

***Earthquake Engineering: From Engineering Seismology to
Performance-Based Engineering***

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Chapter 5, *Engineering Characterization of Ground Motion*, by
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Appendix to Chapter 5
Supplemental Ground Motion (Attenuation) Relations

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A1 Introduction

This Appendix provides equations for all of the ground motion (attenuation) relations that are discussed in Section 5.4. These relations represent those that were used by the U.S. Geological Survey (USGS) in the 2002 update of the U.S. national seismic hazard maps [Frankel *et al.*, 2002]. Even those ground motion relations for which equations were presented in Section 5.4 are given for completeness. All of the ground-motion and seismological parameters defined in the ground motion relations are presented in terms of a consistent set of symbols and functional forms that do not necessarily conform to those used by the authors of these relations. This is done to aid in both the presentation and in the use of these models by seismologists and engineers.

The constants in the ground motion relations are adjusted to give a consistent set of units for the predicted strong-motion parameters, in this case the fraction of gravity (g) for acceleration, where $g \approx 981 \text{ cm/sec}^2$, and centimeters/second (cm/sec) for velocity. If the original relation was given in terms of the response spectral parameter pseudo-velocity (S_v), this parameter was converted to pseudo-acceleration (S_a) using the expressions give in Section 5.3.3.1. Logarithms in the ground motion relations are consistently defined in terms of natural logarithms (ln). However, all other equations, as well as the tabulated versions of the Atkinson and Boore [1995, 1997] and Frankel *et al.* [1996] ground motion relations, were left in terms of their original units and common logarithms (log).

Some of the functional forms were modified so that a single table of regression coefficients could be used. Although this means that the ground motion relations depart from their original mathematical forms, the modifications provide a consistent framework for understanding and applying these relations in an informed and, hopefully, unambiguous manner. This notation is the same as that used by Campbell [2003a, 2003b, 2003d]. As is engineering convention in the United States, the strong-motion parameters are consistently defined in terms of the geometric mean (hereafter referred as the average) of the two horizontal components. This is mentioned because it is standard practice elsewhere to use the largest horizontal component. If a conversion between the two components is necessary, the largest horizontal component can be estimated from the average horizontal component by multiplying by 1.15 [Campbell, 1981; Ansary *et al.*, 1995].

The notation and definitions of the strong-motion and seismological parameters used throughout this Appendix are summarized in a separate section on Notation and Definitions so that they need not be continually repeated. This Appendix also includes the notation used in Section 5.4. Although this requires that the Notation and Definitions section be consulted for the definition of a specific parameter, it saves space and a considerable degree of redundancy to list them in one place. The symbols are categorized for convenience. Two specific parameters, the site category and the faulting category, pose a particular challenge when evaluating the ground motion relations, since each relation defines these parameters somewhat differently. To help in the proper application of each relation, guidance on their use is provided in a series of tables in the Section 5.4, with which the user should become familiar. Table 5.3 provides the definition of

the National Earthquake Hazard Reduction Program (NEHRP) site classes used in the 1997 *Uniform Building Code* (UBC) and the 2000 *International Building Code* (IBC), as well as in the extension of these site classes to include boundary conditions by the California Geological Survey [Wills *et al.*, 2000]. Table 5.4 provides a summary of information about each relation, including how it was used in the development of the 2002 USGS hazard maps. Table 5.5 gives the amplitude caps and the adjustment factors that were used by the USGS to limit the predicted eastern North America (ENA) ground motions to reasonable values and to adjust the ENA ground motions predicted for Very Hard Rock to that representative of the NEHRP B-C boundary site class used as the reference site condition for the maps. Tables 5.6 and 5.7 provide guidance on the definition of the faulting and site categories for each ground motion relation and how the parameters that define these categories should be evaluated. An important aspect of Table 5.7 is an attempt by the writers to provide a nominal value of 30-meter velocity (V_{30}) and a NEHRP site class designation in terms of both the building code and California Geological Survey (CGS) definitions for each site category.

The ground motion relations are grouped into three tectonic categories for presentation purposes; namely, western North America (WNA), eastern North America (ENA), and the Cascadia Subduction Zone (Cascadia S. Z.). In the United States, WNA is commonly referred to as the western United States (WUS) and ENA as the central and eastern United States (CEUS), but the more generic WNA and ENA terms commonly used to refer to both the United States and Canada will be retained in this Appendix. WNA is further divided into a compressional regime, called non-extensional by the USGS, and an extensional regime [Frankel *et al.*, 2002]. The Cascadia S. Z. is further divided into a subduction interface regime and a subduction intraslab (intermediate-depth or Wadati-Benioff) regime. The interface regime is modeled as a fault, whereas the intraslab regime is modeled as background seismicity by the USGS. See Tables 5.4, 5.6 and 5.7 for guidance on how the USGS evaluated each relation for the different types of tectonic environment, faulting mechanism, and site conditions.

A2 Western North America (WNA)

The USGS used five ground motion relations in WNA. These relations were developed by Abrahamson and Silva [1997], Boore *et al.* [1997], Campbell and Bozorgnia [2003], Sadigh *et al.* [1993, 1997], and Spudich *et al.* [1999]. All five relations were used for the extensional regime. The first four were used for the compressional (i.e., non-extensional) regime. All of these relations were developed using the empirical method.

The ground motion relations of Abrahamson and Silva and Campbell and Bozorgnia include a term to account for hanging-wall effects. Somerville and Abrahamson [1995, 2000] suggest that the hanging-wall term primarily models geometrical effects that result from the use of r_{rup} as the distance measure. A similar geometrical effect would be expected from the use of r_{seis} , the distance measure used by Campbell and Bozorgnia. As a result, Somerville and Abrahamson believe hanging-wall effects can theoretically be applied to any dipping fault, regardless of its faulting mechanism. However, in the opinion of the writer and the USGS, there

is insufficient data to test this hypothesis for strike-slip and normal-faulting events. It is for this reason that the USGS only applies these hanging-wall terms to reverse faults in the 2002 update of the national hazard maps [Frankel *et al.*, 2002]. The Campbell and Bozorgnia relation has a built-in function that prevents including hanging-wall effects for strike-slip or normal-faulting events, for firm soil, and for a fault dip greater than 70°.

A2.1 Abrahamson and Silva WNA Model

The ground motion relation developed by Abrahamson and Silva [1997] is given by

$$\ln Y = c_1 + f_1(M_W, r_{rup}) + f_2(M_W)F + f_3(M_W, r_{rup})HW + f_4(S, A_{Rock}) \quad (\text{A1})$$

where Y is the average horizontal or vertical component of peak ground acceleration (PGA) or S_a and

$$f_1(M_W, r_{rup}) = \begin{cases} c_2(M_W - 6.4) + c_3(8.5 - M_W)^{c_4} \\ \quad + [c_5 + c_6(M_W - 6.4)] \ln R & \text{for } M_W \leq 6.4 \\ c_7(M_W - 6.4) + c_3(8.5 - M_W)^{c_4} \\ \quad + [c_5 + c_6(M_W - 6.4)] \ln R & \text{for } M_W > 6.4 \end{cases} \quad (\text{A2})$$

$$R = \sqrt{r_{rup}^2 + c_8^2} \quad (\text{A3})$$

$$f_2(M_W) = \begin{cases} c_9 & \text{for } M_W \leq 5.8 \\ c_9 + \frac{(c_{10} - c_9)(M_W - 5.8)}{0.6} & \text{for } 5.8 < M_W < 6.4 \\ c_{10} & \text{for } M_W \geq 6.4 \end{cases} \quad (\text{A4})$$

$$f_3(M_W, r_{rup}) = f_{HW}(M_W) f_{HW}(r_{rup}) \quad (\text{A5})$$

$$f_{HW}(M_W) = \begin{cases} 0 & \text{for } M_W \leq 5.5 \\ M_W - 5.5 & \text{for } 5.5 < M_W < 6.5 \\ 1 & \text{for } M_W \geq 6.5 \end{cases} \quad (\text{A6})$$

$$f_{HW}(r_{rup}) = \begin{cases} 0 & \text{for } r_{rup} \leq 4 \text{ km} \\ c_{11} \frac{r_{rup} - 4}{4} & \text{for } 4 < r_{rup} \leq 8 \text{ km} \\ c_{11} & \text{for } 8 < r_{rup} \leq 18 \text{ km} \\ c_{11} \left(1 - \frac{r_{rup} - 18}{7}\right) & \text{for } 18 < r_{rup} \leq 25 \text{ km} \\ 0 & \text{for } r_{rup} > 25 \text{ km} \end{cases} \quad (\text{A7})$$

$$f_4(S, A_{Rock}) = [c_{12} + c_{13} \ln(A_{Rock} + c_{14})] S_{Soil} \quad (\text{A8})$$

The standard deviation of $\ln Y$ is defined as a function of magnitude according to the expression

$$\sigma_{\ln Y}(M_w) = \begin{cases} c_{15} & \text{for } M_w \leq 5.0 \\ c_{15} - c_{16}(M_w - 5) & \text{for } 5.0 < M_w < 7.0 \\ c_{15} - 2c_{16} & \text{for } M_w \geq 7.0 \end{cases} \quad (\text{A9})$$

The hanging-wall parameter (HW) quantifies the effect of the hanging wall, where $HW = 1$ for a fault dipping greater than 70° regardless of the faulting mechanism [N. Abrahamson, personal comm., 2002] and when the site is located on the hanging wall (see Figure S1 for the definition of the hanging wall). Note, however, that for simplicity, the USGS sets $HW = 1$ only when a site is located over the rupture plane of a reverse or thrust fault (i.e., when $r_{jb} = 0$). The period-independent regression coefficients in these equations are $c_2 = 0.512$, $c_4 = 2$, $c_6 = 0.17$, $c_7 = -0.144$ and $c_{14} = 0.03$ for the average horizontal component of ground motion, and $c_2 = 0.909$, $c_4 = 3$, $c_6 = 0.06$, $c_7 = 0.275$ and $c_{14} = 0.3$ for the vertical component of ground motion. The remaining regression coefficients are listed in Tables A1 and A2.

A2.2 Boore et al. WNA Model

The ground motion relation developed by Boore *et al.* [1997] is given by

$$\ln Y = c_1 + f_1(M_w, r_{jb}) + f_2(V_{30}) \quad (\text{A10})$$

where Y is the average horizontal component of PGA or S_a and

$$f_1(M_w, r_{jb}) = c_2(M_w - 6) + c_3(M_w - 6)^2 + c_4 \ln R \quad (\text{A11})$$

$$R = \sqrt{r_{jb}^2 + c_5^2} \quad (\text{A12})$$

$$c_1 = \begin{cases} c_{1U} & \text{for unspecified faulting} \\ c_{1S} & \text{for strike-slip faulting} \\ c_{1R} & \text{for reverse faulting} \end{cases} \quad (\text{A13})$$

$$f_2(V_{30}) = c_6 \ln(V_{30}/c_7) \quad (\text{A14})$$

The regression coefficients and the standard deviations of $\ln Y$, which include component-to-component dispersion, are listed in Table A3. Strictly speaking, component-to-component dispersion should not be used with the average horizontal component of ground motion; however, it has been included because the USGS has included it in developing the 2002 hazard maps. The higher standard deviations will lead to higher probabilistic ground motion, especially at long return periods. Also, rather than use c_{1U} to represent unknown or random faulting, the USGS averages c_{1S} and c_{1R} .

A2.3 Campbell and Bozorgnia WNA Model

The ground motion relation developed by Campbell and Bozorgnia [2003] is given by

$$\ln Y = c_1 + f_1(M_W) + f_2(M_W, r_{seis}, S) + f_3(F) + f_4(S) + f_5(HW, M_W, r_{seis}) \quad (\text{A15})$$

where Y is the average horizontal or vertical component of PGA or S_a and

$$f_1(M_W) = c_2 M_W + c_3 (8.5 - M_W)^2 \quad (\text{A16})$$

$$f_2(M_W, r_{seis}, S) = c_4 \ln R \quad (\text{A17})$$

$$R = \sqrt{r_{seis}^2 + g(S)^2 \left(\exp[c_5 M_W + c_6 (8.5 - M_W)^2] \right)^2} \quad (\text{A18})$$

$$g(S) = c_7 + c_8 (S_{VFS} + S_{SR}) + c_9 S_{FR} \quad (\text{A19})$$

$$f_3(F) = c_{10} F_{RV} + c_{11} F_{TH} \quad (\text{A20})$$

$$f_4(S) = c_{12} S_{VFS} + c_{13} S_{SR} + c_{14} S_{FR} \quad (\text{A21})$$

$$f_5(HW, M_w, r_{seis}) = HW f_3(F) f_{HW}(M_w) f_{HW}(r_{seis}) \quad (\text{A22})$$

$$HW = \begin{cases} 0 & \text{for } r_{jb} \geq 5 \text{ km, } \delta > 70^\circ \\ (S_{VFS} + S_{SR} + S_{FR})(5 - r_{jb})/5 & \text{otherwise} \end{cases} \quad (\text{A23})$$

$$f_{HW}(M_w) = \begin{cases} 0 & \text{for } M_w < 5.5 \\ M_w - 5.5 & \text{for } 5.5 \leq M_w \leq 6.5 \\ 1 & \text{for } M_w > 6.5 \end{cases} \quad (\text{A24})$$

$$f_{HW}(r_{seis}) = \begin{cases} c_{15}(r_{seis}/8) & \text{for } r_{seis} < 8 \text{ km} \\ c_{15} & \text{for } r_{seis} \geq 8 \text{ km} \end{cases} \quad (\text{A25})$$

The standard deviation of $\ln Y$ is defined as a function of magnitude according to the expression

$$\sigma_{\ln Y} = \begin{cases} c_{16} - 0.07M_w & \text{for } M_w < 7.4 \\ c_{16} - 0.503 & \text{for } M_w \geq 7.4 \end{cases} \quad (\text{A26})$$

or as a function of PGA according to the expression

$$\sigma_{\ln Y} = \begin{cases} c_{17} + 0.351 & \text{for } \text{PGA} \leq 0.07g \\ c_{17} - 0.132 \ln(\text{PGA}) & \text{for } 0.07g < \text{PGA} < 0.25g \\ c_{17} + 0.183 & \text{for } \text{PGA} \geq 0.25g \end{cases} \quad (\text{A27})$$

The hanging-wall parameter (HW) quantifies the effect of the hanging wall and will always evaluate to zero for Firm Soil, for a distance of 5 km or greater from the surface projection of the rupture plane, and for a fault plane that dips greater than 70° . The magnitude-dependent version of the standard deviation was used in the development of the 2002 USGS hazard maps. The authors of the relation, however, prefer the PGA-dependent version. The regression coefficients for the average horizontal component and the vertical component of ground motion are listed in Tables A4 and A5, respectively.

