, the spectral shape was changed to reflect a 1/T falloff (constant spectral velocity) rather than the previous $1/T^{2/3}$ and the 1.2 factor was eliminated.

The near-source factors are intended to reflect ground shaking close to active faults and are based on fault distance, defined capable magnitudes, and slip rate. These factors are defined for structures located in Seismic Zone 4 (effective peak acceleration of 0.4g) and within 10 to 15 km of active faults. The factors were developed as the approximate ratio of median empirical response spectra (Boore et al., 1993 and Sadigh et al., 1997 as appears in Joyner and Boore, 1988) to the 1997 UBC design spectra for Seismic Zone 4, for sites beyond 15 km from an active source. To develop the ratios, magnitude 7.5 (fault type A) and 7.0 (fault type B) earthquakes were considered for both strike-slip and reverse mechanisms. Deep soil was taken as the most appropriate site condition for which to compute the ratios used to develop the near-source factors. As with NEHRP site coefficients, the near-source factors are intended to reflect a degree of conservatism, based primarily on considering magnitudes **M** 7.5 and **M** 7.0 as reflecting fault types A and B respectively.

The near-source adjustments include both short-period factors ($N_A$) and long-period factors ($N_V$). The $N_A$ factors are based on the ratio of 0.3 second empirical response spectral acceleration to 1.0g while the long period factors are based on the ratio of 1.0 second empirical spectral acceleration to 0.6g. The long-period factors also include a 20% increase for the mean ratio of the larger component to the average horizontal component. Table 1 shows the $N_A$ and $N_B$ factors as well as the 1997 UBC Seismic Source types. To evaluate the closest distance from the source to the site, the distance measure is taken as the horizontal distance to the closest surface projection of the fault rupture. For dipping faults with sites located over the expected rupture surface, this distance is zero. For this distance evaluation, the fault depth (vertical extent) is restricted to 10 km.

The new 2,000 IBC (International Code Council, 1998) design spectra are based on a maximum Considered Earthquake (MCE) which is designed to achieve uniforms risk across the United States, even though the seismic hazard is highly nonuniform (Kircher, 1999). In this approach, the design spectra are defined for rock site conditions (NEHRP B, BC in the central and eastern US, Table 1) with 0.2 second and 1.0 second spectral levels set by attenuation relations either indirectly through USGS hazard maps (Frankal et al., 1996) or directly through a deterministic evaluation using maximum magnitudes, closest distances, and median attenuation relations (Kircher, 1999). As a result, the new 2,000 IBC design spectra for the western United States are tied directly to short- and long-period empirical response spectra. An assessment of how well they perform in predicting recorded motions is presented in Section 6.

## 3.0 DEVELOPMENT OF SITE CATEGORY PROFILES

The development of appropriate NEHRP category profiles for use in this study makes use of the work by Wills and Silva (1998), where generic shear-wave velocity profiles were developed for surficial geologic units in California based on measured velocities. These geologic based categories were then used to develop surficial geology based amplification factors for the San Francisco Bay and Los Angeles areas (Silva et al., 1999b). Comparison of the analytical amplification factors with available empirical factors showed good agreement in overall amplitude levels and frequency ranges (Silva et al., 1999b). These comparisons suggest that the combination of the generic profiles and the methodology employed represent a viable approach to estimating stable effects of site conditions on strong ground motions.

### 3.1 NEHRP Categories

The NEHRP site categories are based on the average shear-wave velocity over the top 30m (100 ft). Table 1 shows the NEHRP 94/97 and UBC 97 site categories. For reference the more qualitative Geomatrix categories are shown along with the approximate relations among the schemes. In general NEHRP categories A and B are intended to reflect rock conditions with A considered to be typical rock for the central and eastern United States (CEUS) but very hard rock for California or the WUS in general. Category B was intended to reflect typical rock for WUS but is likely somewhat stiffer than typical WUS rock site conditions. Categories C, D, and E generally reflect soil with some soft rock falling within the Category C. To see this more clearly, Table 2 shows results from a compilation of surface geology based measured shear-wave velocity profiles located in California while Figures 1 and 2 show the corresponding median profiles (Silva et al., 1999b). The $\overline{v_s}$ (30m) values listed were computed from the median profiles.

For both the San Francisco Bay and Los Angeles regions, the within region median profiles are generally well separated, except for $Q_{oa}$ and $Q_{al}$ in San Francisco, even though some reflect the same NEHRP category. Between regions, the $K_{jf}$ and $M_{xb}$ rock profiles are very similar as are the Tertiary profiles which are show in Figure 3. For the alluvium between regions, Figure 4 shows the Los Angeles $Q_o$ being significantly stiffer, particularly at depth, than the other profiles. Also the San Francisco Bay muds are much softer as expected but are still classified as NEHRP D (Figure 4 and Table 2) due to an average shear-wave velocity just above the D/E boundary of 180 m/sec (Table 1).

### 3.2 Surficial Geology Based Profiles

To develop NEHRP profiles, two choices presented themselves: average the surficial geology profiles within each NEHRP category or select the surficial geology based profile closest to the NEHRP category range center (Table 1). The selection of these alternatives is driven by whether desired amplification factors should be appropriate for median velocities determined by sampled profiles (a small sample of the population) or true category means or mid-range $\overline{v_s}$ (30m) values. This is a serious considerations since the median $\overline{v_s}$ (30m) listed in Table 2, in most cases, depart significantly from the mid-range values, suggesting the consideration of some readjustments to the current boundaries (Wills and Silva, 1998). Not coincidentally these observed median NEHRP-Category $\overline{v_s}$(30m) values have implications for the empirical evaluation of NEHRP amplification factors since the measured shear-wave velocity profiles are dominated by strong motion sites (Borcherdt, 1994a and 1994b; 1996; 1997). For example, the mid-range category NEHRP B value is 1,130m/sec (3,750 ft/sec, Table 1) while the median Franciscan and Granite profiles show values 741 and 843m/sec respectively (Table 2). Additionally, the Tertiary profiles (except the very stiff Saugus) fall below the NEHRP C mid-range value of 560m/sec (1,850 ft/sec) while the alluvium profiles fall significantly below 560m/sec. The Bay muds show the converse, being slightly too stiff (188m/sec, Table 2) to be classified as NEHRP category E. This is a perplexing problem and the approach taken in this work is to assume the currently defined NEHRP categories reflect a viable binning scheme and appropriate amplification factors should then represent mid-range properties ($\overline{v_s}$(30m) values). To accomplish this we selected the surficial geology based profiles closed to the NEHRP mid-range values and uniformly adjusted the entire profiles (adding or subtracting a constant value at all depths) to bring its $\overline{v_s}$(30m) to the corresponding NEHRP mid-range values. Naturally, smooth models were drawn through the median profiles and extended to depth prior to this adjustment process.

### 3.3 Mean Centered NEHRP Category Profiles

For NEHRP Category B, we used $M_{xb}$ and scaled it up from 844m/sec (Table 2) to 1,130m/sec (Table 1) for $\overline{v_s}$(30m). For Category C, $QT_S$ was scaled up from a $\overline{v_s}$(30m) of 466m/sec to 560m/sec while Categories D and E ($Q_y$ and $Q_m$) required decreases in velocities. The $Q_m$ (Bay muds) profile was scaled to give a $\overline{v_s}$(30m) of 152m/sec (500 ft/sec). The adjusted profiles are shown in Figure 5 to a depth of 500 ft. To consider greater depths, the profiles are extended by maintaining the gradients near the 500 ft depths.

For NEHRP Category A, a mid-continent crustal model is used (EPRI, 1993). This model has a surface shear-wave velocity of 2.8 km/sec and is considered appropriate for CEUS hard rock conditions. NEHRP category A then is confined to CEUS crustal conditions but is considered appropriate for very hard rock WUS sites such as exist at some of the Anza array stations in southern California. Some of these site have recorded ground motions which are very similar in spectral composition to CEUS hard rock recordings (Silva and Darragh, 1995). Differences in deep crustal properties between WUS hard rock and CEUS crustal conditions are considered to have a minor effect on expected amplification factors (being a ratio). Provided the overall smooth amplification between source depths and the surface and kappa values are similar between very hard WUS rock and CEUS crustal conditions (Silva and Darragh, 1995), NEHRP amplification factors are expected to be similar as well.

Both WUS and CEUS crustal models are discussed in Section 4.3 (Specification of Control Motions). The shallow profiles (NEHRP B, C, D, and E) are blended in to a generic WUS crustal model (at depths corresponding to a shear-wave velocity of 1 km/sec or 2 km/sec for NEHRP Category B) and are placed on top of the CEUS crustal model. This is done to consider the effects on NEHRP amplification factors (Categories C, D, and E) for sites located in the CEUS over very hard rock (Lin et al., 1996; Kimball and Costantino, 1999).

## 4.0 NEHRP AMPLIFICATION FACTORS

The current NEHRP site amplifciation factors are computed for 5% damped response spectra and are relative to NEHRP site category B. The factors (Table 3) are separated into high- and low-frequency sets, both dependent upon expected Category B peak acceleration values. The high-frequency set (Fa) are taken to reflect average amplification (over category B outcropping) throughout the frequency range where 5% damped response spectral acceleration is nearly constant (Figure 6) (taken as 2 to 10 Hz). The low-frequency factors (Fv) are intended to reflect the nearly constant spectral velocity regions (Figure 6) and are generally taken to be the average over the frequency range of 0.5 to 2.5 Hz. While the nearly constant acceleration and velocity portions of median spectra are strongly category dependent (e.g. Category A spectral acceleration peaks above 20 Hz; Toro et al., 1997) as well as dependent on level of loading for the soft categories, the frequency ranges reflect a reasonable compromise and covers the critical ranges for code applications. The factors are however, dependent upon the frequency ranges used in averaging (Lin et al., 1996; Kimball and Costantino, 1999) and their sensitivity to the frequency ranges is investigated in Section 4. The current factors are shown in Table 3 and range from 0.8 Category A to 3.5 for Category E, all relative to Category B outcropping expected peak acceleration values. Nonlinearity is reflected in the dependence on the reference Category (B) expected outcrop peak acceleration values. The degree of nonlinearity is substantial, driven largely by analyses (Martin and Dobry 1994; Dobry et al., 1999) and empirical analyses have suggested that the current factors reflect both appropriate (Dobry et al., 1999) and inappropriate degrees of nonlinearity (Crouse and McGuire, 1996; Silva and Toro, 1998). As a result, for the cohesionless soils (NEHRP Categories C and D) two sets of nonlinear properties are used, both validated using strong motion recordings. These models are discussed in Section 4.2.

### 4.1 Methodology

The conventional computational approach in developing spectral amplification factors appropriate for specific profiles would involve selection of suitable time histories to serve as control or rock outcrop motions and a suitable nonlinear computational formulation to transmit the motion through the profile. Because of its ease in application and demonstrated success in modeling nonlinear site effects on response spectra (e.g. EPRI, 1993), the equivalent-linear approximation is used to generate the large numbers of amplification factors. To assess any limitations in treating truly nonlinear soil response by equivalent-linear approximations, such as a single level of shear-wave velocity and material damping for all frequencies (and time), comparisons of amplification factors are made between the equivalent-linear analyses and fully nonlinear analyses. Both approaches as implemented in the current analyses are presented in the following sections.

### *4.1.1 Equivalent-Linear Computational Scheme*

The computational scheme which has been most widely employed to evaluate one-dimensional site response assumes vertically-propagating plane shear waves. Departures of soil response from a linear constitutive relation are treated in an approximate manner through the use of the equivalent-linear approach.

The equivalent-linear approach, in its present form, was introduced by Seed and Idriss (1970). This scheme is a particular application of the general equivalent-linear theory introduced by Iwan (1967). Basically, the approach is to approximate a second order nonlinear equation, over a limited range of its variables, by a linear equation. Formally this is done in such a way that an average of the difference between the two systems is minimized. This was done in an ad-hoc manner for ground response modeling by defining an effective strain which is assumed to exist for the duration of the excitation. This value is usually taken as 65% of the peak time-domain strain calculated at the midpoint of each layer, using a linear analysis. Modulus and damping curves are then used to define new parameters for each layer based on the effective strain computations. The linear response calculation is repeated, new effective strains evaluated, and iterations performed until the changes in parameters are below some tolerance level. Generally a few iterations are sufficient to achieve a strain-compatible linear solution.

This stepwise analysis procedure was formalized into a one-dimensional, vertically propagating shear-wave code called SHAKE (Schnabel et al., 1972). Subsequently, this code has easily become the most widely used analysis package for one-dimensional site response calculations.

The advantages of the equivalent-linear approach are that parameterization of complex nonlinear soil models is avoided and the mathematical simplicity of linear analysis is preserved. A truly nonlinear approach requires the specification of the shapes of hysteresis curves and their cyclic dependencies. In the equivalent-linear methodology the soil data are utilized directly and, because at each iteration the problem is linear and the material properties are frequency independent, the damping is rate independent and hysteresis loops close.

While the assumptions of vertically propagating shear waves and equivalent-linear soil response certainly represent approximations to actual conditions, their combination has achieved demonstrated success in modeling observations of site effects (Schnabel et al., 1972; Silva et al., 1988; Schneider et al., 1993; EPRI, 1993).

### *4.1.2 RVT Based Computational Scheme*

The computational scheme employed to compute the site response uses the stochastic model to generate the power spectral density and spectral acceleration of the rock or control motion. This motion or power spectrum is then propagated through the one-dimensional soil profile using the plane-wave propagators of Silva (1976). In this formulation only SH waves are considered. Arbitrary angles of incidence may be specified but normal incidence is used throughout the present analyses.

In order to treat possible material nonlinearities, an RVT (Random Vibration Theory) based equivalent-linear formulation is employed. Random process theory is used to predict peak time domain values of shear strain based upon the shear strain power spectrum. In this sense the procedure is analogous to the program SHAKE except that peak shear strains in SHAKE are measured in the time domain. The purely frequency domain approach obviates a time domain control motion and, perhaps just as significant, eliminates the need for a suite of analyses based on different input motions. This arises because each time domain analysis may be viewed as one realization of a random process. In this case, several realizations of the random process must be sampled to have a statistically stable estimate of site response. The realizations are usually performed by employing different control motions with approximately the same level of peak acceleration and response spectrum.

In the case of the frequency domain approach the estimates of peak shear strain as well as oscillator response are, as a result of the random process theory, fundamentally probabilistic in nature. Stable estimates of site response can then be computed by forming the ratio of spectral acceleration predicted at the surface of a soil profile to the spectral acceleration predicted for the control motion.

The procedure of generating the point-source stochastic power spectrum computing the equivalent-linear layered-soil response, and estimating peak time domain values has been incorporated into a single code termed RASCALS (Silva and Lee, 1987).

### *4.1.3 Nonlinear Computational Scheme*

The computational scheme used to compute one-dimensional nonlinear site response assuming vertically-propagating plane shear waves, utilized the computer program DESRA-MUSC (Qiu, 1997). This program is based on the program DESRA (Lee et al., 1978), with modifications incorporated through research conducted at USC. The program was originally developed as a means of performing Dynamic Effective Stress Response Analyses in the time domain, where time histories of excess pore water pressures could be coupled to response analyses. However, in this application, pore pressure generation was suppressed, and a total stress mode used.

The nonlinear initial loading or backbone curve is modelled using the elasto-plastic Iwan model (Iwan, 1967) which has the versatility of matching any given initial loading curve. The model incorporates an array of elasto-plastic elements (typically 20 elements are used) which allows a failure mode to be initiated. The model automatically provides for hysteretic behavior during cyclic loading following the Masing rules. A similar approach for evaluating nonlinear site response was adopted by Joyner and Chen (1975).

A sub-program was written to develop initial loading curve elements to match any given $G/G_{max}$ versus shear strain amplitude curve. Equivalent viscous damping ratios corresponding to the strain dependent hysteretic damping may also be computed. A small and constant hysteretic damping element was added to simulate damping at very low strains, where the model would predict linear elastic behavior.

A transmitting boundary applied at the base of a soil column under consideration, allows appropriate levels of energy to be radiated back to an underlying elastic half space. The approach used is similar to that suggested by Joyner and Chen (1975) where the input motion at the base of the soil column (the transmitting boundary) is defined by an outcrop motion.

## 4.2 Nonlinear Dynamic Material Properties

### *4.2.1 G/Gmax and Hysteretic Damping Curves*

Four sets of G/Gmax and hysteretic damping curves are used: generic rock (NEHRP B), cohesionless soils (NEHRP C and D), and cohesive soils (NEHRP E) (Table 2). The rock curves (Figure 7) are based on point-source modeling of the rock site empirical attenuation relation of Abrahamson and Silva (1997) for a range in magnitudes and distances using a generic rock profile (Silva et al., 1997).

For the geologic units which are considered cohesionless soils in the San Francisco Bay area (gravels, sands, and low PI clays) in terms of high-strain dynamic material properties (QTs, $Q_{al}$; Table 2), the EPRI (1993) G/Gmax and hysteretic damping curves (Figure 8) have recently been validated at 48 San Francisco Bay area cohesionless soil sites through modeling strong ground motions from the Coyote Lake, Morgan Hill, and Loma Prieta earthquakes (Silva et al., 1997). These curves were developed for generic applications to cohesionless soils in the general range of gravelly sands to low plasticity silts or sandy clays. For application to Quaternary/Tertiary rocks ($QT_S$; NEHRP Category C, Table 2), the implied assumption is that these sites behave more like a stiff soil (gravely sand) than rock. Not an unreasonable assumption considering a surface velocity of about 800 ft/sec (Figure 1).

For the Bay Mud ($Q_m$) categories, generic sections of Fill (15 ft), young Bay Mud (50 ft) and old Bay Clay (30 ft) over Quaternary Alluvium ($Q_{al}$) are assumed. These generic zones are based on an examination of several CALTRANS boreholes located near highway bridges (Cliff Roblee, personal communication) and are used only to assign G/Gmax and hysteretic damping curves. For the Fill material and the Alluvium, EPRI (1993) curves are used. For the young Bay Muds and Old Bay Clay, the Vucetic and Dobry (1991) cohesive soil curves for a *PI* of 30%, an average value for these cohesive soils, are used (Figure 9).

For the geologic units which are considered cohesionless soils in the Los Angeles area ($QT_S$, $Q_o$, $Q_y$, Saugus), recent strong ground motion analyses for about 80 sites which recorded the 1994 Northridge earthquake found the EPRI G/Gmax and hysteretic damping curves showed too much nonlinearity (Silva et al., 1997). As a result, a revised set of G/Gmax and hysteretic damping curves were developed for Peninsular Range cohesionless soils and are shown in Figure 10. Both sets of cohesionless soil curves are used for NEHRP Categories C and D.

### *4.2.2. Nonlinear Soil Models*

As described in Section 4.1.3, the nonlinear soil model is established by first matching the $G/G_{max}$ versus shear strain curve to a nonlinear shear stress versus shear strain backbone or initial loading curve. (Note for all analyses, the water table was assumed below the soil profile.)

The derived normalized backbone curves for the EPRI $G/G_{max}$ curves used for analyses are shown on Figure 11 to 3% shear strain (the limit of the data). Almost all analyses led to cyclic strains less than 3% for EPRI type materials (cohesionless soils) and hence a strength limit was not defined. For the few cases where at shallow depths and for high accelerations, shear strains exceeded 3%, the initial loading curve slope between 1% and 3% was extended linearly. The back calculated match to the $G/G_{max}$ curves is shown on Figure 12. Agreement is generally very good at shear strain levels greater than 0.05%.

The initial loading curves derived for nonlinear analyses for Peninsular Range cohesionless soils are shown on Figure 13, and the match to the $G/G_{max}$ curves shown on Figure 14.

For the soft cohesive soils incorporated in Category E profiles, the initial loading curve derived from the Vucetic and Dobry (1991) PI of 30% $G/G_{max}$ curve is shown on Figure 15, and the match to the $G/G_{max}$ curve shown on Figure 16. For these soils, large accelerations were expected to generate failure. Based on rapid loading tests to large strains reported by Hsu and Vucetic (1999) and Vucetic et al. (1998), the curve was extended beyond 3% shear strain by linearly extending the slope between 1% - 3% to 9%, where failure or a maximum shear stress was assumed. Based on this assumption, ratios of undrained shear strength to vertical confining stress were calculated to be about 0.75, corresponding to a slightly overconsolidated clay.

With the nonlinear initial loading or backbone curves defined, the equivalent viscous damping ratios matching the areas of hysteresis loops generated by cyclic loading at various strain amplitudes may by computed, assuming Masing load–unload behavior. Figure 17, 18, and 19 show computed damping ratios for the three sets of curves described above. In all cases, a one percent low strain hysteretic element is utilized to match low strain damping.

In general, comparisons with the damping curves used for equivalent-linear analyses show that the hysteretic damping becomes significantly greater when shear strains exceed 0.1%, which would occur for soft soil profiles and high site accelerations. However, it needs to be recognized that the $G/G_{max}$ and damping ratio curves represent averages of test data and hence are not necessarily cross correlated. Individual test data reported by Hsu and Vucetic (1999) for example, in many cases show much higher damping ratios at larger strains than the average curves. Unfortunately, for nonlinear hysteretic modelling, an exact match for shear modulus and equivalent viscous damping based on average curves is difficult to accomplish. Better matches occur for test data for specific samples.

## 4.3 Point-Source Model Parameters

The stochastic point-source model is used to compute the motions at the surface of the baserock or reference rock as well as the other profiles. Both qualitative assessments and quantative validations of the stochastic point-source model (Hanks and McGuire, 1981; Boore, 1983, 1986; McGuire et al., 1984; Boore and Atkinson, 1987; Silva and Lee, 1987; Toro and McGuire, 1987; Silva et al., 1990;, et al., 19 EPRI, 1993; Schneider et al., 1993; Silva and Darragh, 1995; Silva et al., 1997; Silva et al.,1999b) have demonstrated that it provides accurate ground motion estimates, making it an appropriate choice to produce ground motions representative of the NEHRP category based profiles.

### *4.3.1 NEHRP Category A and B Kappa Values*

For applications to the North American continent, notably the WUS and CEUS tectonic regions, the definition of NEHRP category B is not unambiguous. Ideally, midrange NEHRP category B should reflect the rock site conditions implicit in WUS empirical attenuation relations, since it is considered as the reference site. However, available borehole shear-wave velocity data suggest much softer conditions (Joyner, 1995; Wills and Silva, 1998), leading to the adoption of the NEHRP B/C boundary ($\overline{v_s}$(30m) = 760 m/sec) as the reference rock site condition for the 1996 National Seismic Hazard Maps (Frankel et al., 1996). Amplification factors for NEHRP categories C, D, and E depend upon the overall stiffiness assumed for category B. This dependence may not be strong however, as the amplification factors are computed relative to category B for expected category B peak acceleration values. Changing the stiffness of category B results in a different distance for the same expected peak acceleration value. As long as the category C, D, and E profiles are computed at the revised distances as well, differences in amplification due to relatively minor differences in the reference site stiffness are driven solely by differences in the NEHRP B response spectral shape, which is appropriate. Since differences in the magnitude of the earthquake used for developing amplification factors (scaled to the same reference peak acceleration value) can result in differences in computed amplification of 5% damped response spectra by about 20%, as much as 30% at or near column resonance frequencies (even for smoothed amplifications), differences in reference motion spectral shape due to relatively minor differences in stiffness is not expected to be a controlling influence. Additionally, the process of averaging over frequency to compute the $F_A$ and $F_V$ values (Table 3) will reduce the effects of reference motion spectral shape on the factors.

#### *4.3.1.1 WUS Kappa Values*

While the issue of an appropriate shallow gradient is reasonably well defined by data (Figure 5), the selection of appropriate site kappa ($\kappa_0$ values for WUS and CEUS category B (and BC boundaries) sites is a perplexing issue. The shallow Category B profile is considered nonlinear to a depth of about 60 ft corresponding to a shear-wave velocity of about 5,000 ft/sec (1.5 km/ sec). At that depth it is merged to the WUS crustal model shown in Figure 20. The kappa contributed by the nonlinear zone of the shallow profile is only about 0.002 sec at low strains (Figure7). Mean kappa values for typical WUS rock sites range from about 0.03 to 0.06 sec (Silva and Darragh, 1995; Boore and Joyner, 1997; Table 4), likely reflecting frequency independent energy loss over the top 1 to 2 km of the crust (Anderson and Hough, 1984). This is the region over which steep velocity gradients exist due to crack closure for soft crustal (active) regions. Kappa values depend upon rock quality, expressed qualitatively by the surficial geologic descriptions shown in Table 4. For WUS, kappa values range from about 0.026 sec for hard rock to about 0.06 sec for sheared (poor) rock site conditions. Evidently these trends in kappa values with rock quality are expressed in the average shear-wave velocity over the top 30m as well, as Figure 21 illustrates. These results are based on kappa values estimated at rock sites which recorded the 1989 **M** 6.9 Loma Prieta earthquake (also includes the Lucerne site for the 1992 **M** 7.2 Landers earthquake). These sites have been drilled and shear-wave velocities measured to depths of at least 30m (100 ft). Figure 21 shows a clear trend of decreasing kappa with increasing $\overline{v_s}$(30m). Based on the fitted equation (Figure 1), site kappa values for midrange NEHRP categories A, B, and BC boundary are 0.008 sec, 0.02

sec, and 0.03 sec respectively (Table 1), assuming Category A has a $\overline{v}_s$(30m) of 2.8 km/sec (Figure 20). These trends are consistent with the qualitative trends shown in Table 4 as well as with recent results of Boore and Joyner (1997) who found $\overline{v}_s$(30m) of 620m/sec for WUS rock (NEHRP C) and an associated site kappa of 0.035 sec. Inversions of the Abrahamson and Silva (1997) and Sadigh et al. (1997) rock empirical attenuation relations gave a kappa value of about 0.04 sec (EPRI, 1993; Silva et al., 1997), consistent with Boore and Joyner (1997) and Silva and Darragh (1995) (Table 4). Since the rock site conditions implied by these empirical relations is likely even softer than the $\overline{v}_s$(30m) value of 620m/sec found by (Boore and Joyner, 1997; Silva et al., 1997), it is likely that the higher range of NEHRP category C is representative of WUS rock strong motion data, provided the current borehole velocity and strong motion data (i.e. recording sites) do not reflect a biased population sample.

Based on these results, a kappa value for the definition of midrange NEHRP B as a reference profile would be about 0.02 sec. However, the value reflected in the WUS rock site strong motion data is closer to 0.04 sec. This kappa value results in WUS rock response spectral shapes which peak near 5 Hz for **M** 6.5 earthquake at source distances within about 50 km. To demonstrate this feature, Figure 22 shows a statistical shape computed from WUS recordings at rock sites for earthquakes in the **M** 6 to 7 magnitude range (Silva et al., 1999a). Also shown on Figure 22 are comparisons to WUS spectral shapes computed using a suite of rock site empirical attenuation relations for the bin mean magnitudes and distances. As the Figure shows, the spectra peak near 5 Hz, consistent with the model spectra computed with a kappa value of 0.04 sec. As Figure 23 demonstrates, the frequency of the peak or maximum in response spectral shapes provides a reasonably good estimation of site kappa values (Silva and Darragh, 1995). Very low kappa values, such as 0.005 sec result in a peak near 40 Hz while a kappa near 0.02 sec shows a spectral peak near 10 Hz. Interestingly, a factor of two change in kappa is reflected in about an octave (factor of two) change in the peak frequency (Silva, 1991). Figure 24 shows a corresponding plot of unnormalized (pseudo absolute spectra) illustrating the dramatic decrease (increase) in high frequency spectral levels for factors of two increase (decrease) in kappa.

For consistency with the rock site strong motion data, the WUS NEHRP B base-case kappa value of 0.04 sec is adopted and comparisons of the amplification factors for a NEHRP B kappa of 0.02 sec will be made.

#### *4.3.1.2 CEUS Kappa Values*

For the CEUS NEHRP B profile, the shallow profile (Figure 5) is placed on top of the CEUS crustal model (Figure 20). This model has a surface shear-wave velocity of about 9,000 ft/sec (2.830 km/sec) which the shallow category B profile reaches at a depth of about 300 ft.

Extending the low-strain damping (Figure 7) to 300 ft in the shallow Category B profile results in a kappa value of about 0.005 sec, near typical CEUS hard rock values (Table 4). With nominal WUS rock kappa values in the range of 0.03 to 0.06 sec (Table 4) and those for CEUS hard rock in the 0.006 to 0.008 sec range (Table 4), an issue also exists regarding an appropriate kappa value for CEUS NEHRP B (and BC). Simply adding the contribution of the shallow Category B contribution of about 0.005 sec to the nominal hard CEUS rock value of 0.006 sec results in a kappa of about 0.01 sec, the same value adopted (for other reasons) for CEUS NEHRP BC boundary in the National Hazard Maps (Frankel et al., 1996). Based on the previous discussion, the kappa value of 0.01 sec is probably too low to be associated with nominal NEHRP Category B or BC gradients unless they overly very hard CEUS rock ($\overline{v_s}$ > 2.5 km/sec) at very shallow depths (≤ 300 ft).

CEUS NEHRP Category B (and BC) is likely typified of by Gulf Coast sandstones as well as CEUS mudstones, claystones, and silstones such as the Charelston area in South Carolina and parts of the Denver basin in Calorodo. As a result, very hard rock (limestone, schists, etc) is more likely to occur at much greater depths resulting in nominal kappa values larger than 0.01 sec. As a result, a nominal kappa value of 0.02 sec is adopted for CEUS NEHRP Category B as well as BC (midrange gradients, Table 1), based principally on Table 4 (CEUS soft rock) and the association of kappa values with $\overline{v_s}$ (30m) based on WUS data (Figure 21).

For NEHRP category A, a kappa value of 0.006 sec is adopted, based on Table 4 (CEUS hard rock) and to be consistent with the conditions assumed in the Toro et al. (1997) CEUS hard rock attenuation relation (EPRI, 1993). This value (0.006 sec) is also consistent with the values found by Silva and Darragh (1995) from recordings at two very hard rock sites at the Anza array in Southern California. NEHRP A amplification factors, although computed assuming CEUS crustal conditions (computed relative to NEHRP category CEUS B), are considered appropriate for WUS NEHRP A crustal conditions.