A2.4 Sadigh *et al.* WNA Model

The ground motion relations developed by Sadigh *et al.* [1993, 1997] are given by

$$\ln Y = c_1 F + c_2 + f(M_w, r_{rup}) \quad (\text{A28})$$

where Y is the average horizontal or vertical component of PGA or S_a and

$$f(M_W, r_{rup}) = c_3 M_W + c_4 (8.5 - M_W)^{2.5} + c_5 \ln R + c_6 \ln(r_{rup} + 2) \quad (\text{A29})$$

$$R = r_{rup} + c_7 \exp(c_8 M_W) \quad (\text{A30})$$

The standard deviation of $\ln Y$ is defined as a function of magnitude according to the expression

$$\sigma_{\ln Y} = \begin{cases} c_9 & \text{for } M_W \leq c_{13} \\ c_{10} - c_{11} M_W & \text{for } c_{13} < M_W < c_{14} \\ c_{12} & \text{for } M_W \geq c_{14} \end{cases} \quad (\text{A31})$$

The regression coefficients for Generic Rock (equivalent to setting $S_{Soil} = 0$ in those ground motion relations that explicitly include this parameter) are listed in Tables A6 and A7 for the average horizontal component and the vertical component of ground motion, respectively. The regression coefficients for Generic Soil (equivalent to setting $S_{Soil} = 1$ in those relations that explicitly include this parameter) are listed in Table A8 for the average horizontal component of ground motion. No regression coefficients are given for the vertical component of ground motion for Generic Soil.

A2.5 Spudich *et al.* WNA Model

The ground motion relation developed by Spudich *et al.* [1999] is given by

$$\ln Y = c_1 + f_1(M_W, r_{jb}) + f_2(S) \quad (\text{A32})$$

where Y is the average horizontal component of PGA or S_a and

$$f_1(M_W, r_{jb}) = c_2(M_W - 6) + c_3(M_W - 6)^2 + c_4 \ln R \quad (\text{A33})$$

$$R = \sqrt{r_{jb}^2 + c_5^2} \quad (\text{A34})$$

$$f_2(S) = c_6 S_{Soil} \quad (\text{A35})$$

The regression coefficients and the standard deviations of $\ln Y$, which include component-to-component dispersion, are listed in Table A9. Strictly speaking, component-to-component dispersion should not be used with the average horizontal component of ground motion; however, it has been included because the USGS has included it in developing the 2002

hazard maps. The higher standard deviations will lead to higher probabilistic ground motion, especially at long return periods.

A3 Eastern North America (ENA)

The USGS used five ground motion relations in ENA. These relations were developed by Atkinson and Boore [1995, 1997], Campbell [2001, 2003c], Frankel *et al.* [1996], Somerville *et al.* [2001], and Toro *et al.* [1997]. Because of the limited number of strong-motion recordings in this region, none of these relations were developed using the empirical method. The Atkinson and Boore, Frankel *et al.*, and Toro *et al.* relations were developed using the stochastic method [Boore, 2003]. The Campbell relation was developed using the hybrid empirical method [Campbell, 2001, 2003c]. The Somerville *et al.* relation was developed using the theoretical (kinematic dislocation modeling) method. These later two relations inherently include finite faulting effects. The stochastic relations were developed from point-source earthquake models. They approximately account for finite-faulting effects by the substitution of r_{jb} for r_{hypo} and the use of a “fictitious” depth term (see Section 5.4.4.1)

All of the ground motion relations, except for those of Atkinson and Boore and Frankel *et al.*, provide ground-motion estimates for Very Hard Rock ($V_{30} = 2800$ m/sec). The USGS adjusted these estimates to the NEHRP B-C boundary ($V_{30} = 760$ m/sec), the reference site condition used in the USGS hazard maps, based on adjustment factors given in Tables 5.5 and 5.7. Certainly, Very Hard Rock, and in many cases the NEHRP B-C boundary, are not typical site conditions encountered in engineering investigations, even in ENA, so some adjustment must be made for local site conditions. Atkinson and Boore provide a site term to use with their ground motion relation, but this term corresponds to Deep Firm Soil ($V_{30} = 500$ m/sec, depth > 60 m) and was calculated using the stochastic method assuming linear site response. As a result, this site term might not be appropriate for the larger ground motions of engineering interest. One simple approach would be to assume that Very Hard Rock represents NEHRP site class A and use the site factors in the U.S. building codes [e.g., BSSC, 2001; see also Chapter 4] to approximate the effect of local site conditions for other NEHRP site classes. One of the problems with this approach is that these site factors are only given for spectral accelerations averaged over short periods ($T_n = 0.1\text{--}0.5$ sec) and long periods ($T_n = 0.5\text{--}2.0$ sec), so judgment must be applied in order to use these factors with individual spectral periods. Another problem is that NEHRP site class A is usually associated with a 30-meter velocity of around 1890 m/sec [Savy *et al.*, 1987], which is much less than that of Very Hard Rock. Boore [2003] suggests that nonlinear soil effects should be taken into account using a nonlinear site-response analysis [see Chapter 4 for a discussion of nonlinear site-response analysis]. Additional guidance on incorporating site effects is provided by Savy *et al.* [1987], EPRI [1993], and Hwang *et al.* [1997].

A3.1 Atkinson and Boore ENA Model

Atkinson and Boore [1995, 1997] developed two ENA ground motion relations for Very Hard Rock ($V_{30} = 2800$ m/sec). The one they recommend, because of its better accuracy, for $5.0 \leq M_w \leq 7.25$ and $10 \leq r_{hypo} \leq 500$ km is provided only in tabular form (Tables A10–A19). These tables list the common logarithm of r_{hypo} ($\log r_{hypo}$) in km and the common logarithm of the average horizontal component of PGA or S_a ($\log Y$) in cm/sec². Ground-motion values in g can be obtained by dividing Y by 981 cm/sec²/g. Values for other magnitudes, distances, and periods can be obtained by linear interpolation of M_w , $\log r_{hypo}$, and $\log T_n$. Standard deviations (σ_{lnY}) for selected periods are listed in Table A20.

The less accurate equation form of the relation is given by

$$\ln Y = c_1 + f_1(M_w, r_{hypo}) + f_2(S) \quad (\text{A36})$$

where Y is the average horizontal component of PGA, PGV or S_a and

$$f_1(M_w, r_{hypo}) = c_2(M_w - 6) + c_3(M_w - 6)^2 - \ln r_{hypo} + c_4 r_{hypo} \quad (\text{A37})$$

$$f_2(S) = c_5 S_{Deep} \quad (\text{A38})$$

The regression coefficients and the recommended values of the standard deviations of $\ln Y$ [Atkinson, 1995] are listed in Table A20. The value of c_5 was theoretically developed using the stochastic method, so caution should be used when applying this coefficient to high ground-motion amplitudes where nonlinear soil behavior might be expected. The equations overestimate the simulated values for $M_w < 5.5$ and $r_{hypo} > 30$ km. This bias is not an issue in most seismic hazard studies. It also tends to smooth-out the flat part of the attenuation between 70 and 130 km that is caused by critical reflections off the base of the crust.

In order to avoid the magnitude and distance limitations in the ground-motion tables and to directly provide estimates of $\log \text{PGA}$ and $\log S_a$ in g for the NEHRP B-C boundary ($V_{30} = 760$ m/sec), the USGS used a revised set of ground-motion tables developed by D.M. Boore [Frankel *et al.*, 2002; D.M. Boore, written comm., 2003]. These estimates used the same stochastic model as that used to develop the original ground-motion tables with the exception of substituting the shallow part of the site velocity and density profile with that used to develop the Frankel *et al.* [1996] ground-motion tables for the NEHRP B-C boundary. These revised ground-motion values for $5.0 \leq M_w \leq 8.2$ and $10 \leq r_{hypo} \leq 1000$ km are listed in Tables A21–A27 [D.M. Boore, written comm., 2003]. Values for other magnitudes, distances, and periods can be obtained by linear interpolation of M_w , $\log r_{hypo}$, and $\log T_n$. For $r_{hypo} < 10$ km, the USGS used $r_{hypo} = 10$ km. Even though the authors provided estimates of standard deviation, the USGS used a consistent set of standard deviations (σ_{lnY}) for all of the ENA relations equal to 0.75 for PGA and S_a at $T_n \leq 0.5$ sec and 0.8 for S_a at $T_n > 0.5$ sec for purposes of developing the 2002 hazard maps.

A3.2 Campbell ENA Model

The ground motion relation developed by Campbell [2001, 2003c] is given by

$$\ln Y = c_1 + f_1(M_w) + f_2(M_w, r_{rup}) + f_3(r_{rup}) \quad (\text{A39})$$

where Y is the average horizontal component of PGA or S_a and

$$f_1(M_w) = c_2 M_w + c_3 (8.5 - M_w)^2 \quad (\text{A40})$$

$$f_2(M_w, r_{rup}) = c_4 \ln R + (c_5 + c_6 M_w) r_{rup} \quad (\text{A41})$$

$$R = \sqrt{r_{rup}^2 + [c_7 \exp(c_8 M_w)]^2} \quad (\text{A42})$$

$$f_3(r_{rup}) = \begin{cases} 0 & \text{for } r_{rup} \leq 70 \text{ km} \\ c_9 (\ln r_{rup} - \ln 70) & \text{for } 70 < r_{rup} \leq 130 \text{ km} \\ c_9 (\ln r_{rup} - \ln 70) + c_{10} (\ln r_{rup} - \ln 130) & \text{for } r_{rup} > 130 \text{ km} \end{cases} \quad (\text{A43})$$

The standard deviation of $\ln Y$ is defined as a function of magnitude according to the expression

$$\sigma_{\ln Y} = \begin{cases} c_{11} + c_{12} M_w & \text{for } M_w < 7.16 \\ c_{13} & \text{for } M_w \geq 7.16 \end{cases} \quad (\text{A44})$$

Even though the author provided estimates of standard deviation, the USGS used a consistent set of standard deviations ($\sigma_{\ln Y}$) for all of the ENA relations equal to 0.75 for PGA and S_a at $T_n \leq 0.5$ sec and 0.8 for S_a at $T_n > 0.5$ sec for purposes of developing the 2002 hazard maps. The regression coefficients for this relation are listed in Table A28.

A3.3 Frankel *et al.* ENA Model

The ground motion relation developed by Frankel *et al.* [1996] is provided only in tabular form (Tables A29–A35). These tables, valid for $5.0 \leq M_w \leq 8.2$ and $10 \leq r_{hypo} \leq 1000$ km, list $\log r_{hypo}$ in km and \log PGA or $\log S_a$ in g for the average horizontal component of ground motion. Values for other magnitudes, distances, and periods can be obtained by linear interpolation of M_w , $\log r_{hypo}$, and $\log T_n$. For $r_{hypo} < 10$ km, the USGS used $r_{hypo} = 10$ km. Frankel *et al.* [1996] provided tables for PGA and S_a at periods of only 0.2, 0.3 and 1.0 sec. At the writers' request, A. Frankel [written comm., 2003] provided additional S_a tables at periods of 0.1, 0.5 and 2.0 sec, which the USGS used in conjunction with the published tables to develop uniform hazard

spectra for sites throughout the United States using the 1996 USGS seismic hazard database [Leyendecker *et al.*, 2000; Frankel and Leyendecker, 2001]. Frankel *et al.* did not recommend specific values of standard deviation to use with these tables; however, the USGS used a consistent set of standard deviations ($\sigma_{\ln Y}$) for all of the ENA relations equal to 0.75 for PGA and S_a at $T_n \leq 0.5$ sec and 0.8 for S_a at $T_n > 0.5$ sec for purposes of developing the 2002 hazard maps.

A3.4 Somerville *et al.* ENA Model

The ground motion relation developed by Somerville *et al.* [2001] is given by

$$\ln Y = c_1 + f_1(M_w) + f_2(M_w, r_{rup}) + f_3(r_{rup}) \quad (\text{A45})$$

where Y is the average horizontal or vertical component of PGA or S_a and

$$f_1(M_w) = c_2(M_w - 6.4) + c_3(8.5 - M_w)^2 \quad (\text{A46})$$

$$f_2(M_w, r_{rup}) = c_4(M_w - 6.4) \ln R + c_5 r_{rup} \quad (\text{A47})$$

$$f_3(r_{rup}) = \begin{cases} c_6 \ln R & \text{for } r_{rup} < 50 \text{ km} \\ c_6 \ln R_1 + c_7(\ln R - \ln R_1) & \text{for } r_{rup} \geq 50 \text{ km} \end{cases} \quad (\text{A48})$$

$$R = \sqrt{r_{rup}^2 + c_8^2} \quad (\text{A49})$$

$$R_1 = \sqrt{50^2 + c_8^2} \quad (\text{A50})$$

The regression coefficients and the standard deviations of $\ln Y$ are listed in Table A36. Even though the authors provided estimates of standard deviation, the USGS used a consistent set of standard deviations ($\sigma_{\ln Y}$) for all of the ENA relations equal to 0.75 for PGA and S_a at $T_n \leq 0.5$ sec and 0.8 for S_a at $T_n > 0.5$ sec for purposes of developing the 2002 hazard maps. Four sets of regression coefficients are given, one each for the average horizontal and vertical component of ground motion, one for a rifted domain, and one for a non-rifted domain. The rifted domain is characterized by more frequent, larger, and deeper earthquakes. There are two types of rifted domain in ENA, one along the continental margin and one in the interior of the continent. The rifted domain along the continental margin lies along the Atlantic Coast. The rifted domain within the continental interior includes the system of failed rifts that lies west of the continental margin, such as the St. Lawrence (part of the Iapetus margin) and its branches the Saguenay Graben and the Ottawa rift; the Reelfoot Rift; and the Southern Oklahoma Aulacogen.

The location of the rifted domain in ENA is represented approximately by the eastern and western margins of the Phanerozoic Rim Zone described by Wheeler and Frankel [2000]. The USGS used only the rifted-domain relation in the development of the 2002 hazard maps. Also, since the authors of this relation do not recommend its use for $M_w < 6.0$, the USGS did not use it with background seismicity sources.

A3.5 Toro *et al.* ENA Model

The ground motion relation developed by Toro *et al.* [1997] is given by

$$\ln Y = c_1 + f_1(M) + f_2(r_{jb}) \quad (\text{A51})$$

where Y is the average horizontal component of PGA or S_a , $M = M_w$ or m_{Lg} and

$$f_1(M) = c_2(M - 6) + c_3(M - 6)^2 \quad (\text{A52})$$

$$f_2(r_{jb}) = c_4 \ln R + c_5 g(R) + c_6 R \quad (\text{A53})$$

$$g(R) = \begin{cases} 0 & \text{for } R \leq 100 \text{ km} \\ \ln(R/100) & \text{for } R > 100 \text{ km} \end{cases} \quad (\text{A54})$$

$$R = \sqrt{r_{jb}^2 + c_7^2} \quad (\text{A55})$$

The standard deviation of $\ln Y$ is defined as a function of magnitude and distance according to the expression

$$\sigma_{\ln Y} = \sqrt{\sigma_{\ln Y}^2(M) + \sigma_{\ln Y}^2(r_{jb})} \quad (\text{A56})$$

where $\sigma_{\ln Y}(M)$ and $\sigma_{\ln Y}(r_{jb})$ are computed by linear interpolation of the values given in Table A37. Even though the authors give estimates of standard deviation, the USGS used a consistent set of standard deviations ($\sigma_{\ln Y}$) for all of the ENA relations equal to 0.75 for PGA and S_a at $T_n \leq 0.5$ sec and 0.8 for S_a at $T_n > 0.5$ sec for purposes of developing the 2002 hazard maps.

The regression coefficients for this relation are listed in Table A37. Four sets of regression coefficients are given, one for M_w , one for m_{Lg} , one for the Midcontinent region, and one for the Gulf Coast region. The Gulf Coast region represents the lowlands that border the Gulf of Mexico and includes Louisiana, the southeastern coast of Texas, and the southern areas of Alabama and Mississippi [EPRI, 1993]. The Midcontinent region covers the remaining part of ENA. The USGS used the Midcontinent version for all seismic sources, the M_w version for faults, and the m_{Lg} version for background seismicity in developing the 2002 hazard maps.

A4 Cascadia Subduction Zone

The USGS used three ground motion relations for the Cascadia S. Z. These relations were developed by Atkinson and Boore [2003], Youngs *et al.* [1997], and Sadigh *et al.* [1997]. The latter two were used for subduction interface events. The first two were used for intraslab (intermediate-depth or Wadati-Benioff) events.

A4.1 Atkinson and Boore Subduction-Zone Model

The subduction-zone ground motion relation developed by Atkinson and Boore [2003] is given by

$$\ln Y = c_1 + f_1(M_w, r_{rup}, h_{hypo}) + f_2(S)f_3(A_B) \quad (\text{A57})$$

where Y is the average horizontal component of PGA or S_a and

$$c_1 = \begin{cases} c_{1A} & \text{for all regions} \\ c_{1C} & \text{for Cascadia} \\ c_{1J} & \text{for Japan} \end{cases} \quad (\text{A58})$$

$$f_1(M_w, r_{rup}, h_{hypo}) = c_2 M_w + g(M_w) \ln R + c_3 R + c_4 h_{hypo} \quad (\text{A59})$$

$$g(M_w) = -\exp(c_5 + c_6 M_w) \quad (\text{A60})$$

$$R = \sqrt{r_{rup}^2 + [c_7 \exp(c_8 M_w)]^2} \quad (\text{A61})$$

$$f_2(S) = c_9 S_C + c_{10} S_D + c_{11} S_E \quad (\text{A62})$$

$$f_3(A_B) = \begin{cases} 0 & \text{for } A_B \geq 0.510g \text{ and } T_n \leq 0.5 \text{ sec} \\ 1 - \left(\frac{A_B - 0.102}{0.408} \right) & \text{for } 0.102 < A_B < 0.510g \text{ and } T_n \leq 0.5 \text{ sec} \\ 1 - \left(T_n^{-1} - 1 \right) \left(\frac{A_B - 0.102}{0.408} \right) & \text{for } 0.102 < A_B < 0.510g \text{ and } 0.5 < T_n < 1.0 \text{ sec} \\ 1 & \text{for } A_B \leq 0.102g \text{ or } T_n \geq 1.0 \text{ sec} \end{cases} \quad (\text{A63})$$

The period-independent regression coefficients are $c_6 = 0.00724$ and $c_7 = 1.167$. The remaining regression coefficients and the standard deviations of $\ln Y$ are listed in Table A38. Two sets of regression coefficients are given, one for interface events (equivalent to setting $z_T = 0$ in those ground motion relations that explicitly include this parameter) and one for intraslab events (equivalent to setting $z_T = 1$ in those relations that explicitly include this parameter). The authors of the relation recommend setting $M_w = 8.5$ for interface events, $M_w = 8.0$ for intraslab events, and $h_{hypo} = 100$ km for all events for magnitudes and depths larger than these values.

A4.2 Youngs *et al.* Subduction-Zone Model

The ground motion relation developed by Youngs *et al.* [1997] is given by

$$\ln Y = c_1 + f_1(M_w) + f_2(M_w, r_{rup}, h_{hypo}) + f_3(z_T) \quad (\text{A64})$$

where Y is the average horizontal component of PGA or S_a and

$$f_1(M_w) = c_2 M_w + c_3 (10 - M_w)^3 \quad (\text{A65})$$

$$f_2(M_w, r_{rup}, h_{hypo}) = c_4 \ln R + c_5 h_{hypo} \quad (\text{A66})$$

$$R = r_{rup} + c_6 \exp(c_7 M_w) \quad (\text{A67})$$

$$f_3(z_T) = c_8 z_T \quad (\text{A68})$$

The standard deviation of $\ln Y$ is defined as a function of magnitude according to the expression

$$\sigma_{\ln Y} = \begin{cases} c_9 + c_{10} M_w & \text{for } M_w \leq 8.0 \\ c_{11} & \text{for } M_w > 8.0 \end{cases} \quad (\text{A69})$$

The regression coefficients are listed in Table A39. Two sets of regression coefficients are given, one for Generic Rock (equivalent to setting $S_{Soil} = 0$ in those ground motion relations that explicitly include this parameter) and one for Generic Soil (equivalent to setting $S_{Soil} = 1$ in those relations that explicitly include this parameter).

A4.3 Sadigh *et al.* Subduction-Zone Model

At short distances, the USGS uses the shallow crustal ground motion relation of Sadigh *et al.* [1997] as an alternative to the Youngs *et al.* [1997] relation for subduction interface events. This

relation is meant to account for the possibility that the empirical database for subduction earthquakes is insufficient to allow for a reliable prediction of near-source ground motion. This is because theoretical modeling studies have suggested that near-source ground motions from subduction interface events could be as large as those observed for shallow crustal earthquakes [e.g., Youngs *et al.*, 1997; Gregor *et al.*, 2002]. The USGS evaluates this alternative Sadigh *et al.* relation for reverse faulting and by setting $M_w = 8.5$ for events with magnitudes larger than this value.

References

- Abrahamson, N.A. and Silva, W.J. (1997). "Empirical response spectral attenuation relations for shallow crustal earthquakes." *Seismological Research Letters*, 68, 94–127.
- Atkinson, G.M. (1995). "Optimal choice of magnitude scales for seismic hazard analysis." *Seismological Research Letters*, 66, 51–55.
- Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30.
- Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.
- Atkinson, G.M. and Boore, D.M. (2003). "Empirical ground-motion relations for subduction zone earthquakes and their application to Cascadia and other regions." *Bulletin of the Seismological Society of America*, 93, 1703–1729.
- Boore, D.M. (2003). "Prediction of ground motion using the stochastic method." *Pure and Applied Geophysics*, 160, 635–676.
- Boore, D.M., Joyner, W.B. and Fumal, T.E. (1997). "Equations for estimating horizontal response spectra and peak acceleration from western North American earthquakes: a summary of recent work." *Seismological Research Letters*, 68, 128–153.
- Building Seismic Safety Council (2001). "The 2000 NEHRP recommended provisions for new buildings and other structures." *FEMA 368*, Federal Emergency Management Agency, Washington, D.C.
- Campbell, K.W. (2001). "Development of semi-empirical attenuation relationships for CEUS." U.S. Geological Survey, Award 01HQGR0011, final report.
- Campbell, K.W. (2003a). "Strong motion attenuation relations," In *International Handbook of Earthquake and Engineering Seismology*, Ed. W.H.K. Lee, H. Kanamori, P.C. Jennings, and C. Kisslinger, Part B, pp. 1003–1012, Academic Press, London.
- Campbell, K.W. (2003b). "A contemporary guide to strong motion attenuation relations." In *International Handbook of Earthquake and Engineering Seismology*, Ed. W.H.K. Lee, H. Kanamori, P.C. Jennings, and C. Kisslinger, Handbook CD, Academic Press, London.
- Campbell, K.W. (2003c). "Prediction of strong ground motion using the hybrid empirical method and its use in the development of ground motion (attenuation) relations in eastern North America," *Bulletin of the Seismological Society of America*, 93, 1012–1033.

- Campbell, K.W. (2003d). "Engineering models of strong ground motion." In *Earthquake Engineering Handbook*, Ed. W.F. Chen and C. Scawthorn, Chapter 5, 76p., CRC Press, Boca Raton, Florida.
- Campbell, K.W. and Bozorgnia, Y. (2003). "Updated near-source ground motion (attenuation) relations for the horizontal and vertical components of PGA and acceleration response spectra." *Bulletin of the Seismological Society of America*, 93, 314–331.
- Electric Power Research Institute (1993). "Guidelines for determining design basis ground motions," Vol. 1, *EPRI TR-102293*, Palo Alto, California.
- Frankel, A.D. and Leyendecker, E.V. (2001). "Seismic hazard curves and uniform hazard response spectra for the United States." U.S. Geological Survey, *CD Version 3.10*, March.
- Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E., Dickman, N., Hanson, S. and Hopper, M. (1996). "National seismic hazard maps: documentation June 1996," *U.S. Geological Survey, Open-File Rept. 96-532*.
- Frankel, A.D., Petersen, M.D., Mueller, C.S., Haller, K.M., Wheeler, R.L., Leyendecker, E.V., Wesson, R.L., Harmsen, S.C., Cramer, C.H., Perkins, D.M. and Rukstales, K.S. (2002). "Documentation for the 2002 update of the national seismic hazard maps," *U.S. Geological Survey, Open-File Rept. 02-420*.
- Gregor, N.J., Silva, W.J., Wong, I.G., and Youngs, R.R. (2002). "Ground motion attenuation relationships for Cascadia subduction zone megathrust earthquakes based on a stochastic finite-fault model." *Bulletin of the Seismological Society of America*, 92, 1923–1932.
- Hwang, H.H.M., Huijie, L. and Huo, J.R. (1997). "Site coefficients for design of buildings in eastern North America." *Soil Dynamics and Earthquake Engineering*, 16, 29–40.
- Leyendecker, E.V., Hunt, J.R., Frankel, A.D. and Rukstales, K.S. (2000). "Development of maximum considered earthquake ground motion maps." *Earthquake Spectra*, 16, 21–40.
- 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." *Proceedings, ATC-17-1 Seminar on Seismic Isolation, Passive Energy Dissipation, and Active Control*, San Francisco, 1, 11–23.
- Sadigh, K., Chang, C.Y., Egan, J.A., Makdisi, F. and Youngs, R.R. (1997). "Attenuation relationships for shallow crustal earthquakes based on California strong motion data." *Seismological Research Letters*, 68, 180–189.
- Savy, J.B., Bernreuter, D.L. and Chen, J.C. (1987). "A methodology to correct for effect of the local site characteristics in seismic hazard analyses" In *Ground Motion and Engineering Seismology*, Ed. A.S. Cakmak, Elsevier, Amsterdam, 243–255.
- Somerville, P. and Abrahamson, N. (1995). "Ground motion prediction for thrust earthquakes." *Proceedings, SMIP95 Seminar on Seismological and Engineering Implications of Recent Strong-Motion Data*, San Francisco, 11–23.
- Somerville, P. and Abrahamson, N. (2000). "Prediction of ground motions for thrust earthquakes," *CSMIP/00-01 (OSMS 00-03)*, California Strong Motion Instrumentation

Program, Sacramento, California.