#### *4.3.2 NEHRP Category C, D and E Kappa Values*

For the soil profiles, NEHRP Category C, D, and E, the small strain damping (Figure 8, 9, and 10) contributes a kappa value of about 0.01 sec. For WUS applications, the profiles are placed at a depth in the generic California crustal model (Figure 20) corresponding to a shear-wave velocity of 1 km/sec. Inversions of the Abrahamson and Silva (1997) Sadigh et al., (1997) soil empirical attenuation relations gave a low-strain kappa value of about 0.04 sec (about the same as rock, Section 4.3.1.1). This implies a rock kappa for the materials beneath the soils of about 0.03 sec, in general agreement with Figure 21 assuming an average shear-wave velocity of about 1 km/sec.

For applications to CEUS NEHRP Categories C, D, and E, these results imply a lower total kappa value for deep soil sites overlying hard rock. With the hard rock CEUS site kappa of 0.006 to 0.008 sec (Section 4.3.1.2), the addition of the deep soil low strain kappa of about 0.01 sec implies a total kappa of about 0.02 sec. This is about half the corresponding WUS deep soil value of 0.04 sec. With these differences, deep soil sites are expected to have different spectral shapes than corresponding deep WUS soil sites, at low loading levels (Silva et al., 1999a).

#### *4.3.3 Magnitude, Stress Drops, and Q(f) Models*

To generate the motions, a **M** 6.5 earthquake is used with the distance (epicentral) varied to produce a suite of distinct peak acceleration values at the surface of the reference rock unit (Table 5). The same source and path parameters are then used for the other unit profiles resulting in a suite of amplification factors as a function of reference rock outcrop peak acceleration values (Toro et al., 1992; EPRI, 1993; Silva, 1999b). For the point-source, a stress drop of 64 bars is used for all the WUS profiles. This value is based on inversions of the Abrahamson and Silva, 1997 empirical attenuation relation (Silva et al., 1997) which showed a magnitude dependency with stress drop decreasing for increasing **M** (EPRI, 1993; Atkinson and Silva, 1997).

CEUS stress drops are assumed to follow the same magnitude scaling as WUS. The **M** 5.5 stress drop was set to 160 bars to correspond to Atkinson's (1993) value, which is based on high frequency spectral levels from CEUS earthquakes. In her database of CEUS earthquakes the mean magnitude is about 5.5. The stress drop scaling results in a **M** 6.5 CEUS stress drop of 110 bars. Interestingly, these stress drop values result in an average difference of about a factor of two between CEUS (110 bars, Table 5) and WUS (64 bars, Table 5), in agreement with Hanks and Johnston's (1992) analyses of intensity data.

The Q(f) model is 275 $f^{0.6}$ for WUS crustal conditions. These values were determined from inversions of Peninsular Range earthquakes Northridge, San Fernando, and Whittier Narrows at 180 sites over the fault distance range of about 10 to 200 km (Silva et al., 1997). The Q(f) model for CEUS is based on inversions of the **M** 5.8 Saguenay earthquake at sites over the distance range of 40 to 500 km.

To generate motions which cover the range from linear response to very large expected NEHRP Category B horizontal motions, seven distances are run with reference rock outcrop peak accelerations ranging from 0.05g to 0.75g (Table 5). The magnitude and stress drop is fixed at **M** 6.5 and 64 bars (110 bars for the CEUS) respectively with the assumption that the amplification factors (ratios) are not highly sensitive to either magnitude or stress drop (EPRI, 1993). Since the profiles are randomized in velocity and layer thickness, the median peak acceleration does not exactly correspond to the target peak acceleration (Table 5). In general, the median values are very close, within about 10% of the target, which is considered acceptable since the amplification vary little for a 10% change in input motions.

### *4.3.4 Incorporation of Site Parameter Variability*

The profile randomization scheme, which varies both layer velocity and thickness, is based on a correlation model developed from an analysis of variance on about 500 measured shear-wave velocity profiles (EPRI, 1993; Silva et al., 1997). Figure 25 shows the Franciscan outcrop 5% damped pseudo acceleration spectra (median and $\pm$ 1 $\sigma$ for the lowest level of motion, 0.05g. The profile is varied to a depth corresponding to a shear-wave velocity of about 2 km/sec (6,400 ft/sec, Figure 5), a depth of about 250 ft. The parametric variation, reflected in the sigma ($\sigma_{\ln}$ = 0.15 for PGA), includes profile velocity and layer thickness variation in addition to variability in the G/Gmax and hysteretic damping curves.

To accommodate variability in the modulus reduction and damping curves on a generic basis, the curves are independently randomized about the base case values. A log normal distribution is assumed with a $\sigma_{\ln}$ of 0.35 at a cyclic shear strain of 3 x $10^{-2}$% with upper and lower bounds of 2$\sigma$. The distribution is based on an analysis of variance of measured $G/G_{max}$ and hysteretic damping curves and is considered appropriate for applications to generic (material type specific) nonlinear properties. The truncation is necessary to prevent modulus reduction or damping models that are not physically possible. The random curves are generated by sampling the transformed normal distribution with a $\sigma_{\ln}$ of 0.35, computing the change in normalized modulus reduction or percent damping at 3 x $10^{-2}$% shear strain, and applying this factor at all strains. The random perturbation factor is reduced or tapered near the ends of the strain range to preserve the general shape of the median curves (Silva, 1992). The same profile and material randomization procedure is used at the soil sites as well, resulting in median and $\pm$ 1$\sigma$ amplification corresponding to parametric variability in site properties.

The parametric variability shown in Figure 25 then represents the contribution to the uncertainty in strong ground motions due to the top 200 to 300 ft at hard California rock (NEHRP B) sites in WUS, a maximum $\sigma_{\ln}$ of about 0.2 to 0.3. Adding the parametric variability of site kappa, assuming a $\sigma_{\ln\kappa}$ = 0.3 (EPRI, 1993), would increase the ground motion variability by an additional $\sigma_{\ln}$ of about 0.2, to a total of about 0.3 to 0.4.

In addition, peak acceleration, peak particle velocity, and peak particle displacement were computed for the reference site outcrop. Levels of reference rock outcrop peak acceleration values of 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.75g, are used to accommodate the effects of material nonlinearity upon site response. Table 5 shows the magnitude (**M**), distance (*D*), peak acceleration, peak particle velocity, and peak particle displacement computed for the NEHRP B WUS and CEUS outcrop motions. Figure 26 shows NEHRP category median spectra for both WUS and CEUS conditions at an expected peak acceleration value of 0.5g. For the CEUS, results are shown using kappa values of 0.02 sec and 0.04 sec.

For the CEUS NEHRP B motions using a kappa value of 0.04 sec, Figure 26 shows motions similar to WUS NEHRP (kappa = 0.04 sec) at high frequency (≥ 2 Hz). At low frequency (≤ 2 Hz) the CEUS motions are lower due to the absence of the shallow crustal amplification (Figure 20). The CEUS NEHRP motions using a (preferred) kappa value of 0.02 sec exceed the kappa = 0.04 sec motions at high frequency (≥ 10 Hz) and are much lower at low frequency (≤ 2 Hz). As a result, NEHRP Category C, D, and E amplification factors may differ from WUS counterparts due to these differences in reference rock spectral shape as well as the CEUS soils overlying much stiffer rock conditions (Kimball and Costantino, 1999).

For all the profiles, since the randomization process is over the profile properties only, the input motions (below some depth) remain unchanged. Including the variation of input motions with randomized source and path parameters ($\Delta\sigma$, source depth, and Q(f)) results in the same median spectral estimates but with increased fractile levels (Silva et al., 1999b). This is an important result, allowing a convenient decoupling in parametric variations between site and source and path parameters.

#### *4.3.5 Control Motion Time Histories*

To generate control time histories for the nonlinear soil site response runs, base of soil outcrop motions are generated which correspond to the prescribed distances for the suite of NEHRP category B outcrop peak acceleration values. This provides time histories which are consistent with the motions input to the equivalent-linear soil response analyses. Figure 27 compares response spectra computed from the base of soil outcrop (RVT spectra and spectra computed from the time history) and median NEHRP category B motions for 0.5g. The base of soil outcrop motions are somewhat lower than the surficial rock (NEHRP B) outcrop motions due to the absence of the shallow velocity gradient (Figure 1). These are expected trends as base-of soil and rock outcrop motions reflect different rock velocity gradients than surficial rock conditions (Silva et al., 1999a). The corresponding synthetic time histories were generated using the method of Silva and Lee (1987) and are shown in Figure 28 for the same case. The motions (acceleration, velocity, and displacement) appear realistic as the phase spectrum is taken from a recorded motion (of similar magnitude and distance). The six remaining base-of-soil outcrop time histories were generated using the same procedure.

## 4.4 Development of NEHRP Site Amplification Factors

Site amplification factors are computed as the ratio of 5% damping response spectral acceleration (Sa) computed at the surface of each site for each randomized profile to the median 5% damping response spectral acceleration (Sa) computed for the reference rock outcrop motion (e.g. Figure 25). In addition, peak acceleration, peak particle velocity, and peak particle displacement were computed for the site and reference outcrop as well. Levels of reference rock outcrop peak acceleration values of 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.75g were used to accommodate the effects of material nonlinearity upon site response. Table 5 shows the magnitude (**M**), distance (R), peak acceleration, peak particle velocity, and peak particle displacement computed for the outcrop motions.

The amplification factors, 5% damped Sa/Sa (reference NEHRP Category B), are computed at approximately 90 frequencies from approximately 0.10 Hz to 100 Hz.

### *4.4.1 NEHRP Profile Depths for Category C, D, and E*

To accommodate the effects of variable soil depth on the amplification factors and their parametric uncertainties, depth to 1 km/sec (3,280 ft/sec, Figure 5) material is varied between 100 ft and 1,000 ft assuming a uniform distribution. This variation results in a mean profile depth of about 500 ft for NEHRP Categories C and D. For the very soft NEHRP Category E, the depth is limited to 650 ft, based on Bay mud shear-wave velocity profiles in the San Francisco Bay Area as well as profiles from Lotung Taiwan, the Imperial Valley in California, and fill sites near Kobe Japan. Velocity data from these areas suggest that extrapolating the gradient for NEHRP Category E to depths exceeding 600 to 700 ft is probably not realistic, resulting in shear-wave velocities which are too low.

Due to the randomizing over depth, only a minor contribution of the fundamental resonance is present. The variability reflects parametric uncertainty in the profile, and includes profile layer thickness, shear-wave velocity, profile depth and $G/G_{max}$ and hysteretic damping curves. The first layer of the crust (base of the profile) is also randomly varied assuming a lognormal distribution with a $\sigma_{ln}$ of 0.3 (EPRI, 1993).

The consideration of profile depth randomization points to the issue of appropriate profile depths for the NEHRP Categories. This issue was discussed earlier and comparisons of amplification factors computed for NEHRP Categories C and D considering mean soil depths from 100 ft to 1,000 ft (Category E, 100 ft to 650 ft) are presented in Section 4.4.5. For Categories which do not consider soil depth explicitly, amplification factors should be developed as envelopes of the factors computed for a suite of profile mean depths (Silva et al., 1999a). The addition of depth bins to the NEHRP site categories could be used to reduce conservation for cases where soil depth is known. Ignorance should be penalized and knowledge rewarded.

### *4.4.2 NEHRP Categories A and BC*

#### *4.4.2.1 NEHRP Category A*

Response spectral amplifications (median and ± 1σ values) computed for NEHRP Category A using equivalent-linear analyses are shown in Figure 29. Due to the extreme stiffness of the Category A shear-wave velocity profile (Figure 20), the response is linear and the amplification factors are largely independent of control motion level. The only effects of nonlinearity are in the change in response spectral shapes of the Category B motions as the outcrop peak acceleration levels increase. As Figure 29 shows, the amplification of Category A is very similar for median Category B outcrop peak acceleration values ranging from 0.05 to 0.75g. In the frequency range of about 0.5 Hz to about 10 Hz, the amplification is less than 1 and is properly reflected in the Fa and Fv values of 0.8 shown in Table 3. Median amplifications for a suite of frequency ranges is also shown in Figure 29. For the NEHRP ranges (2 to 10 Hz and 0.5 to 2.5 Hz), the amplification for Category A is less than 1.

#### *4.4.2.2 NEHRP Category BC*

This category (Figure 5) provides the reference or soft rock motions for the CEUS USGS shaking hazard maps (Frankel et al., 1996). A low-strain site kappa value of 0.04 sec was assumed to be appropriate for this category (Section 4.3.1) and the amplification relative to CEUS Category B (kappa = 0.02 sec) is shown in Figure 30 using equivalent-linear analyses. The maximum amplification is about 2.0 in the 1 to 2 Hz frequency range and is largely independent of loading level due to the combination of a relatively high low-strain stiffness (Figure 5) and relatively linear $G/G_{max}$ and hysteretic damping curves for depths exceeding 20 ft (Figure 7).

The frequency averaged amplifications shown in Figure 30 (bottom plot) indicate levels near 1.5, except for the 0.2 to 0.7 Hz range. These trends suggest that care should be exercised in supplanting the Category B reference with a BC boundary reference since peak accelerations are affected as well as NEHRP Fa and Fv amplification values.

To illustrate potential differences in the expected median amplification factors for different nonlinear dynamic material properties, Figure 31 shows factors computed for the rock, Peninsular Range, and EPRI $G/G_{max}$ and hysteretic damping curves. For frequencies up to about 10 Hz and CEUS NEHRP Category B median peak acceleration values up to 0.75g, little difference is seen in the factors. NEHRP BC boundary ( $\overline{v_s}$(30m) = 750 m/sec, Table 1; Figure 5) is sufficiently stiff in median properties such that little nonlinear effects are anticipated at frequencies less than about 10 Hz, even at very high loading conditions.

### *4.4.3 NEHRP Category C*

#### *4.4.3.1 WUS Conditions*

For WUS NEHRP Category C and Peninsular Range nonlinear properties, Figure 32 shows expected median and ± 1$\sigma$ amplification factors computed using equivalent-linear analyses for WUS Category B median peak acceleration values ranging from 0.1g to 0.75g. The Category C profile (Figure 5) is randomized in depth from 100 ft to 1,000 ft along with randomized velocities, layer thicknesses, and nonlinear properties (Section 4.3.4). As a result, profile resonances are smoothed over and the amplification factors for 5% damped response spectra are smoothly varying functions of frequency. The mean profile depth is about 500 ft (randomized between 100 ft and 1,000 ft assuming a uniform distribution), resulting in a maximum amplification in the frequency range of about 1 to 2 Hz. Maximum values are near 2 and decrease with increasing frequency up to about 10 Hz. The increase in amplification for frequencies exceeding about 10 Hz is due to the saturation of the soil acceleration response spectra to peak acceleration. The amplification factors simply reflect the change in shape of the rock spectra (Figure 25), shifting the peak in the rock spectra to lower frequencies and increasing the rock peak accelerations by about 20 to 30%, depending on expected rock peak acceleration values.

##### *4.4.3.1.1 Effects of Nonlinear Dynamic Material Properties*

To examine the effects of nonlinear dynamic material properties (between northern and southern California, Section 4.2) on the Category C amplification factors, Figure 33 compares results using the Peninsular Range and EPRI $G/G_{max}$ and hysteretic damping curves. For this stiff profile, little difference is seen in the median amplification factors for Category B peak accelerations up to 0.5g. At 0.75g, the Peninsular Range $G/G_{max}$ and hysteretic damping curves show amplifications about 10% to 15% larger than those using the EPRI curves, for frequencies exceeding about 5 Hz.

##### *4.4.3.1.2 Effects of Profile Depth*

The base-case depth randomization range is 100 to 1,000 ft giving a mean depth of about 500 ft. To assess the effects of both a narrower depth range as well as a suite of mean profile depths on the amplification factors, the depth categories listed in Table 6 were used to develop amplification factors. The ranges were chosen to reflect about a factor of 2 in mean profile depths between depth categories (bins), thereby separating the fundamental column resonances by about an octave. This separation is intended to illustrate any significantly different levels of median amplification which may exist between the suite of depth bins or categories (Table 6).

The resulting median amplification factors are shown in Figure 34 compared to the base-case amplification factors (100 to 1,000 ft, Table 6) all using the Peninsular Range $G/G_{max}$ and hysteretic damping curves. Interestingly, for this NEHRP category (C), which is a very stiff soil (Figure 5), the base-case amplification factors accommodate mean profile depths from about 100 ft to 1,000 ft. The base-case factors (mean profile depth of about 500 ft) are a little low for both very deep profiles at very low frequencies ($\leq$ 0.5 Hz) and very shallow profiles for frequencies above about 1 Hz. Increasing the median base-case factors by 10 to 20% would easily accommodate the range in mean profile depths.

#### *4.4.3.1.3 Comparison to Nonlinear Analyses*

Amplification factors computed using the fully nonlinear code DESRA-MUSC (Appendix A) and nonlinear properties calibrated with the Peninsular Range $G/G_{max}$ and hysteretic damping curves (Section 4.2.2) are shown in Figure 35. The nonlinear amplification factors are not as smooth as those computed using the RVT based equivalent-linear scheme as only one control motion time history (Figure 28) was used for each loading level. For a more rigorous comparison, multiple time histories should be used, each matched to the control motion response spectra, since we are holding the input motion fixed (no variability). In general, the agreement with the equivalent-linear factors shown in Figure 32 appears good in median and $\pm 1\sigma$ values. Similar sigma values suggest the relative insensitivity to $G/G_{max}$ and hysteretic damping values (within reasonable ranges) since they are not varied in the nonlinear analyses.

Comparisons between the Peninsular Range (Figure 10) and EPRI (Figure 8) $G/G_{max}$ and hysteretic damping curves used in the nonlinear analyses are shown in Figure 36. As with the equivalent-linear comparisons (Figure 33), little difference is seen in the amplification factors, even for expected median input motions of 0.75g. The NEHRP C profile is too stiff to generate high enough strains over a large enough depth range to show large differences in expected motions due to the differences in nonlinear dynamic material properties. For a direct comparison between amplification factors computed using nonlinear and equivalent-linear approaches, Figure 37 shows expected median values for the range in rock motions using the Peninsular Range nonlinear dynamic material properties. In the frequency range of 1 to 10 Hz, the comparison is quite good. At the higher loading levels ($\geq$ 0.4g), and for frequencies above about 10 Hz, the nonlinear results exceed the equivalent-linear. At peak acceleration (100 Hz) however, the two approaches compare quite favorably. Interestingly at low frequency, particularly around 0.3 Hz, the equivalent-linear factors exceed the nonlinear factors at all loading levels. This artifact may be a consequence of using only one time history in the nonlinear analyses as there is no compelling physical explanation for this low-frequency discrepancy. A more appropriate nonlinear analyses may have been to use five-to-ten control motion time histories which match a smooth target (RVT spectrum) either individually or on average. For each random profile and time history, amplifications (surface spectrum divided by corresponding Category B surface spectrum) would be computed and the average (log) taken of the entire suite.

For the EPRI curves, Figure 38 shows the corresponding comparison. The results are similar to the comparisons using the Peninsular Range curves.

#### *4.4.3.2 CEUS Conditions*

For CEUS NEHRP Category C and Peninsular Range nonlinear properties, Figure 39 shows the expected median and $\pm 1\sigma$ amplification factors for CEUS Category B median peak acceleration values ranging from 0.1 to 0.75g. As with the WUS Category C, the profile is randomized in depth between 100 ft and 1,000 ft, resulting in a mean depth of about 500 ft. The general shape of the CEUS factors is quite similar to the WUS factors (Figure 32), showing a peak near 1 Hz at a value near 2. The CEUS factors show more variability, probably due to the larger impedance contrast at the soil-rock boundary, which results in stronger profile resonances.

##### *4.4.3.2.1 Effects of Nonlinear Dynamic Material Properties*

Comparisons of the CEUS NEHRP Category C median amplification factors computed using the Peninsular Range (Figure 10) and EPRI (Figure 8) nonlinear dynamic material properties are show in Figure 40. As with the Category C WUS comparisons, the difference is small for frequencies below about 10 Hz, except at the highest loading level (median CEUS NEHRP B expected value of 0.75g). At the highest loading level, the more nonlinear EPRI curves show somewhat lower amplifications due to higher damping levels. The corresponding increase in low frequency levels due to the corresponding larger frequency shift resulting from the EPRI curves is apparent from 0.1 Hz to about 0.5 Hz, but is much less significant. As with the corresponding WUS Category C comparison (Figure 33), the profile is too stiff (Figure 5) to show large differences in response due to reasonable differences in nonlinear properties.

#### *4.4.3.2.2 Comparison of WUS and CEUS Category C Amplification Factors*

A comparison of the WUS and CEUS median factors is shown in Figure 41 using both the Peninsular Range and EPRI nonlinear dynamic material properties. Interestingly, for all loading levels the WUS factors using the Peninsular Range $G/G_{max}$ and hysteretic damping curves provide the largest factors over most of the frequency range. Also, the WUS factors tend to be larger than the CEUS factors, especially for frequencies exceeding about 3 Hz. Nonlinear effects appear to be stronger in the CEUS factors, probably due to the larger impedance contrast across the soil-rock interface and the greater degree of high frequency energy present at the base of the CEUS soil (Figure 26). These differences in amplification factors between WUS and CEUS NEHRP Category C profiles suggest that differences in spectral shapes should also exist between WUS and CEUS deep ($\leq$ 1,000 ft) soil sites (Kimball and Costantino, 1999; Silva et al., 1999a). For bottomless (very deep) profiles, the differences are probably insignificant as the total (soil plus rock) kappa values and overall velocity gradients (over depths corresponding to frequencies above 0.1 to 0.2 Hz) become very similar.

### *4.4.4 NEHRP Category D*

#### *4.4.4.1 WUS Conditions*

Figure 42 shows the amplification factors computed for WUS Category D using the Peninsular Range nonlinear dynamic material properties. As with the Category C factors (Section 4.4.3), the profile (Figure 5) is randomized in depth between 100 ft and 1,000 ft (mean depth $\approx$ 500 ft) and layer thicknesses are varied along with shear-wave velocities as well as $G/G_{max}$ and hysteretic damping curves. Compared to Category C factors (Figure 32), the Category D factors show similar shapes but are significantly larger (peak values 3 around 1 Hz) at all frequencies for low loading levels. The effects of nonlinearity are greater for Category D compared to Category C due to the softer profile (Figure 5), showing a decrease in amplification in peak acceleration from a factor of 2 at 0.1g to about 1 at 0.75g (NEHRP B expected peak acceleration). Also, the shift in increased amplification at low frequency (0.3 Hz) is apparent over the same range in loading levels. Along with this change in high-and low-frequency amplification is an accompanying increase in the variability. This is probably due to the higher strain levels, increasing the effects of nonlinear properties and their associated variabilities. A feature not evident in the stiffer Category C results (Figure 32).

#### *4.4.4.1.1 Effects of Nonlinear Dynamic Material Properties*

Comparisons of median amplification factors computed using Peninsular Range and EPRI $G/G_{max}$ and hysteretic damping curves are shown in Figure 43. For this profile, which is much softer than Category C (Figure 5), the differences in amplification between the two sets of nonlinear properties is large, even at the 0.1g loading level. Beginning at about 1 Hz, the Peninsular Range curves show significantly larger amplification, about a 30% maximum, than the EPRI curves. The amplification computed using the EPRI curves is slightly larger at low frequency, due to the slightly shifted mean profile resonance, but the difference is less than about 5%.

#### *4.4.4.1.2 Effects of Profile Depth*

As with NEHRP Category C, the effects of a suite of mean category depths of 125 ft, 250 ft, 500 ft, and 1,000 ft (Table 6) are examined. Figure 44 shows the median amplification factors compared to the base-case depth bin (100 to 1,000 ft, mean ≈ 500 ft). At low-frequency (below about 1 Hz), the factors show a regular trend, increasing as profile mean depth increases with the base-case profile near the mid-range. At high-frequency, the trend generally reverses as expected and the suite of factors form a tighter band. For frequencies above about 0.4 Hz and for profiles in depth less than about 700 ft, the base-case amplifications are within about 10 to 15% of the largest factors and reflect a reasonable compromise for code applications, except perhaps for shallow profiles (≤ 200 ft). For low frequencies (≤ 0.4 Hz) and deep profiles (≤ 700 ft), the base-case amplification factors are clearly unconservative. At high frequency (≤ 1 to 2 Hz) the base-case factors may be too low for shallow profiles (≤ 200 ft) being below the 125 ft depth category (Table 6) by up to about 20%.

#### *4.4.4.1.3 Comparison to Nonlinear Analyses*

Amplification factors computed using the nonlinear code DESRA-MUSC with Peninsular Range nonlinear properties are shown in Figure 45. As with the Category C nonlinear analyses (Figure 35), the Category D nonlinear analyses result in amplification factors with similar overall shapes and levels to those computed using equivalent-linear analyses.

Comparison between results using the Peninsular Range and EPRI calibrated nonlinear properties (Section 4.2.2) are shown in Figure 46. As with the equivalent-linear comparison (Figure 43), a significant difference exists between the two sets of nonlinear properties with the more linear Peninsular Range curves showing the larger amplifications. For the EPRI $G/G_{max}$ and hysteretic damping curves and at high loading levels, the nonlinear analyses show very low high-frequency (≥ 10 Hz) amplification (large deamplification). This may be partially attributed to the larger high-strain damping shown by the nonlinear model (Figure 17) compared to the damping used for the equivalent-linear analyses. This has traditionally been an important issue in comparing equivalent-linear and nonlinear analyses. Using nonlinear backbone curve models, it is relatively easy to match $G/G_{max}$ curves (e.g. Figure 16) but an eract match to a corresponding damping curve may not be prossible (Figure 17).

Another aspect of the fully nonlinear analyses contributing to the larger deamplification is the ability of the model to accommodate yielding or soil failure at very high strain levels. Near surface yield will attenuate high frequency surface motions, a condition which can not be simulated by equivalent-linear analyses. This condition occurs for cases where randomized velocities for a particular realization are very low and the loading levels are high. For example, the shear wave velocity is only of the order of 92 m/s for the top two layers (EPRI $G/G_{max}$ and hysteretic damping curves) for the randomized soil profile G005029. As a result, the soil yielded at a depth of 10 ft and developed a large shear strain of 15% corresponding to ground lurch under the shaking level of 0.75g, as shown on Figure 47. The permanent lurch deformation in terms of shear strain is about 5% at the end of shaking. Note the continued low strain cyclic behavior at the tail end of the earthquake. The peak ground acceleration was attenuated to 0.33g. The acceleration response spectra at the ground surface for all shaking levels are shown on Figure 48.

For a direct comparison of amplification factors computed using nonlinear and equivalent-linear analyses, Figure 49 shows median factors using Peninsular range properties. The comparison is similar to Category C (Figure 37) and shows the equivalent-linear analyses with larger amplifications at low frequency ($\leq$ 1 Hz) than the nonlinear analyses and higher amplification at high frequency ($\geq$ 5 Hz). At peak acceleration (100 Hz) the equivalent-linear results exceed the nonlinear results at all loading levels, reflecting the effects of higher damping and soil yield.

For the EPRI curves, Figure 50 shows the corresponding comparison. The results are similar but show a larger difference between the equivalent-linear and nonlienar analyses at peak acceleration.

### *4.4.4.2 CEUS Conditions*

For CEUS conditions, Figure 51 shows median and $\pm$ 1$\sigma$ amplification factors computed using the Peninsular Range $G/G_{max}$ and hysteretic damping curves. The overall shapes and trends are similar to the WUS results (Figure 42) showing somewhat more variability with frequency, similar to the Category C results (Figure 39).

#### *4.4.4.2.1 Effects of Nonlinear Dynamic Material Properties*

Figure 52 Compares median amplification factors computed for CEUS conditions using Peninsular Range and EPRI nonlinear curves. As with the WUS Category D comparison (Figure 43), the difference is large for frequencies exceeding about 2 to 3 Hz with the Peninsular Range (more linear) curves showing significantly larger amplifications.

For a more complete comparison, Figure 53 shows NEHRP Category D amplifications computed for both WUS and CEUS conditions using Peninsular Range and EPRI $G/G_{max}$ and hysteretic damping curves. In general, as with the Category C comparison (Figure 41), the WUS Peninsular Range show the highest amplification.

### *4.4.5 NEHRP Category E*

This category corresponds to soft soils (Figure 5) and is based on a generic San Francisco Bay mud profile scaled down to a $\overline{v}_s$(30m) of 152m/sec (500 ft/sec) (Sections 3 and 4). For this generic Bay mud profile, only the EPRI cohesionless soil and Vucetic and Dobry (1991) clay $G/G_{max}$ and hysteretic damping curves are used (Section 4.2.1).

#### ***4.4.5.1 WUS Conditions***

For WUS conditions Figure 54 shows the median and $\pm 1\sigma$ sigma WUS amplification factors for NEHRP Category E. The factors are large at low frequency, ranging about 3 from about 0.4 Hz to about 1 Hz at low loading levels. This is somewhat lower than the 3.5 factor in the current NEHRP provision at 0.1g (Table 3) but the NEHRP factor reflects an average over the frequency range of 0.5 Hz to 2.5 Hz. Additionally, the NEHRP $F_A$ and $F_V$ factors are intended to reflect considerable conservatism and may be interpreted as being more consistent with $+ 1\sigma$ levels than median estimates. For low loading levels, NEHRP Category B peak accelerations of 0.2g and below, the development of the NEHRP factors was guided primarily from recording of the 1989 **M** 6.9 Loma Prieta earthquake at sites along margins of the San Francisco Bay. These sites are located at considerable distances from the source ($\approx$ 50 to 100 km) and likely experienced less high-frequency energy in input motions than sites located much closer to lower magnitude earthquakes (to maintain similar Category B peak acceleration), as response spectral shapes depend on distance (Silva and Green, 1989; Abrahamson and Shedlock 1997). Consequently these large distance soft soil sites likely reflect smaller degrees of nonlinearity than may be expected for closer sites subjected to input motions consistent with comparable Category B peak accelerations.