- Somerville, P., Collins, N., Abrahamson, N., Graves, R. and Saikia, C. (2001). "Ground motion attenuation relations for the central and eastern United States." U.S. Geological Survey, Award 99HQGR0098, final report.
- Spudich, P., Joyner, W.B., Lindh, A.G., Boore, D.M., Margaris, B.M. and Fletcher, J.B. (1999). "SEA99: a revised ground motion prediction relation for use in extensional tectonic regimes." *Bulletin of the Seismological Society of America*, 89, 1156–1170.
- Toro, G.R., Abrahamson, N.A. and Schneider, J.F. (1997). "Model of strong ground motions from earthquakes in central and eastern North America: best estimates and uncertainties." *Seismological Research Letters*, 68, 41–57.
- Wheeler, R.L. and Frankel, A. (2000). "Geology in the 1996 USGS seismic hazard maps, central and eastern United States." *Seismological Research Letters*, 71, 273–282.
- Wills, C.J., Petersen, M., Bryant, W.A., Reichle, M., Saucedo, G.J., Tan, S., Taylor, G. and Treiman, J. (2000). "A site-conditions map for California based on geology and shear-wave velocity." *Bulletin of the Seismological Society of America*, 90, S187–S208.
- Youngs, R.R., Chiou, S.J., Silva, W.J. and Humphrey, J.R. (1997). "Strong ground motion attenuation relationships for subduction zone earthquakes." *Seismological Research Letters*, 68, 58–73.

Notation and Definitions

Functions

- $\exp(x)$ = e^x , where $e = \ln(10) = 2.30259$
 $\ln(x)$ = natural logarithm of x , where $x = \exp[\ln(x)]$
 $\log(x)$ = common logarithm of x , where $x = 10^{\log(x)}$

Ground Motion Parameters

- A_B = Value of PGA for NEHRP site class B [Atkinson and Boore, 2003]
 A_{Rock} = Value of PGA for Generic Rock ($S_{Soil} = 0$) [Abrahamson and Silva, 1997]
PGA = Peak ground acceleration (g)
PGV = Peak ground velocity (cm/sec)
 S_a = Acceleration response of a single-degree-of-freedom system (g , 5% damping)
 Y = Peak ground motion (generic)
 Y_{Dir} = Peak ground motion (generic) including rupture directivity effects
 $\sigma_{\ln Y}$ = Standard deviation of $\ln Y$
 $\sigma_{\ln Y, Dir}$ = Standard deviation of $\ln Y_{Dir}$

Magnitude Parameters

m_{Lg}	= Lg-wave magnitude used in eastern United States (equivalent to m_N in Canada)
M	= Earthquake magnitude (generic)
M_w	= Moment magnitude (equivalent to \mathbf{M})

Distance Parameters

r_{epi}	= Epicentral distance (km)
r_{hypo}	= Hypocentral distance (km)
r_{jb}	= Closest distance to the surface projection of the rupture plane (km)
r_{rup}	= Closest distance to the rupture plane (km)
r_{seis}	= Closest distance to the seismogenic part of the rupture plane (km)
R	= Distance to the earthquake source or a term involving this distance (generic)

Depth Parameters

d_{rup}	= Average depth to top of the rupture plane (km)
d_{seis}	= Average depth to top of the seismogenic part of the rupture plane (km)
h_{hypo}	= Hypocentral or focal depth (km)
H_{bot}	= Depth to the bottom of the seismogenic part of the fault (km)
H_{top}	= Depth to the top of the fault (km)
H_{seis}	= Depth to the top of the seismogenic part of the fault (km)

Faulting Mechanism Parameters (see Table 5.6)

F	= Indicator variable for the faulting mechanism (generic)
F_{RV}	= Indicator variable for reverse faulting ($\delta > 45^\circ$) [Campbell and Bozorgnia, 2003]
F_{TH}	= Indicator variable for thrust faulting ($\delta \leq 45^\circ$) [Campbell and Bozorgnia, 2003]
λ	= Rake (direction of slip vector on the fault plane): 0° , pure left-lateral strike slip faulting 90° , pure reverse faulting 180° , pure right-lateral strike slip faulting 270° or -90° , pure normal faulting

Site Parameters (see Tables 5.3 and 5.7)

S	= Indicated variable for location site conditions (generic)
S_C	= Indicator variable for NEHRP site class C [Atkinson and Boore, 2003]
S_D	= Indicator variable for NEHRP site class D [Atkinson and Boore, 2003]

S_E	= Indicator variable for NEHRP site Class E [Atkinson and Boore, 2003]
S_{VFS}	= Indicator variable for Very Firm Soil [Campbell and Bozorgnia, 2003]
S_{SR}	= Indicator variable for Soft Rock [Campbell and Bozorgnia, 2003]
S_{FR}	= Indicator variable for Firm Rock [Campbell and Bozorgnia, 2003]
S_{Deep}	= Indicator variable for Deep Stiff Soil in ENA [Atkinson and Boore, 1997]
S_{Soil}	= Indicator variable for Generic Soil in WNA
V_s	= Shear-wave velocity (generic)
V_{30}	= Average value of V_s in the top 30 m (100 ft) of a site profile (30-meter velocity)

Hanging-Wall Parameter

HW	= Indicator variable for a site located on the hanging wall of the rupture plane
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Source Directivity Parameters

d	= Effective rupture width for estimating directivity effects for dip-slip faults
DR	= Fraction of fault rupture length (s / L) or width (d / W) rupturing towards a site
L	= Length of the fault rupture plane
s	= Effective rupture length for estimating directivity effects for strike-slip faults
ϕ	= Zenith angle between fault rupture plane and ray path to a site for dip-slip faults
θ	= Azimuth angle between rupture plane and ray path to a site for strike-slip faults

Miscellaneous Parameters

f	= Wave frequency ($1/T$, Hz)
g	= fraction of gravity (981 cm/sec ²)
T	= Period [$1/f$, sec]
T_n	= Natural period of a single-degree-of-freedom system
W	= Down-dip width of the fault rupture plane (km)
z_T	= Indicator variable for subduction interface and subduction intraslab events
δ	= Angle of the fault plane with respect to the Earth's surface (dip angle)
π	= Archimedes number (3.141593)

TABLE A1 Coefficients for the Average Horizontal Component of the Abrahamson and Silva WNA Model

T_n (s)	c_1	c_3	c_5	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{15}	c_{16}
PGA	1.640	0.0000	-1.1450	5.60	0.610	0.260	0.370	-0.417	-0.230	0.70	0.135
0.02	1.640	0.0000	-1.1450	5.60	0.610	0.260	0.370	-0.417	-0.230	0.70	0.135
0.03	1.690	0.0143	-1.1450	5.60	0.610	0.260	0.370	-0.470	-0.230	0.70	0.135
0.04	1.780	0.0245	-1.1450	5.60	0.610	0.260	0.370	-0.555	-0.251	0.71	0.135
0.05	1.870	0.0280	-1.1450	5.60	0.610	0.260	0.370	-0.620	-0.267	0.71	0.135
0.06	1.940	0.0300	-1.1450	5.60	0.610	0.260	0.370	-0.665	-0.280	0.72	0.135
0.075	2.037	0.0300	-1.1450	5.58	0.610	0.260	0.370	-0.628	-0.280	0.73	0.135
0.09	2.100	0.0300	-1.1450	5.54	0.610	0.260	0.370	-0.609	-0.280	0.74	0.135
0.10	2.160	0.0280	-1.1450	5.50	0.610	0.260	0.370	-0.598	-0.280	0.74	0.135
0.12	2.272	0.0180	-1.1450	5.39	0.610	0.260	0.370	-0.591	-0.280	0.75	0.135
0.15	2.407	0.0050	-1.1450	5.27	0.610	0.260	0.370	-0.577	-0.280	0.75	0.135
0.17	2.430	-0.0040	-1.1350	5.19	0.610	0.260	0.370	-0.522	-0.265	0.76	0.135
0.20	2.406	-0.0138	-1.1150	5.10	0.610	0.260	0.370	-0.445	-0.245	0.77	0.135
0.24	2.293	-0.0238	-1.0790	4.97	0.610	0.232	0.370	-0.350	-0.223	0.77	0.135
0.30	2.114	-0.0360	-1.0350	4.80	0.610	0.198	0.370	-0.219	-0.195	0.78	0.135
0.36	1.955	-0.0460	-1.0052	4.62	0.610	0.170	0.370	-0.123	-0.173	0.79	0.135
0.40	1.860	-0.0518	-0.9880	4.52	0.610	0.154	0.370	-0.065	-0.160	0.79	0.135
0.46	1.717	-0.0594	-0.9652	4.38	0.592	0.132	0.370	0.020	-0.136	0.80	0.132
0.50	1.615	-0.0635	-0.9515	4.30	0.581	0.119	0.370	0.085	-0.121	0.80	0.130
0.60	1.428	-0.0740	-0.9218	4.12	0.557	0.091	0.370	0.194	-0.089	0.81	0.127
0.75	1.160	-0.0862	-0.8852	3.90	0.528	0.057	0.331	0.320	-0.050	0.81	0.123
0.85	1.020	-0.0927	-0.8648	3.81	0.512	0.038	0.309	0.370	-0.028	0.82	0.121
1.00	0.828	-0.1020	-0.8383	3.70	0.490	0.013	0.281	0.423	0.000	0.83	0.118
1.50	0.260	-0.1200	-0.7721	3.55	0.438	-0.049	0.210	0.600	0.040	0.84	0.110
2.00	-0.150	-0.1400	-0.7250	3.50	0.400	-0.094	0.160	0.610	0.040	0.85	0.105
3.00	-0.690	-0.1726	-0.7250	3.50	0.400	-0.156	0.089	0.630	0.040	0.87	0.097
4.00	-1.130	-0.1956	-0.7250	3.50	0.400	-0.200	0.039	0.640	0.040	0.88	0.092
5.00	-1.460	-0.2150	-0.7250	3.50	0.400	-0.200	0.000	0.664	0.040	0.89	0.087

Adapted from: Abrahamson, N.A. and Silva, W.J. (1997). "Empirical response spectral attenuation relations for shallow crustal earthquakes." *Seismological Research Letters*, 68, 94–127.

TABLE A2 Coefficients for the Vertical Component of the Abrahamson and Silva WNA Model

T_n (s)	c_1	c_3	c_5	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{15}	c_{16}
PGA	1.642	0.0000	-1.2520	6.00	0.390	-0.050	0.630	-0.140	-0.220	0.76	0.085
0.02	1.642	0.0000	-1.2520	6.00	0.390	-0.050	0.630	-0.140	-0.220	0.76	0.085
0.03	2.100	0.0000	-1.3168	6.00	0.432	-0.050	0.630	-0.140	-0.220	0.76	0.085
0.04	2.420	0.0000	-1.3700	6.00	0.469	-0.050	0.630	-0.140	-0.220	0.76	0.085
0.05	2.620	-0.0002	-1.3700	6.00	0.496	-0.050	0.630	-0.140	-0.220	0.76	0.085
0.06	2.710	-0.0004	-1.3700	6.00	0.518	-0.050	0.630	-0.140	-0.220	0.76	0.085
0.075	2.750	-0.0007	-1.3700	6.00	0.545	-0.050	0.630	-0.129	-0.220	0.76	0.085
0.09	2.730	-0.0009	-1.3700	6.00	0.567	-0.050	0.630	-0.119	-0.220	0.76	0.085
0.10	2.700	-0.0010	-1.3700	6.00	0.580	-0.050	0.630	-0.114	-0.220	0.76	0.085
0.12	2.480	-0.0015	-1.2986	6.00	0.580	-0.017	0.630	-0.104	-0.220	0.74	0.075
0.15	2.170	-0.0022	-1.2113	6.00	0.580	0.024	0.630	-0.093	-0.220	0.72	0.063
0.17	1.960	-0.0025	-1.1623	5.72	0.580	0.047	0.604	-0.087	-0.220	0.70	0.056
0.20	1.648	-0.0030	-1.0987	5.35	0.580	0.076	0.571	-0.078	-0.220	0.69	0.050
0.24	1.312	-0.0035	-1.0274	4.93	0.580	0.109	0.533	-0.069	-0.220	0.69	0.050
0.30	0.878	-0.0042	-0.9400	4.42	0.580	0.150	0.488	-0.057	-0.220	0.69	0.050
0.36	0.617	-0.0047	-0.9004	4.01	0.571	0.150	0.450	-0.048	-0.220	0.69	0.050
0.40	0.478	-0.0050	-0.8776	3.77	0.539	0.150	0.428	-0.043	-0.220	0.69	0.050
0.46	0.271	-0.0056	-0.8472	3.45	0.497	0.150	0.400	-0.035	-0.220	0.69	0.050
0.50	0.145	-0.0060	-0.8291	3.26	0.471	0.150	0.383	-0.031	-0.220	0.69	0.050
0.60	-0.087	-0.0068	-0.7896	2.85	0.416	0.150	0.345	-0.022	-0.220	0.69	0.050
0.75	-0.344	-0.0083	-0.7488	2.50	0.348	0.150	0.299	-0.010	-0.220	0.69	0.050
0.85	-0.469	-0.0097	-0.7451	2.50	0.309	0.150	0.273	-0.004	-0.220	0.69	0.050
1.00	-0.602	-0.0115	-0.7404	2.50	0.260	0.150	0.240	0.004	-0.220	0.69	0.050
1.50	-0.966	-0.0180	-0.7285	2.50	0.260	0.058	0.240	0.025	-0.220	0.69	0.050
2.00	-1.224	-0.0240	-0.7200	2.50	0.260	-0.008	0.240	0.040	-0.220	0.69	0.050
3.00	-1.581	-0.0431	-0.7200	2.50	0.260	-0.100	0.240	0.040	-0.220	0.72	0.050
4.00	-1.857	-0.0565	-0.7200	2.50	0.260	-0.100	0.240	0.040	-0.220	0.75	0.050
5.00	-2.053	-0.0670	-0.7200	2.50	0.260	-0.100	0.240	0.040	-0.220	0.78	0.050

Adapted from: Abrahamson, N.A. and Silva, W.J. (1997). "Empirical response spectral attenuation relations for shallow crustal earthquakes." *Seismological Research Letters*, 68, 94–127.

TABLE A3 Coefficients for the Boore *et al.* WNA Model

T_n (s)	c_{1U}	c_{1S}	c_{1R}	c_2	c_3	c_4	c_5	c_6	c_7	$\sigma_{\ln Y}$
PGA	-0.242	-0.313	-0.117	0.527	0.000	-0.778	5.57	-0.371	1396	0.468
0.10	1.059	1.006	1.087	0.753	-0.226	-0.934	6.27	-0.212	1112	0.440
0.11	1.130	1.072	1.164	0.732	-0.230	-0.937	6.65	-0.211	1291	0.437
0.12	1.174	1.109	1.215	0.721	-0.233	-0.939	6.91	-0.215	1452	0.437
0.13	1.200	1.128	1.246	0.711	-0.233	-0.939	7.08	-0.221	1596	0.435
0.14	1.208	1.135	1.261	0.707	-0.230	-0.938	7.18	-0.228	1718	0.435
0.15	1.204	1.128	1.264	0.702	-0.228	-0.937	7.23	-0.238	1820	0.435
0.16	1.192	1.112	1.257	0.702	-0.226	-0.935	7.24	-0.248	1910	0.436
0.17	1.173	1.090	1.242	0.702	-0.221	-0.933	7.21	-0.258	1977	0.436
0.18	1.151	1.063	1.222	0.705	-0.216	-0.930	7.16	-0.270	2037	0.435
0.19	1.122	1.032	1.198	0.709	-0.212	-0.927	7.10	-0.281	2080	0.435
0.20	1.089	0.999	1.170	0.711	-0.207	-0.924	7.02	-0.292	2118	0.435
0.22	1.019	0.925	1.104	0.721	-0.198	-0.918	6.83	-0.315	2158	0.438
0.24	0.941	0.847	1.033	0.732	-0.189	-0.912	6.62	-0.338	2178	0.439
0.26	0.861	0.764	0.958	0.744	-0.180	-0.906	6.39	-0.360	2173	0.439
0.28	0.780	0.681	0.881	0.758	-0.168	-0.899	6.17	-0.381	2158	0.441
0.30	0.700	0.598	0.803	0.769	-0.161	-0.893	5.94	-0.401	2133	0.443
0.32	0.619	0.518	0.725	0.783	-0.152	-0.888	5.72	-0.420	2104	0.445
0.34	0.540	0.439	0.648	0.794	-0.143	-0.882	5.50	-0.438	2070	0.449
0.36	0.462	0.361	0.570	0.806	-0.136	-0.877	5.30	-0.456	2032	0.450
0.38	0.385	0.286	0.495	0.820	-0.127	-0.872	5.10	-0.472	1995	0.453
0.40	0.311	0.212	0.423	0.831	-0.120	-0.867	4.91	-0.487	1954	0.454
0.42	0.239	0.140	0.352	0.840	-0.113	-0.862	4.74	-0.502	1919	0.458
0.44	0.169	0.073	0.282	0.852	-0.108	-0.858	4.57	-0.516	1884	0.460
0.46	0.102	0.005	0.217	0.863	-0.101	-0.854	4.41	-0.529	1849	0.463
0.48	0.036	-0.058	0.151	0.873	-0.097	-0.850	4.26	-0.541	1816	0.464
0.50	-0.025	-0.122	0.087	0.884	-0.090	-0.846	4.13	-0.553	1782	0.469
0.55	-0.176	-0.268	-0.063	0.907	-0.078	-0.837	3.82	-0.579	1710	0.474
0.60	-0.314	-0.401	-0.203	0.928	-0.069	-0.830	3.57	-0.602	1644	0.480
0.65	-0.440	-0.523	-0.331	0.946	-0.060	-0.823	3.36	-0.622	1592	0.485
0.70	-0.555	-0.634	-0.452	0.962	-0.053	-0.818	3.20	-0.639	1545	0.492
0.75	-0.661	-0.737	-0.562	0.979	-0.046	-0.813	3.07	-0.653	1507	0.497
0.80	-0.760	-0.829	-0.666	0.992	-0.041	-0.809	2.98	-0.666	1476	0.502
0.85	-0.851	-0.915	-0.761	1.006	-0.037	-0.805	2.92	-0.676	1452	0.505
0.90	-0.933	-0.993	-0.848	1.018	-0.035	-0.802	2.89	-0.685	1432	0.511
0.95	-1.010	-1.066	-0.932	1.027	-0.032	-0.800	2.88	-0.692	1416	0.515
1.00	-1.080	-1.133	-1.009	1.036	-0.032	-0.798	2.90	-0.698	1406	0.520
1.10	-1.208	-1.249	-1.145	1.052	-0.030	-0.795	2.99	-0.706	1396	0.528
1.20	-1.315	-1.345	-1.265	1.064	-0.032	-0.794	3.14	-0.710	1400	0.533
1.30	-1.407	-1.428	-1.370	1.073	-0.035	-0.793	3.36	-0.711	1416	0.540
1.40	-1.483	-1.495	-1.460	1.080	-0.039	-0.794	3.62	-0.709	1442	0.545
1.50	-1.550	-1.552	-1.538	1.085	-0.044	-0.796	3.92	-0.704	1479	0.550
1.60	-1.605	-1.598	-1.608	1.087	-0.051	-0.798	4.26	-0.697	1524	0.554
1.70	-1.652	-1.634	-1.668	1.089	-0.058	-0.801	4.62	-0.689	1581	0.558
1.80	-1.689	-1.663	-1.718	1.087	-0.067	-0.804	5.01	-0.679	1644	0.561
1.90	-1.720	-1.685	-1.763	1.087	-0.074	-0.808	5.42	-0.667	1714	0.565
2.00	-1.743	-1.699	-1.801	1.085	-0.085	-0.812	5.85	-0.655	1795	0.566

Adapted from: Boore, D.M., Joyner, W.B. and Fumal, T.E. (1997). "Equations for estimating horizontal response spectra and peak acceleration from western North American earthquakes: a summary of recent work." *Seismological Research Letters*, 68, 128–153.

TABLE A4 Coefficients for the Average Horizontal Component of the Campbell and Bozorgnia WNA Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}
Unc PGA	-2.896	0.812	0.000	-1.318	0.616	0	0.187	-0.029	-0.064	0.179	0.307	-0.062	-0.195	-0.320	1.028
Cor PGA	-4.033	0.812	0.036	-1.061	0.766	0.034	0.041	-0.005	-0.018	0.343	0.351	-0.123	-0.138	-0.289	0.940
0.05	-3.740	0.812	0.036	-1.121	0.724	0.032	0.058	-0.004	-0.028	0.302	0.362	-0.140	-0.158	-0.205	0.980
0.075	-3.076	0.812	0.050	-1.252	0.648	0.040	0.121	-0.005	-0.051	0.243	0.333	-0.150	-0.196	-0.208	1.004
0.10	-2.661	0.812	0.060	-1.308	0.621	0.046	0.166	-0.009	-0.068	0.224	0.313	-0.146	-0.253	-0.258	1.016
0.15	-2.270	0.812	0.041	-1.324	0.613	0.031	0.212	-0.033	-0.081	0.318	0.344	-0.176	-0.267	-0.284	1.049
0.20	-2.771	0.812	0.030	-1.153	0.704	0.026	0.098	-0.014	-0.038	0.296	0.342	-0.148	-0.183	-0.359	1.063
0.30	-2.999	0.812	0.007	-1.080	0.752	0.007	0.059	-0.007	-0.022	0.359	0.385	-0.162	-0.157	-0.585	1.069
0.40	-3.511	0.812	-0.015	-0.964	0.842	-0.016	0.024	-0.002	-0.005	0.379	0.438	-0.078	-0.129	-0.557	1.075
0.50	-3.556	0.812	-0.035	-0.964	0.842	-0.036	0.023	-0.002	-0.004	0.406	0.479	-0.122	-0.130	-0.701	1.081
0.75	-3.709	0.812	-0.071	-0.964	0.842	-0.074	0.021	-0.002	-0.002	0.347	0.419	-0.108	-0.124	-0.796	1.144
1.0	-3.867	0.812	-0.101	-0.964	0.842	-0.105	0.019	0	0	0.329	0.338	-0.073	-0.072	-0.858	1.176
1.5	-4.093	0.812	-0.150	-0.964	0.842	-0.155	0.019	0	0	0.217	0.188	-0.079	-0.056	-0.954	1.176
2.0	-4.311	0.812	-0.180	-0.964	0.842	-0.187	0.019	0	0	0.060	0.064	-0.124	-0.116	-0.916	1.176
3.0	-4.817	0.812	-0.193	-0.964	0.842	-0.200	0.019	0	0	-0.079	0.021	-0.154	-0.117	-0.873	1.176
4.0	-5.211	0.812	-0.202	-0.964	0.842	-0.209	0.019	0	0	-0.061	0.057	-0.054	-0.261	-0.889	1.176

Note: Uncorrected PGA is to be used only when an estimate of PGA is required. Corrected PGA is to be used when an estimate of PGA compatible with spectral ordinates is required. *Adapted from:* Campbell, K.W. and Y. Bozorgnia, Y. (2003). "Updated near-source ground motion (attenuation) relations for the horizontal and vertical components of PGA and acceleration response spectra." *Bulletin of the Seismological Society of America*, 93, 314–331.

TABLE A5 Coefficients for the Vertical Component of the Campbell and Bozorgnia WNA Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}
Unc PGA	-2.807	0.756	0	-1.391	0.544	0	0.191	0.044	-0.014	0.091	0.223	-0.096	-0.212	-0.199	1.107
Cor PGA	-3.108	0.756	0	-1.287	0.587	0	0.142	0.046	-0.040	0.253	0.173	-0.135	-0.138	-0.256	1.051
0.05	-1.918	0.756	0	-1.517	0.498	0	0.309	0.069	-0.023	0.058	0.100	-0.195	-0.274	-0.219	1.196
0.075	-1.504	0.756	0	-1.551	0.487	0	0.343	0.083	0.000	0.135	0.182	-0.224	-0.303	-0.263	1.216
0.10	-1.672	0.756	0	-1.473	0.513	0	0.282	0.062	0.001	0.168	0.210	-0.198	-0.275	-0.252	1.194
0.15	-2.323	0.756	0	-1.280	0.591	0	0.171	0.045	0.008	0.223	0.238	-0.170	-0.175	-0.270	1.160
0.20	-2.998	0.756	0	-1.131	0.668	0	0.089	0.028	0.004	0.234	0.256	-0.098	-0.041	-0.311	1.113
0.30	-3.721	0.756	0.007	-1.028	0.736	0.007	0.050	0.010	0.004	0.249	0.328	-0.026	0.082	-0.265	1.069
0.40	-4.536	0.756	-0.015	-0.812	0.931	-0.018	0.012	0	0	0.299	0.317	-0.017	0.022	-0.257	1.075
0.50	-4.651	0.756	-0.035	-0.812	0.931	-0.043	0.012	0	0	0.243	0.354	-0.020	0.092	-0.293	1.081
0.75	-4.903	0.756	-0.071	-0.812	0.931	-0.087	0.012	0	0	0.295	0.418	0.078	0.091	-0.349	1.144
1.0	-4.950	0.756	-0.101	-0.812	0.931	-0.124	0.012	0	0	0.266	0.315	0.043	0.101	-0.481	1.176
1.5	-5.073	0.756	-0.150	-0.812	0.931	-0.184	0.012	0	0	0.171	0.211	-0.038	-0.018	-0.518	1.176
2.0	-5.292	0.756	-0.180	-0.812	0.931	-0.222	0.012	0	0	0.114	0.115	0.033	-0.022	-0.503	1.194
3.0	-5.748	0.756	-0.193	-0.812	0.931	-0.238	0.012	0	0	0.179	0.159	-0.010	-0.047	-0.539	1.247
4.0	-6.042	0.756	-0.202	-0.812	0.931	-0.248	0.012	0	0	0.237	0.134	-0.059	-0.267	-0.606	1.285

Note: Uncorrected PGA is to be used only when an estimate of PGA is required. Corrected PGA is to be used when an estimate of PGA compatible with spectral ordinates is required. *Adapted from:* Campbell, K.W. and Y. Bozorgnia, Y. (2003). "Updated near-source ground motion (attenuation) relations for horizontal and vertical components of PGA and acceleration response spectra." *Bulletin of the Seismological Society of America*, 93, 314–331.