Because the EPRI nonlinear curves are used for the cohesionless soils in the column and the PI of Bay mud clays is comparatively low (*PI* = 30%), the effects of nonlinearity are large. At the higher loading levels ($\geq$ 0.3g), cyclic shear strains are large enough to induce failure in some of the randomized columns (at depths corresponding to cohesionless soils) and will be discussed in the comparison to nonlinear analyses. The deamplification of high frequency motions at high loading levels is extreme and may not be realistic. Application of these nonlinear properties to the soft soils of the Imperial Valley results in too much nonlinearity compared to observed ground motions from the 1979 **M** 6.5 Imperial Valley earthquake and its **M** 5.2 aftershock (Silva et al., 1997). Conversely, these nonlinear properties appear to provide reasonable comparison to recordings at the Port Island vertical array for the **M** 6.9 Kobe earthquake (Silva and Costantino, 1998). Clearly more data including recordings of strong motions, velocity profiles, and reliable laboratory testing of dynamic material properties are needed for soft soil profile related studies.

#### *4.4.5.1.1 Comparison to Nonlinear Analyses*

Figure 55 shows the median and $\pm$ 1$\sigma$ amplification factors computed with the DESRA-MUSC program. Similar to the NEHRP Category D nonlinear analyses using the EPRI curves (Figure 46), the nonlinear analyses show strong high frequency deamplification, particularly for frequencies above 10 Hz. The corresponding equivalent-linear factors increase with increasing frequency above 10 Hz, reflecting a change in spectral shape with some reduction in peak acceleration. The nonlinear factors however reflect an overall truncation in high frequency energy or a flat spectrum. This again may be a consequence of the nonlinear damping exceeding the equivalent-linear damping for both the EPRI and Vucetic and Dobry (1991) curves (Figures 17 and 19), and yielding or failure of the soft soils at high strain levels.

As with the nonlinear Category D analyses, yielding at high strains has occurred. In this case yielding occurred for 7 soil profiles out of 30 under the highest shaking level 0.75g.

For the soil profile G005010, yielding started at the shaking level of 0.5g. The shear-wave velocities are below 80 m/s for the top five layers, and as low as 57 m/s for layers 3 and 4. The maximum shear-strain of 25% occurred in Layer 4, at the depth of 12 ft under the shaking level of 0.75g (Figure 56). The permanent lurch deformation in terms of shear strain is about 15% at the end of shaking. The shear strength is only about 150 psf. The peak ground acceleration has been attenuated to 0.14g, as a result of yielding behavior. The acceleration response spectra at the ground surface for all shaking levels are shown in Figure 57.

Soil profile G005021 represents the case with a shear-strain larger than 3% occurred at a depth of 103 ft, under 0.75g shaking. No yielding occurred during the shaking, because the shear-wave velocity is about 130 m/s at shallow depth and 180 m/s for deep soil layers. However, the maximum shear-strain at the depth of 12 ft is about 5%, and acceleration time history shows attenuation of peak ground acceleration as shown on Figure 58. Figure 59 shows the acceleration response spectra at the ground surface for all shaking levels.

Figure 60 compares the equivalent-linear and nonlinear factors and shows reasonable agreement in the 1 Hz to 10 Hz range. At low frequency, as with Categories C and D, the equivalent-linear factors are higher. Peak accelerations remain higher for equivalent-linear analyses (as with Category D EPRI curves, Figure 50).

#### *4.4.5.2 CEUS Conditions*

For CEUS conditions, Figure 61 shows the expected median and ± 1σ amplification factors and Figure 62 compares the WUS and CEUS median factors. For CEUS conditions, the effects of nonlinearity are significantly greater with the WUS factors generally larger than the CEUS. These results reflect similar trends as seen for Category D results (Figure 53).

## 5.0 SUMMARY AND CONCLUSIONS OF NEHRP AMPLIFICATION FACTORS

Median and $\pm$ $1\sigma$ site amplification factors for 5% damped response spectra have been computed for mean centered NEHRP site Categories (BC), C, D, and E assuming both WUS and CEUS crustal conditions. The variability in the expected amplification factors ($\sigma_{\ln} \approx 0.2$ to 0.3) is due to randomization over depth to very stiff conditions as well as randomized shear-wave velocities, layer thicknesses, and $G/G_{max}$ and hysteretic damping curves. Material property probability distributions, including layer thicknesses, were based on analyses of variance of measured profile as well as $G/G_{max}$ and hysteretic damping curves. Additionally, comparisons were made for Categories C, D, and E between equivalent-linear and fully nonlinear site response analyses using the computer code DESRA-MUSC. In general, there was good agreement between the two approaches over much of the frequency ranges. Because the nonlinear damping exceeded that of the equivalent-linear at high strains, nonlinear amplification factors were below the equivalent-linear factors for the softer Category profiles at high loading levels.

Results computed in this study for NEHRP Category A showed values less than 1, about 0.8 at high frequency ($\geq$ 1 Hz to 10 Hz) and close to 1 at low frequency ($\leq$ 1 Hz). These results are consistent with the current NEHRP factors of 0.8 for Category A $F_A$ and $F_V$ site factors.

To provide a convenient illustration to both summarize and compare results of this study with existing NEHRP $F_A$ and $F_V$ factors as well as illustrate the effects of frequency range in developing Category C, D, and E factors, Figure 63 shows median estimates averaged over the frequency ranges of 2 Hz to 10 Hz (NEHRP Fa range), 0.7 to 2.0 Hz, 0.5 to 2.5 Hz (NEHRP Fv range), and 0.2 to 0.7 Hz. In the figure, results for both EPRI (Figure 63b) and Peninsular Range curves (Figure 63a) are shown for Categories BC, C, and D (Category E analyses used a single suite of curves and is repeated for convenience). In addition, both WUS and CEUS conditions are shown along with the current NEHRP $F_A$ (open circles) and $F_V$ (x's) values. For Category BC the factors are about 1.4 for frequencies of 0.5 Hz and above and near 1 at low frequency for both WUS and CEUS conditions. Noninearity is apparent in the 2 Hz to 10 Hz range using the EPRI $G/G_{max}$ and hysteretic damping curves (Figure 63b).

For Category C, the factors for 0.7 Hz to 2 Hz and 0.5 Hz to 2.5 Hz (dotted lines in Figure 63) are similar, larger for WUS than CEUS and show little effects of nonlinearity, having a maximum value near 2 and generally remain above 1.5. This is very different than the current NEHRP factors which range from 1.7 to 1.3 (open circles in Figure 63), depending on loading level. Empirical analyses for NEHRP $F_A$ and $F_V$ factors by Crouse and McGuire (1998) and Silva and Toro (1998) showed similar trends. Interestingly, analyses of recorded strong ground motions from the 1994 **M** 6.7 Northridge earthquake showed general agreement with the NEHRP $F_A$ factors (Dobry et al., 1999). This more focused study sampled largely San Fernando Valley and Los Angeles Basin sites over the expected Category B peak acceleration ranges of 0.1 to 0.25g. At very low frequency shown in Figure 63a and 63b (0.2 Hz to 0.7 Hz) the factors are largely linear, average around 1.5, and are larger for WUS conditions.

For the high frequency NEHRP range Figure 63 (2 Hz to 10 Hz, solid lines) shows little nonlinearity for Peninsular Range, curves varying from about 1.5 to 1.2 for WUS conditions, under the full range of loading conditions. For the EPRI curves the values decrease to about 1 at 0.75g. The values are generally larger for WUS conditions than CEUS conditions, both of which exceed the current NEHRP factors (x's in Figure 63). These results are also consistent with the observations of Crouse and McGuire (1998), Silva and Toro (1998), and Dobry et al. (1999).

For NEHRP Category D, the 0.7 Hz to 2.0 Hz and 0.5 Hz to 2.5 Hz factors are very similar but now with larger differences between the other factors. The 2 Hz to 10 Hz factors have a maximum near 2 (WUS, Peninsular Range curves) and decrease to less than 1 at 0.75g. There is a large difference in the 2 Hz to 10 Hz factors between analyses using the Peninsular Range and EPRI curves. The Peninsular Range factors are about 0.5 units above those computed using the EPRI curves for loading levels exceeding about 0.2g for both WUS and CEUS conditions. For the WUS and CEUS Peninsular Range amplification (Figure 63a), the agreement is generally good with the current Fa factors while the EPRI amplifications fall below those of the NEHRP, particularly for the CEUS (Figure 63b).

The 0.5 Hz to 2.5 Hz ($F_V$ range) factors are around 2.5 (WUS conditions) at 0.1g and decrease to around 2.0 for Peninsular Range curves and about 1.5 for the EPRI curves. For this frequency range, the Peninsular Range values exceed the current NEHRP $F_V$ factors at low loading levels while the EPRI amplification factors agree very well with the current $F_V$ values.

Additionally, for Category D, analyses using a suite of mean depth bins showed depth to very stiff conditions results in larger high-frequency factors for shallow profiles ($\leq$ 200 ft) and larger low-frequency factors for very deep ($\geq$ 700 ft) profiles than the base-case depth range (100 ft to 1,000 ft). These results suggested that either depth bins be developed or amplification factors should be based on enveloping the results for a suite of mean depth categories.

For NEHRP Category E, Figures 63a and 63b show continued similarity for the 0.7 Hz to 2.0 Hz and 0.5 Hz to 2.5 Hz ranges and an increased separation between the high (2 Hz to 10 Hz) and very low (0.2 Hz to 0.7 Hz) ranges.

For both WUS and CEUS conditions, the current $F_A$ and $F_V$ values exceed the expected median factors by about 1 unit in amplification. These results suggest a substantial degree of conservatism in the NEHRP Category E factors. A large degree of conservatism was intended, considering the sparse data set of strong ground motions recorded at soft soil sites available at the time the factors were developed.

Further studies are clearly needed regarding the response of soft soils to earthquake loading. Recent data (recordings and site properties) from the Kobe, Chi Chi, and Turkey earthquakes should provide additional observational trends in the response of soft soils. More careful laboratory testing of nonlinear dynamic material properties is also needed to help resolve the effects of confining pressure on medium-to-low plasticity clays ($PI < 50\%$ to $60\%$). This is essential to understand over what depth ranges potential nonlinear effects may be significant and included in analyses.

Results of this study also showed that profile category depth is an important issue in developing amplification factors. Randomizing over a broad depth range is appropriate but may result in unconservative factors for shallow ($\leq$ 200 ft) and very deep ($\geq$ 1,000 ft) depending on frequency ranges of interest. Either establishing depth bins or using amplification factor which are envelopes of factors computed for a suite of mean profile depths are approaches to resolve the issue.

Median shear-wave velocity profiles, conditional on surficial geology, do not reflect NEHRP mid-range Categories. If these samples reflect profile populations, mid-range amplification factors will be biased for average site conditions. Either the NEHRP Category ranges in shear-wave velocity should be shifted to better reflect measured profile statistics or the amplification factors should be adjusted (increased) accordingly.

While there are a number of limitations in this study; assumptions in material dynamic properties, kappa values, and ground motion model, the general results suggest that the NEHRP amplification factor should be revisited (particularly Categories C and D) both analytically and empirically. Additionally, the shear-wave velocity ranges defining the Categories should be reevaluated. This is a natural consequence of increased strong motion data, additional and more complete site characterizations, and an increase in our site response knowledge base.

## 6.0 ASSESSMENT OF NEAR-SOURCE EFFECTS ON BUILDING CODE DESIGN SPECTRA

The near-fault factors in the 1997 UBC were developed prior to the 1994 **M** 6.7 Northridge, California; 1995 **M** 6.9 Kobe, Japan; 1999 **M** 7.6 Chi-Chi, Taiwan; 1999 **M** 7.4 Kocaeli (Izmit), and; **M** 7.1 Duzce, Turkey earthquakes. Also, several widely used current empirical attenuation relationships (Abrahamson and Silva, 1997; Boore and others, 1997; Campbell, 1997; Idriss, 1991, 1994; Sadigh and others, 1997 ) were published before the 1999 Chi-Chi, Taiwan and 1999 Kocaeli and Duzce, Turkey earthquakes. These large magnitude earthquakes significantly increase the strong-motion data set for moment magnitude greater than 7 and for closest rupture distances less than about 20 km.

### 6.1 Approach

The 1997 UBC design spectra and empirical attenuation relationships are reevaluated with the strong motion data in the Pacific Engineering and Analysis (PE&A) database including the data collected from these five recent events. UBC (1997) design spectra for Seismic Zones 3 and 4 are compared to statistical spectra (recorded motions averaged within **M** and *D* bins) computed from appropriate recorded motions.

In addition, residuals (ln observed motion minus ln expected motions) from the five attenuation relationships (listed above) are analyzed as a function of period, distance, and magnitude for an assessment of how well they capture near-fault spectral levels at rock sites. Since the empirical attenuation relationships are for very general rock and soil classification (with the exception of Boore and others, 1997) the residuals are computed using data from Geomatrix site Category A (rock with Vs > 600 m/s or < 5m of soil over rock) and B (shallow stiff soil, up to 20 m of soil over rock) (Table 1).

### 6.2 1997 UBC

The near-fault terms in the 1997 UBC are fault distance dependent (closest distance ($D$) $\leq$ 15 km) and vary in amplitude from 1.0 to 1.5 in the acceleration range (0.3 sec) and from 1.0 to 2.0 in the velocity range (1.0 sec) (Table 1). These factors were developed by the SEAOC Ground Motion Subcommittee which was chaired by Dr. Charles Kircher (1993 to 1996). The factors are based on the empirical attenuation relations of Boore and others (1993) and Sadigh (1993) (see Commentary Section in the 1997 UBC and Kircher (1998)) and do not reflect the near-fault data recorded during the Northridge, Kobe, Chi-Chi, and recent Turkey earthquakes.

To assess the appropriateness of the code design spectra for near-fault ground motions, UBC (1997) design spectra are compared to statistical spectra in the fault distance range of 0 to 50 km. Since the design spectrum varies as a function of distance, six distance groupings are used in the reexamination. These distance groupings are: 0 to 2 km, 2 to 5 km, 5 to 10 km, 10 to 15 km, 15 to 30 km and 30 to 50 km. In the first 5 distance ranges ( $\leq$ 30 km), comparisons are made to UBC (1997) design spectra for Seismic Zone 4, calculated at the limiting distances for each bin. In the largest fault distance range (30 to 50 km), the UBC (1997) design spectrum for Seismic Zone 3 is compared to the statistical spectra.

Format of Figures

In each figure the design spectra are shown as solid lines for both the smallest and largest distance range. The spectral data computed from the recorded motions are displayed in one of two manners. First, if the number of components of 5% damped response spectrum in the distance range is 10 or larger then three statistical spectra are shown. These spectra are the median (dotted curve), + 1$\sigma$ (dashed curve), and -1$\sigma$ (dashed curve). Spectral statistics are computed assuming a lognormal distribution. Second, if fewer than 10 components are available in the distance range, then all of the 5% damped spectra are plotted without statistical averaging as dashed curves. The six distance groupings are shown in separate frames on each figure to examine trends with distance.

Two representations are shown of the same comparison. The first figure is a log-log plot of spectral acceleration (Sa) versus period from 0.01 (100 Hz) to 10 seconds. The companion figure is a linear-log plot of Sa versus period from 0.1 (10 Hz) to 10 seconds. The second figure highlights the period range of engineering interest. For each distance range, comparisons are made for three fault types and NEHRP site categories as defined in the 1997 UBC (Table 1). The Fault classes are A, B, and C and the NEHRP (1997) site Categories are B, C, and D both of which are defined in Table 1. There are not enough available data for a comparison with NEHRP site Categories A or E (Table 1).

Tables 7 through 15 list the response spectral data used as a function of closest distance for NEHRP site Categories B, C, and D and for the three fault classes (A, B, and C). The tables list earthquake name, moment magnitude, station identification information, closest distance, Geomatrix and USGS site classifications, high-pass and low-pass filter corners, and peak acceleration values. In these tables, USGS site classification A, B, and C correspond to NEHRP Categories B, C and D, respectively. To supplement the data set, Geomatrix site Categories were used when the site did not have an assigned USGS/NEHRP Categories. In this case, Geomatrix site Categories A, B and C were placed in NEHRP Categories B, C, and D, respectively. This association was based on a strong correlation between NEHRP and

Geomatrix site categories, as can be seen in these Tables.

### *6.2.1 NEHRP Category B*

Results of the code design spectra comparisons for NEHRP Category B are shown in Figures 64 to 69 for the UBC (1997) provisions. In several cases the UBC design spectra are above the median or median + 1$\sigma$ (lognormal) statistical spectra implying some conservatism but the margin is highly variable with period.

Fault class A (**M** $\geq$ 7): statistical spectra are computed only for the distance bins of 0 to 2 km (N=20 components) and 30 to 50 km (N=28) in Figures 64 and 65. In the distance range of 0 to 2 km the UBC design spectra are above the median spectrum for all periods and above the median + 1$\sigma$ spectrum for periods greater than 0.3 seconds. The statistical spectra are computed from 18 records recorded during the Chi-Chi, Taiwan earthquake and two records from the Landers earthquake (Table 6). For the three distance ranges of 2 to 5 km (N = 2), 10 to 15 km (N = 4), and 30 to 50 km (N = 28) the UBC design spectra are generally greater than the available data at all periods. Recall that for the distance range 30 to 50 km, the comparison is made with the Seismic Zone 3 UBC spectra. In this case, with 28 components, the comparison shows considerable conservatism in the UBC design spectrum.

In the distance range of 5 to 10 km (N=4) the recorded motions generally exceed the UBC design spectra and the variability is large. For the distance range of 15 to 30 km, only two recorded spectra (one site) are available. Table 7 lists the spectral data used in the analyses.

Fault class B (6.5 $\leq$ **M** < 7): statistical spectra are computed only for the two distance bins greater than 15 km. For these distances the UBC design spectra are above the median + 1$\sigma$ spectrum for all periods. Sufficient data are available for these distances to suggest that the code spectra reflect considerable conservatism. For the distance ranges of 0 to 2 km (N=6), 2 to 5 km (N = 2), 5 to 10 km (N = 8), and 10 to 15 km (N = 4) some of the recorded spectral data exceed the UBC design spectra, especially for periods less than about 1 second. At longer periods the design spectra are generally greater than the spectra calculated from data. These results are similar to those for Fault class A where too few records are available to estimate fractiles, the variability in the components is large and conclusions regarding the adequacy of the design spectra can not be made unambiguously. The data used are listed in Table 8.

Fault class C (5.75 $\leq$ **M** < 6.5): no data are in the PE&A strong motion database for distances between 10 to 15 km in Figures 68 and 69. Statistical spectra are computed for the two distance bins greater than 15 km and the 5 to 10 km bin. For these distances the design spectra are above the median + 1$\sigma$ spectra for all periods. For the two close-in distance ranges of 0 to

2 km (N=2) and 2 to 5 km (N = 4) several of the recorded motions exceed the design spectra, especially for periods less than about 1 second. At longer periods the design spectra are generally greater than the recorded motions. Table 9 lists the data used.

### *6.2.2 NEHRP Category C*

Results of the comparisons of design spectra and statistical spectra for NEHRP Category C are shown in Figures 70 to 75. In several cases the UBC design spectra are above the median or median + $1\sigma$ (lognormal) statistical spectra implying some conservatism, but the margin is highly variable with period.

Fault class A ($\mathbf{M} \geq 7$): Unfortunately, no data are in the PE&A strong motion database (Table 9) for distances between 0 to 2 km in Figures 70 and 71. Statistical spectra are computed for the three distance bins greater than 10 km. These data were recorded during the Landers, Cape Mendocino, Tabas, Chi-Chi, and recent Turkey earthquakes. For these distances the UBC design spectra are generally near or above the median + $1\sigma$ spectra for all periods. Recall that for the distance range 30 to 50 km, the comparison is made with the UBC Seismic Zone 3 design spectra. For the remaining distance ranges of 2 to 5 km (N = 3) and 5 to 10 km (N = 6) nearly all of the recorded motions are near or below the UBC design spectra. The exceptions are the data from station CHY028 from the Chi-Chi, Taiwan earthquake (Table 10). In general the 1997 UBC spectra reflect conservative design values.

Fault class B ($6.5 \leq \mathbf{M} < 7$): Statistical spectra are computed for the distance bins of 0 to 2 km (N=14) and for all bins greater than 10 km in Figures 72 and 73. In these 4 distance ranges the UBC design spectra are near or above the median + $1\sigma$ spectra at all periods. For the remaining two distance ranges of 2 to 5 km (N = 6) and 5 to 10 km (N = 6) most of the observed motions are comparable to or below the UBC design spectra, however, some of the spectra exceed the UBC design levels near 0.2 to 0.4 seconds. Table 11 lists the data used in this comparison.

Fault class C ($5.75 \leq \mathbf{M} < 6.5$): Statistical spectra are computed for all bins greater than 5 km in Figures 74 and 75. In these 4 distance ranges the UBC design spectra are above the median spectra for all periods. For the remaining two close-in distance ranges of 0 to 2 km (N = 4) and 2 to 5 km (N = 2) most of the observed motions are comparable to or below the design spectra, however, some of the spectra exceed the UBC design spectra near 0.2 to 0.4 seconds. Table 12 lists the data used in this comparison.

### *6.2.3 NEHRP Category D*

Results of the code spectral level comparisons for NEHRP Category D are shown in Figures 76 to 81 for the UBC (1997) provisions.

Fault class A (**M** ≥ 7): statistical spectra are computed for all distance bins except the 2 km to 5 km bin, which contains only 4 spectra (Table 13). In all distance ranges the design spectra are above the median spectra for all periods and generally above the median + 1σ level for most of the period range (Figures 76 and 77). The only exception in the distance range from 0 to 2 km where the median + 1σ spectra exceeds the UBC spectra for periods less than about 1 second. The data in this distance range were recorded during the Cape Mendocino (2 components), Tabas (2 components), and Chi-Chi (4 components) earthquakes (Table 12). In general the design spectra compare very favorably with the currently available strong motion data.

Fault class B (6.5 ≤ **M** < 7):Statistical spectra are computed for the all distance bins (Table 14). In all distance ranges the UBC spectra are generally above the median spectra for all periods and near or slightly below the median + 1σ spectra in Figures 78 and 79. The main exception is in the distance range from 2 to 5 km where the median level exceeds the UBC design spectra at 5 km for periods less than about 0.5 second.

Fault class C (5.75 ≤ **M** < 6.5): Unfortunately, no data are in the PE&A strong motion database for distances between 0 to 2 km (Figures 80 and 81 and Table 15). For distances greater than 2 km, the UBC design spectra are above the median spectra of the recorded motions for all periods and generally above the median + 1σ spectra as well. The only exception in this case is the distance range from 5 to 10 km where the median + 1σ spectrum exceeds the design spectrum for a narrow range of periods near 0.4 second.

## 6.3 2000 IBC

The 2000 IBC design spectra are to be based either on probabilistic shaking hazard maps or deterministic evaluations at close distances to large active sources (Kircher, 1999). Both of these approaches rely on rock site empirical attenuation relations for WUS crustal sources. To assess the potential appropriateness of the 2,000 IBC design spectra, residuals between recorded motions and a suite of empirical WUS crustal attenuation relations is examined. The WUS crustal empirical WUS crustal relations include the following: Abrahamson and Silva (1997) (AS), Boore and others (1997) (BAO); Campbell (1997) (CAMP), Idriss (1991, 1994) (IMI) and Sadigh and others (1997) (SAO). To select rock site data, Geomatrix geotechnical site Categories A and B (Table 1) are assumed and the strong motion recordings binned into magnitude ranges (**M** ≥7, 6 ≤ **M** <7, 5 ≤ **M** < 6 and **M** ≥ 6.75). These magnitude ranges were chosen to generally reflect: (1) large earthquakes (**M** > 7) as well as a significant amount of data which were unavailable at the time the empirical relations were developed; (2) moderate earthquakes (**M** 6 to 7) and a data set which was used in developing the empirical relations; (3) small earthquakes (**M** 5 to 6); and (4) large earthquakes (**M** 6.75). For the Boore and others (1997) relationship a $\overline{v}_s$(30m) of 760 m/sec was used. The depth to basement was taken a 2 km (Campbell, personal communication, 1999).

In the analyses presented, the residuals are computed as observed average horizontal component spectra minus the expected average horizontal component computed from each empirical relation. The subtraction (rather than division) occurs because logarithms (natural log) are used as strong motion data are generally assumed to be log normally distributed random variables. For each earthquake and site, each empirical relation was used to provide an estimate of the response spectrum. Source mechanisms, site locations for hanging-wall verses foot-wall, as well as source-to-site distance definitions were all considered in computing the expected motions. The residuals are smoothed (over distance) and are plotted versus closest distance or Joyner-Boore distance (as appropriate for each attenuation relationship) from 0 to 50 km at nine frequencies and for peak horizontal ground acceleration. The nine frequencies are 20, 10, 5, 2, 1, 0.5, 0.33, 0.25 and 0.20 Hz. (Note that not all of the attenuation relationships include all of these frequencies. For these cases the residuals are not calculated.) Residuals are also not calculated for frequencies outside of the usable data bandwidth of the processed acceleration time histories (the low-frequency filter corners of the processed strong motion data listed in Tables 7 to 15). Additionally, the residuals within each magnitude bin have been weighted so that each earthquake has an equal contribution to the residual at each oscillator frequency.

For the distance range of 0 to 50 km, the mean magnitudes and mean distances in the database are listed in Table 16 along with the number of available components. For the largest magnitude bin (**M** > 7), 79 components are available while the other bins range from about 100 to 200 components. With these numbers of data, the residuals do have statistical stability and meaningful conclusions can be drawn from the analyses.

For the **M** > 6.75 bin, 70 components of the available 139 (Table 16) were recorded during the Gazli, Tabas, Nahanni, Spitak, Loma Prieta, Cape Mendocino, Landers, and Kobe earthquakes, which were included in the development of most of the considered empirical attenuation relationships. For the 79 components in the **M** > 7 bin, only 10 components were previously recorded during the Tabas, Cape Mendocino, and Landers earthquakes and available for inclusion in the development of the empirical attenuation relationships. The recent data contributed significantly to the larger magnitude comparisons.

Since the residuals clustered as a function of frequency, two plots are shown for each magnitude bin. A plot of the smoothed (over distance) residuals at high frequency (PGA, 20, 10, and 5 Hz) are shown in Figures 82, 84, 86, and 88. The low frequency (2, 1, 0.5, 0.333, 0.25, and 0.20 Hz) plots are shown in Figures 83, 85, 87, and 89. It is important to emphasize that in the residual plots, because natural logs are used, the misfit (departure from zero) must be raised to an exponential. For example, a residual of 0.5 actually implies an average departure of about 50% ($e^{0.5}$) from the data. A positive residual corresponds to an underprediction while a negative residual corresponds to an overprediction. For the **M** 5 to 6 and **M** 6 to 7 comparisons it is expected that the residuals be centered around zero as the empirical attenuation relations were developed using a significant portion of these data. For the **M** > 6.76 and **M** > 7 bins, which include a significant portion of new data (recorded after the attenuation relations were developed) the residuals may be regarded more as an evaluation of predictions.

For **M** ≥ 7 (Figure 82), nearly all of the smoothed residuals are less than 0. Hence most of the attenuation relations are conservative and predict motions that exceed the recorded motions from the recent Taiwan and Turkey earthquakes for PGA, 20, 10 and 5 Hz 5% damped response spectral ordinates. At lower frequencies however (Figure 83) the residuals tend to be closer to 0 with all 5 relationships estimating larger motions than observed for distances greater than about 35 km. At closer distances, from about 10 km to 35 km, the empirical attenuation relations tend to underestimate the data, particularly for the AS, BAO, SAO, and IMI relations. The relation of CAMP shows some frequencies with motions that are a little low. At very close distances there is a strong tendency for the AS, BAO, IMI, and SAO relations to predict motions that are below the data for frequencies lower than about 2 Hz. Interestingly this tendency does not occur for CAMP, which tends to produce motions that are larger than observed.

For **M** ≥ 6.75 (Figures 84 and 85), the residuals tend to be closer to 0 than in the **M** ≥ 7 case. Also, the over-prediction for distances greater than about 35 km is smaller. This result is consistent with the fact that a greater proportion of the data for this magnitude range was used in developing the attenuation relations.

For 6 ≤ **M** < 7.0 (Figures 86 and 87), the residuals generally oscillate about 0 as a function of distance. This is expected since all of these data were available when the attenuation relations were developed. However, residuals for the Boore and others (BAO) relation tend to be positive, implying that the relation has a tendency to predict motions that are lower than observed for this magnitude and distance range.

For 5 ≤ **M** < 6.0 (Figures 88 and 89), the residuals again oscillate about 0 as a function of distance. This is expected since all of these data were available when the attenuation relations were developed. However, all 5 relationships predict lower motions than observed for distances greater than about 35 km particularly at high frequency ($\geq$ 5 Hz). Interestingly, at low frequency, the CAMP relation shows a distance trend in bias going from negative to positive as distance increases.

Since the largest and most stable biases were encountered for the **M** > 7 bin which is dominated by the recent Taiwan and Turkey earthquakes, these results suggest that the crustal empirical relations should be updated.

## 7.0 SUMMARY AND CONCLUSIONS ON NEAR-SOURCE MOTIONS

Existing recordings of strong ground motions that include the recent Taiwan and Turkey earthquakes have been used to evaluate the 1997 UBC design spectra as well as five WUS crustal empirical attenuation relations. Since the 2,000 IBC makes use of empirical rock attenuation relations either implicitly in probabilistic ground shaking maps or directly in deterministic shaking hazard evaluations at close distances to large active earthquake sources, evaluation of frequently used empirical relations is intended to provide some insights into the 2,000 IBC code design levels for the WUS.

For the comparisons to the 1997 UBC, design spectra for Seismic Source Types A, B, and C as well as Seismic Zones 4 and 3 and NEHRP site Categories B, C, D, and E were compared to statistical spectra computed from recorded motions. In general, for cases where more than 10 components of data were available (most cases) permitting reliable estimates of fractiles, the UBC 1997 design spectra exceeded the median statistical spectra, in many cases being near or exceeding + 1$\sigma$ estimates. In general, for the currently available data, 1997 UBC code design spectra reflect conservative design levels.

This is particularly true for Seismic Zone 3 where the UBC 1997 design spectra significantly exceed median + 1$\sigma$ estimates. For Fault type A (**M** $\geq$ 7) and the closest distance range (0 km to 2 km) the design spectra exceed median estimates and are close to + 1$\sigma$ values for most of the period range. For NEHRP site Category D, the most populated site Category, Fault type A design spectra exceed + 1$\sigma$ estimates suggesting conservative design values for the range in earthquake magnitudes currently available. For cases where fewer than ten components were available and the individual components displayed, the wide range typically encountered in recordings of strong ground motion was observed.

In an analysis of residuals using five of the frequently employed WUS rock site empirical attenuation relations several interesting features were observed. For large magnitude earthquakes (**M** > 7), which is dominated by data not available when the relations considered were developed, the relations tended to predict larger motions than observed at high ($\geq$ 5 Hz) frequencies. Conversely the relations tended to underpredict at low frequency ($\leq$ 2 Hz). This was most apparent in the 10 km to 35 km distance range with three relations (Abrahamson and Silva, Idriss, and Sadigh and others) showing the trend within 10 km. For the **M** $\geq$ 6.75 and **M** 6 to 7 bins, the relations produced much smaller residuals in general with a tendency to be more accurate at high frequency ($\geq$ 5 Hz) than at low frequency ($\leq$ 2 Hz) and biased a little high over most of the oscillator frequency range. The exception was Boore and others which was biased a little low from about 5 km to about 35 and at most frequencies.

Over the low magnitude range (**M** 5 to 6), four of the relations showed little bias overall within about 35 km at high frequency (≥ 5 Hz) but all showed a large positive bias (under prediction) beginning around 35 km. The Boore and others relation showed a positive bias over most of the distance range. At low frequency, the relations generally showed little or no bias, except for Campbell, which showed a large negative bias (over prediction) at the closed distance but with the bias decreasing as distance increased.

These results suggest that the relations perform reasonably well except at low frequency (≤ 2 Hz) for the recent large magnitude Taiwan and Turkey earthquakes. As is often the case when large magnitude earthquakes occur and which produce significant amounts of strong motion data, empirical attenuation relations require updating, along with other design tools. Clearly these earthquakes have presented the case for doing so.

## 8.0 REFERENCES


Abrahamson, N.A. and W.J. Silva (1997). "Empirical response spectral attenuation relations for shallow crustal earthquakes." *Seism. Res. Lett.*, 68(1), 94-127.

Abrahamson, N.A and K.M. Shedlock (1997). "Overview." *Seis. Research Lett.*, 68(1), 9-23.

Anderson, J. G. and S. E. Hough (1984). "A Model for the Shape of the Fourier Amplitude Spectrum of Acceleration at High Frequencies." *Bull. of Seism. Soc. Am.*, 74(5), 1969-1993.

Atkinson, G.M and W.J. Silva (1997). "An empirical study of earthquake source spectra for California earthquakes." *Bull. Seism. Soc. Am.* 87(1), 97-113.

Atkinson, G.M. (1993). "Source spectra for earthquakes in eastern North America." *Bull. Seism. Soc. Am.,* 83(6), 1778-1798.

Boore, D.M, and W.B. Joyner (1997). "Site amplifications for generic rock sites." Bull. *Seism. Soc. Am.*, 87(2), 327-341.

Boore, D. M., W. B. Joyner, and T. E. Fumal (1997).“Equations for estimating horizontal response spectra and peak acceleration from Western North American earthquakes: A summary of recent work.” *Seism. Res. Lett.* 68(1), 24-40.

Boore, D.M., W.B. Joyner, and T.E. Fumal (1993). "Estimation of response spectra and peak acceleration from western North American earthquakes: An interim report." *USGS* Open-File Rept. 93-509.

Boore, D.M., and Atkinson, G.M. (1987). "Stochastic prediction of ground motion and spectral response parameters at hard-rock sites in eastern North America." *Bull. Seism. Soc. Am.*, 77(2), 440-467.

Boore, D.M. (1986). "Short-period P- and S-wave radiation from large earthquakes: implications for spectral scaling relations." *Bull. Seism. Soc. Am.*, 76(1) 43-64.

Boore, D.M. (1983). "Stochastic simulation of high-frequency ground motions based on seismological models of the radiated spectra." *Bull. Seism. Soc. Am.*, 73, 1865-1894.

Borcherdt, R. D. (1997). “Estimates of site-dependent response spectra for new and existing highway facilities (methodology and justification).” *Proc. Of the NCEER Workshop on the Nat'l Representation of Seismic Ground Motion for New and Existing Highway Facilities*, edited by M.S. Power and R.L. Mayes.

Borcherdt, R. D. (1996). "Preliminary amplification estimates inferred from strong ground-motion recordings of the Northridge earthquake of January 17, 1994." *Proceedings of the Internatonal Workshop on Site Response Subjected to Strong Earthquake Motions,* edited by Iai, (2), 21-46.

Borcherdt, R. D. (1994a). "Simplified site classes and empirical amplification factors for site-dependent code provisions." *Proc. Of the NCEER/SEAOC/BSSC Workshop on Site Response During Earthquakes and Seismic Code Provisions,* University of Southern Calif., Los Angeles, 1992, edited by G.R. Martin.

Borcherdt, R. D. (1994b). "Estimates of site-dependent response spectra for design (methodology and justification)." *Earthquake Spectra*, 10(4), 617-653.

Borcherdt, R. G. and G. Glassmoyer (1992). "On the Characteristics of Local Geology and Their Influence on Ground Motions Generated by the Loma Prieta Earthquake in the San Francisco Bay region, California." *Bull. Seism. Soc. Am.*, 82(2), 603-641.

Crouse, C. B. and J.W. McGuire (1996). "Site response studies for purpose of revising NEHRP seismic provisions." *Earthquake Spectra,* 12(3), 407-439.

Dobry, R., R. Ramos, and M.S. Power (1999). "Site factors and site categories in seismic codes." *MCEER*-99-0010.

Dobry, R., G. R. Martin, E. Parra, and A. Bhattacharyya (1994). "Development of site-dependent ratios of elastic response spectra (RRS) and site categories for building seismic codes." *Proc. of the NCEER/SEAOC/BSSC Workshop on Site Response During Earthquakes and Seismic code Provisions*, edited by G.R. Martin, University of Southern Calififornia.

Dobry, R., R. S. Ladd, F. Y. Yokel, R. M. Chung and D. Powell (1982). "Prediction of Pore Water Pressure Build-Up and Liquefaction of Sands During Earthquakes by th Cyclic Strain Method." *NBS Building Science Series 138*, National Bureau of Standards.

Electric Power Research Institute (1993). "Guidelines for determining design basis ground motions." Palo Alto, Calif: Electric Power Research Institute, vol. 1-5, EPRI TR-102293.
vol. 1: Methodology and guidelines for estimating earthquake ground motion in eastern North America.
vol. 2: Appendices for ground motion estimation.
vol. 3: Appendices for field investigations.
vol. 4: Appendices for laboratory investigations.
vol. 5: Quantification of seismic source effects.

Frankel, A., C. Mueller, T. Barnhard, D. Perkins, E.V. Leyendecker, N. Dickman, S. Hanson, and M. Hopper (1996). "National Seismic Hazard Maps: Documentation, June 1996." *U.S. Geological Survey* Open-File Report 96-532.

Hanks, T.C. and A.C. Johnston (1992). "Common features of the excitation and propagation of strong ground motion for north American earthquakes." *Bull. Seism. Soc. Am.*, 82(1), 1-23.

Hanks, T.C., and McGuire, R.K. (1981). "The character of high-frequency strong ground motion." *Bull. Seism. Soc. Am.*, 71, 2071-2095.

Hsu, C-C. And M. Vucetic (1999). "Results of cyclic and dynamic simple shear tests on soils from Tazana and Rinaldi sites conducted for Rosrine Project and other research purposes." *UCLA* Research Report No. ENG-99-205.

Idriss, I. M. (1991). "Earthquake ground motions at soft soil sites." *Proceedings: 2nd Int'l Confer. on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics*, Saint Louis, Missouri, Invited Paper LP01, 2265-2272.

Iwan, W.D. (1967). "On a class of models for the yielding behavior of continuous and composite systems." *J. Appl. Mech.,* 34, 612-617.

Joyner, W.B.(1995). "Advocacy Paper #4, Soil is the most appropriate reference site condition, in ATC 35-2, Preprints: *National Earthquake Ground Motion Mapping Workshop, ATC.*

Joyner, W.B., T.E. Fumal, and G. Glassmoyer (1994) "Empirical spectral response ratios for strong motion data from the 1989 Loma Prieta, California, Earthquake." *Proc. of The NCEER/SEAOC/BSSC Workshop on Site Response During Earthquakes and Seismic Code Provisions,* edited by G.R. Martin, University of Southern California.

Joyner, H.B. and D.M. Boore (1988) "Measurement, characteristics and prediction of strong ground motion." State-of-the-Art Report, *Proc., Specialty Conf. on Earthquake Engineering and Soil Dynamics II--Recent Adv. in Ground Motion Evaluation, ASCE,* Partk City, Utah, 43-102.

Joyner, W.B., and A.T.F.Chen (1975). "Calculation of nonlinear ground response in earthquake." *Bull. Seism. Soc. Am.*, 65(5), 1315-1336.

Campbell, K. W. (1997). "Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity and pseudo-absolute acceleration response spectra." *Seism. Res. Lett.* 68(1), 154-179

Kimball, J., and C. Costantino (1999). "Site response factors for the eastern United States as compared to NEHRP 97 recommendations." *Proc. of the BNL, NEA/CSNI/R(2000)2.*

Kircher, C.A. (1999). "United States building code approach to variations in regional seismicity." *Invited Paper - 1999 Annual Meeting of the New Zealand Society of Earthquake Engineering, Rotorua, New Zealand.*

Kircher, C.A. (1998). "New ground shaking design criteria." *SEWC Structural Engineers World Congress, San Francisco, California.*

Lee, M.K.W., W.D.L. Finn and W.D. Liam (1978). "DESRA-2" Dynamic effective stress response analysis of soil deposit with energy transmitting boundary including assessment of liquefaction potential."Department of Civil Engineering, University of British Columbia.

Lin, H., Hwang, H. H-M., and Huo, J-R. (1996). "A study on site coefficients for new site categories specified in the NEHRP provisions." Center for Earthquake Research and Information, The University of Memphis. Memphis, Tennessee.

McGuire, R.K., A.M. Becker, and N.C. Donovan (1984). "Spectral estimates of seismic shear waves." *Bull. Seism. Soc. Am.*, 74(4), 1427-1440.

Marek, A.R., J.D. Bray and N. Abrahamson (1998). "Task 3: Characterization of site response general site categories." *Research supported by the Pacific Engineering Earthquake Center, PG&E and the David and Lucile Packard Foundation.*

Martin, G.R., editor, (1994). "*Proc. Of the NCEER/SEAOC/BSSC Workshop on Site Response During Earthquakes and Seismic Code Provisions,* University of S. Calif., Los Angeles.

Martin, G.R., and Dobry, R. (1994). "Earthquake site response and seismic code provisions." *NCEER* Bulletin, 8(4).

Mathieson, R.B. et al., (1984). "Recommendations concerning seismic design and zonation." Critical Aspects of Earthquake Ground Motion and Bld. Damage Potential. *ATC-10-1.*

NEHRP97, 1998, NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, *FEMA* 302 303, 1997 Edition.

Qiu, P. (1997). "*Earthquake induced nonlinear ground deformation analyses.*" Ph D. Dissertation, Department of Civil Engineering, UCLA.

Rinne, E.E. (1994). "Development of new site coefficients for building codes." *Proc. Fifth U.S. Nat. Conf. On Earthquake Engineering, Chicago,* 3, 69-78.

Sadigh, C.-Y. Chang, J.A. Egan, F. Makdisi, and R.R. Youngs (1997). "Attenuation relationships for shallow crustal earthquakes based on California strong motion data." *Seism. Soc. Am.*, 68(1), 180-189.

Sadigh, K., Chang, C.-Y, Abrahamson, N.A., Chiou, S.J. and Power, M.S. (1993). "Specification of Long period ground motions: Updated attenuation relationships for rock site conditions and adjustment factors for near-fault effects." in Proc. ATC-17-1, Seminar on Seismic

Isolation, Passive Energy Dissipation, and Active Control, March 11-12, San Francisco, California, 59-70.

Schnabel, P.B., Lysmer, J., and Seed, H.B. (1972). *SHAKE: a Computer Program for Earthquake Response Analysis of Horizontally Layered Sites.* Earthq. Engin. Res. Center, Univ. of Calif. at Berkeley, EERC 72-12.

Schneider, J.F., W.J. Silva, and C.L. Stark (1993). Ground motion model for the 1989 **M** 6.9 Loma Prieta earthquake including effects of source, path and site. *Earthquake Spectra,* 9(2), 251-287.

Seed, R.B, S.E. Dickenson, and C.M. Mok (1994a). "Site effects on strong shaking and seismic risk; recent developments for seismic design codes and practice." *Am. Soc. Of Civil Engineering Str. Congress,* 12(1), 573-578.

Seed, R.B, S.E. Dickenson, G.A. Rau, R.K. White, and C.M. Mok (1994b). "Observations regarding seismic response analyses for soft and deep clay sites." *Proc. of The NCEER/SEAOC/BSSC Workshop on Site Response During Earthquakes and Seismic Code Provisions,* edited by G.R. Martin, UCLA.

Seed, H.B. and I.M. Idriss (1970). "*Soil moduli and damping factors for dynamic response analyses.*" Earthq. Eng. Res. Center, Univ. of Calif. at Berkeley, Report No. UCB/EERC-70/10.

Seismology Committee of the Structural Engineers Association of California. 1996. *Recommended Lateral Force Requirements and Commentary.* (Sacramento, CA: SEAOC).

Silva, W. J. R. McGuire, and C. Costantino. (1999a). "Comparison of Site Specific Soil UHS to Soil Motions Computed with Rock UHS."*Proc. of the BNL, NEA/CSNI/R(2000)2.*

Silva, W. J.,S. Li, B. Darragh, and N. Gregor (1999b). "Surface Geology Based Strong Motion Amplification Factors for the San Francisco Bay and Los Angeles Areas."*A PEARL report to PG&E/CEC/Caltrans,* Award No. SA2120-59652.

Silva, W.J. and G. Toro (1998) "Verification of response spectral shapes and anchor points for different site categories for building design codes." California Department of Conservation, Division of Mines and Geology, Report CSMIP/97-08

Silva, W.J., N. Abrahamson, G. Toro and C. Costantino. (1997). "Description and validation of the stochastic ground motion model." Report Submitted to Brookhaven National Laboratory, Associated Universities, Inc. Upton, New York 11973, Contract No. 770573.

Silva, W.J. and R. Darragh (1995). "Engineering characterization of earthquake strong ground motion recorded at rock sites." Palo Alto, Calif:Electric Power Research Institute, TR-102261.

Silva, W.J. (1992). "Factors controlling strong ground motions and their associated uncertainties." *Dynamic Analysis and Design Considerations for High Level Nuclear Waste Repositories, ASCE* 132-161.

Silva, W.J. (1991). "Global characteristics and site geometry." Chapter 6 in Proceedings: NSF/EPRI Workshop on Dynamic Soil Properties and Site Characterization. Palo Alto, Calif.: Electric Power Research Institute, NP-7337.

Silva, W.J., R.B. Darragh, and I.G. Wong (1990). "Engineering characterization of earthquake strong ground motions with applications to the Pacific Northwest." in Hays, W.W., ed., *Proceedings of the Third NEHRP Workshop on earthquake Hazards in the Puget sound/Portland region*, U.S. geological Survey Open-File report.

Silva, W.J., and Green, R.K. (1989). "Magnitude and distance scaling of response spectral shapes for rock sites with applications to North American tectonic environment." *Earthquake Spectra,* 5(3), 591-624.

Silva, W. J.; Turcotte, T.; Moriwaki, Y. (1988). "Soil Response to Earthquake Ground Motion," Electric Power Research Institute, Walnut Creek, California, Report No. NP-5747.

Silva, W.J., Lee, K. (1987) "WES RASCAL code for synthesizing earthquake ground motions" State-of-the-Art for Assessing Earthquake Hazards in the United States, Report 24, U.S. Army Engineers Waterways Experiment Station, Misc. Paper S-73-1.

Silva, W.J. (1976). "Body Waves in a Layered Anelastic soilid." *Bull. Seis. Soc. Am.*, vol. 66(5), 1539-1554.

Toro, G.R., N.A. Abrahamson, and J.F. Schneider (1997). "Model of strong ground motions from earthquakes in Central and Eastern North America: Best estimates and uncertainties." *Seism. Res. Lett.*, 68(1), 41-57.

Toro, G.R., Silva, W.J., McGuire, R.K., and Herrmann, R.B. (1992). "Probabilistic seismic hazard mapping of the Mississippi embayment." *Seism. Res. Letters,* 63(3), 449-500.

Toro, G.R., and McGuire, R.K. (1987). "An investigation into earthquake ground motion characteristics in eastern North America." *Bull. Seism. Soc. Am.*, 77, 468-489.

Uniform Building Code (1997) *Uniform Building Code."* Published by International Conference of Building Officials, Whittier, California.

Wills, C.J. and W.J. Silva (1998). "Shear-wave velocity characteristics of geologic units in California." *Earthquake Spectra*, 14(3), 533-556.

Vucetic, M.., C-C Hsu, and M. Doroudian (1998). "Results of cyclic and dynamic simple shear tests on soils from La Ciengca site conducted for Rosrine Project and other research purposes." *UCLA* Research Report, No. ENG-98-200

Vucetic, M. and R. Dobry (1991). "Effects of Soil Plasticity on Cyclic Response," *Journal of Geotechnical Engineering, ASCE*, 117(1), 89-107.

Table 1

SITE CLASSIFICATIONS

Average shear-wave velocity to a depth of 30m (≈ 100 ft) is:

| NEHRP 1994 | UBC 1997 |
|---|---|
| A = > 1,500 m/s | 5,000 ft/sec |
| B = 760 - 1,500 (1,130)* | 2,500 - 5,000 (3,750)* |
| C = 360 - 760 (560)* | 1,200 - 2,500 (1,850)* |
| D = 180 - 360 (270)* | 600 - 1,200 (900)* |
| E = < 180 | 600 ft/sec |

| Soil Profile Type | Description |
|---|---|
| A | Hard rock with measured shear-wave velocity, $\overline{v}_s > 5{,}000$ ft/sec (1,500 m/sec) |
| B | Rock with 2,500 ft/sec < $\overline{v}_s \leq 5{,}000$ ft/sec (760 m/sec < $\overline{v}_s \leq 1{,}500$ m/sec) |
| C | Very dense soil and soft rock with 1,200 ft/sec < $\overline{v}_s \leq 2{,}500$ ft/sec (360 m/sec < $\overline{v}_s \leq 760$ m/sec) or with either $\overline{N} > 50$ or $\overline{S}_u \geq 2{,}000$ psf (100 kPa) |
| D | Stiff soil with 600 ft/sec < $\overline{v}_s \leq 1{,}200$ ft/sec (180 m/sec < $\overline{v}_s \leq 360$ m/sec) or with either $15 \leq \overline{N} \leq 50$ or 1,000 psf $\leq \overline{S}_u \leq$ 2,000 psf (50 kPa $\leq \overline{S}_u \leq$ 100 kPa) |
| E | A soil profile with $\overline{v}_s < 600$ ft/sec (180 m/sec) or any profile with more than 10 ft (3m) of soft clay defined as soil with $PI > 20$, $\omega \geq 40\%$, and $\overline{S}_u < 500$ psf (25 kPa) |
| F | Soil requiring site-specific evaluations:<br>i. Soil vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clayss, collapsible weakly cemented soils.<br>2. Peats and/or highly organic clays {$H > 10$ ft (3m) of peat and/or highly organic clay where $H$ = thickness of soil)<br>3. Very high plasticity clays ($H > 25$ ft (8m) with $PI > 75$)<br>4. Very thick soft/medium stiff clays ($H > 120$ ft (36m))<br>Exception: When the soil properties are not shown in sufficient detail to determine the Soil Profile Type, Type D shall be used. Soil Profile Types E or F need not be assumed unless the regulatory agency determines that Types E or F may be present at the site or in the event that Types E or F are established by the geotechnical data. |

*Mid-range values adopted for amplification factors

Table 1 (Cont.)

SITE CLASSIFICATIONS

GEOMATRIX Site Classification

Geotechnical subsurface characteristics (Robert Youngs, personal communications)

A = Rock. Instrument on rock ($V_S$ > 600 mps or < 5m of soil over rock.

B = Shallow (stiff) soil. Instrument on/in soil profile up to 20m thick overlying rock.

C = Deep narrow soil. Instrument on/in soil profile at least 20m thick overlying rock, in a narrow canyon or valley no more than several km wide.

D = Deep broad soil. Instrument on/in a soil profile at least 20m thick overlying rock, in a broad valley.

E = Soft deep soil. Instrument on/in deep soil profile with average $V_S$ < 150 mps.

Relations To Building Code Classifications

| UBC | NEHRP | GEOMATRIX |
|---|---|---|
| S1 | B + C | A + B |
| S2 | C + D | C + D |
| S3 | E | E |
| S4 | ---- | ---- |

| 1997 UBC NEAR-SOURCE FACTOR, $N_A$ | | | |
|---|---|---|---|
| Seismic Source | Closest Distance to Active Source | | |
| | ≤ 2 km | 5 km | 10 km |
| Type A | 1.5 | 1.2 | 1.0 |
| Type B | 1.2 | 1.0 | 1.0 |
| Type C | 1.0 | 1.0 | 1.0 |

| Table 1 (Cont.) | | | |
|---|---|---|---|
| 1997 UBC NEAR-SOURCE FACTOR, $N_V$ | | | |
| Seismic Source | Closest Distance to Active Source | | |
| | ≤ 2 km | 5 km | 10 km |
| Type A | 2.0 | 1.6 | 1.2 |
| Type B | 1.6 | 1.2 | 1.0 |
| Type C | 1.0 | 1.0 | 1.0 |
| 1997 UBC Seismic Source Types | | | |
| Seismic Source | Seismic Source Description | Source Properties | |
| | | Maximum Moment Magnitude, **M** | Slip Rate, SR (mm/year) |
| Type A | Capable of Producing Large Magnitude Events <u>and</u> High Rate of Seismic Activity | **M** ≥7.0 | SR ≥ 5 |
| Type B | Not Type A or Type C Seismic Source | | |
| Type C | Not Capable of Producing Large Magnitude Events <u>and</u> Low Rate of Seismic Activity | **M** < 6.5 | SR ≤ 2 |

Table 2
SURFACE GEOLOGY BASED PROFILES, SITE CLASSES, AND DYNAMIC MATERIAL PROPERTIES

| SAN FRANCISCO BAY AREA | | | | | |
|---|---|---|---|---|---|
| Geology | Average Velocity over 30m | Site Classes | | Number of Profiles | G/Gmax and Hysteretic Damping |
| | | USGS | NEHRP | | |
| $K_{jf}$(Franciscan) | 771.44 m/s | A | B | 30 | Generic rock |
| $TM_{zs}$(Tertiary Bedrock) | 506.13 m/s | B | C | 18 | Generic rock |
| $QT_s$(Quaternary/Tertiary) | 466.12 m/s | B | C | 9 | EPRI |
| $Q_{oa}$(older alluvium) | 353.44 m/s | C | D | 16 | EPRI |
| $Q_{al}$(Quaternary alluvium) | 296.49 m/s | C | D | 37 | EPRI |
| $Q_{oa} + Q_{al}$ | 312.15 m/s | C | D | 53 | EPRI |
| $Q_m$(Bay mud) | 187.87 m/s | C | D | 60 | Vucetic/Doby, EPRI |
| | | | | 170 | |
| LOS ANGELES AREA | | | | | |
| Geology | Average Velocity over 30m | Site Classes | | Number of Profiles | G/Gmax and Hysteretic Damping |
| | | USGS | NEHRP | | |
| $M_{xb}$ (Granite) | 843.78 m/s | A | B | 8 | Generic rock |
| $T_S$ (Saugus) | 576.81 m/s | B | C | 4 | Peninsular Range |
| $T_S$ (Tertiary) | 436.39 m/s | B | C | 43 | Generic rock |
| $Q_o$(Older alluvium) | 391.24 m/s | B | C | 124 | Peninsular Range |
| $QT_S$ ($Q_o + T_S$) | 508.61 m/s | B | C | 171 | Peninsular Range |
| $Q_y$(Quaternary alluvium) | 317.68 m/s | C | D | 219 | Peninsular Range |
| | | | | 398 | |

| Table 3<br>**$F_A$ and $F_V$ VALUES** | | | | | |
|---|---|---|---|---|---|
| Soil Profile Type | $F_A$ For Shaking Intensity Levels | | | | |
| | $A_a \leq 0.1$ | $A_a = 0.2$ | $A_a = 0.3$ | $A_a = 0.4$ | $A_a \geq 0.50^a$ |
| A | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| B | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| C | 1.2 | 1.2 | 1.1 | 1.0 | 1.0 |
| D | 1.6 | 1.4 | 1.2 | 1.1 | 1.0 |
| E | 2.5 | 1.7 | 1.2 | 0.9 | b |
| F | b | b | b | b | b |
| Soil Profile Type | $F_V$ For Shaking Intensity Levels | | | | |
| | $A_V \leq 0.1$ | $A_V = 0.2$ | $A_V = 0.3$ | $A_V = 0.4$ | $A_V \geq 0.50^a$ |
| A | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| B | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| C | 1.7 | 1.6 | 1.5 | 1.4 | 1.3 |
| D | 2.4 | 2.0 | 1.8 | 1.6 | 1.5 |
| E | 3.5 | 3.2 | 2.8 | 2.4 | b |
| F | b | b | b | b | b |

Fa: Evaluated over the frequency range of 2 to 10 Hz.
Fv: Evaluated over the frequency range of 0.5 to 2.5 Hz.

Note: Use straight line interpolation for intermediate values of $A_a$ and $A_V$

[a] Values for $A_a$, $A_V$ > 0.4 are applicable to the provisions for seismically isolated and certain other structure

[b] Site specific geotechnical investigation and dynamic site response analyses shall be performed.

Table 4

KAPPA VALUES FOR "AVERAGE" SITE CONDITIONS IN WUS AND CEUS*

| Tectonic | "Average" Site Condition | N+ | Median Kappa (sec) | $\sigma_{ln}$ | Range of Kappa for This Site Condition (sec) |
|---|---|---|---|---|---|
| WUS | Hard rock | 11 | 0.026 | 0.58 | 0.010 - 0.060 |
| | Weathered hard rock | 9 | 0.035 | 0.52 | 0.015 - 0.100 |
| | Soft rock | 15 | 0.045 | 0.51 | 0.015 - 0.080 |
| | Sheared rock | 4 | 0.062 | 0.41 | 0.040 - 0.120 |
| | Combined | 39 | 0.037 | 0.59 | 0.010 - 0.120 |
| | | | | | |
| CEUS | Hard rock | 16 | 0.007 | 0.42 | 0.004 - 0.016 |
| | Soft rock | 3 | 0.017 | 0.09 | 0.015 - 0.018 |
| | Sheared rock | 1 | 0.025 | | 0.025 |
| | Combined | 20 | 0.008 | 0.55 | 0.004 - 0.025 |

*Based on template fits using spectral shapes (Silva and Darragh, 1995)
+Number of records

"Average" Site Condition is defined as:

Hard Rock: WNA as granite, schist, carbonate, slate
ENA as granitic pluton, carbonate, sites in Canadian Shield region (Saguenay, New Hampshire).