TABLE A6 Coefficients for the Average Horizontal Component of the Sadigh *et al.* WNA Generic Rock Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}
$M_W \leq 6.5$														
PGA	0.182	-0.624	1.0	0	-2.100	0	3.6564	0.250	0	1.39	0.14	0.38	0	7.21
0.05	0.182	-0.090	1.0	0.006	-2.128	-0.082	3.6564	0.250	0	1.39	0.14	0.38	0	7.21
0.07	0.182	0.110	1.0	0.006	-2.128	-0.082	3.6564	0.250	0	1.40	0.14	0.39	0	7.21
0.09	0.182	0.212	1.0	0.006	-2.140	-0.052	3.6564	0.250	0	1.40	0.14	0.39	0	7.21
0.10	0.182	0.275	1.0	0.006	-2.148	-0.041	3.6564	0.250	0	1.41	0.14	0.40	0	7.21
0.12	0.182	0.348	1.0	0.005	-2.162	-0.014	3.6564	0.250	0	1.41	0.14	0.40	0	7.21
0.14	0.182	0.307	1.0	0.004	-2.144	0	3.6564	0.250	0	1.42	0.14	0.41	0	7.21
0.15	0.182	0.285	1.0	0.002	-2.130	0	3.6564	0.250	0	1.42	0.14	0.41	0	7.21
0.17	0.182	0.239	1.0	0	-2.110	0	3.6564	0.250	0	1.42	0.14	0.41	0	7.21
0.20	0.182	0.153	1.0	-0.004	-2.080	0	3.6564	0.250	0	1.43	0.14	0.42	0	7.21
0.24	0.182	0.060	1.0	-0.011	-2.053	0	3.6564	0.250	0	1.44	0.14	0.43	0	7.21
0.30	0.182	-0.057	1.0	-0.017	-2.028	0	3.6564	0.250	0	1.45	0.14	0.44	0	7.21
0.40	0.182	-0.298	1.0	-0.028	-1.990	0	3.6564	0.250	0	1.48	0.14	0.47	0	7.21
0.50	0.182	-0.588	1.0	-0.040	-1.945	0	3.6564	0.250	0	1.50	0.14	0.49	0	7.21
0.75	0.182	-1.208	1.0	-0.050	-1.865	0	3.6564	0.250	0	1.52	0.14	0.51	0	7.21
1.0	0.182	-1.705	1.0	-0.055	-1.800	0	3.6564	0.250	0	1.53	0.14	0.52	0	7.21
1.5	0.182	-2.407	1.0	-0.065	-1.725	0	3.6564	0.250	0	1.53	0.14	0.52	0	7.21
2.0	0.182	-2.945	1.0	-0.070	-1.670	0	3.6564	0.250	0	1.53	0.14	0.52	0	7.21
3.0	0.182	-3.700	1.0	-0.080	-1.610	0	3.6564	0.250	0	1.53	0.14	0.52	0	7.21
4.0	0.182	-4.230	1.0	-0.100	-1.570	0	3.6564	0.250	0	1.53	0.14	0.52	0	7.21
5.0	0.182	-4.714	1.0	-0.100	-1.540	0	3.6564	0.250	0	1.53	0.14	0.52	0	7.21
7.5	0.182	-5.530	1.0	-0.110	-1.510	0	3.6564	0.250	0	1.53	0.14	0.52	0	7.21
$M_W > 6.5$														
PGA	0.182	-1.274	1.1	0	-2.100	0	0.6160	0.524	0	1.39	0.14	0.38	0	7.21
0.05	0.182	-0.740	1.1	0.006	-2.128	-0.082	0.6160	0.524	0	1.39	0.14	0.38	0	7.21
0.07	0.182	-0.540	1.1	0.006	-2.128	-0.082	0.6160	0.524	0	1.40	0.14	0.39	0	7.21
0.09	0.182	-0.438	1.1	0.006	-2.140	-0.052	0.6160	0.524	0	1.40	0.14	0.39	0	7.21
0.10	0.182	-0.375	1.1	0.006	-2.148	-0.041	0.6160	0.524	0	1.41	0.14	0.40	0	7.21
0.12	0.182	-0.302	1.1	0.005	-2.162	-0.014	0.6160	0.524	0	1.41	0.14	0.40	0	7.21
0.14	0.182	-0.343	1.1	0.004	-2.144	0	0.6160	0.524	0	1.42	0.14	0.41	0	7.21
0.15	0.182	-0.365	1.1	0.002	-2.130	0	0.6160	0.524	0	1.42	0.14	0.41	0	7.21
0.17	0.182	-0.411	1.1	0	-2.110	0	0.6160	0.524	0	1.42	0.14	0.41	0	7.21
0.20	0.182	-0.497	1.1	-0.004	-2.080	0	0.6160	0.524	0	1.43	0.14	0.42	0	7.21
0.24	0.182	-0.590	1.1	-0.011	-2.053	0	0.6160	0.524	0	1.44	0.14	0.43	0	7.21
0.30	0.182	-0.707	1.1	-0.017	-2.028	0	0.6160	0.524	0	1.45	0.14	0.44	0	7.21
0.40	0.182	-0.948	1.1	-0.028	-1.990	0	0.6160	0.524	0	1.48	0.14	0.47	0	7.21
0.50	0.182	-1.238	1.1	-0.040	-1.945	0	0.6160	0.524	0	1.50	0.14	0.49	0	7.21
0.75	0.182	-1.858	1.1	-0.050	-1.865	0	0.6160	0.524	0	1.52	0.14	0.51	0	7.21
1.0	0.182	-2.355	1.1	-0.055	-1.800	0	0.6160	0.524	0	1.53	0.14	0.52	0	7.21
1.5	0.182	-3.057	1.1	-0.065	-1.725	0	0.6160	0.524	0	1.53	0.14	0.52	0	7.21
2.0	0.182	-3.595	1.1	-0.070	-1.670	0	0.6160	0.524	0	1.53	0.14	0.52	0	7.21
3.0	0.182	-4.350	1.1	-0.080	-1.610	0	0.6160	0.524	0	1.53	0.14	0.52	0	7.21
4.0	0.182	-4.880	1.1	-0.100	-1.570	0	0.6160	0.524	0	1.53	0.14	0.52	0	7.21
5.0	0.182	-5.364	1.1	-0.100	-1.540	0	0.6160	0.524	0	1.53	0.14	0.52	0	7.21
7.5	0.182	-6.180	1.1	-0.110	-1.510	0	0.6160	0.524	0	1.53	0.14	0.52	0	7.21

Adapted from: 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." *Proceedings, ATC-17-1 Seminar on Seismic Isolation, Passive Energy Dissipation, and Active Control*, San Francisco, 1, 11–23; and Sadigh, K., Chang, C.Y., Egan, J.A., Makdisi, F. and Youngs, R.R. (1997). "Attenuation relationships for shallow crustal earthquakes based on California strong motion data." *Seismological Research Letters*, 68, 180–189.

TABLE A7 Coefficients for the Vertical Component of the Sadigh *et al.* WNA Generic Rock Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}
$M_W \leq 6.5$														
PGA	0.0953	-0.4300	1.0	0	-2.300	0	3.5701	0.228	0.68	3.08	0.40	0.48	6.0	6.5
0.04	0.0953	0.3379	1.0	0	-2.450	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.05	0.0953	0.5041	1.0	0	-2.450	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.06	0.0953	0.6095	1.0	0	-2.450	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.07	0.0953	0.6896	1.0	0	-2.450	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.09	0.0953	0.6718	1.0	-0.00330	-2.420	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.10	0.0953	0.6252	1.0	-0.00468	-2.400	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.12	0.0953	0.5535	1.0	-0.00707	-2.380	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.14	0.0953	0.3813	1.0	-0.00909	-2.333	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.15	0.0953	0.2524	1.0	-0.01000	-2.300	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.17	0.0953	0.0122	1.0	-0.01462	-2.241	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.20	0.0953	-0.3005	1.0	-0.02061	-2.164	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.24	0.0953	-0.6678	1.0	-0.02734	-2.077	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.30	0.0953	-1.1392	1.0	-0.03558	-1.971	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.40	0.0953	-1.7656	1.0	-0.04619	-1.835	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.50	0.0953	-2.2748	1.0	-0.05442	-1.729	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
0.75	0.0953	-3.2062	1.0	-0.06939	-1.536	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
1.0	0.0953	-3.8818	1.0	-0.08000	-1.400	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
1.5	0.0953	-4.2618	1.0	-0.08554	-1.400	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
2.0	0.0953	-4.5719	1.0	-0.08946	-1.400	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
2.5	0.0953	-4.8167	1.0	-0.09251	-1.400	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
3.0	0.0953	-5.0364	1.0	-0.09500	-1.400	0	3.5701	0.228	0.75	2.91	0.36	0.57	6.0	6.5
$M_W > 6.5$														
PGA	0.0953	-1.0800	1.1	0	-2.300	0	0.7030	0.478	0.68	3.08	0.40	0.48	6.0	6.5
0.04	0.0953	-0.3121	1.1	0	-2.450	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.05	0.0953	-0.1459	1.1	0	-2.450	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.06	0.0953	-0.0405	1.1	0	-2.450	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.07	0.0953	0.03956	1.1	0	-2.450	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.09	0.0953	0.0218	1.1	-0.00330	-2.420	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.10	0.0953	-0.0248	1.1	-0.00468	-2.400	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.12	0.0953	-0.0965	1.1	-0.00707	-2.380	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.14	0.0953	-0.2687	1.1	-0.00909	-2.333	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.15	0.0953	-0.3976	1.1	-0.01000	-2.300	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.17	0.0953	-0.6378	1.1	-0.01462	-2.241	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.20	0.0953	-0.9505	1.1	-0.02061	-2.164	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.24	0.0953	-1.3178	1.1	-0.02734	-2.077	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.30	0.0953	-1.7893	1.1	-0.03558	-1.971	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.40	0.0953	-2.4157	1.1	-0.04619	-1.835	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.50	0.0953	-2.9248	1.1	-0.05442	-1.729	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
0.75	0.0953	-3.8562	1.1	-0.06939	-1.536	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
1.0	0.0953	-4.5318	1.1	-0.08000	-1.400	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
1.5	0.0953	-4.9118	1.1	-0.08554	-1.400	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
2.0	0.0953	-5.2219	1.1	-0.08946	-1.400	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
2.5	0.0953	-5.4667	1.1	-0.09251	-1.400	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5
3.0	0.0953	-5.6864	1.1	-0.09500	-1.400	0	0.7030	0.478	0.75	2.91	0.36	0.57	6.0	6.5

Adapted from: 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." *Proceedings, ATC-17-1 Seminar on Seismic Isolation, Passive Energy Dissipation, and Active Control*, San Francisco, 1, 11–23.

TABLE A8 Coefficients for the Average Horizontal Component of the Sadigh *et al.* WNA Generic Soil Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}
$M_W \leq 6.5$														
PGA	0.2500	-2.1700	1.0	0	-1.700	0	2.1863	0.320	0	1.520	0.16	0.40	0	7.0
0.075	0.2500	-1.7128	1.0	0.005	-1.700	0	2.1863	0.320	0	1.540	0.16	0.42	0	7.0
0.10	0.2500	-1.5305	1.0	0.005	-1.700	0	2.1863	0.320	0	1.540	0.16	0.42	0	7.0
0.20	0.2500	-1.2513	1.0	-0.004	-1.700	0	2.1863	0.320	0	1.565	0.16	0.45	0	7.0
0.30	0.2500	-1.2153	1.0	-0.014	-1.700	0	2.1863	0.320	0	1.580	0.16	0.46	0	7.0
0.40	0.2254	-1.2449	1.0	-0.024	-1.700	0	2.1863	0.320	0	1.595	0.16	0.48	0	7.0
0.50	0.2291	-1.3206	1.0	-0.033	-1.700	0	2.1863	0.320	0	1.610	0.16	0.49	0	7.0
0.75	0.2292	-1.4690	1.0	-0.051	-1.700	0	2.1863	0.320	0	1.635	0.16	0.52	0	7.0
1.0	0.1910	-1.6035	1.0	-0.065	-1.700	0	2.1863	0.320	0	1.660	0.16	0.54	0	7.0
1.5	0.1480	-1.8465	1.0	-0.090	-1.700	0	2.1863	0.320	0	1.690	0.16	0.57	0	7.0
2.0	0.0973	-2.0699	1.0	-0.108	-1.700	0	2.1863	0.320	0	1.700	0.16	0.58	0	7.0
3.0	0.0396	-2.4501	1.0	-0.139	-1.700	0	2.1863	0.320	0	1.710	0.16	0.59	0	7.0
4.0	-0.0133	-2.7974	1.0	-0.160	-1.700	0	2.1863	0.320	0	1.710	0.16	0.59	0	7.0
$M_W > 6.5$														
PGA	0.2500	-2.1700	1.0	0	-1.700	0	0.3825	0.5882	0	1.520	0.16	0.40	0	7.0
0.075	0.2500	-1.7128	1.0	0.005	-1.700	0	0.3825	0.5882	0	1.540	0.16	0.42	0	7.0
0.10	0.2500	-1.5305	1.0	0.005	-1.700	0	0.3825	0.5882	0	1.540	0.16	0.42	0	7.0
0.20	0.2500	-1.2513	1.0	-0.004	-1.700	0	0.3825	0.5882	0	1.565	0.16	0.45	0	7.0
0.30	0.2500	-1.2153	1.0	-0.014	-1.700	0	0.3825	0.5882	0	1.580	0.16	0.46	0	7.0
0.40	0.2254	-1.2449	1.0	-0.024	-1.700	0	0.3825	0.5882	0	1.595	0.16	0.48	0	7.0
0.50	0.2291	-1.3206	1.0	-0.033	-1.700	0	0.3825	0.5882	0	1.610	0.16	0.49	0	7.0
0.75	0.2292	-1.4690	1.0	-0.051	-1.700	0	0.3825	0.5882	0	1.635	0.16	0.52	0	7.0
1.0	0.1910	-1.6035	1.0	-0.065	-1.700	0	0.3825	0.5882	0	1.660	0.16	0.54	0	7.0
1.5	0.1480	-1.8465	1.0	-0.090	-1.700	0	0.3825	0.5882	0	1.690	0.16	0.57	0	7.0
2.0	0.0973	-2.0699	1.0	-0.108	-1.700	0	0.3825	0.5882	0	1.700	0.16	0.58	0	7.0
3.0	0.0396	-2.4501	1.0	-0.139	-1.700	0	0.3825	0.5882	0	1.710	0.16	0.59	0	7.0
4.0	-0.0133	-2.7974	1.0	-0.160	-1.700	0	0.3825	0.5882	0	1.710	0.16	0.59	0	7.0

Adapted from: Sadigh, K., Chang, C.Y., Egan, J.A., Makdisi, F. and Youngs, R.R. (1997). "Attenuation relationships for shallow crustal earthquakes based on California strong motion data." *Seismological Research Letters*, 68, 180–189.

TABLE A9 Coefficients for the Spudich *et al.* WNA Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	$\sigma_{\ln Y}$
PGA	0.688	0.527	0	-1.052	7.27	0.258	0.468
0.10	2.189	0.753	-0.226	-1.250	9.99	0.147	0.630
0.11	2.119	0.732	-0.230	-1.207	9.84	0.147	0.610
0.12	2.055	0.721	-0.233	-1.173	9.69	0.150	0.591
0.13	1.996	0.711	-0.233	-1.145	9.54	0.154	0.580
0.14	1.942	0.707	-0.230	-1.122	9.39	0.159	0.568
0.15	1.892	0.702	-0.228	-1.103	9.25	0.166	0.558
0.16	1.846	0.702	-0.226	-1.088	9.12	0.173	0.551
0.17	1.801	0.702	-0.221	-1.075	8.99	0.180	0.546
0.18	1.758	0.705	-0.216	-1.064	8.86	0.187	0.542
0.19	1.718	0.709	-0.212	-1.055	8.74	0.196	0.539
0.20	1.680	0.711	-0.207	-1.047	8.63	0.203	0.536
0.22	1.608	0.721	-0.198	-1.036	8.41	0.219	0.532
0.24	1.539	0.732	-0.189	-1.029	8.22	0.235	0.531
0.26	1.478	0.744	-0.180	-1.024	8.04	0.249	0.531
0.28	1.420	0.758	-0.168	-1.021	7.87	0.265	0.532
0.30	1.364	0.769	-0.161	-1.020	7.72	0.279	0.534
0.32	1.311	0.783	-0.152	-1.019	7.58	0.290	0.534
0.34	1.260	0.794	-0.143	-1.020	7.45	0.304	0.536
0.36	1.212	0.806	-0.136	-1.021	7.33	0.315	0.539
0.38	1.165	0.820	-0.127	-1.023	7.22	0.327	0.543
0.40	1.120	0.831	-0.120	-1.025	7.11	0.338	0.545
0.42	1.079	0.840	-0.113	-1.027	7.02	0.348	0.548
0.44	1.037	0.852	-0.108	-1.030	6.93	0.357	0.550
0.46	0.997	0.863	-0.101	-1.032	6.85	0.366	0.555
0.48	0.959	0.873	-0.097	-1.035	6.77	0.375	0.556
0.50	0.920	0.884	-0.090	-1.038	6.70	0.382	0.559
0.55	0.830	0.907	-0.078	-1.044	6.55	0.401	0.566
0.60	0.745	0.928	-0.069	-1.051	6.42	0.417	0.574
0.65	0.665	0.946	-0.060	-1.057	6.32	0.431	0.579
0.70	0.588	0.962	-0.053	-1.062	6.23	0.442	0.585
0.75	0.515	0.979	-0.046	-1.067	6.17	0.454	0.592
0.80	0.446	0.992	-0.041	-1.071	6.11	0.461	0.598
0.85	0.378	1.006	-0.037	-1.075	6.07	0.467	0.602
0.90	0.314	1.018	-0.035	-1.078	6.04	0.474	0.607
0.95	0.251	1.027	-0.032	-1.081	6.02	0.479	0.615
1.0	0.190	1.036	-0.032	-1.083	6.01	0.484	0.620
1.1	0.074	1.052	-0.030	-1.085	6.01	0.490	0.628
1.2	-0.033	1.064	-0.032	-1.086	6.03	0.493	0.640
1.3	-0.137	1.073	-0.035	-1.085	6.07	0.493	0.650
1.4	-0.236	1.080	-0.039	-1.083	6.13	0.490	0.658
1.5	-0.330	1.085	-0.044	-1.079	6.21	0.488	0.669
1.6	-0.420	1.087	-0.051	-1.075	6.29	0.484	0.679
1.7	-0.508	1.089	-0.058	-1.070	6.39	0.477	0.689
1.8	-0.591	1.087	-0.067	-1.063	6.49	0.470	0.699
1.9	-0.673	1.087	-0.074	-1.056	6.60	0.463	0.708
2.0	-0.751	1.085	-0.085	-1.049	6.71	0.454	0.718

Adapted from: Spudich, P., Joyner, W.B., Lindh, A.G., Boore, D.M., Margaris, B.M. and Fletcher, J.B. (1999). "SEA99: a revised ground motion prediction relation for use in extensional tectonic regimes." *Bulletin of the Seismological Society of America*, 89, 1156–1170.

TABLE A10 Values of log PGA (cm/sec²) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	2.57	2.63	2.72	2.78	2.85	2.93	2.98	3.06	3.13	3.18
1.1	2.38	2.48	2.56	2.64	2.71	2.79	2.87	2.93	3.00	3.08
1.2	2.21	2.32	2.41	2.49	2.58	2.66	2.74	2.80	2.87	2.94
1.3	2.05	2.14	2.26	2.34	2.43	2.51	2.60	2.67	2.74	2.82
1.4	1.88	1.98	2.10	2.20	2.30	2.38	2.46	2.55	2.62	2.70
1.5	1.70	1.81	1.92	2.03	2.12	2.23	2.30	2.41	2.48	2.55
1.6	1.52	1.63	1.75	1.86	1.96	2.06	2.16	2.24	2.33	2.39
1.7	1.34	1.45	1.57	1.67	1.79	1.89	1.99	2.08	2.17	2.25
1.8	1.13	1.26	1.37	1.50	1.61	1.70	1.82	1.91	1.99	2.08
1.9	1.01	1.14	1.26	1.38	1.50	1.59	1.71	1.81	1.89	1.97
2.0	0.95	1.08	1.19	1.32	1.43	1.54	1.64	1.74	1.83	1.91
2.1	0.88	1.01	1.14	1.25	1.36	1.48	1.58	1.68	1.76	1.85
2.2	0.73	0.86	0.97	1.09	1.22	1.33	1.44	1.53	1.62	1.73
2.3	0.54	0.66	0.78	0.91	1.03	1.16	1.26	1.37	1.46	1.57
2.4	0.28	0.43	0.56	0.69	0.80	0.94	1.05	1.16	1.27	1.37
2.5	0.07	0.21	0.36	0.49	0.62	0.74	0.86	0.97	1.09	1.19
2.6	-0.15	-0.01	0.13	0.27	0.42	0.54	0.66	0.77	0.89	1.01
2.7	-0.40	-0.24	-0.11	0.05	0.17	0.31	0.45	0.58	0.69	0.81

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A11 Values of $\log S_a$ ($T_n = 0.05$ sec; cm/sec 2) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	2.90	3.00	3.08	3.15	3.23	3.28	3.36	3.43	3.51	3.57
1.1	2.72	2.83	2.93	3.00	3.08	3.15	3.26	3.30	3.38	3.45
1.2	2.58	2.67	2.79	2.86	2.95	3.04	3.11	3.20	3.26	3.32
1.3	2.40	2.54	2.61	2.72	2.81	2.89	2.97	3.04	3.11	3.20
1.4	2.26	2.38	2.46	2.57	2.66	2.78	2.85	2.93	3.00	3.08
1.5	2.08	2.20	2.32	2.40	2.51	2.61	2.71	2.79	2.86	2.93
1.6	1.90	2.04	2.15	2.26	2.36	2.45	2.54	2.63	2.73	2.77
1.7	1.72	1.85	1.97	2.08	2.20	2.28	2.38	2.49	2.58	2.62
1.8	1.54	1.66	1.78	1.90	2.00	2.11	2.23	2.32	2.38	2.46
1.9	1.41	1.54	1.66	1.78	1.89	2.00	2.08	2.20	2.28	2.38
2.0	1.36	1.49	1.60	1.72	1.83	1.94	2.04	2.11	2.20	2.30
2.1	1.30	1.41	1.52	1.64	1.76	1.85	1.97	2.08	2.11	2.23
2.2	1.11	1.26	1.34	1.48	1.59	1.71	1.81	1.90	1.98	2.08
2.3	0.91	1.04	1.15	1.28	1.40	1.49	1.59	1.70	1.77	1.86
2.4	0.53	0.66	0.77	0.90	1.04	1.15	1.23	1.34	1.46	1.54
2.5	0.26	0.40	0.53	0.63	0.76	0.89	1.00	1.11	1.23	1.32
2.6	-0.01	0.11	0.26	0.38	0.52	0.63	0.76	0.86	0.98	1.08
2.7	-0.32	-0.16	-0.04	0.11	0.23	0.38	0.49	0.63	0.73	0.85

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A12 Values of $\log S_a$ ($T_n = 0.077$ sec; cm/sec^2) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{\text{hypo}}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	2.74	2.83	2.93	3.04	3.11	3.18	3.26	3.32	3.40	3.45
1.1	2.60	2.70	2.81	2.88	2.98	3.04	3.11	3.20	3.28	3.34
1.2	2.45	2.57	2.65	2.74	2.84	2.93	3.00	3.08	3.15	3.23
1.3	2.28	2.40	2.52	2.60	2.72	2.79	2.88	2.94	3.04	3.11
1.4	2.15	2.23	2.36	2.48	2.56	2.67	2.74	2.84	2.92	2.99
1.5	1.98	2.11	2.23	2.32	2.41	2.52	2.61	2.69	2.79	2.86
1.6	1.82	1.92	2.04	2.18	2.28	2.36	2.46	2.54	2.64	2.72
1.7	1.65	1.77	1.88	2.00	2.11	2.20	2.32	2.40	2.51	2.58
1.8	1.46	1.59	1.72	1.83	1.93	2.04	2.15	2.26	2.34	2.41
1.9	1.38	1.49	1.61	1.73	1.83	1.95	2.08	2.15	2.23	2.34
2.0	1.32	1.45	1.58	1.69	1.81	1.91	2.00	2.11	2.20	2.28
2.1	1.28	1.40	1.52	1.63	1.75	1.85	1.95	2.04	2.15	2.23
2.2	1.15	1.26	1.38	1.49	1.61	1.72	1.81	1.91	2.00	2.08
2.3	0.95	1.08	1.18	1.32	1.43	1.53	1.64	1.74	1.84	1.94
2.4	0.69	0.81	0.93	1.08	1.18	1.28	1.40	1.51	1.60	1.72
2.5	0.45	0.58	0.71	0.83	0.94	1.04	1.18	1.28	1.38	1.48
2.6	0.18	0.30	0.43	0.56	0.68	0.80	0.91	1.04	1.11	1.23
2.7	-0.14	0.00	0.15	0.26	0.38	0.51	0.63	0.76	0.86	0.98

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A13 Values of $\log S_a$ ($T_n = 0.13$ sec; cm/sec 2) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	2.57	2.68	2.80	2.85	2.98	3.04	3.15	3.20	3.28	3.36
1.1	2.45	2.54	2.65	2.76	2.83	2.94	3.00	3.08	3.15	3.23
1.2	2.28	2.40	2.52	2.59	2.70	2.81	2.91	2.98	3.04	3.11
1.3	2.15	2.26	2.38	2.46	2.58	2.66	2.76	2.83	2.92	2.99
1.4	1.98	2.11	2.26	2.34	2.45	2.53	2.65	2.72	2.81	2.89
1.5	1.83	1.96	2.08	2.20	2.32	2.40	2.49	2.58	2.68	2.78
1.6	1.67	1.82	1.94	2.04	2.15	2.26	2.36	2.45	2.54	2.63
1.7	1.52	1.67	1.77	1.90	2.00	2.11	2.23	2.32	2.41	2.49
1.8	1.36	1.49	1.60	1.73	1.86	1.96	2.04	2.18	2.28	2.36
1.9	1.26	1.41	1.53	1.64	1.77	1.88	1.98	2.08	2.18	2.28
2.0	1.23	1.36	1.49	1.61	1.73	1.86	1.97	2.04	2.15	2.23
2.1	1.20	1.34	1.45	1.57	1.68	1.82	1.91	2.04	2.11	2.20
2.2	1.08	1.23	1.34	1.45	1.57	1.68	1.79	1.89	1.99	2.08
2.3	0.92	1.04	1.18	1.30	1.43	1.53	1.64	1.76	1.84	1.94
2.4	0.72	0.86	0.97	1.11	1.23	1.34	1.45	1.57	1.67	1.79
2.5	0.52	0.66	0.78	0.93	1.04	1.15	1.26	1.36	1.48	1.58
2.6	0.28	0.43	0.54	0.69	0.81	0.92	1.04	1.15	1.26	1.36
2.7	0.00	0.15	0.28	0.43	0.53	0.67	0.79	0.90	1.00	1.11

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A14 Values of $\log S_a$ ($T_n = 0.2$ sec; cm/sec^2) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{\text{hypo}}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	2.34	2.48	2.58	2.70	2.81	2.88	2.94	3.04	3.15	3.20
1.1	2.18	2.34	2.45	2.56	2.66	2.77	2.85	2.95	3.04	3.11
1.2	2.04	2.20	2.34	2.43	2.56	2.64	2.72	2.83	2.90	2.99
1.3	1.95	2.04	2.18	2.30	2.43	2.52	2.61	2.71	2.79	2.89
1.4	1.79	1.91	2.04	2.18	2.30	2.40	2.51	2.59	2.65	2.77
1.5	1.65	1.77	1.89	2.04	2.15	2.26	2.36	2.46	2.56	2.64
1.6	1.48	1.65	1.76	1.89	2.00	2.11	2.23	2.36	2.43	2.51
1.7	1.34	1.49	1.64	1.73	1.86	1.97	2.08	2.20	2.30	2.38
1.8	1.20	1.34	1.48	1.59	1.73	1.85	1.95	2.04	2.15	2.26
1.9	1.11	1.26	1.40	1.52	1.64	1.75	1.87	1.98	2.08	2.18
2.0	1.11	1.20	1.36	1.48	1.62	1.75	1.85	1.96	2.04	2.15
2.1	1.08	1.20	1.34	1.46	1.59	1.70	1.83	1.94	2.00	2.11
2.2	0.95	1.11	1.23	1.36	1.49	1.60	1.71	1.82	1.92	2.04
2.3	0.83	0.98	1.08	1.23	1.34	1.46	1.58	1.71	1.81	1.91
2.4	0.64	0.81	0.93	1.08	1.20	1.32	1.45	1.56	1.68	1.76
2.5	0.49	0.61	0.79	0.91	1.04	1.15	1.28	1.40	1.49	1.60
2.6	0.30	0.43	0.57	0.70	0.85	0.97	1.08	1.18	1.32	1.43
2.7	0.08	0.20	0.34	0.48	0.60	0.74	0.88	1.00	1.08	1.20