Weathered hard rock: WNA as weathered granitic rock and tonalite

Soft rock: WNA as sandstone and breccias
ENA as sandstone and claystone

Sheared rock: WNA as site near fault zone (Gilroy #6) or greenstone site in Franciscan (Redwood City, Hayward).
ENA as site near fault zone (Nahanni River Site #1)

| Table 5<br>NEHRP B WUS<br>$\kappa = 0.04$ sec | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Target Outcrop PGA(g) | Median Outcrop PGA(g) | Median Outcrop PGV(cm/sec) | Median Outcrop PGD(cm) | Median Outcrop V/A (cm/sec/g) | Median Outcrop AD/V$^2$ (gcm/cm/sec$^2$) | Dist. (km) | Depth (km) | **M** | $\Delta\sigma$ (bars) |
| 0.05 | 0.05 | 5.72 | 2.58 | 113.06 | 3.91 | 40.00 | 8.00 | 6.5 | 64 |
| 0.10 | 0.10 | 10.72 | 4.74 | 106.96 | 4.06 | 21.50 | 8.00 | 6.5 | 64 |
| 0.20 | 0.19 | 19.80 | 8.67 | 103.54 | 4.15 | 10.00 | 8.00 | 6.5 | 64 |
| 0.30 | 0.31 | 31.91 | 13.89 | 101.94 | 4.19 | 1.00 | 8.00 | 6.5 | 64 |
| 0.40 | 0.39 | 39.98 | 17.80 | 103.71 | 4.21 | 3.00 | 6.00 | 6.5 | 64 |
| 0.50 | 0.51 | 52.88 | 23.49 | 103.09 | 4.23 | 1.00 | 5.00 | 6.5 | 64 |
| 0.75 | 0.74 | 76.98 | 34.78 | 104.38 | 4.25 | 1.00 | 3.50 | 6.5 | 64 |

Q(f) = 275 $f^{0.6}$ (Los Angeles; based on regional inversions, Silva et al., 1997)
Kappa = 0.04 sec

| NEHRP B CEUS<br>$\kappa = 0.04$ sec | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Target Outcrop PGA(g) | Median Outcrop PGA(g) | Median Outcrop PGV(cm/sec) | Median Outcrop PGD(cm) | Median Outcrop V/A (cm/sec/g) | Median Outcrop AD/V$^2$ (gcm/cm/sec$^2$) | Dist. (km) | Depth (km) | **M** | $\Delta\sigma$ (bars) |
| 0.05 | 0.05 | 3.99 | 1.50 | 81.40 | 4.53 | 70.00 | 8.00 | 6.5 | 110 |
| 0.10 | 0.10 | 8.17 | 2.99 | 78.90 | 4.56 | 35.00 | 8.00 | 6.5 | 110 |
| 0.20 | 0.20 | 15.50 | 5.64 | 77.90 | 4.58 | 18.00 | 8.00 | 6.5 | 110 |
| 0.30 | 0.31 | 24.27 | 8.80 | 77.45 | 4.59 | 10.00 | 8.00 | 6.5 | 110 |
| 0.40 | 0.41 | 31.31 | 11.34 | 77.24 | 4.60 | 6.00 | 8.00 | 6.5 | 110 |
| 0.50 | 0.51 | 39.03 | 14.12 | 77.09 | 4.60 | 1.00 | 8.00 | 6.5 | 110 |
| 0.75 | 0.78 | 59.92 | 21.63 | 76.78 | 4.61 | 1.00 | 5.20 | 6.5 | 110 |

Q(f) = 351 $f^{0.84}$ (based on Saguenay inversions, Silva et al., 1997)
Kappa = 0.040 sec

Table 5 (continue)

NEHRP B CEUS

$\kappa$ = 0.02 sec

| Target Outcrop PGA(g) | Median Outcrop PGA(g) | Median Outcrop PGV(cm/sec) | Median Outcrop PGD(cm) | Median Outcrop V/A (cm/sec/g) | Median Outcrop AD/V$^2$ (gcm/cm/sec$^2$) | Dist. (km) | Depth (km) | M | $\Delta\sigma$ (bars) |
|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 0.05 | 3.03 | 1.09 | 58.14 | 6.07 | 105.00 | 8.00 | 6.5 | 110 |
| 0.10 | 0.10 | 5.68 | 1.91 | 54.67 | 6.04 | 55.00 | 8.00 | 6.5 | 110 |
| 0.20 | 0.20 | 10.83 | 3.60 | 53.49 | 6.10 | 30.00 | 8.00 | 6.5 | 110 |
| 0.30 | 0.30 | 16.00 | 5.30 | 53.10 | 6.12 | 20.00 | 8.00 | 6.5 | 110 |
| 0.40 | 0.41 | 21.68 | 7.16 | 52.90 | 6.12 | 14.00 | 8.00 | 6.5 | 110 |
| 0.50 | 0.52 | 27.54 | 9.08 | 52.82 | 6.12 | 10.00 | 8.00 | 6.5 | 110 |
| 0.75 | 0.76 | 40.14 | 13.20 | 52.83 | 6.11 | 7.20 | 5.20 | 6.5 | 110 |

Q(f) = 351 $f^{0.84}$ (based on Saguenay inversions, Silva et al., 1997)

Kappa = 0.020 sec

| Table 6<br><br>PROFILE DEPTH CATEGORIES | |
|---|---|
| Category (ft) | Depth Range (ft) |
| 125 | 80 - 180 |
| 250 | 180 - 400 |
| 500 | 400 - 750 |
| 1,000 | 750 - 1,500 |
| | |
| Base Cases | |
| Categories C and D | 100 - 1,000 |
| Category E | 100 - 650 |

Table 7: 5% RESPONE SPECTRA FOR NEHRP B FAULT CLASS A (**M** GE 7)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | Site Codes USGS | Filter Corners HP (hz) | Filter Corners LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU052 | .0 | --- | A | .00 | .00 | .448 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU052 | .0 | --- | A | .00 | .00 | .356 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU078 | .0 | --- | A | .00 | .00 | .307 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU078 | .0 | --- | A | .00 | .00 | .449 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU079 | .0 | --- | A | .00 | .00 | .425 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU079 | .0 | --- | A | .00 | .00 | .592 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU084 | .0 | --- | A | .00 | .00 | .431 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU084 | .0 | --- | A | .00 | .00 | 1.009 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU089 | .0 | --- | A | .00 | .00 | .229 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU089 | .0 | --- | A | .00 | .00 | .355 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU072 | .2 | --- | A | .00 | .00 | .378 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU072 | .2 | --- | A | .00 | .00 | .474 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU067 | .3 | --- | A | .00 | .00 | .319 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU067 | .3 | --- | A | .00 | .00 | .499 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU065 | .9 | --- | A | .00 | .00 | .574 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU065 | .9 | --- | A | .00 | .00 | .789 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU071 | 1.0 | --- | A | .00 | .00 | .651 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU071 | 1.0 | --- | A | .00 | .00 | .528 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 24 | Lucerne # | 1.1 | A-A | A | .00 | 60.00 | .727 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 24 | Lucerne # | 1.1 | A-A | A | .00 | 60.00 | .789 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU087 | 3.1 | --- | A | .00 | .00 | .114 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU087 | 3.1 | --- | A | .00 | .00 | .121 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY080 | 6.7 | --- | A | .00 | .00 | .859 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY080 | 6.7 | --- | A | .00 | .00 | .808 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89005 | Cape Mendocino # | 8.5 | IFA | A | .07 | 23.00 | 1.497 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89005 | Cape Mendocino # | 8.5 | IFA | A | .07 | 23.00 | 1.039 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | ALS | 12.2 | --- | A | .00 | .00 | .149 |

Table 7: 5% RESPONE SPECTRA FOR NEHRP B FAULT CLASS A (**M** GE 7) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | ALS | 12.2 | --- | A | .00 | .00 | .217 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY074 | 12.2 | --- | A | .00 | .00 | .160 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY074 | 12.2 | --- | A | .00 | .00 | .234 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU045 | 24.0 | --- | A | .00 | .00 | .522 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU045 | 24.0 | --- | A | .00 | .00 | .472 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU034 | 32.9 | --- | A | .00 | .00 | .105 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU034 | 32.9 | --- | A | .00 | .00 | .253 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU047 | 33.0 | --- | A | .00 | .00 | .407 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU047 | 33.0 | --- | A | .00 | .00 | .298 |
| 0143 | Duzce, Turkey | 1999 | 1112 | | 7.1 | ERD | 99999 | Mudurnu | 34.6 | --A | - | .08 | .00 | .123 |
| 0143 | Duzce, Turkey | 1999 | 1112 | | 7.1 | ERD | 99999 | Mudurnu | 34.6 | --A | - | .08 | .00 | .059 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY042 | 34.9 | --- | A | .00 | .00 | .066 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY042 | 34.9 | --- | A | .00 | .00 | .100 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY086 | 35.4 | --- | A | .00 | .00 | .206 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY086 | 35.4 | --- | A | .00 | .00 | .102 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | NST | 36.9 | --- | A | .00 | .00 | .398 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | NST | 36.9 | --- | A | .00 | .00 | .311 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA024 | 39.5 | --- | A | .00 | .00 | .025 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA024 | 39.5 | --- | A | .00 | .00 | .022 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | KAU054 | 39.6 | --- | A | .00 | .00 | .080 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | KAU054 | 39.6 | --- | A | .00 | .00 | .086 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 22161 | Twentynine Palms # | 41.9 | AGA | A | .12 | 23.00 | .080 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 22161 | Twentynine Palms # | 41.9 | AGA | A | .12 | 23.00 | .060 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA056 | 44.4 | --- | A | .00 | .00 | .108 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA056 | 44.4 | --- | A | .00 | .00 | .104 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY052 | 45.0 | --- | A | .00 | .00 | .154 |

Table 7: 5% RESPONE SPECTRA FOR NEHRP B FAULT CLASS A (**M** GE 7) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY052 | 45.0 | --- | A | .00 | .00 | .086 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY102 | 45.9 | --- | A | .00 | .00 | .050 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY102 | 45.9 | --- | A | .00 | .00 | .042 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY081 | 47.7 | --- | A | .00 | .00 | .045 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY081 | 47.7 | --- | A | .00 | .00 | .054 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY050 | 50.0 | --- | A | .00 | .00 | .067 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY050 | 50.0 | --- | A | .00 | .00 | .107 |

Table 8: 5% RESPONE SPECTRA FOR NEHRP B FAULT CLASS B (**M** 6.5 TO 6.99)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Site Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 279 | Pacoima Dam | .0 | AMB | A | .10 | 35.00 | 1.226 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 279 | Pacoima Dam | .0 | AMB | A | .50 | 35.00 | 1.160 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24207 | Pacoima Dam (downstr) # | .0 | AGA | A | .16 | 23.00 | .415 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24207 | Pacoima Dam (downstr) # | .0 | AGA | A | .16 | 23.00 | .434 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | Kobe University | .2 | --A | A | .10 | 30.00 | .290 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | Kobe University | .2 | --A | A | .10 | 30.00 | .310 |
| 0041 | Gazli, USSR | 1976 | 0517 | | 6.8 | | 9201 | Karakyr | 3.0 | AAA | - | .50 | 38.00 | .608 |
| 0041 | Gazli, USSR | 1976 | 0517 | | 6.8 | | 9201 | Karakyr | 3.0 | AAA | - | .50 | 38.00 | .718 |
| 0099 | Nahanni, Canada | 1985 | 1223 | | 6.8 | | 6097 | Site 1 | 6.0 | IZA | - | .05 | 62.00 | .978 |
| 0099 | Nahanni, Canada | 1985 | 1223 | | 6.8 | | 6097 | Site 1 | 6.0 | IZA | - | .05 | 62.00 | 1.096 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 16 | LGPC | 6.1 | --A | - | .10 | .00 | .563 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 16 | LGPC | 6.1 | --A | - | .10 | .00 | .605 |
| 0099 | Nahanni, Canada | 1985 | 1223 | | 6.8 | | 6098 | Site 2 | 8.0 | IZA | - | .10 | 62.00 | .489 |
| 0099 | Nahanni, Canada | 1985 | 1223 | | 6.8 | | 6098 | Site 2 | 8.0 | IZA | - | .05 | 62.00 | .323 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24207 | Pacoima Dam (upper left) # | 8.1 | IGA | A | .16 | 23.00 | 1.585 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24207 | Pacoima Dam (upper left) # | 8.1 | IGA | A | .16 | 23.00 | 1.285 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 13 | BRAN | 10.3 | --A | - | .10 | .00 | .453 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 13 | BRAN | 10.3 | --A | - | .10 | .00 | .501 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47379 | Gilroy Array #1 | 10.5 | IFA | A | .20 | 50.00 | .411 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47379 | Gilroy Array #1 | 10.5 | IFA | A | .20 | 50.00 | .473 |
| 0099 | Nahanni, Canada | 1985 | 1223 | | 6.8 | | 6099 | Site 3 | 16.0 | IZA | - | .10 | 62.00 | .148 |
| 0099 | Nahanni, Canada | 1985 | 1223 | | 6.8 | | 6099 | Site 3 | 16.0 | IZA | - | .05 | 62.00 | .139 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57217 | Coyote Lake Dam (SW Abut) | 21.8 | IFA | - | .10 | 31.00 | .151 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57217 | Coyote Lake Dam (SW Abut) | 21.8 | IFA | - | .10 | 33.00 | .484 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 266 | Pasadena - Old Seismo Lab | 21.9 | CGA | A | .50 | 35.00 | .089 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 266 | Pasadena - Old Seismo Lab | 21.9 | CGA | A | .50 | 35.00 | .202 |

Table 8: 5% RESPONE SPECTRA FOR NEHRP B FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90017 | LA - Wonderland Ave | 22.7 | --A | A | .13 | 30.00 | .112 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90017 | LA - Wonderland Ave | 22.7 | --A | A | .10 | 30.00 | .172 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 104 | Santa Anita Dam | 27.0 | IGA | - | .20 | 35.00 | .151 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 104 | Santa Anita Dam | 27.0 | IGA | - | .20 | 35.00 | .212 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 285 | Santa Felita Dam (Outlet) | 27.5 | ABA | - | .10 | 20.00 | .148 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 285 | Santa Felita Dam (Outlet) | 27.5 | ABA | - | .10 | 13.00 | .152 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 121 | Fairmont Dam | 29.1 | AGA | - | .50 | 35.00 | .071 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 121 | Fairmont Dam | 29.1 | AGA | - | .50 | 35.00 | .109 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1032 | Hollister - SAGO Vault | 29.9 | FGA | A | .10 | 32.00 | .036 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1032 | Hollister - SAGO Vault | 29.9 | FGA | A | .10 | 31.00 | .060 |
| 0121 | Spitak, Armenia | 1988 | 1207 | | 6.8 | | 12 | Gukasian | 30.0 | A-A | - | .50 | 25.00 | .199 |
| 0121 | Spitak, Armenia | 1988 | 1207 | | 6.8 | | 12 | Gukasian | 30.0 | A-A | - | .50 | 25.00 | .175 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24592 | LA - City Terrace # | 35.4 | IMA | - | .20 | 46.00 | .263 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24592 | LA - City Terrace # | 35.4 | IMA | - | .20 | 46.00 | .316 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24305 | Leona Valley #1 # | 37.7 | IGA | - | .20 | 23.00 | .089 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24305 | Leona Valley #1 # | 37.7 | IGA | - | .20 | 23.00 | .073 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24307 | Leona Valley #3 # | 37.8 | IGA | A | .20 | 23.00 | .084 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24307 | Leona Valley #3 # | 37.8 | IGA | A | .20 | 23.00 | .106 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24399 | Mt Wilson - CIT Seis Sta # | 37.8 | IGA | A | .08 | .00 | .234 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24399 | Mt Wilson - CIT Seis Sta # | 37.8 | IGA | A | .08 | .00 | .134 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90019 | San Gabriel - E Grand Ave | 39.5 | --A | A | .13 | 30.00 | .141 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90019 | San Gabriel - E Grand Ave | 39.5 | --A | A | .10 | 30.00 | .256 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47377 | Monterey City Hall | 42.7 | CGA | A | .20 | 28.00 | .073 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47377 | Monterey City Hall | 42.7 | CGA | A | .20 | 22.00 | .063 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24644 | Sandberg - Bald Mtn # | 43.4 | IGB | A | .12 | 46.00 | .091 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24644 | Sandberg - Bald Mtn # | 43.4 | IGB | A | .12 | 46.00 | .098 |

Table 8: 5% RESPONE SPECTRA FOR NEHRP B FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24310 | Antelope Buttes # | 48.4 | IGA | A | .12 | 23.00 | .046 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24310 | Antelope Buttes # | 48.4 | IGA | A | .12 | 23.00 | .068 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | Chihaya | 48.7 | --A | A | .05 | 40.00 | .093 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | Chihaya | 48.7 | --A | A | .08 | 40.00 | .108 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 23595 | Littlerock - Brainard Can # | 49.7 | IGA | A | .20 | 46.00 | .072 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 23595 | Littlerock - Brainard Can # | 49.7 | IGA | A | .20 | 46.00 | .060 |

Table 9: 5% RESPONE SPECTRA FOR NEHRP B FAULT CLASS C (**M** 5.75 TO 6.49)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Site Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57217 | Coyote Lake Dam (SW Abut) | .1 | IFA | - | .10 | 39.00 | .711 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57217 | Coyote Lake Dam (SW Abut) | .1 | IFA | - | .10 | 45.00 | 1.298 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90019 | San Gabriel - E Grand Ave # | 4.1 | --A | A | .35 | 25.00 | .304 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90019 | San Gabriel - E Grand Ave # | 4.1 | --A | A | .35 | 25.00 | .199 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1651 | Transmitter Hill | 4.5 | APA | - | .10 | 30.00 | .840 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1651 | Transmitter Hill | 4.5 | APA | - | .08 | 40.00 | 1.083 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1703 | Sulphur Baths (temp) | 5.5 | APA | - | .30 | 25.00 | .141 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1703 | Sulphur Baths (temp) | 5.5 | APA | - | .30 | 25.00 | .127 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5072 | Whitewater Trout Farm | 7.3 | AHC | A | .10 | 40.00 | .492 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5072 | Whitewater Trout Farm | 7.3 | AHC | A | .15 | 45.00 | .612 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1608 | Oil Fields Fire Station - FF | 7.4 | IPA | - | .20 | 30.00 | .219 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1608 | Oil Fields Fire Station - FF | 7.4 | IPA | - | .10 | 30.00 | .187 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1608 | Oil Fields Fire Station Pad | 7.4 | APA | - | .05 | 30.00 | .217 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1608 | Oil Fields Fire Station Pad | 7.4 | APA | - | .08 | 25.00 | .210 |
| 0001 | Helena, Montana | 1935 | 1031 | 1838 | 6.2 |  | 2022 | Carroll College | 8.0 | EZA | - | .20 | 15.00 | .150 |
| 0001 | Helena, Montana | 1935 | 1031 | 1838 | 6.2 |  | 2022 | Carroll College | 8.0 | EZA | - | .20 | 15.00 | .173 |
| 0036 | Oroville | 1975 | 0801 | 2020 | 6.0 | CDWR | 1051 | Oroville Seismograph Station | 8.0 | AJA | - | 1.00 | 10.00 | .092 |
| 0036 | Oroville | 1975 | 0801 | 2020 | 6.0 | CDWR | 1051 | Oroville Seismograph Station | 8.0 | AJA | - | 1.00 | 10.00 | .072 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1605 | Skunk Hollow | 9.2 | APA | - | .07 | 30.00 | .375 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1605 | Skunk Hollow | 9.2 | APA | - | .10 | 30.00 | .233 |
| 0056 | Mammoth Lakes | 1980 | 0525 | 1634 | 6.3 | CDMG | 54214 | Long Valley Dam (Upr L Abut) | 15.5 | IVA | - | .10 | 57.00 | .430 |
| 0056 | Mammoth Lakes | 1980 | 0525 | 1634 | 6.3 | CDMG | 54214 | Long Valley Dam (Upr L Abut) | 15.5 | IVA | - | .10 | 50.00 | .271 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 47379 | Gilroy Array #1 | 16.2 | IFA | A | .10 | 29.00 | .069 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 47379 | Gilroy Array #1 | 16.2 | IFA | A | .10 | 40.00 | .098 |
| 0060 | Mammoth Lakes | 1980 | 0526 | 1858 | 6.1 | CDMG | 54214 | Long Valley Dam (Upr L Abut) | 17.5 | IVA | - | .50 | 31.00 | .110 |
| 0060 | Mammoth Lakes | 1980 | 0526 | 1858 | 6.1 | CDMG | 54214 | Long Valley Dam (Upr L Abut) | 17.5 | IVA | - | .50 | 23.00 | .071 |

Table 9: 5% RESPONE SPECTRA FOR NEHRP B FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0104 | Chalfant Valley | 1986 | 0720 | 1429 | 5.9 | CDMG | 54424 | Bishop - Paradise Lodge | 18.4 | AVA | - | .11 | 30.00 | .046 |
| 0104 | Chalfant Valley | 1986 | 0720 | 1429 | 5.9 | CDMG | 54424 | Bishop - Paradise Lodge | 18.4 | AVA | - | .13 | 30.00 | .095 |
| 0058 | Mammoth Lakes | 1980 | 0525 | 1944 | 6.0 | CDMG | 54214 | Long Valley Dam (Downst) | 19.7 | IVA | - | .15 | 40.00 | .107 |
| 0058 | Mammoth Lakes | 1980 | 0525 | 1944 | 6.0 | CDMG | 54214 | Long Valley Dam (Downst) | 19.7 | IVA | - | .20 | 35.00 | .070 |
| 0058 | Mammoth Lakes | 1980 | 0525 | 1944 | 6.0 | CDMG | 54214 | Long Valley Dam (L Abut) | 19.7 | IVA | - | .35 | 50.00 | .104 |
| 0058 | Mammoth Lakes | 1980 | 0525 | 1944 | 6.0 | CDMG | 54214 | Long Valley Dam (L Abut) | 19.7 | IVA | - | .20 | 50.00 | .077 |
| 0058 | Mammoth Lakes | 1980 | 0525 | 1944 | 6.0 | CDMG | 54214 | Long Valley Dam (Upr L Abut) | 19.7 | IVA | - | .20 | 40.00 | .484 |
| 0058 | Mammoth Lakes | 1980 | 0525 | 1944 | 6.0 | CDMG | 54214 | Long Valley Dam (Upr L Abut) | 19.7 | IVA | - | .10 | 40.00 | .188 |
| 0061 | Mammoth Lakes | 1980 | 0527 | 1451 | 6.0 | CDMG | 54214 | Long Valley Dam (Upr L Abut) | 20.0 | IVA | - | .50 | 40.00 | .921 |
| 0061 | Mammoth Lakes | 1980 | 0527 | 1451 | 6.0 | CDMG | 54214 | Long Valley Dam (Upr L Abut) | 20.0 | IVA | - | .20 | 51.00 | .408 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24399 | Mt Wilson - CIT Seis Sta | 21.2 | IGA | A | .60 | 40.00 | .123 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24399 | Mt Wilson - CIT Seis Sta | 21.2 | IGA | A | .70 | 40.00 | .186 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54424 | Bishop - Paradise Lodge | 23.0 | AVA | - | .20 | 30.00 | .165 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54424 | Bishop - Paradise Lodge | 23.0 | AVA | - | .10 | 40.00 | .161 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90017 | LA - Wonderland Ave # | 24.6 | --A | A | .53 | 25.00 | .039 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90017 | LA - Wonderland Ave # | 24.6 | --A | A | .70 | 25.00 | .047 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36177 | Parkfield - Vineyard Cany 2E | 24.6 | IFA | - | .20 | 30.00 | .161 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12206 | Silent Valley - Poppet Flat | 25.8 | IGA | A | .50 | 47.00 | .139 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12206 | Silent Valley - Poppet Flat | 25.8 | IGA | A | .50 | 49.00 | .113 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 108 | Carbon Canyon Dam (L Abut) | 26.8 | AMA | - | .80 | 40.00 | .200 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 108 | Carbon Canyon Dam (L Abut) | 26.8 | AMA | - | .50 | 40.00 | .221 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 46175 | Slack Canyon | 27.7 | IGA | - | .20 | 21.00 | .166 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 46175 | Slack Canyon | 27.7 | IGA | - | .20 | 21.00 | .153 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36438 | Parkfield - Stone Corral 4E | 29.6 | IMA | - | .20 | 21.00 | .063 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36438 | Parkfield - Stone Corral 4E | 29.6 | IMA | - | .20 | 22.00 | .072 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36437 | Parkfield - Stone Corral 3E | 31.8 | IMA | - | .20 | 23.00 | .151 |

Table 9: 5% RESPONE SPECTRA FOR NEHRP B FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36437 | Parkfield - Stone Corral 3E | 31.8 | IMA | - | .20 | 30.00 | .106 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36176 | Parkfield - Vineyard Cany 3W | 32.3 | IPA | - | .20 | 30.00 | .098 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36176 | Parkfield - Vineyard Cany 3W | 32.3 | IPA | - | .20 | 30.00 | .137 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54214 | Long Valley Dam (Downst) | 33.4 | IVA | - | .10 | 40.00 | .095 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54214 | Long Valley Dam (Downst) | 33.4 | IVA | - | .10 | 40.00 | .056 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54214 | Long Valley Dam (L Abut) | 33.4 | IVA | - | .10 | 50.00 | .082 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54214 | Long Valley Dam (L Abut) | 33.4 | IVA | - | .10 | 50.00 | .074 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36422 | Parkfield - Stone Corral 2E | 34.4 | IMA | - | .20 | 25.00 | .061 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36422 | Parkfield - Stone Corral 2E | 34.4 | IMA | - | .20 | 30.00 | .095 |
| 0043 | Friuli, Italy | 1976 | 0915 | 0315 | 6.1 | | 8022 | San Rocco | 36.1 | ABA | - | .10 | 32.00 | .060 |
| 0043 | Friuli, Italy | 1976 | 0915 | 0315 | 6.1 | | 8022 | San Rocco | 36.1 | ABA | - | .10 | 33.00 | .134 |
| 0045 | Santa Barbara | 1978 | 0813 | | 6.0 | USGS | 106 | Cachuma Dam Toe | 36.6 | AAA | - | .10 | 36.00 | .072 |
| 0045 | Santa Barbara | 1978 | 0813 | | 6.0 | USGS | 106 | Cachuma Dam Toe | 36.6 | AAA | - | .20 | 30.00 | .034 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36450 | Parkfield - Cholame 3E | 38.4 | IMA | - | .20 | 23.00 | .044 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36450 | Parkfield - Cholame 3E | 38.4 | IMA | - | .20 | 22.00 | .056 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54101 | Tinemaha Res. Free Field | 40.6 | AVA | - | .50 | 30.00 | .037 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54101 | Tinemaha Res. Free Field | 40.6 | AVA | - | .50 | 30.00 | .037 |
| 0061 | Mammoth Lakes | 1980 | 0527 | 1451 | 6.0 | CDMG | 54424 | Bishop - Paradise Lodge | 43.7 | AVA | - | .20 | 40.00 | .091 |
| 0061 | Mammoth Lakes | 1980 | 0527 | 1451 | 6.0 | CDMG | 54424 | Bishop - Paradise Lodge | 43.7 | AVA | - | .20 | 40.00 | .114 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5230 | Santa Rosa Mountain | 43.8 | AGA | - | 1.50 | 60.00 | .102 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5230 | Santa Rosa Mountain | 43.8 | AGA | - | 1.50 | 60.00 | .103 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5224 | Anza - Red Mountain | 45.6 | AGA | A | .30 | 35.00 | .104 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5224 | Anza - Red Mountain | 45.6 | AGA | A | .60 | 40.00 | .129 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5160 | Anza Fire Station | 46.7 | AHC | A | .50 | 40.00 | .099 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5160 | Anza Fire Station | 46.7 | AHC | A | .60 | 30.00 | .067 |

Table 10: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS A (**M** GE 7)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Sakarya | 3.3 | --B | - | 1.20 | 40.00 | .415 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU103 | 4.0 | --- | B | .00 | .00 | .152 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU103 | 4.0 | --- | B | .00 | .00 | .130 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY028 | 7.3 | --- | B | .00 | .00 | .765 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY028 | 7.3 | --- | B | .00 | .00 | .636 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Izmit | 7.7 | --B | - | 1.50 | 30.00 | .174 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Izmit | 7.7 | --B | - | 2.40 | 30.00 | .229 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU120 | 8.1 | --- | B | .00 | .00 | .198 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU120 | 8.1 | --- | B | .00 | .00 | .227 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 22170 | Joshua Tree # | 11.3 | AGC | B | .07 | 23.00 | .274 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 22170 | Joshua Tree # | 11.3 | AGC | B | .07 | 23.00 | .284 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89324 | Rio Dell Overpass - FF # | 12.3 | APC | B | .07 | 23.00 | .385 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89324 | Rio Dell Overpass - FF # | 12.3 | APC | B | .07 | 23.00 | .549 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU109 | 13.0 | --- | B | .00 | .00 | .162 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU109 | 13.0 | --- | B | .00 | .00 | .152 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU104 | 13.6 | --- | B | .00 | .00 | .089 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU104 | 13.6 | --- | B | .00 | .00 | .103 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89486 | Fortuna - Fortuna Blvd # | 13.7 | IQD | B | .07 | 23.00 | .116 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89486 | Fortuna - Fortuna Blvd # | 13.7 | IQD | B | .07 | 23.00 | .114 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU048 | 14.3 | --- | B | .00 | .00 | .179 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU048 | 14.3 | --- | B | .00 | .00 | .119 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY029 | 15.2 | --- | B | .00 | .00 | .238 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY029 | 15.2 | --- | B | .00 | .00 | .289 |
| 0143 | Duzce, Turkey | 1999 | 1112 | | 7.1 | ERD | 99999 | Bolu | 16.0 | --B | - | .05 | .00 | .754 |
| 0143 | Duzce, Turkey | 1999 | 1112 | | 7.1 | ERD | 99999 | Bolu | 16.0 | --B | - | .05 | .00 | .822 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU039 | 16.7 | --- | B | .00 | .00 | .139 |

Table 10: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS A (**M** GE 7) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU039 | 16.7 | --- | B | .00 | .00 | .197 |
| 0046 | Tabas, Iran | 1978 | 0916 | | 7.4 | | 9102 | Dayhook | 17.0 | ABB | - | .10 | .00 | .328 |
| 0046 | Tabas, Iran | 1978 | 0916 | | 7.4 | | 9102 | Dayhook | 17.0 | ABB | - | .10 | .00 | .406 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Arcelik | 17.0 | --B | - | .80 | 70.00 | .211 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Arcelik | 17.0 | --B | - | .90 | 70.00 | .134 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Gebze | 17.0 | --B | - | .80 | 25.00 | .270 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Gebze | 17.0 | --B | - | 1.00 | 30.00 | .144 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 5071 | Morongo Valley | 17.7 | AHC | B | .00 | .00 | .188 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 5071 | Morongo Valley | 17.7 | AHC | B | .00 | .00 | .140 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU059 | 17.8 | --- | B | .00 | .00 | .165 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU059 | 17.8 | --- | B | .00 | .00 | .160 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY035 | 18.1 | --- | B | .00 | .00 | .249 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY035 | 18.1 | --- | B | .00 | .00 | .251 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU105 | 18.1 | --- | B | .00 | .00 | .126 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU105 | 18.1 | --- | B | .00 | .00 | .113 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU070 | 19.1 | --- | B | .00 | .00 | .160 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU070 | 19.1 | --- | B | .00 | .00 | .254 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU107 | 20.3 | --- | B | .00 | .00 | .147 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU107 | 20.3 | --- | B | .00 | .00 | .131 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 12149 | Desert Hot Springs # | 22.5 | AQD | B | .07 | 23.00 | .171 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 12149 | Desert Hot Springs # | 22.5 | AQD | B | .07 | 23.00 | .154 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 23 | Coolwater | 22.8 | --D | B | .10 | 30.00 | .283 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 23 | Coolwater | 22.8 | --D | B | .10 | 30.00 | .417 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU031 | 26.7 | --- | B | .00 | .00 | .125 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU031 | 26.7 | --- | B | .00 | .00 | .115 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 5070 | North Palm Springs | 27.7 | AHD | B | .00 | .00 | .136 |

Table 10: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS A (**M** GE 7) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 5070 | North Palm Springs | 27.7 | AHD | B | .00 | .00 | .134 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 100 | Mission Creek Fault | 27.8 | --- | B | .00 | .00 | .126 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 100 | Mission Creek Fault | 27.8 | --- | B | .05 | .00 | .125 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY046 | 29.4 | --- | B | .00 | .00 | .190 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY046 | 29.4 | --- | B | .00 | .00 | .146 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Iznik | 29.7 | --B | - | .20 | 25.00 | .094 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Iznik | 29.7 | --B | - | .20 | 25.00 | .125 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89530 | Shelter Cove Airport # | 32.6 | IFB | B | .50 | 23.00 | .229 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89530 | Shelter Cove Airport # | 32.6 | IFB | B | .50 | 23.00 | .189 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Goynuk | 35.5 | --B | - | .20 | 30.00 | .140 |
| 0141 | Kocaeli, Turkey | 1999 | 0817 | | 7.4 | ERD | 99999 | Goynuk | 35.5 | --B | - | .15 | 25.00 | .120 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89509 | Eureka - Myrtle & West # | 35.8 | IHD | B | .16 | 23.00 | .154 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89509 | Eureka - Myrtle & West # | 35.8 | IHD | B | .16 | 23.00 | .178 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 23559 | Barstow # | 37.7 | IQD | B | .07 | 23.00 | .132 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 23559 | Barstow # | 37.7 | IQD | B | .07 | 23.00 | .135 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA038 | 37.9 | --- | B | .00 | .00 | .058 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA038 | 37.9 | --- | B | .00 | .00 | .037 |
| 0012 | Kern County | 1952 | 0721 | 1153 | 7.4 | USGS | 1095 | Taft Lincoln School | 42.0 | FQD | B | .05 | 13.00 | .156 |
| 0012 | Kern County | 1952 | 0721 | 1153 | 7.4 | USGS | 1095 | Taft Lincoln School | 42.0 | FQD | B | .05 | 13.00 | .178 |
| 0143 | Duzce, Turkey | 1999 | 1112 | | 7.1 | ERD | 99999 | Sakarya | 42.7 | --B | - | .05 | 40.00 | .018 |
| 0143 | Duzce, Turkey | 1999 | 1112 | | 7.1 | ERD | 99999 | Sakarya | 42.7 | --B | - | .05 | 40.00 | .025 |

Table 11: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS B (**M** 6.5 TO 6.99)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57007 | Corralitos | .0 | APB | B | .20 | 40.00 | .644 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57007 | Corralitos | .0 | APB | B | .20 | 40.00 | .479 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 0655 | Jensen Filter Plant # | .0 | --D | B | .08 | .00 | .424 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 0655 | Jensen Filter Plant # | .0 | --D | B | .20 | .00 | .593 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 00000 | LA Dam | .0 | --- | B | .10 | .00 | .511 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 00000 | LA Dam | .0 | --- | B | .12 | .00 | .349 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 75 | Sylmar - Converter Sta East # | .0 | --D | B | .00 | .00 | .828 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 75 | Sylmar - Converter Sta East # | .0 | --D | B | .00 | .00 | .493 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 0637 | Sepulveda VA # | .4 | --D | B | .10 | .00 | .753 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 0637 | Sepulveda VA # | .4 | --D | B | .00 | .00 | .939 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | KJMA | .6 | --B | B | .05 | .00 | .821 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | KJMA | .6 | --B | B | .05 | .00 | .599 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 5051 | Parachute Test Site | .7 | AQD | B | .06 | 20.00 | .455 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 5051 | Parachute Test Site | .7 | AQD | B | .12 | 23.00 | .377 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24514 | Sylmar - Olive View Med FF # | 3.6 | AQD | B | .12 | 23.00 | .604 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24514 | Sylmar - Olive View Med FF # | 3.6 | AQD | B | .12 | 23.00 | .843 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 5108 | Santa Susana Ground # | 3.7 | --- | B | .20 | .00 | .279 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 5108 | Santa Susana Ground # | 3.7 | --- | B | .00 | .00 | .290 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 286 | Superstition Mtn. | 4.3 | AGA | B | .30 | 20.00 | .682 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 286 | Superstition Mtn. | 4.3 | AGA | B | .30 | 25.00 | .894 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90056 | Newhall - W Pico Canyon Rd. | 7.1 | --C | B | .05 | 30.00 | .455 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90056 | Newhall - W Pico Canyon Rd. | 7.1 | --C | B | .10 | 30.00 | .325 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24088 | Pacoima Kagel Canyon # | 8.1 | AMB | B | .14 | 23.00 | .301 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24088 | Pacoima Kagel Canyon # | 8.1 | AMB | B | .14 | 23.00 | .433 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90009 | N Hollywood - Coldwater Can | 8.3 | --C | B | .10 | 30.00 | .298 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90009 | N Hollywood - Coldwater Can | 8.3 | --C | B | .10 | 30.00 | .271 |

Table 11: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47006 | Gilroy - Gavilan Coll. | 10.9 | AFB | B | .20 | 45.00 | .357 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47006 | Gilroy - Gavilan Coll. | 10.9 | AFB | B | .20 | 35.00 | .325 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58065 | Saratoga - Aloha Ave | 11.7 | AQD | B | .10 | 38.00 | .512 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58065 | Saratoga - Aloha Ave | 11.7 | AQD | B | .10 | 50.00 | .324 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58235 | Saratoga - W Valley Coll. | 12.0 | AQD | B | .10 | 38.00 | .255 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58235 | Saratoga - W Valley Coll. | 12.0 | AQD | B | .10 | 49.00 | .332 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58135 | UCSC Lick Observatory | 12.5 | AKA | B | .20 | 40.00 | .450 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58135 | UCSC Lick Observatory | 12.5 | AKA | B | .20 | 40.00 | .395 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 5081 | Topanga - Fire Sta # | 12.6 | --- | B | .20 | .00 | .364 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 5081 | Topanga - Fire Sta # | 12.6 | --- | B | .30 | .00 | .266 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5051 | Parachute Test Site | 14.0 | AQD | B | .10 | 40.00 | .111 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5051 | Parachute Test Site | 14.0 | AQD | B | .10 | 40.00 | .204 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90058 | Sunland - Mt Gleason Ave | 14.7 | --C | B | .05 | 30.00 | .127 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90058 | Sunland - Mt Gleason Ave | 14.7 | --C | B | .05 | 30.00 | .157 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 638 | Brentwood V.A. Hospital | 16.3 | --D | B | .00 | .00 | .187 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 638 | Brentwood V.A. Hospital | 16.3 | --D | B | .00 | .00 | .165 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90059 | Burbank - Howard Rd. | 16.6 | --B | B | .10 | 30.00 | .120 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90059 | Burbank - Howard Rd. | 16.6 | --B | B | .10 | 30.00 | .163 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24688 | LA - UCLA Grounds | 16.8 | IQ- | B | .08 | 25.00 | .278 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24688 | LA - UCLA Grounds | 16.8 | IQ- | B | .08 | 25.00 | .474 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 128 | Lake Hughes #12 | 17.0 | AEB | B | .50 | 35.00 | .366 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 128 | Lake Hughes #12 | 17.0 | AEB | B | .50 | 35.00 | .283 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90049 | Pacific Palisades - Sunset | 17.1 | --B | B | .05 | 30.00 | .469 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90049 | Pacific Palisades - Sunset | 17.1 | --B | B | .05 | 30.00 | .197 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 15 | UCSC | 18.1 | --B | - | .10 | .00 | .309 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 15 | UCSC | 18.1 | --B | - | .10 | .00 | .396 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 126 | Lake Hughes #4 | 19.6 | IGA | B | .50 | 35.00 | .192 |

Table 11: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 24278 | Castaic - Old Ridge Route | 24.2 | A-B | B | .50 | 35.00 | .324 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 24278 | Castaic - Old Ridge Route | 24.2 | A-B | B | .50 | 35.00 | .268 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24607 | Lake Hughes #12A # | 24.8 | IHC | B | .12 | 46.00 | .174 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24607 | Lake Hughes #12A # | 24.8 | IHC | B | .12 | 46.00 | .257 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24278 | Castaic - Old Ridge Route # | 25.4 | AMB | B | .12 | 23.00 | .568 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24278 | Castaic - Old Ridge Route # | 25.4 | AMB | B | .12 | 23.00 | .514 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 80053 | Pasadena - CIT Athenaeum | 25.7 | CQD | B | .50 | 35.00 | .088 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 80053 | Pasadena - CIT Athenaeum | 25.7 | CQD | B | .20 | 35.00 | .110 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90018 | Hollywood - Willoughby Ave | 25.7 | --D | B | .10 | 30.00 | .136 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90018 | Hollywood - Willoughby Ave | 25.7 | --D | B | .13 | 30.00 | .245 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 286 | Superstition Mtn Camera | 26.0 | AGA | B | .10 | 40.00 | .109 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 286 | Superstition Mtn Camera | 26.0 | AGA | B | .10 | 40.00 | .195 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24157 | LA - Baldwin Hills # | 26.2 | IPB | B | .16 | 23.00 | .239 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24157 | LA - Baldwin Hills # | 26.2 | IPB | B | .16 | 23.00 | .168 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24396 | Malibu - Point Dume Sch # | 27.4 | AMB | B | .30 | 23.00 | .130 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24396 | Malibu - Point Dume Sch # | 27.4 | AMB | B | .30 | 23.00 | .084 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90047 | Playa Del Rey - Saran | 27.9 | --D | B | .10 | 30.00 | .136 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90047 | Playa Del Rey - Saran | 27.9 | --D | B | .10 | 30.00 | .076 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 262 | Palmdale Fire Station | 28.6 | AQD | B | .50 | 35.00 | .121 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 262 | Palmdale Fire Station | 28.6 | AQD | B | .50 | 35.00 | .151 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 127 | Lake Hughes #9 # | 28.9 | AGA | B | .08 | .00 | .165 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 127 | Lake Hughes #9 # | 28.9 | AGA | B | .08 | .00 | .217 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90021 | LA - N Westmoreland | 29.0 | --D | B | .20 | 30.00 | .401 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90021 | LA - N Westmoreland | 29.0 | --D | B | .20 | 30.00 | .361 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24611 | LA - Temple & Hope # | 29.5 | IMA | B | .20 | 46.00 | .126 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24611 | LA - Temple & Hope # | 29.5 | IMA | B | .20 | 46.00 | .184 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90065 | Glendora - N Oakbank | 30.9 | --D | B | .50 | 30.00 | .040 |

Table 11: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90065 | Glendora - N Oakbank | 30.9 | --D | B | .10 | 30.00 | .092 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90020 | LA - W 15th St | 32.4 | --C | B | .13 | 30.00 | .104 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90020 | LA - W 15th St | 32.4 | --C | B | .13 | 30.00 | .159 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90033 | LA - Cypress Ave | 32.8 | --C | B | .20 | 30.00 | .210 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90033 | LA - Cypress Ave | 32.8 | --C | B | .13 | 30.00 | .149 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24605 | LA - Univ. Hospital # | 32.8 | IMA | B | .20 | 46.00 | .493 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24605 | LA - Univ. Hospital # | 32.8 | IMA | B | .20 | 46.00 | .214 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24469 | Lake Hughes #4 - Camp Mend # | 33.2 | IGA | B | .12 | 23.00 | .057 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24469 | Lake Hughes #4 - Camp Mend # | 33.2 | IGA | B | .12 | 23.00 | .084 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90032 | LA - N Figueroa St | 33.4 | --C | B | .30 | 30.00 | .128 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90032 | LA - N Figueroa St | 33.4 | --C | B | .30 | 30.00 | .174 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47189 | SAGO South - Surface | 34.1 | IGB | B | .10 | 25.00 | .073 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47189 | SAGO South - Surface | 34.1 | IGB | B | .10 | 30.00 | .067 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24523 | Lake Hughes #4B - Camp Mend # | 34.1 | IGA | B | .12 | 23.00 | .036 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24523 | Lake Hughes #4B - Camp Mend # | 34.1 | IGA | B | .12 | 23.00 | .063 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1601 | Palo Alto - SLAC Lab | 35.0 | AMA | B | .20 | 33.00 | .194 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1601 | Palo Alto - SLAC Lab | 35.0 | AMA | B | .20 | 28.00 | .278 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24401 | San Marino - SW Academy # | 35.2 | AQD | B | .30 | 23.00 | .116 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24401 | San Marino - SW Academy # | 35.2 | AQD | B | .60 | 23.00 | .150 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24400 | LA - Obregon Park # | 35.9 | AQD | B | .60 | 23.00 | .355 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24400 | LA - Obregon Park # | 35.9 | AQD | B | .90 | 23.00 | .563 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24461 | Alhambra - Fremont School | 36.1 | AMD | B | .12 | 25.00 | .101 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24461 | Alhambra - Fremont School | 36.1 | AMD | B | .12 | 25.00 | .079 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 269 | Pearblossom Pump | 37.4 | AGB | B | .20 | 35.00 | .102 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 269 | Pearblossom Pump | 37.4 | AGB | B | .20 | 35.00 | .136 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24271 | Lake Hughes #1 # | 37.7 | APC | B | .12 | 23.00 | .087 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24271 | Lake Hughes #1 # | 37.7 | APC | B | .12 | 23.00 | .077 |

Table 11: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Site Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0040 | Friuli, Italy | 1976 | 0506 | 2000 | 6.5 | | 8012 | Tolmezzo | 37.7 | ABB | - | .10 | 30.00 | .351 |
| 0040 | Friuli, Italy | 1976 | 0506 | 2000 | 6.5 | | 8012 | Tolmezzo | 37.7 | ABB | - | .10 | 30.00 | .315 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58127 | Woodside | 38.7 | APB | B | .10 | 25.00 | .080 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58127 | Woodside | 38.7 | APB | B | .10 | 25.00 | .082 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 14403 | LA - 116th St School # | 38.9 | AQD | B | .16 | 23.00 | .208 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 14403 | LA - 116th St School # | 38.9 | AQD | B | .16 | 23.00 | .133 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 14196 | Inglewood - Union Oil # | 40.0 | IQD | B | .16 | 23.00 | .091 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 14196 | Inglewood - Union Oil # | 40.0 | IQD | B | .16 | 23.00 | .101 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57064 | Fremont - Mission San Jose | 42.0 | AMB | B | .20 | 24.00 | .124 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57064 | Fremont - Mission San Jose | 42.0 | AMB | B | .20 | 28.00 | .106 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1161 | APEEL 9 - Crystal Springs Res | 46.4 | IQA | B | .20 | 40.00 | .113 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1161 | APEEL 9 - Crystal Springs Res | 46.4 | IQA | B | .20 | 40.00 | .104 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58378 | APEEL 7 - Pulgas | 46.5 | IEA | B | .10 | 30.00 | .156 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58378 | APEEL 7 - Pulgas | 46.5 | IEA | B | .10 | 22.00 | .088 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58373 | APEEL 10 - Skyline | 46.6 | I-A | B | .10 | 25.00 | .103 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58373 | APEEL 10 - Skyline | 46.6 | I-A | B | .10 | 20.00 | .088 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 14405 | Rolling Hills Est-Rancho Vista | 48.4 | AP- | B | .15 | 25.00 | .116 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 14405 | Rolling Hills Est-Rancho Vista | 48.4 | AP- | B | .15 | 25.00 | .106 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58262 | Belmont - Envirotech | 48.7 | BFA | B | .20 | 22.00 | .108 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58262 | Belmont - Envirotech | 48.7 | BFA | B | .20 | 30.00 | .110 |
| 0040 | Friuli, Italy | 1976 | 0506 | 2000 | 6.5 | | 8002 | Barcis | 49.7 | ABB | - | .20 | 30.00 | .029 |
| 0040 | Friuli, Italy | 1976 | 0506 | 2000 | 6.5 | | 8002 | Barcis | 49.7 | ABB | - | .20 | 30.00 | .030 |

Table 12: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS C (**M** 5.75 TO 6.49)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Site Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0045 | Santa Barbara | 1978 | 0813 | | 6.0 | USGS | 283 | Santa Barbara Courthouse | .0 | CQD | B | .10 | 26.00 | .102 |
| 0045 | Santa Barbara | 1978 | 0813 | | 6.0 | USGS | 283 | Santa Barbara Courthouse | .0 | CQD | B | .10 | 30.00 | .203 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1604 | Oil City | 1.8 | APB | - | .15 | 30.00 | .866 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1604 | Oil City | 1.8 | APB | - | .80 | 30.00 | .447 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1652 | Anderson Dam (Downstream) | 2.6 | AFD | B | .10 | 30.00 | .423 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1652 | Anderson Dam (Downstream) | 2.6 | AFD | B | .10 | 38.00 | .289 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12149 | Desert Hot Springs | 8.0 | AQD | B | .50 | 46.00 | .331 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12149 | Desert Hot Springs | 8.0 | AQD | B | .50 | 40.00 | .271 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90033 | LA - Cypress Ave # | 8.1 | --C | B | .33 | 25.00 | .156 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90033 | LA - Cypress Ave # | 8.1 | --C | B | .28 | 25.00 | .137 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90032 | LA - N Figueroa St # | 8.1 | --C | B | .30 | 25.00 | .151 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90032 | LA - N Figueroa St # | 8.1 | --C | B | .20 | 25.00 | .166 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5070 | North Palm Springs | 8.2 | AHD | B | .15 | 20.00 | .594 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5070 | North Palm Springs | 8.2 | AHD | B | .23 | 30.00 | .694 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1609 | Palmer Ave | 9.2 | APB | - | .06 | 20.00 | .272 |
| 0080 | Coalinga | 1983 | 0722 | 0239 | 5.8 | USGS | 1609 | Palmer Ave | 9.2 | APB | - | .09 | 20.00 | .290 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5071 | Morongo Valley | 10.1 | AHC | B | .08 | 50.00 | .218 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5071 | Morongo Valley | 10.1 | AHC | B | .08 | 50.00 | .205 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24461 | Alhambra - Fremont School | 10.5 | AMD | B | .50 | 35.00 | .333 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24461 | Alhambra - Fremont School | 10.5 | AMD | B | .30 | 40.00 | .414 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24400 | LA - Obregon Park | 11.4 | AQD | B | .40 | 35.00 | .450 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24400 | LA - Obregon Park | 11.4 | AQD | B | .40 | 35.00 | .400 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57383 | Gilroy Array #6 | 11.8 | IKB | B | .10 | 35.00 | .222 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57383 | Gilroy Array #6 | 11.8 | IKB | B | .10 | 27.00 | .292 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 709 | Garvey Res. - Control Bldg | 12.1 | APB | - | .15 | 40.00 | .384 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 709 | Garvey Res. - Control Bldg | 12.1 | APB | - | .20 | 40.00 | .457 |
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 1265 | Del Valle Dam (Toe) | 12.9 | ABB | - | .10 | 25.00 | .125 |

Table 12: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 1265 | Del Valle Dam (Toe) | 12.9 | ABB | - | .15 | 20.00 | .229 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24401 | San Marino - SW Academy | 14.7 | AQD | B | .40 | 40.00 | .128 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24401 | San Marino - SW Academy | 14.7 | AQD | B | .40 | 40.00 | .204 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 80053 | Pasadena - CIT Athenaeum | 15.4 | CQD | B | .30 | 40.00 | .174 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 80053 | Pasadena - CIT Athenaeum | 15.4 | CQD | B | .30 | 35.00 | .101 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5069 | Fun Valley | 15.8 | AHC | B | .21 | 35.00 | .129 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5069 | Fun Valley | 15.8 | AHC | B | .25 | 40.00 | .119 |
| 0025 | Parkfield | 1966 | 0628 | 0426 | 6.1 | CDMG | 1438 | Temblor pre-1969 | 16.1 | IJA | B | .20 | 14.00 | .357 |
| 0025 | Parkfield | 1966 | 0628 | 0426 | 6.1 | CDMG | 1438 | Temblor pre-1969 | 16.1 | IJA | B | .20 | 15.00 | .272 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 47006 | Gilroy - Gavilan Coll. | 16.2 | AFB | B | .10 | 30.00 | .114 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 47006 | Gilroy - Gavilan Coll. | 16.2 | AFB | B | .10 | 30.00 | .095 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90021 | LA - N Westmoreland # | 16.6 | --D | B | .30 | 25.00 | .214 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90021 | LA - N Westmoreland # | 16.6 | --D | B | .30 | 25.00 | .199 |
| 0025 | Parkfield | 1966 | 0628 | 0426 | 6.1 | CDMG | 1016 | Cholame #12 | 17.3 | IBB | B | .20 | 20.00 | .059 |
| 0025 | Parkfield | 1966 | 0628 | 0426 | 6.1 | CDMG | 1016 | Cholame #12 | 17.3 | IBB | B | .20 | 20.00 | .063 |
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 67070 | Antioch - 510 G St | 20.8 | ACD | B | .20 | 13.00 | .051 |
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 67070 | Antioch - 510 G St | 20.8 | ACD | B | .20 | 13.00 | .023 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 14403 | LA - 116th St School | 22.5 | AQD | B | .20 | 30.00 | .294 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 14403 | LA - 116th St School | 22.5 | AQD | B | .20 | 30.00 | .396 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57007 | Corralitos | 22.7 | APB | B | .20 | 24.00 | .081 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57007 | Corralitos | 22.7 | APB | B | .20 | 26.00 | .109 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 697 | Orange Co. Reservoir | 23.0 | APB | - | .40 | 30.00 | .185 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 697 | Orange Co. Reservoir | 23.0 | APB | - | .30 | 30.00 | .198 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 951 | Brea Dam (L Abut) | 23.3 | IPB | - | .50 | 40.00 | .118 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 951 | Brea Dam (L Abut) | 23.3 | IPB | - | .50 | 30.00 | .149 |

Table 12: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Site Dist (km) | Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0073 | Westmorland | 1981 | 0426 | 1209 | 5.8 | USGS | 5051 | Parachute Test Site | 24.1 | AQD | B | .10 | 30.00 | .242 |
| 0073 | Westmorland | 1981 | 0426 | 1209 | 5.8 | USGS | 5051 | Parachute Test Site | 24.1 | AQD | B | .10 | 33.00 | .155 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 14196 | Inglewood - Union Oil | 25.2 | IQD | B | .60 | 40.00 | .299 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 14196 | Inglewood - Union Oil | 25.2 | IQD | B | .25 | 40.00 | .247 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90061 | Big Tujunga, Angeles Nat F # | 25.5 | --C | B | .40 | 25.00 | .126 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90061 | Big Tujunga, Angeles Nat F # | 25.5 | --C | B | .90 | 25.00 | .178 |
| 0104 | Chalfant Valley | 1986 | 0720 | 1429 | 5.9 | CDMG | 54T03 | Lake Crowley - Shehorn Res. | 26.0 | AAB | - | .16 | 30.00 | .051 |
| 0104 | Chalfant Valley | 1986 | 0720 | 1429 | 5.9 | CDMG | 54T03 | Lake Crowley - Shehorn Res. | 26.0 | AAB | - | .16 | 25.00 | .031 |
| 0073 | Westmorland | 1981 | 0426 | 1209 | 5.8 | USGS | 286 | Superstition Mtn Camera | 26.5 | AGA | B | .70 | 30.00 | .071 |
| 0073 | Westmorland | 1981 | 0426 | 1209 | 5.8 | USGS | 286 | Superstition Mtn Camera | 26.5 | AGA | B | .70 | 30.00 | .116 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90014 | Beverly Hills - 12520 Mulhol # | 27.2 | --C | B | .35 | 25.00 | .089 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90014 | Beverly Hills - 12520 Mulhol # | 27.2 | --C | B | .33 | 22.00 | .138 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90058 | Sunland - Mt Gleason Ave # | 27.5 | --C | B | .28 | 25.00 | .089 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90058 | Sunland - Mt Gleason Ave # | 27.5 | --C | B | .28 | 25.00 | .072 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36453 | Parkfield - Fault Zone 11 | 28.4 | IMB | - | .20 | 21.00 | .097 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36453 | Parkfield - Fault Zone 11 | 28.4 | IMB | - | .20 | 28.00 | .087 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90008 | Sun Valley - Sunland # | 29.3 | --B | B | .30 | 25.00 | .075 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90008 | Sun Valley - Sunland # | 29.3 | --B | B | .38 | 25.00 | .074 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36449 | Parkfield - Fault Zone 8 | 29.6 | IMB | - | .20 | 21.00 | .131 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36449 | Parkfield - Fault Zone 8 | 29.6 | IMB | - | .20 | 27.00 | .116 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 22170 | Joshua Tree | 29.8 | AGC | B | .50 | 30.00 | .052 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 22170 | Joshua Tree | 29.8 | AGC | B | .50 | 24.00 | .065 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36445 | Parkfield - Fault Zone 15 | 29.9 | IQB | - | .20 | 20.00 | .168 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36445 | Parkfield - Fault Zone 15 | 29.9 | IQB | - | .20 | 22.00 | .117 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90090 | Villa Park - Serrano Ave # | 30.1 | --B | B | .70 | 25.00 | .046 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90090 | Villa Park - Serrano Ave # | 30.1 | --B | B | .55 | 25.00 | .072 |

Table 12: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1377 | San Juan Bautista, 24 Polk St | 30.3 | AQD | B | .10 | 21.00 | .044 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1377 | San Juan Bautista, 24 Polk St | 30.3 | AQD | B | .10 | 21.00 | .036 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90009 | N Hollywood - Coldwater Can # | 30.8 | --C | B | .20 | 25.00 | .116 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90009 | N Hollywood - Coldwater Can # | 30.8 | --C | B | .30 | 25.00 | .250 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57064 | Fremont - Mission San Jose | 31.4 | AMB | B | .50 | 21.00 | .025 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57064 | Fremont - Mission San Jose | 31.4 | AMB | B | .20 | 18.00 | .021 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36443 | Parkfield - Fault Zone 9 | 31.9 | IPB | - | .20 | 23.00 | .057 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36443 | Parkfield - Fault Zone 9 | 31.9 | IPB | - | .20 | 28.00 | .050 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12204 | San Jacinto - Soboba | 32.0 | AGC | B | .50 | 48.00 | .250 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12204 | San Jacinto - Soboba | 32.0 | AGC | B | .50 | 49.00 | .239 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90015 | LA - Chalon Rd # | 32.6 | --B | B | .38 | 25.00 | .036 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90015 | LA - Chalon Rd # | 32.6 | --B | B | .75 | 25.00 | .020 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90048 | Santa Monica - Second St # | 32.6 | --B | B | .53 | 25.00 | .033 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90048 | Santa Monica - Second St # | 32.6 | --B | B | .28 | 25.00 | .034 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90006 | Sun Valley - Roscoe Blvd # | 32.6 | --D | B | .25 | 25.00 | .202 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90006 | Sun Valley - Roscoe Blvd # | 32.6 | --D | B | .28 | 25.00 | .223 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36454 | Parkfield - Fault Zone 6 | 32.8 | IPB | - | .20 | 24.00 | .055 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36454 | Parkfield - Fault Zone 6 | 32.8 | IPB | - | .20 | 24.00 | .056 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90007 | Panorama City - Roscoe # | 33.0 | --D | B | .25 | 23.00 | .105 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90007 | Panorama City - Roscoe # | 33.0 | --D | B | .20 | 25.00 | .108 |
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 57064 | Fremont - Mission San Jose | 33.1 | AMB | B | .30 | 13.00 | .044 |
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 57064 | Fremont - Mission San Jose | 33.1 | AMB | B | .30 | 20.00 | .055 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90005 | Pacoima Kagel Canyon USC # | 34.0 | --D | B | .30 | 25.00 | .119 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90005 | Pacoima Kagel Canyon USC # | 34.0 | --D | B | .23 | 25.00 | .133 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36414 | Parkfield - Fault Zone 4 | 34.3 | IPB | - | .20 | 22.00 | .067 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36414 | Parkfield - Fault Zone 4 | 34.3 | IPB | - | .20 | 28.00 | .120 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36446 | Parkfield - Vineyard Cany 4W | 34.6 | IMB | - | .20 | 30.00 | .064 |

Table 12: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36446 | Parkfield - Vineyard Cany 4W | 34.6 | IMB | - | .20 | 27.00 | .046 |
| 0064 | Victoria, Mexico | 1980 | 0609 | 0328 | 6.1 | UNAMUCSD | 6604 | Cerro Prieto | 34.8 | AVA | B | .20 | 62.00 | .621 |
| 0064 | Victoria, Mexico | 1980 | 0609 | 0328 | 6.1 | UNAMUCSD | 6604 | Cerro Prieto | 34.8 | AVA | B | .20 | 62.00 | .587 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5043 | Hurkey Creek Park | 34.9 | AQB | B | .60 | 50.00 | .240 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5043 | Hurkey Creek Park | 34.9 | AQB | B | .50 | 50.00 | .187 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5157 | Cranston Forest Station | 35.3 | AQB | B | .60 | 45.00 | .153 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 5157 | Cranston Forest Station | 35.3 | AQB | B | .60 | 45.00 | .169 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54T03 | Lake Crowley - Shehorn Res. | 36.0 | AAB | - | .50 | 30.00 | .163 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 54T03 | Lake Crowley - Shehorn Res. | 36.0 | AAB | - | .50 | 30.00 | .091 |
| 0043 | Friuli, Italy | 1976 | 0915 | 0315 | 6.1 |  | 8014 | Forgaria Cornino | 36.1 | ABB | B | .50 | 40.00 | .260 |
| 0043 | Friuli, Italy | 1976 | 0915 | 0315 | 6.1 |  | 8014 | Forgaria Cornino | 36.1 | ABB | B | .20 | 42.00 | .212 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36416 | Parkfield - Gold Hill 2W | 36.6 | IPB | - | .20 | 21.00 | .083 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36416 | Parkfield - Gold Hill 2W | 36.6 | IPB | - | .20 | 20.00 | .074 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36440 | Parkfield - Vineyard Cany 5W | 37.1 | IHB | - | .20 | 21.00 | .062 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90044 | Rancho Palos Verdes - Luconia # | 37.7 | --C | B | .45 | 21.00 | .021 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90044 | Rancho Palos Verdes - Luconia # | 37.7 | --C | B | .53 | 25.00 | .021 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24088 | Pacoima Kagel Canyon | 37.9 | AMB | B | .35 | 20.00 | .166 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24088 | Pacoima Kagel Canyon | 37.9 | AMB | B | .45 | 20.00 | .164 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 13122 | Featherly Park - Maint | 38.6 | AMC | B | .80 | 25.00 | .071 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 13122 | Featherly Park - Maint | 38.6 | AMC | B | .90 | 25.00 | .087 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90001 | Sylmar - Sayre St # | 38.6 | --D | B | .25 | 25.00 | .051 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90001 | Sylmar - Sayre St # | 38.6 | --D | B | .28 | 25.00 | .046 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36420 | Parkfield - Gold Hill 3W | 38.8 | IPB | - | .20 | 30.00 | .137 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36420 | Parkfield - Gold Hill 3W | 38.8 | IPB | - | .20 | 30.00 | .122 |
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 58219 | APEEL 3E Hayward CSUH | 40.3 | AVA | B | .20 | 25.00 | .072 |
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 58219 | APEEL 3E Hayward CSUH | 40.3 | AVA | B | .20 | 25.00 | .057 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36230 | Parkfield - Cholame 2E | 40.5 | IJB | - | .50 | 23.00 | .026 |

Table 12: 5% RESPONE SPECTRA FOR NEHRP C FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Site Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36230 | Parkfield - Cholame 2E | 40.5 | IJB | - | .20 | 22.00 | .037 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36433 | Parkfield - Gold Hill 4W | 41.0 | IPB | - | .20 | 31.00 | .056 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36433 | Parkfield - Gold Hill 4W | 41.0 | IPB | - | .20 | 30.00 | .097 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36434 | Parkfield - Gold Hill 5W | 43.7 | IPB | - | .20 | 26.00 | .073 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36434 | Parkfield - Gold Hill 5W | 43.7 | IPB | - | .20 | 30.00 | .054 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 58135 | UCSC Lick Observatory | 44.1 | AKA | B | .50 | 21.00 | .039 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 58135 | UCSC Lick Observatory | 44.1 | AKA | B | .50 | 22.00 | .076 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 23497 | Rancho Cucamonga - Law & J | 44.3 | IHD | B | .60 | 50.00 | .060 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 23497 | Rancho Cucamonga - Law & J | 44.3 | IHD | B | .60 | 50.00 | .050 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90050 | Malibu - Las Flores Canyon # | 46.3 | --B | B | .65 | 25.00 | .065 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90050 | Malibu - Las Flores Canyon # | 46.3 | --B | B | .65 | 25.00 | .055 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24514 | Sylmar - Olive View Med FF | 47.7 | AQD | B | .35 | 20.00 | .065 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24514 | Sylmar - Olive View Med FF | 47.7 | AQD | B | .40 | 20.00 | .055 |

Table 13: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS A (**M** GE 7)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | Site Codes USGS | Filter Corners HP (hz) | Filter Corners LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89156 | Petrolia # | .0 | IMD | C | .07 | 23.00 | .590 |
| 0127 | Cape Mendocino | 1992 | 0425 | 1806 | 7.1 | CDMG | 89156 | Petrolia # | .0 | IMD | C | .07 | 23.00 | .662 |
| 0046 | Tabas, Iran | 1978 | 0916 | | 7.4 | | 9101 | Tabas | .0 | ABC | - | .05 | .00 | .836 |
| 0046 | Tabas, Iran | 1978 | 0916 | | 7.4 | | 9101 | Tabas | .0 | ABC | - | .05 | .00 | .852 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU074 | .3 | --- | C | .00 | .00 | .375 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU074 | .3 | --- | C | .00 | .00 | .598 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU068 | .5 | --- | C | .00 | .00 | .369 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU068 | .5 | --- | C | .00 | .00 | .512 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU129 | 1.1 | --- | C | .00 | .00 | .623 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU129 | 1.1 | --- | C | .00 | .00 | 1.003 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | WNT | 1.1 | --- | C | .00 | .00 | .614 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | WNT | 1.1 | --- | C | .00 | .00 | .939 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU075 | 1.4 | --- | C | .00 | .00 | .262 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU075 | 1.4 | --- | C | .00 | .00 | .331 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU102 | 1.7 | --- | C | .00 | .00 | .172 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU102 | 1.7 | --- | C | .00 | .00 | .304 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU076 | 1.9 | --- | C | .00 | .00 | .428 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU076 | 1.9 | --- | C | .00 | .00 | .347 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU101 | 2.9 | --- | C | .00 | .00 | .259 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU101 | 2.9 | --- | C | .00 | .00 | .212 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU049 | 4.4 | --- | C | .00 | .00 | .247 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU049 | 4.4 | --- | C | .00 | .00 | .278 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU082 | 5.7 | --- | C | .00 | .00 | .187 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU082 | 5.7 | --- | C | .00 | .00 | .225 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU | 5.7 | --- | C | .00 | .00 | .191 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU | 5.7 | --- | C | .00 | .00 | .205 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU054 | 5.9 | --- | C | .00 | .00 | .194 |

Table 13: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS A (**M** GE 7) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | Site Codes USGS | Filter Corners HP (hz) | Filter Corners LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU054 | 5.9 | --- | C | .00 | .00 | .146 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU053 | 6.6 | --- | C | .00 | .00 | .134 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU053 | 6.6 | --- | C | .00 | .00 | .226 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU055 | 6.8 | --- | C | .00 | .00 | .212 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU055 | 6.8 | --- | C | .00 | .00 | .262 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU051 | 8.2 | --- | C | .00 | .00 | .236 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU051 | 8.2 | --- | C | .00 | .00 | .160 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU136 | 8.9 | --- | C | .00 | .00 | .174 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU136 | 8.9 | --- | C | .00 | .00 | .170 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY024 | 9.0 | --- | C | .00 | .00 | .165 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY024 | 9.0 | --- | C | .00 | .00 | .281 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU122 | 9.0 | --- | C | .00 | .00 | .261 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU122 | 9.0 | --- | C | .00 | .00 | .211 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU060 | 9.4 | --- | C | .00 | .00 | .103 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU060 | 9.4 | --- | C | .00 | .00 | .201 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | NSY | 9.7 | --- | C | .00 | .00 | .118 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | NSY | 9.7 | --- | C | .00 | .00 | .121 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU128 | 9.7 | --- | C | .00 | .00 | .166 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU128 | 9.7 | --- | C | .00 | .00 | .144 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU138 | 10.1 | --- | C | .00 | .00 | .211 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU138 | 10.1 | --- | C | .00 | .00 | .206 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU050 | 10.3 | --- | C | .00 | .00 | .131 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU050 | 10.3 | --- | C | .00 | .00 | .146 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU063 | 10.3 | --- | C | .00 | .00 | .133 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU063 | 10.3 | --- | C | .00 | .00 | .183 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY101 | 11.1 | --- | C | .00 | .00 | .398 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY101 | 11.1 | --- | C | .00 | .00 | .340 |

Table 13: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS A (**M** GE 7) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | Site Codes USGS | Filter Corners HP (hz) | Filter Corners LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU056 | 11.1 | --- | C | .00 | .00 | .143 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU056 | 11.1 | --- | C | .00 | .00 | .157 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | WGK | 11.1 | --- | C | .00 | .00 | .455 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | WGK | 11.1 | --- | C | .00 | .00 | .345 |
| 0006 | Imperial Valley | 1940 | 0519 | 0437 | 7.0 | USGS | 117 | El Centro Array #9 | 12.0 | EQD | C | .20 | 15.00 | .313 |
| 0006 | Imperial Valley | 1940 | 0519 | 0437 | 7.0 | USGS | 117 | El Centro Array #9 | 12.0 | EQD | C | .20 | 15.00 | .215 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU100 | 12.1 | --- | C | .00 | .00 | .113 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU100 | 12.1 | --- | C | .00 | .00 | .110 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU057 | 12.5 | --- | C | .00 | .00 | .102 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU057 | 12.5 | --- | C | .00 | .00 | .113 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU046 | 14.3 | --- | C | .00 | .00 | .118 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU046 | 14.3 | --- | C | .00 | .00 | .143 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY006 | 14.9 | --- | C | .00 | .00 | .358 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY006 | 14.9 | --- | C | .00 | .00 | .355 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU064 | 15.0 | --- | C | .00 | .00 | .116 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU064 | 15.0 | --- | C | .00 | .00 | .111 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU123 | 15.1 | --- | C | .00 | .00 | .135 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU123 | 15.1 | --- | C | .00 | .00 | .152 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU106 | 15.2 | --- | C | .00 | .00 | .124 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU106 | 15.2 | --- | C | .00 | .00 | .160 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU036 | 16.6 | --- | C | .00 | .00 | .124 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU036 | 16.6 | --- | C | .00 | .00 | .137 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU061 | 17.7 | --- | C | .00 | .00 | .157 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU061 | 17.7 | --- | C | .00 | .00 | .136 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY034 | 20.2 | --- | C | .00 | .00 | .300 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY034 | 20.2 | --- | C | .00 | .00 | .248 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY036 | 20.3 | --- | C | .00 | .00 | .204 |

Table 13: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS A (**M** GE 7) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY036 | 20.3 | --- | C | .00 | .00 | .029 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU038 | 22.4 | --- | C | .00 | .00 | .146 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU038 | 22.4 | --- | C | .00 | .00 | .145 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU042 | 23.3 | --- | C | .00 | .00 | .212 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU042 | 23.3 | --- | C | .00 | .00 | .253 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU029 | 24.7 | --- | C | .00 | .00 | .198 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU029 | 24.7 | --- | C | .00 | .00 | .158 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY010 | 25.3 | --- | C | .00 | .00 | .174 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY010 | 25.3 | --- | C | .00 | .00 | .225 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY041 | 25.9 | --- | C | .00 | .00 | .642 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY041 | 25.9 | --- | C | .00 | .00 | .303 |
| 0046 | Tabas, Iran | 1978 | 0916 | | 7.4 | | 70 | Boshrooyeh | 26.1 | --C | - | .04 | 20.00 | .107 |
| 0046 | Tabas, Iran | 1978 | 0916 | | 7.4 | | 70 | Boshrooyeh | 26.1 | --C | - | .04 | 20.00 | .089 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 22074 | Yermo Fire Station # | 26.3 | AQD | C | .07 | 23.00 | .245 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 22074 | Yermo Fire Station # | 26.3 | AQD | C | .07 | 23.00 | .152 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY047 | 29.3 | --- | C | .00 | .00 | .181 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY047 | 29.3 | --- | C | .00 | .00 | .168 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY087 | 34.4 | --- | C | .00 | .00 | .127 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY087 | 34.4 | --- | C | .00 | .00 | .135 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 12025 | Palm Springs Airport # | 36.7 | IQD | C | .07 | 23.00 | .076 |
| 0129 | Landers | 1992 | 0628 | 1158 | 7.3 | CDMG | 12025 | Palm Springs Airport # | 36.7 | IQD | C | .07 | 23.00 | .089 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA034 | 36.8 | --- | C | .00 | .00 | .142 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA034 | 36.8 | --- | C | .00 | .00 | .137 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA053 | 37.4 | --- | C | .00 | .00 | .028 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU033 | 38.1 | --- | C | .00 | .00 | .185 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU033 | 38.1 | --- | C | .00 | .00 | .158 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA032 | 38.2 | --- | C | .00 | .00 | .110 |

Table 13: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS A (**M** GE 7) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA032 | 38.2 | --- | C | .00 | .00 | .153 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA036 | 38.7 | --- | C | .00 | .00 | .060 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA036 | 38.7 | --- | C | .00 | .00 | .073 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA054 | 38.7 | --- | C | .00 | .00 | .051 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA054 | 38.7 | --- | C | .00 | .00 | .016 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA005 | 39.0 | --- | C | .00 | .00 | .135 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA005 | 39.0 | --- | C | .00 | .00 | .147 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA006 | 39.1 | --- | C | .00 | .00 | .088 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA006 | 39.1 | --- | C | .00 | .00 | .093 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | ESL | 40.2 | --- | C | .00 | .00 | .074 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | ESL | 40.2 | --- | C | .00 | .00 | .068 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA020 | 40.2 | --- | C | .00 | .00 | .068 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA020 | 40.2 | --- | C | .00 | .00 | .058 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA035 | 41.2 | --- | C | .00 | .00 | .073 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA035 | 41.2 | --- | C | .00 | .00 | .079 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY014 | 41.4 | --- | C | .00 | .00 | .260 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY014 | 41.4 | --- | C | .00 | .00 | .228 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA030 | 41.8 | --- | C | .00 | .00 | .082 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA030 | 41.8 | --- | C | .00 | .00 | .071 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA037 | 42.1 | --- | C | .00 | .00 | .126 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA037 | 42.1 | --- | C | .00 | .00 | .110 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA039 | 42.2 | --- | C | .00 | .00 | .075 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA039 | 42.2 | --- | C | .00 | .00 | .083 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY088 | 42.8 | --- | C | .00 | .00 | .211 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY088 | 42.8 | --- | C | .00 | .00 | .151 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU095 | 43.4 | --- | C | .00 | .00 | .699 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU095 | 43.4 | --- | C | .00 | .00 | .374 |

Table 13: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS A (**M** GE 7) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | Site Codes USGS | Filter Corners HP (hz) | Filter Corners LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY015 | 43.5 | --- | C | .00 | .00 | .152 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | CHY015 | 43.5 | --- | C | .00 | .00 | .144 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA055 | 44.3 | --- | C | .00 | .00 | .087 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA055 | 44.3 | --- | C | .00 | .00 | .089 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA033 | 44.7 | --- | C | .00 | .00 | .167 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA033 | 44.7 | --- | C | .00 | .00 | .165 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU098 | 45.0 | --- | C | .00 | .00 | .100 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | TCU098 | 45.0 | --- | C | .00 | .00 | .106 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA041 | 45.8 | --- | C | .00 | .00 | .086 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA041 | 45.8 | --- | C | .00 | .00 | .081 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA031 | 46.2 | --- | C | .00 | .00 | .100 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA031 | 46.2 | --- | C | .00 | .00 | .093 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA002 | 49.9 | --- | C | .00 | .00 | .091 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA002 | 49.9 | --- | C | .00 | .00 | .051 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA017 | 50.0 | --- | C | .00 | .00 | .085 |
| 0142 | Chi-Chi, Taiwan | 1999 | 0920 | | 7.6 | CWB | 99999 | HWA017 | 50.0 | --- | C | .00 | .00 | .083 |

Table 14: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS B (**M** 6.5 TO 6.99)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 25282 | Camarillo | .0 | AH- | C | .10 | 25.00 | .125 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 25282 | Camarillo | .0 | AH- | C | .10 | 25.00 | .121 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 77 | Rinaldi Receiving Sta # | .0 | --C | C | .00 | .00 | .838 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 77 | Rinaldi Receiving Sta # | .0 | --C | C | .00 | .00 | .472 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90055 | Simi Valley - Katherine Rd | .0 | --B | C | .50 | 30.00 | .877 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90055 | Simi Valley - Katherine Rd | .0 | --B | C | .40 | 30.00 | .640 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90003 | Northridge - 17645 Saticoy St | .1 | --D | C | .10 | 30.00 | .368 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90003 | Northridge - 17645 Saticoy St | .1 | --D | C | .10 | 30.00 | .477 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 74 | Sylmar - Converter Sta # | .2 | --D | C | .00 | .00 | .612 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 74 | Sylmar - Converter Sta # | .2 | --D | C | .00 | .00 | .897 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5155 | EC Meloland Overpass FF | .5 | IDD | C | .10 | 40.00 | .314 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5155 | EC Meloland Overpass FF | .5 | IDD | C | .10 | 50.00 | .296 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5028 | El Centro Array #7 | .6 | AQD | C | .10 | 40.00 | .338 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5028 | El Centro Array #7 | .6 | AQD | C | .10 | 40.00 | .463 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 942 | El Centro Array #6 | 1.3 | IQD | C | .10 | 40.00 | .410 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 942 | El Centro Array #6 | 1.3 | IQD | C | .10 | 40.00 | .439 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6616 | Aeropuerto Mexicali | 1.4 | I-D | C | .05 | .00 | .327 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6616 | Aeropuerto Mexicali | 1.4 | I-D | C | .05 | .00 | .260 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5054 | Bonds Corner | 2.6 | AQD | C | .10 | 40.00 | .588 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5054 | Bonds Corner | 2.6 | AQD | C | .10 | 40.00 | .775 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 958 | El Centro Array #8 | 3.8 | AQD | C | .10 | 40.00 | .602 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 958 | El Centro Array #8 | 3.8 | AQD | C | .10 | 40.00 | .454 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24087 | Arleta - Nordhoff Fire Sta # | 3.9 | AQD | C | .12 | 23.00 | .344 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24087 | Arleta - Nordhoff Fire Sta # | 3.9 | AQD | C | .12 | 23.00 | .308 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 952 | El Centro Array #5 | 4.0 | IQD | C | .10 | 40.00 | .519 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 952 | El Centro Array #5 | 4.0 | IQD | C | .10 | 40.00 | .379 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24436 | Tarzana - Cedar Hill # | 4.1 | APB | C | .10 | 23.00 | 1.779 |

Table 14: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24436 | Tarzana - Cedar Hill # | 4.1 | APB | C | .10 | 23.00 | .990 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24279 | Newhall - Fire Sta # | 4.5 | AQD | C | .12 | 23.00 | .583 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24279 | Newhall - Fire Sta # | 4.5 | AQD | C | .12 | 23.00 | .590 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5165 | El Centro Differential Array | 5.1 | IQD | C | .10 | 40.00 | .352 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5165 | El Centro Differential Array | 5.1 | IQD | C | .10 | 40.00 | .480 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90006 | Sun Valley - Roscoe Blvd | 6.1 | --D | C | .10 | 30.00 | .303 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90006 | Sun Valley - Roscoe Blvd | 6.1 | --D | C | .10 | 30.00 | .443 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 955 | El Centro Array #4 | 6.8 | IQD | C | .10 | 40.00 | .485 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 955 | El Centro Array #4 | 6.8 | IQD | C | .10 | 40.00 | .360 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5055 | Holtville Post Office | 7.5 | AQD | C | .10 | 40.00 | .253 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5055 | Holtville Post Office | 7.5 | AQD | C | .10 | 40.00 | .221 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5154 | EC County Center FF | 7.6 | IDD | C | .10 | 40.00 | .213 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5154 | EC County Center FF | 7.6 | IDD | C | .10 | 35.00 | .235 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6619 | SAHOP Casa Flores | 8.4 | I-C | C | .20 | .00 | .287 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6619 | SAHOP Casa Flores | 8.4 | I-C | C | .20 | .00 | .506 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5060 | Brawley Airport | 8.5 | AQD | C | .10 | 40.00 | .160 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5060 | Brawley Airport | 8.5 | AQD | C | .10 | 40.00 | .220 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 412 | El Centro Array #10 | 8.5 | AQD | C | .10 | 40.00 | .171 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 412 | El Centro Array #10 | 8.5 | AQD | C | .10 | 40.00 | .224 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47125 | Capitola | 8.6 | AQC | C | .20 | 48.00 | .529 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47125 | Capitola | 8.6 | AQC | C | .20 | 40.00 | .443 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5053 | Calexico Fire Station | 10.6 | AQD | C | .10 | 40.00 | .275 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5053 | Calexico Fire Station | 10.6 | AQD | C | .20 | 40.00 | .202 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47380 | Gilroy Array #2 | 12.1 | IQD | C | .20 | 40.00 | .367 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47380 | Gilroy Array #2 | 12.1 | IQD | C | .20 | 31.00 | .322 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90057 | Canyon Country - W Lost Cany | 12.2 | --D | C | .05 | 30.00 | .410 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90057 | Canyon Country - W Lost Cany | 12.2 | --D | C | .10 | 30.00 | .482 |

Table 14: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5058 | El Centro Array #11 | 12.6 | AQD | C | .20 | 40.00 | .364 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5058 | El Centro Array #11 | 12.6 | AQD | C | .10 | 40.00 | .380 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6617 | Cucapah | 12.9 | IQD | C | .05 | .00 | .309 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 11369 | Westmorland Fire Sta | 13.3 | ADD | C | .10 | 35.00 | .172 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 11369 | Westmorland Fire Sta | 13.3 | ADD | C | .10 | 40.00 | .211 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 01335 | El Centro Imp. Co. Cent | 13.9 | AQD | C | .10 | 40.00 | .358 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 01335 | El Centro Imp. Co. Cent | 13.9 | AQD | C | .10 | 38.00 | .258 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47381 | Gilroy Array #3 | 14.0 | IHD | C | .10 | 33.00 | .555 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47381 | Gilroy Array #3 | 14.0 | IHD | C | .10 | 40.00 | .367 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5169 | Westmorland Fire Sta | 15.0 | ADD | C | .10 | 40.00 | .074 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5169 | Westmorland Fire Sta | 15.0 | ADD | C | .10 | 40.00 | .110 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57382 | Gilroy Array #4 | 15.8 | AHD | C | .20 | 28.00 | .417 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57382 | Gilroy Array #4 | 15.8 | AHD | C | .20 | 30.00 | .212 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90053 | Canoga Park - Topanga Can | 15.8 | --D | C | .05 | 30.00 | .356 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90053 | Canoga Park - Topanga Can | 15.8 | --D | C | .05 | 30.00 | .420 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5115 | El Centro Array #2 | 16.0 | IQD | C | .10 | 40.00 | .315 |
| 0125 | Erzican, Turkey | 1992 | 0313 | | 6.9 | | 95 | Erzincan | 16.9 | --D | C | .10 | .00 | .515 |
| 0125 | Erzican, Turkey | 1992 | 0313 | | 6.9 | | 95 | Erzincan | 16.9 | --D | C | .10 | .00 | .496 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6621 | Chihuahua | 17.7 | IQD | C | .05 | .00 | .270 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6621 | Chihuahua | 17.7 | IQD | C | .05 | .00 | .254 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 931 | El Centro Array #12 | 18.0 | IQD | C | .10 | 40.00 | .143 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 931 | El Centro Array #12 | 18.0 | IQD | C | .10 | 40.00 | .116 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 5060 | Brawley Airport | 18.2 | AQD | C | .10 | 23.00 | .156 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 5060 | Brawley Airport | 18.2 | AQD | C | .13 | 20.00 | .116 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24389 | LA - Century City CC North # | 18.3 | IQD | C | .14 | 23.00 | .256 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24389 | LA - Century City CC North # | 18.3 | IQD | C | .14 | 23.00 | .222 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90060 | La Crescenta - New York | 19.7 | --C | C | .30 | 30.00 | .178 |

Table 14: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90060 | La Crescenta - New York | 19.7 | --C | C | .10 | 30.00 | .159 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24303 | LA - Hollywood Stor FF # | 20.8 | IPD | C | .20 | 23.00 | .231 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24303 | LA - Hollywood Stor FF # | 20.8 | IPD | C | .20 | 23.00 | .358 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 5052 | Plaster City | 21.0 | AQD | C | .30 | 20.00 | .121 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 5052 | Plaster City | 21.0 | AQD | C | .20 | 18.00 | .186 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24538 | Santa Monica City Hall # | 21.1 | IQD | C | .14 | 23.00 | .883 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24538 | Santa Monica City Hall # | 21.1 | IQD | C | .14 | 23.00 | .370 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5056 | El Centro Array #1 | 22.0 | AQD | C | .10 | 40.00 | .139 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5056 | El Centro Array #1 | 22.0 | AQD | C | .10 | 40.00 | .134 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5059 | El Centro Array #13 | 22.0 | AQD | C | .20 | 40.00 | .117 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5059 | El Centro Array #13 | 22.0 | AQD | C | .20 | 40.00 | .139 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90063 | Glendale - Las Palmas | 22.9 | --C | C | .13 | 30.00 | .357 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90063 | Glendale - Las Palmas | 22.9 | --C | C | .10 | 30.00 | .206 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5061 | Calipatria Fire Station | 23.0 | BQD | C | .10 | 40.00 | .128 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5061 | Calipatria Fire Station | 23.0 | BQD | C | .10 | 40.00 | .078 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6622 | Compuertas | 23.2 | IQD | C | .20 | .00 | .186 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6622 | Compuertas | 23.2 | IQD | C | .20 | .00 | .147 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90091 | LA - Saturn St | 23.2 | --D | C | .10 | 30.00 | .474 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90091 | LA - Saturn St | 23.2 | --D | C | .10 | 30.00 | .439 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | Abeno | 23.8 | --D | C | .05 | 40.00 | .222 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | Abeno | 23.8 | --D | C | .05 | 40.00 | .235 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90016 | LA - N Faring Rd | 23.9 | --B | C | .13 | 30.00 | .273 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90016 | LA - N Faring Rd | 23.9 | --B | C | .13 | 30.00 | .242 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57425 | Gilroy Array #7 | 24.3 | AHB | C | .20 | 40.00 | .226 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57425 | Gilroy Array #7 | 24.3 | AHB | C | .20 | 35.00 | .323 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 |  | 135 | LA - Hollywood Stor FF | 24.6 | IPD | C | .20 | 35.00 | .210 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 |  | 135 | LA - Hollywood Stor FF | 24.6 | IPD | C | .20 | 35.00 | .174 |

Table 14: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1656 | Hollister Diff. Array | 25.8 | IQD | C | .10 | 40.00 | .269 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1656 | Hollister Diff. Array | 25.8 | IQD | C | .10 | 33.00 | .279 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57066 | Agnews State Hospital | 27.0 | AQD | C | .20 | 30.00 | .172 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57066 | Agnews State Hospital | 27.0 | AQD | C | .20 | 30.00 | .159 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1695 | Sunnyvale - Colton Ave. | 27.5 | AHD | C | .10 | 40.00 | .207 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1695 | Sunnyvale - Colton Ave. | 27.5 | AHD | C | .10 | 32.00 | .209 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1028 | Hollister City Hall | 28.2 | CHD | C | .10 | 29.00 | .247 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1028 | Hollister City Hall | 28.2 | CHD | C | .10 | 30.00 | .215 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 5061 | Calipatria Fire Station | 28.3 | BQD | C | .23 | 20.00 | .180 |
| 0120 | Superstitn Hills(B) | 1987 | 1124 | 1316 | 6.7 | USGS | 5061 | Calipatria Fire Station | 28.3 | BQD | C | .23 | 18.00 | .247 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24612 | LA - Pico & Sentous # | 29.0 | IHD | C | .20 | 46.00 | .103 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24612 | LA - Pico & Sentous # | 29.0 | IHD | C | .20 | 46.00 | .186 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57191 | Halls Valley | 29.3 | IFC | C | .20 | 22.00 | .134 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 57191 | Halls Valley | 29.3 | IFC | C | .20 | 22.00 | .103 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90034 | LA - Fletcher Dr | 29.5 | --D | C | .13 | 30.00 | .162 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90034 | LA - Fletcher Dr | 29.5 | --D | C | .15 | 30.00 | .240 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | Tadoka | 30.5 | --D | C | .05 | 40.00 | .294 |
| 0133 | Kobe | 1995 | 0116 | 2046 | 6.9 | CEOR | 99999 | Tadoka | 30.5 | --D | C | .05 | 40.00 | .195 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90054 | LA - Centinela St | 30.9 | --D | C | .13 | 30.00 | .465 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90054 | LA - Centinela St | 30.9 | --D | C | .20 | 30.00 | .322 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47179 | Salinas - John & Work | 31.4 | AHD | C | .10 | 30.00 | .091 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 47179 | Salinas - John & Work | 31.4 | AHD | C | .10 | 28.00 | .112 |
| 0017 | Northern Calif | 1954 | 1221 | 1956 | 6.5 | USGS | 1023 | Ferndale City Hall | 31.5 | BQD | C | .20 | 20.00 | .159 |
| 0017 | Northern Calif | 1954 | 1221 | 1956 | 6.5 | USGS | 1023 | Ferndale City Hall | 31.5 | BQD | C | .50 | 13.00 | .189 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5052 | Plaster City | 32.0 | AQD | C | .10 | 40.00 | .042 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5052 | Plaster City | 32.0 | AQD | C | .10 | 40.00 | .057 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6605 | Delta | 32.7 | IQD | C | .05 | .00 | .238 |

Table 14: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6605 | Delta | 32.7 | IQD | C | .05 | .00 | .351 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90096 | LA - S. Vermont Ave | 34.7 | --D | C | .30 | 30.00 | .164 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90096 | LA - S. Vermont Ave | 34.7 | --D | C | .30 | 30.00 | .071 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58264 | Palo Alto - 1900 Embarc. | 34.8 | BQD | C | .20 | 32.00 | .204 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 58264 | Palo Alto - 1900 Embarc. | 34.8 | BQD | C | .20 | 30.00 | .213 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 724 | Niland Fire Station | 36.0 | AQD | C | .10 | 30.00 | .109 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 724 | Niland Fire Station | 36.0 | AQD | C | .10 | 40.00 | .069 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90022 | LA - S Grand Ave | 36.9 | --D | C | .30 | 30.00 | .290 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90022 | LA - S Grand Ave | 36.9 | --D | C | .30 | 30.00 | .264 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90046 | Manhattan Beach - Manhattan | 36.9 | --C | C | .23 | 30.00 | .201 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90046 | Manhattan Beach - Manhattan | 36.9 | --C | C | .05 | 30.00 | .128 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90095 | Pasadena - N Sierra Madre | 37.4 | --C | C | .30 | 30.00 | .245 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90095 | Pasadena - N Sierra Madre | 37.4 | --C | C | .20 | 30.00 | .174 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24575 | Elizabeth Lake # | 37.6 | IHD | C | .16 | 46.00 | .155 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24575 | Elizabeth Lake # | 37.6 | IHD | C | .16 | 46.00 | .109 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24306 | Leona Valley #2 # | 37.7 | IH- | C | .20 | 23.00 | .091 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24306 | Leona Valley #2 # | 37.7 | IH- | C | .20 | 23.00 | .063 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24308 | Leona Valley #4 # | 38.1 | IQ- | C | .20 | 23.00 | .079 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24308 | Leona Valley #4 # | 38.1 | IQ- | C | .20 | 23.00 | .057 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24055 | Leona Valley #5 - Ritter # | 38.3 | IQC | C | .20 | 23.00 | .146 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24055 | Leona Valley #5 - Ritter # | 38.3 | IQC | C | .20 | 23.00 | .092 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24309 | Leona Valley #6 # | 38.5 | IHD | C | .20 | 23.00 | .178 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24309 | Leona Valley #6 # | 38.5 | IHD | C | .20 | 23.00 | .131 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 25148 | Point Mugu - Laguna Peak # | 38.9 | AMA | C | .30 | 23.00 | .134 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 25148 | Point Mugu - Laguna Peak # | 38.9 | AMA | C | .30 | 23.00 | .223 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24576 | Anaverde Valley - City R # | 39.1 | IHD | C | .20 | 46.00 | .044 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24576 | Anaverde Valley - City R # | 39.1 | IHD | C | .20 | 46.00 | .060 |

Table 14: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90025 | LA - E Vernon Ave | 39.3 | --D | C | .20 | 30.00 | .120 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90025 | LA - E Vernon Ave | 39.3 | --D | C | .10 | 30.00 | .153 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90099 | Arcadia - Arcadia Av | 40.6 | --D | C | .25 | 30.00 | .104 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90099 | Arcadia - Arcadia Av | 40.6 | --D | C | .30 | 30.00 | .083 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90079 | Downey - Birchdale | 40.7 | --D | C | .30 | 30.00 | .165 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90079 | Downey - Birchdale | 40.7 | --D | C | .30 | 30.00 | .171 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1686 | Fremont - Emerson Court | 42.4 | AQB | C | .10 | 31.00 | .192 |
| 0122 | Loma Prieta | 1989 | 1018 | 0005 | 6.9 | CDMG | 1686 | Fremont - Emerson Court | 42.4 | AQB | C | .10 | 32.00 | .141 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90093 | Arcadia - Campus Dr | 42.4 | --D | C | .30 | 30.00 | .089 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90093 | Arcadia - Campus Dr | 42.4 | --D | C | .23 | 30.00 | .110 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90045 | Lawndale - Osage Ave | 42.4 | --D | C | .13 | 30.00 | .084 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90045 | Lawndale - Osage Ave | 42.4 | --D | C | .13 | 30.00 | .152 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90094 | Bell Gardens - Jaboneria | 42.5 | --D | C | .13 | 30.00 | .098 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90094 | Bell Gardens - Jaboneria | 42.5 | --D | C | .13 | 30.00 | .068 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24521 | Palmdale - Hwy 14 & Palmdale # | 43.3 | IQC | C | .20 | 46.00 | .061 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 24521 | Palmdale - Hwy 14 & Palmdale # | 43.3 | IQC | C | .20 | 46.00 | .067 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6610 | Victoria | 43.5 | IQD | C | .05 | .00 | .122 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 6610 | Victoria | 43.5 | IQD | C | .20 | .00 | .167 |
| 0028 | Borrego Mtn | 1968 | 0409 | 0230 | 6.8 | USGS | 117 | El Centro Array #9 | 45.0 | EQD | C | .20 | 12.00 | .130 |
| 0028 | Borrego Mtn | 1968 | 0409 | 0230 | 6.8 | USGS | 117 | El Centro Array #9 | 45.0 | EQD | C | .20 | 12.00 | .057 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 14368 | Downey - Co Maint Bldg # | 45.1 | AQD | C | .20 | 23.00 | .158 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 14368 | Downey - Co Maint Bldg # | 45.1 | AQD | C | .20 | 23.00 | .230 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90078 | Compton - Castlegate St | 45.2 | --D | C | .10 | 30.00 | .088 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90078 | Compton - Castlegate St | 45.2 | --D | C | .20 | 30.00 | .136 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90066 | El Monte - Fairview Av | 45.5 | --D | C | .15 | 30.00 | .122 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90066 | El Monte - Fairview Av | 45.5 | --D | C | .30 | 30.00 | .163 |
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 994 | Gormon - Oso Pump Plant | 46.7 | EBC | C | .10 | 23.00 | .084 |

Table 14: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS B (**M** 6.5 TO 6.99) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0030 | San Fernando | 1971 | 0209 | 1400 | 6.6 | | 994 | Gormon - Oso Pump Plant | 46.7 | EBC | C | .10 | 30.00 | .105 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90077 | Santa Fe Springs - E.Joslin | 48.9 | --D | C | .30 | 30.00 | .135 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90077 | Santa Fe Springs - E.Joslin | 48.9 | --D | C | .30 | 30.00 | .123 |
| 0009 | Borrego | 1942 | 1021 | 1622 | 6.5 | USGS | 117 | El Centro Array #9 | 49.0 | EQD | C | .10 | 15.00 | .068 |
| 0009 | Borrego | 1942 | 1021 | 1622 | 6.5 | USGS | 117 | El Centro Array #9 | 49.0 | EQD | C | .10 | 15.00 | .044 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5066 | Coachella Canal #4 | 49.0 | AQD | C | .20 | 40.00 | .115 |
| 0050 | Imperial Valley | 1979 | 1015 | 2316 | 6.5 | UNAMUCSD | 5066 | Coachella Canal #4 | 49.0 | AQD | C | .20 | 40.00 | .128 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90069 | Baldwin Park - N Holly | 49.0 | --D | C | .20 | 30.00 | .090 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90069 | Baldwin Park - N Holly | 49.0 | --D | C | .23 | 30.00 | .123 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90040 | Carson - Catskill Ave | 49.2 | --D | C | .20 | 30.00 | .087 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 90040 | Carson - Catskill Ave | 49.2 | --D | C | .30 | 30.00 | .083 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 25281 | Port Hueneme - Naval Lab. # | 50.0 | AHD | C | .14 | 23.00 | .103 |
| 0131 | Northridge | 1994 | 0117 | 1231 | 6.7 | CDMG | 25281 | Port Hueneme - Naval Lab. # | 50.0 | AHD | C | .14 | 23.00 | .086 |

Table 15: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS C (**M** 5.75 TO 6.49)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57191 | Halls Valley | 3.4 | IFC | C | .20 | 26.00 | .156 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57191 | Halls Valley | 3.4 | IFC | C | .20 | 30.00 | .312 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90094 | Bell Gardens - Jaboneria # | 5.7 | --D | C | .25 | 25.00 | .219 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90094 | Bell Gardens - Jaboneria # | 5.7 | --D | C | .10 | 25.00 | .212 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90066 | El Monte - Fairview Av # | 5.7 | --D | C | .33 | 25.00 | .120 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90066 | El Monte - Fairview Av # | 5.7 | --D | C | .13 | 25.00 | .228 |
| 0025 | Parkfield | 1966 | 0628 | 0426 | 6.1 | CDMG | 1013 | Cholame #2 | 6.6 | IHD | C | .20 | 10.00 | .476 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90073 | Hacienda Heights - Colima # | 6.8 | --C | C | .23 | 25.00 | .195 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90073 | Hacienda Heights - Colima # | 6.8 | --C | C | .45 | 25.00 | .201 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90071 | West Covina - S Orange # | 6.8 | --B | C | .23 | 25.00 | .137 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90071 | West Covina - S Orange # | 6.8 | --B | C | .23 | 25.00 | .179 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90025 | LA - E Vernon Ave # | 7.3 | --D | C | .18 | 25.00 | .146 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90025 | LA - E Vernon Ave # | 7.3 | --D | C | .16 | 25.00 | .175 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90077 | Santa Fe Springs - E Joslin # | 7.3 | --D | C | .35 | 25.00 | .426 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90077 | Santa Fe Springs - E Joslin # | 7.3 | --D | C | .35 | 25.00 | .443 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90069 | Baldwin Park - N Holly # | 8.8 | --D | C | .13 | 25.00 | .127 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90069 | Baldwin Park - N Holly # | 8.8 | --D | C | .50 | 25.00 | .061 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90072 | La Puente - Rimgrove Av # | 8.8 | --D | C | .18 | 25.00 | .143 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90072 | La Puente - Rimgrove Av # | 8.8 | --D | C | .50 | 21.00 | .118 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90093 | Arcadia - Campus Dr # | 9.2 | --D | C | .15 | 25.00 | .300 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90093 | Arcadia - Campus Dr # | 9.2 | --D | C | .38 | 25.00 | .163 |
| 0025 | Parkfield | 1966 | 0628 | 0426 | 6.1 | CDMG | 1014 | Cholame #5 | 9.3 | IHC | C | .20 | 17.00 | .442 |
| 0025 | Parkfield | 1966 | 0628 | 0426 | 6.1 | CDMG | 1014 | Cholame #5 | 9.3 | IHC | C | .20 | 20.00 | .367 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90074 | La Habra - Briarcliff # | 10.9 | --C | C | .25 | 25.00 | .183 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90074 | La Habra - Briarcliff # | 10.9 | --C | C | .25 | 25.00 | .131 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57382 | Gilroy Array #4 | 12.8 | AHD | C | .10 | 25.00 | .224 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57382 | Gilroy Array #4 | 12.8 | AHD | C | .10 | 27.00 | .348 |

Table 15: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR MODY HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | Site Codes USGS | Filter Corners HP (hz) | Filter Corners LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0025 | Parkfield | 1966 0628 0426 | 6.1 | CDMG | 1015 | Cholame #8 | 13.0 | ABB | C | .20 | 20.00 | .246 |
| 0025 | Parkfield | 1966 0628 0426 | 6.1 | CDMG | 1015 | Cholame #8 | 13.0 | ABB | C | .20 | 20.00 | .273 |
| 0073 | Westmorland | 1981 0426 1209 | 5.8 | USGS | 5169 | Westmorland Fire Sta | 13.3 | ADD | C | .08 | 40.00 | .368 |
| 0073 | Westmorland | 1981 0426 1209 | 5.8 | USGS | 5169 | Westmorland Fire Sta | 13.3 | ADD | C | .05 | 40.00 | .496 |
| 0090 | Morgan Hill | 1984 0424 2115 | 6.2 | CDMG | 57425 | Gilroy Array #7 | 14.0 | AHB | C | .10 | 31.00 | .190 |
| 0090 | Morgan Hill | 1984 0424 2115 | 6.2 | CDMG | 57425 | Gilroy Array #7 | 14.0 | AHB | C | .10 | 30.00 | .113 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90070 | Covina - W Badillo # | 14.2 | --D | C | .28 | 25.00 | .134 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90070 | Covina - W Badillo # | 14.2 | --D | C | .38 | 25.00 | .081 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90034 | LA - Fletcher Dr # | 14.4 | --D | C | .28 | 25.00 | .171 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90034 | LA - Fletcher Dr # | 14.4 | --D | C | .30 | 25.00 | .213 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90022 | LA - S Grand Ave # | 14.5 | --D | C | .35 | 25.00 | .191 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90022 | LA - S Grand Ave # | 14.5 | --D | C | .28 | 25.00 | .149 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90095 | Pasadena - Old House Rd # | 14.5 | --C | C | .28 | 25.00 | .231 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90095 | Pasadena - Old House Rd # | 14.5 | --C | C | .23 | 25.00 | .258 |
| 0090 | Morgan Hill | 1984 0424 2115 | 6.2 | CDMG | 47381 | Gilroy Array #3 | 14.6 | IHD | C | .10 | 37.00 | .194 |
| 0090 | Morgan Hill | 1984 0424 2115 | 6.2 | CDMG | 47381 | Gilroy Array #3 | 14.6 | IHD | C | .10 | 32.00 | .200 |
| 0090 | Morgan Hill | 1984 0424 2115 | 6.2 | CDMG | 47380 | Gilroy Array #2 | 15.1 | IQD | C | .20 | 31.00 | .162 |
| 0090 | Morgan Hill | 1984 0424 2115 | 6.2 | CDMG | 47380 | Gilroy Array #2 | 15.1 | IQD | C | .10 | 37.00 | .212 |
| 0053 | Livermore | 1980 0124 1900 | 5.8 | CDMG | 57187 | San Ramon - Eastman Kodak | 15.7 | ABB | C | .08 | 20.00 | .154 |
| 0053 | Livermore | 1980 0124 1900 | 5.8 | CDMG | 57187 | San Ramon - Eastman Kodak | 15.7 | ABB | C | .20 | 20.00 | .076 |
| 0033 | Point Mugu | 1973 0221 1445 | 5.8 | CDMG | 272 | Port Hueneme | 16.0 | BBD | C | .20 | 25.00 | .112 |
| 0033 | Point Mugu | 1973 0221 1445 | 5.8 | CDMG | 272 | Port Hueneme | 16.0 | BBD | C | .20 | 30.00 | .083 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90023 | LA - W 70th St # | 16.3 | --D | C | .30 | 25.00 | .198 |
| 0117 | Whittier Narrows | 1987 1001 1442 | 6.0 | CDMG | 90023 | LA - W 70th St # | 16.3 | --D | C | .20 | 25.00 | .151 |
| 0103 | N. Palm Springs | 1986 0708 0920 | 6.0 | USGS | 12025 | Palm Springs Airport | 16.6 | IQD | C | .20 | 50.00 | .158 |
| 0103 | N. Palm Springs | 1986 0708 0920 | 6.0 | USGS | 12025 | Palm Springs Airport | 16.6 | IQD | C | .20 | 60.00 | .187 |
| 0053 | Livermore | 1980 0124 1900 | 5.8 | CDMG | 57134 | San Ramon Fire Station | 16.7 | ABB | C | .15 | 15.00 | .058 |

Table 15: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 57134 | San Ramon Fire Station | 16.7 | ABB | C | .20 | 15.00 | .040 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90078 | Compton - Castlegate St # | 16.9 | --D | C | .09 | 25.00 | .332 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90078 | Compton - Castlegate St # | 16.9 | --D | C | .28 | 25.00 | .333 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90068 | Covina - S Grand Ave # | 17.1 | --C | C | .45 | 25.00 | .076 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90068 | Covina - S Grand Ave # | 17.1 | --C | C | .40 | 25.00 | .068 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90087 | Brea - S Flower Av # | 17.9 | --D | C | .16 | 25.00 | .115 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 14368 | Downey - Co Maint Bldg | 18.3 | AQD | C | .20 | 30.00 | .221 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 14368 | Downey - Co Maint Bldg | 18.3 | AQD | C | .25 | 30.00 | .141 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90080 | LB - Orange Ave # | 18.3 | --D | C | .12 | 25.00 | .255 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90080 | LB - Orange Ave # | 18.3 | --D | C | .28 | 25.00 | .149 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90063 | Glendale - Las Palmas # | 19.0 | --C | C | .28 | 25.00 | .296 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90063 | Glendale - Las Palmas # | 19.0 | --C | C | .45 | 25.00 | .166 |
| 0095 | Bishop (Rnd Val) | 1984 | 1123 | 1912 | 5.8 | USGS | 1661 | McGee Creek - Surface | 19.0 | IQC | - | 1.50 | 40.00 | .088 |
| 0095 | Bishop (Rnd Val) | 1984 | 1123 | 1912 | 5.8 | USGS | 1661 | McGee Creek - Surface | 19.0 | IQC | - | 1.00 | 40.00 | .128 |
| 0073 | Westmorland | 1981 | 0426 | 1209 | 5.8 | USGS | 724 | Niland Fire Station | 19.4 | AQD | C | .30 | 33.00 | .105 |
| 0073 | Westmorland | 1981 | 0426 | 1209 | 5.8 | USGS | 724 | Niland Fire Station | 19.4 | AQD | C | .30 | 33.00 | .176 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90091 | LA - Saturn St # | 20.8 | --D | C | .25 | 25.00 | .099 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90091 | LA - Saturn St # | 20.8 | --D | C | .23 | 25.00 | .141 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90084 | Lakewood - Del Amo Blvd # | 20.9 | --D | C | .30 | 25.00 | .277 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90084 | Lakewood - Del Amo Blvd # | 20.9 | --D | C | .30 | 25.00 | .178 |
| 0073 | Westmorland | 1981 | 0426 | 1209 | 5.8 | USGS | 5060 | Brawley Airport | 22.0 | AQD | C | .15 | 40.00 | .169 |
| 0073 | Westmorland | 1981 | 0426 | 1209 | 5.8 | USGS | 5060 | Brawley Airport | 22.0 | AQD | C | .70 | 33.00 | .171 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90060 | La Crescenta - New York # | 22.7 | --C | C | .40 | 25.00 | .134 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90060 | La Crescenta - New York # | 22.7 | --C | C | .30 | 25.00 | .141 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90012 | Burbank - N Buena Vista # | 23.7 | --D | C | .25 | 25.00 | .233 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90012 | Burbank - N Buena Vista # | 23.7 | --D | C | .30 | 25.00 | .190 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90088 | Anaheim - W Ball Rd # | 24.4 | --D | C | .25 | 25.00 | .060 |

Table 15: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90088 | Anaheim - W Ball Rd # | 24.4 | --D | C | .50 | 25.00 | .055 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90045 | Lawndale - Osage Ave # | 25.1 | --D | C | .35 | 25.00 | .066 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90045 | Lawndale - Osage Ave # | 25.1 | --D | C | .38 | 25.00 | .053 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24303 | LA - Hollywood Stor FF | 25.2 | IPD | C | .40 | 25.00 | .221 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24303 | LA - Hollywood Stor FF | 25.2 | IPD | C | .40 | 25.00 | .124 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36455 | Parkfield - Vineyard Cany 1E | 26.7 | IQC | - | .20 | 24.00 | .167 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36455 | Parkfield - Vineyard Cany 1E | 26.7 | IQC | - | .20 | 23.00 | .230 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24157 | LA - Baldwin Hills | 27.0 | IPB | C | .30 | 35.00 | .142 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24157 | LA - Baldwin Hills | 27.0 | IPB | C | .40 | 30.00 | .159 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90054 | LA - Centinela St # | 27.7 | --D | C | .30 | 25.00 | .059 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90054 | LA - Centinela St # | 27.7 | --D | C | .25 | 25.00 | .044 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90040 | Carson - Catskill Ave # | 28.1 | --D | C | .18 | 25.00 | .042 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90040 | Carson - Catskill Ave # | 28.1 | --D | C | .55 | 25.00 | .059 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36457 | Parkfield - Fault Zone 16 | 28.1 | IQC | - | .20 | 26.00 | .195 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36457 | Parkfield - Fault Zone 16 | 28.1 | IQC | - | .20 | 27.00 | .122 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff. Array | 28.3 | IQD | C | .20 | 29.00 | .089 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff. Array | 28.3 | IQD | C | .20 | 23.00 | .088 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff Array #1 | 28.3 | IQD | C | .20 | 33.00 | .095 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff Array #1 | 28.3 | IQD | C | .20 | 30.00 | .088 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff Array #3 | 28.3 | IQD | C | .10 | 30.00 | .078 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff Array #3 | 28.3 | IQD | C | .20 | 30.00 | .081 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff Array #4 | 28.3 | IQD | C | .10 | 30.00 | .098 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff Array #4 | 28.3 | IQD | C | .20 | 30.00 | .092 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff Array #5 | 28.3 | IQD | C | .20 | 30.00 | .098 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1656 | Hollister Diff Array #5 | 28.3 | IQD | C | .20 | 30.00 | .101 |
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 57063 | Tracy - Sewage Treatm Plant | 28.5 | BQC | C | .15 | 20.00 | .050 |
| 0053 | Livermore | 1980 | 0124 | 1900 | 5.8 | CDMG | 57063 | Tracy - Sewage Treatm Plant | 28.5 | BQC | C | .08 | 15.00 | .073 |

Table 15: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90016 | LA - N Faring Rd # | 28.5 | --B | C | .55 | 25.00 | .048 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90016 | LA - N Faring Rd # | 28.5 | --B | C | .40 | 25.00 | .053 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90010 | Studio City - Coldwater Can # | 28.7 | --D | C | .28 | 25.00 | .177 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90010 | Studio City - Coldwater Can # | 28.7 | --D | C | .30 | 25.00 | .231 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 23525 | Pomona - 4th & Locust FF | 28.8 | IQD | C | .50 | 30.00 | .067 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 23525 | Pomona - 4th & Locust FF | 28.8 | IQD | C | .55 | 30.00 | .056 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90046 | Manhattan Beach - Manhattan # | 28.9 | --C | C | .40 | 25.00 | .054 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57066 | Agnews State Hospital | 29.4 | AQD | C | .20 | 14.00 | .032 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 57066 | Agnews State Hospital | 29.4 | AQD | C | .20 | 13.00 | .032 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36138 | Parkfield - Fault Zone 12 | 29.5 | IHC | - | .20 | 20.00 | .110 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36138 | Parkfield - Fault Zone 12 | 29.5 | IHC | - | .20 | 20.00 | .112 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36448 | Parkfield - Vineyard Cany 1W | 29.5 | IQC | - | .50 | 26.00 | .081 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36448 | Parkfield - Vineyard Cany 1W | 29.5 | IQC | - | .50 | 23.00 | .087 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36456 | Parkfield - Fault Zone 14 | 29.9 | IHC | - | .20 | 23.00 | .282 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36456 | Parkfield - Fault Zone 14 | 29.9 | IHC | - | .10 | 23.00 | .274 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90013 | Beverly Hills - 14145 Mulhol # | 30.3 | --C | C | .33 | 25.00 | .104 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90013 | Beverly Hills - 14145 Mulhol # | 30.3 | --C | C | .35 | 25.00 | .126 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36447 | Parkfield - Vineyard Cany 2W | 30.7 | IHC | - | .20 | 30.00 | .073 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36447 | Parkfield - Vineyard Cany 2W | 30.7 | IHC | - | .20 | 30.00 | .083 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36431 | Parkfield - Fault Zone 7 | 31.0 | IQC | - | .20 | 30.00 | .122 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36431 | Parkfield - Fault Zone 7 | 31.0 | IQC | - | .20 | 30.00 | .119 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24390 | LA - Century City CC South | 31.3 | IQD | C | .20 | 25.00 | .051 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24390 | LA - Century City CC South | 31.3 | IQD | C | .30 | 25.00 | .063 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24389 | LA - Century City CC North | 31.4 | IQD | C | .60 | 30.00 | .078 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24389 | LA - Century City CC North | 31.4 | IQD | C | .35 | 30.00 | .111 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1028 | Hollister City Hall | 32.5 | CHD | C | .20 | 19.00 | .071 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 1028 | Hollister City Hall | 32.5 | CHD | C | .20 | 24.00 | .071 |

Table 15: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | USGS | Filter Corners HP (hz) | LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90062 | Mill Creek, Angeles Nat For # | 34.5 | --B | C | .40 | 25.00 | .089 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90062 | Mill Creek, Angeles Nat For # | 34.5 | --B | C | .63 | 25.00 | .071 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90002 | Fountain Valley - Euclid # | 35.0 | --D | C | .30 | 25.00 | .071 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90002 | Fountain Valley - Euclid # | 35.0 | --D | C | .30 | 25.00 | .062 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90082 | Terminal Island - S Seaside # | 35.7 | --D | C | .20 | 25.00 | .042 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90082 | Terminal Island - S Seaside # | 35.7 | --D | C | .28 | 25.00 | .041 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 1661 | McGee Creek Surface | 36.3 | IQC | - | .10 | 50.00 | .078 |
| 0105 | Chalfant Valley | 1986 | 0721 | 1442 | 6.2 | CDMG | 1661 | McGee Creek Surface | 36.3 | IQC | - | .10 | 35.00 | .083 |
| 0064 | Victoria, Mexico | 1980 | 0609 | 0328 | 6.1 | UNAMUCSD | 6621 | Chihuahua | 36.6 | IQD | C | .20 | 22.00 | .150 |
| 0064 | Victoria, Mexico | 1980 | 0609 | 0328 | 6.1 | UNAMUCSD | 6621 | Chihuahua | 36.6 | IQD | C | .20 | 27.00 | .092 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 47125 | Capitola | 38.1 | AQC | C | .20 | 30.00 | .099 |
| 0090 | Morgan Hill | 1984 | 0424 | 2115 | 6.2 | CDMG | 47125 | Capitola | 38.1 | AQC | C | .20 | 28.00 | .142 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90049 | Pacific Palisades - Sunset # | 38.6 | --B | C | .45 | 25.00 | .063 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90049 | Pacific Palisades - Sunset # | 38.6 | --B | C | .50 | 25.00 | .038 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24087 | Arleta - Nordhoff Fire Sta | 38.9 | AQD | C | .40 | 30.00 | .093 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24087 | Arleta - Nordhoff Fire Sta | 38.9 | AQD | C | .50 | 30.00 | .091 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12202 | San Jacinto Vall. Cem | 39.6 | AQD | C | .20 | 38.00 | .069 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12202 | San Jacinto Vall. Cem | 39.6 | AQD | C | .20 | 31.00 | .063 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90003 | Northridge - 17645 Saticoy St # | 39.8 | --D | C | .23 | 25.00 | .161 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90003 | Northridge - 17645 Saticoy St # | 39.8 | --D | C | .20 | 25.00 | .118 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36441 | Parkfield - Vineyard Cany 6W | 41.0 | IPC | - | .20 | 25.00 | .054 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36441 | Parkfield - Vineyard Cany 6W | 41.0 | IPC | - | .20 | 27.00 | .076 |
| 0064 | Victoria, Mexico | 1980 | 0609 | 0328 | 6.1 | UNAMUCSD | 6617 | Cucapah | 41.9 | IQD | C | .20 | 44.00 | .092 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 13197 | Huntington Beach - Lake St | 42.8 | AQD | C | .25 | 25.00 | .045 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 13197 | Huntington Beach - Lake St | 42.8 | AQD | C | .17 | 25.00 | .044 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24436 | Tarzana - Cedar Hill | 43.0 | APB | C | .60 | 40.00 | .449 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 24436 | Tarzana - Cedar Hill | 43.0 | APB | C | .60 | 40.00 | .644 |

Table 15: 5% RESPONE SPECTRA FOR NEHRP D FAULT CLASS C (**M** 5.75 TO 6.49) (Cont.)

| No. | Earthquake | Date & Time YEAR | MODY | HRMN | Mag | Own | No. | Station | Closest Dist (km) | Site Codes Geom | Site Codes USGS | Filter Corners HP (hz) | Filter Corners LP (hz) | PGA (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12331 | Hemet Fire Station | 43.3 | AQD | C | .50 | 35.00 | .144 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12331 | Hemet Fire Station | 43.3 | AQD | C | .50 | 31.00 | .132 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36410 | Parkfield - Cholame 3W | 43.9 | IHC | - | .20 | 21.00 | .098 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36410 | Parkfield - Cholame 3W | 43.9 | IHC | - | .20 | 24.00 | .084 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36411 | Parkfield - Cholame 4W | 44.7 | IHC | - | .20 | 21.00 | .136 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36411 | Parkfield - Cholame 4W | 44.7 | IHC | - | .20 | 23.00 | .136 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12026 | Indio - Coachella Canal | 45.7 | IQD | C | .50 | 30.00 | .053 |
| 0103 | N. Palm Springs | 1986 | 0708 | 0920 | 6.0 | USGS | 12026 | Indio - Coachella Canal | 45.7 | IQD | C | .50 | 33.00 | .050 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36412 | Parkfield - Cholame 4AW | 46.0 | IHC | - | .20 | 21.00 | .047 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36412 | Parkfield - Cholame 4AW | 46.0 | IHC | - | .20 | 20.00 | .078 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90057 | Canyon Country - W Lost Cany # | 46.4 | --D | C | .38 | 25.00 | .109 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90057 | Canyon Country - W Lost Cany # | 46.4 | --D | C | .23 | 22.00 | .103 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36227 | Parkfield - Cholame 5W | 47.3 | IHC | C | .20 | 22.00 | .147 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36227 | Parkfield - Cholame 5W | 47.3 | IHC | C | .20 | 22.00 | .131 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90053 | Canoga Park - Topanga Can # | 47.4 | --D | C | .25 | 25.00 | .139 |
| 0117 | Whittier Narrows | 1987 | 1001 | 1442 | 6.0 | CDMG | 90053 | Canoga Park - Topanga Can # | 47.4 | --D | C | .28 | 25.00 | .116 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36432 | Parkfield - Gold Hill 6W | 48.0 | IPC | - | .20 | 30.00 | .059 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36432 | Parkfield - Gold Hill 6W | 48.0 | IPC | - | .20 | 30.00 | .069 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36451 | Parkfield - Cholame 6W | 49.0 | IHC | - | .50 | 21.00 | .126 |
| 0076 | Coalinga | 1983 | 0502 | 2342 | 6.4 | CDMG | 36451 | Parkfield - Cholame 6W | 49.0 | IHC | - | .20 | 28.00 | .102 |
| 0008 | Northern Calif | 1941 | 1003 | 1614 | 6.4 | USGS | 1023 | Ferndale City Hall | 49.6 | BQD | C | .20 | 13.00 | .114 |
| 0008 | Northern Calif | 1941 | 1003 | 1614 | 6.4 | USGS | 1023 | Ferndale City Hall | 49.6 | BQD | C | .50 | 13.00 | .122 |

| Table 16<br><br>MEAN MAGNITUDES AND DISTANCES | | | |
|---|---|---|---|
| **M** Range | $\overline{M}$ | $\overline{D}$ | Number of Components |
| 5 - 6 | 5 - 57 | 19.8 | 210 |
| 6 - 7 | 6 - 58 | 26.8 | 228 |
| > 6.75 | 7 - 23 | 23.7 | 139 |
| > 7.0 | 7 - 48 | 22.9 | 79 |