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A15 Values of $\log S_a$ ($T_n = 0.31$ sec; cm/sec 2) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	2.08	2.23	2.32	2.43	2.58	2.68	2.77	2.89	2.98	3.04
1.1	1.92	2.08	2.20	2.34	2.45	2.56	2.66	2.78	2.87	2.96
1.2	1.79	1.93	2.11	2.20	2.32	2.46	2.56	2.64	2.75	2.83
1.3	1.66	1.81	1.95	2.08	2.20	2.32	2.45	2.54	2.62	2.74
1.4	1.53	1.66	1.83	1.95	2.11	2.23	2.32	2.43	2.51	2.63
1.5	1.38	1.52	1.68	1.84	1.94	2.08	2.20	2.32	2.40	2.51
1.6	1.28	1.41	1.56	1.66	1.83	1.95	2.08	2.18	2.28	2.38
1.7	1.08	1.26	1.40	1.56	1.70	1.81	1.92	2.04	2.18	2.26
1.8	0.96	1.11	1.26	1.40	1.53	1.67	1.80	1.90	2.04	2.11
1.9	0.90	1.08	1.20	1.32	1.45	1.60	1.72	1.84	1.94	2.04
2.0	0.87	1.00	1.18	1.30	1.45	1.60	1.70	1.81	1.91	2.04
2.1	0.85	1.00	1.15	1.32	1.43	1.56	1.68	1.79	1.91	2.04
2.2	0.76	0.93	1.08	1.20	1.34	1.49	1.59	1.69	1.83	1.93
2.3	0.63	0.80	0.93	1.08	1.23	1.36	1.46	1.60	1.72	1.81
2.4	0.51	0.66	0.81	0.96	1.08	1.23	1.36	1.48	1.59	1.70
2.5	0.34	0.52	0.66	0.80	0.94	1.08	1.20	1.34	1.46	1.56
2.6	0.18	0.34	0.49	0.63	0.79	0.90	1.04	1.18	1.30	1.40
2.7	-0.01	0.15	0.30	0.46	0.61	0.75	0.87	0.98	1.11	1.20

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A16 Values of $\log S_a$ ($T_n = 0.5$ sec; cm/sec^2) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{\text{hypo}}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	1.68	1.85	2.00	2.15	2.32	2.43	2.53	2.65	2.74	2.86
1.1	1.63	1.76	1.90	2.04	2.18	2.30	2.45	2.54	2.61	2.74
1.2	1.45	1.61	1.78	1.91	2.08	2.15	2.30	2.43	2.56	2.64
1.3	1.32	1.51	1.62	1.79	1.93	2.04	2.18	2.30	2.41	2.54
1.4	1.20	1.36	1.51	1.65	1.86	1.96	2.08	2.20	2.32	2.41
1.5	1.08	1.23	1.38	1.54	1.67	1.81	1.95	2.04	2.20	2.30
1.6	0.98	1.11	1.28	1.41	1.57	1.73	1.86	1.98	2.08	2.20
1.7	0.80	0.96	1.15	1.30	1.43	1.59	1.70	1.83	1.94	2.08
1.8	0.64	0.85	0.99	1.15	1.28	1.45	1.58	1.70	1.83	1.94
1.9	0.59	0.74	0.91	1.08	1.23	1.36	1.52	1.63	1.78	1.89
2.0	0.59	0.76	0.90	1.08	1.23	1.34	1.49	1.62	1.76	1.88
2.1	0.57	0.75	0.88	1.08	1.20	1.34	1.48	1.61	1.73	1.86
2.2	0.48	0.64	0.81	0.97	1.15	1.26	1.40	1.53	1.64	1.76
2.3	0.38	0.53	0.72	0.86	1.00	1.18	1.32	1.43	1.54	1.66
2.4	0.23	0.41	0.58	0.75	0.90	1.04	1.20	1.34	1.49	1.57
2.5	0.11	0.30	0.48	0.63	0.78	0.93	1.04	1.20	1.34	1.46
2.6	-0.04	0.15	0.30	0.49	0.62	0.79	0.92	1.08	1.20	1.34
2.7	-0.18	0.00	0.15	0.32	0.48	0.62	0.79	0.92	1.04	1.18

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A17 Values of $\log S_a$ ($T_n = 0.77$ sec; cm/sec 2) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	1.32	1.48	1.65	1.81	2.00	2.08	2.23	2.36	2.48	2.63
1.1	1.26	1.41	1.54	1.72	1.86	1.97	2.11	2.26	2.38	2.51
1.2	1.11	1.28	1.45	1.61	1.73	1.85	2.00	2.15	2.28	2.38
1.3	0.94	1.20	1.34	1.48	1.61	1.73	1.89	2.04	2.15	2.28
1.4	0.86	1.04	1.20	1.36	1.49	1.66	1.78	1.91	2.04	2.18
1.5	0.71	0.87	1.04	1.23	1.38	1.52	1.66	1.81	1.92	2.08
1.6	0.58	0.76	0.95	1.08	1.26	1.41	1.53	1.70	1.84	1.93
1.7	0.48	0.63	0.80	0.97	1.15	1.30	1.45	1.57	1.68	1.84
1.8	0.28	0.49	0.67	0.83	0.97	1.15	1.32	1.43	1.58	1.71
1.9	0.26	0.45	0.63	0.76	0.92	1.11	1.23	1.40	1.52	1.66
2.0	0.26	0.43	0.58	0.78	0.94	1.08	1.23	1.36	1.51	1.63
2.1	0.26	0.43	0.60	0.76	0.92	1.04	1.23	1.34	1.48	1.61
2.2	0.15	0.36	0.52	0.69	0.85	0.99	1.15	1.28	1.40	1.54
2.3	0.08	0.23	0.43	0.60	0.73	0.89	1.08	1.20	1.34	1.46
2.4	-0.04	0.15	0.34	0.51	0.64	0.83	0.97	1.08	1.26	1.36
2.5	-0.15	0.04	0.20	0.38	0.53	0.68	0.85	0.99	1.15	1.28
2.6	-0.29	-0.12	0.04	0.26	0.40	0.58	0.71	0.86	1.00	1.18
2.7	-0.43	-0.24	-0.08	0.11	0.30	0.45	0.59	0.74	0.89	1.04

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A18 Values of $\log S_a$ ($T_n = 1.25$ sec; cm/sec^2) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{\text{hypo}}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	1.00	1.15	1.28	1.46	1.61	1.79	1.88	2.04	2.18	2.32
1.1	0.88	1.04	1.20	1.34	1.53	1.63	1.79	1.93	2.08	2.18
1.2	0.74	0.90	1.08	1.26	1.38	1.52	1.69	1.79	1.96	2.08
1.3	0.60	0.84	1.00	1.11	1.28	1.45	1.56	1.71	1.85	1.98
1.4	0.52	0.68	0.86	1.00	1.18	1.32	1.48	1.57	1.74	1.86
1.5	0.36	0.57	0.75	0.90	1.04	1.20	1.34	1.51	1.62	1.79
1.6	0.23	0.41	0.60	0.75	0.92	1.08	1.23	1.36	1.53	1.66
1.7	0.08	0.30	0.49	0.62	0.80	0.96	1.08	1.23	1.38	1.54
1.8	-0.03	0.15	0.34	0.53	0.66	0.81	0.97	1.11	1.28	1.40
1.9	-0.09	0.11	0.26	0.41	0.61	0.79	0.92	1.08	1.20	1.34
2.0	-0.09	0.11	0.28	0.46	0.61	0.75	0.95	1.04	1.18	1.36
2.1	-0.10	0.08	0.26	0.40	0.60	0.78	0.90	1.04	1.18	1.32
2.2	-0.17	0.04	0.20	0.38	0.51	0.67	0.83	0.98	1.11	1.28
2.3	-0.28	-0.05	0.11	0.28	0.43	0.61	0.74	0.91	1.00	1.18
2.4	-0.38	-0.17	0.04	0.20	0.32	0.51	0.66	0.81	0.97	1.08
2.5	-0.48	-0.27	-0.07	0.08	0.26	0.43	0.57	0.72	0.88	1.04
2.6	-0.55	-0.40	-0.21	-0.03	0.15	0.32	0.46	0.62	0.76	0.92
2.7	-0.72	-0.49	-0.33	-0.11	0.04	0.18	0.34	0.49	0.64	0.80

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A19 Values of $\log S_a$ ($T_n = 2.0$ sec; cm/sec^2) for the Tabulated Version of the Atkinson and Boore ENA Very Hard Rock Model

$\log r_{\text{hypo}}$ (km)	Moment Magnitude, M_W									
	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	7.00	7.25
1.0	0.73	0.87	0.94	1.15	1.28	1.43	1.56	1.70	1.81	1.93
1.1	0.58	0.74	0.90	1.00	1.18	1.30	1.45	1.61	1.72	1.83
1.2	0.43	0.58	0.76	0.95	1.04	1.20	1.32	1.46	1.61	1.76
1.3	0.20	0.45	0.64	0.82	0.95	1.11	1.26	1.36	1.51	1.62
1.4	0.11	0.32	0.51	0.68	0.85	0.98	1.15	1.26	1.41	1.56
1.5	0.00	0.23	0.40	0.54	0.71	0.86	1.04	1.15	1.30	1.45
1.6	-0.18	0.08	0.26	0.43	0.61	0.77	0.89	1.04	1.20	1.30
1.7	-0.25	-0.07	0.15	0.32	0.45	0.66	0.80	0.89	1.08	1.20
1.8	-0.40	-0.18	0.00	0.20	0.36	0.51	0.66	0.79	0.95	1.08
1.9	-0.49	-0.26	-0.08	0.11	0.28	0.43	0.60	0.78	0.89	1.04
2.0	-0.49	-0.26	-0.05	0.11	0.30	0.43	0.60	0.73	0.87	1.04
2.1	-0.46	-0.26	-0.06	0.11	0.30	0.45	0.59	0.72	0.90	0.99
2.2	-0.54	-0.32	-0.11	0.04	0.20	0.40	0.53	0.64	0.81	0.95
2.3	-0.62	-0.40	-0.21	-0.05	0.11	0.30	0.45	0.59	0.76	0.86
2.4	-0.72	-0.51	-0.30	-0.09	0.04	0.26	0.36	0.52	0.64	0.80
2.5	-0.85	-0.60	-0.39	-0.19	-0.04	0.11	0.28	0.41	0.57	0.71
2.6	-0.89	-0.68	-0.48	-0.28	-0.12	0.04	0.18	0.34	0.49	0.62
2.7	-1.05	-0.82	-0.60	-0.41	-0.23	-0.07	0.08	0.26	0.36	0.52

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A20 Coefficients for the Equation Version of the Atkinson and Boore ENA Very Hard Rock Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	$\sigma_{\ln Y}$	
						M_W	m_{Lg}
PGA	1.841	0.686	-0.123	-0.00311	—	—	—
PGV	4.697	0.972	-0.0859	0	—	—	—
0.050	2.762	0.755	-0.110	-0.00520	-0.069	—	—
0.077	2.463	0.797	-0.113	-0.00352	—	—	—
0.10	2.301	0.829	-0.121	-0.00279	0.345	0.622	0.668
0.13	2.140	0.864	-0.129	-0.00207	—	—	—
0.20	1.749	0.963	-0.148	-0.00105	0.553	0.599	0.714
0.31	1.265	1.094	-0.165	-0.00024	—	—	—
0.50	0.620	1.267	-0.147	0	0.668	0.553	0.783
0.77	-0.094	1.391	-0.118	0	—	—	—
1.00	-0.508	1.428	-0.094	0	0.622	0.553	0.990
1.25	-0.900	1.462	-0.071	0	—	—	—
2.00	-1.660	1.460	-0.039	0	0.622	—	—

Adapted from: Atkinson, G.M. and Boore, D.M. (1995). "New ground motion relations for eastern North America." *Bulletin of the Seismological Society of America*, 85, 17–30; and Atkinson, G.M. and Boore, D.M. (1997). "Some comparisons between recent ground motion relations." *Seismological Research Letters*, 68, 24–40.

TABLE A21 Values of log PGA (g) for the Tabulated Version of the Atkinson and Boore ENA NEHRP B-C Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-0.36	-0.30	-0.24	-0.18	-0.12	-0.06	0.00	0.05	0.11	0.16	0.21	0.27	0.32	0.37	0.42	0.48	0.53
1.1	-0.53	-0.46	-0.39	-0.32	-0.25	-0.19	-0.13	-0.07	-0.01	0.04	0.10	0.15	0.21	0.26	0.31	0.36	0.42
1.2	-0.70	-0.62	-0.54	-0.47	-0.40	-0.33	-0.26	-0.20	-0.14	-0.08	-0.02	0.04	0.09	0.15	0.20	0.25	0.30
1.3	-0.87	-0.78	-0.70	-0.62	-0.54	-0.47	-0.40	-0.33	-0.27	-0.20	-0.14	-0.09	-0.03	0.03	0.08	0.14	0.19
1.4	-1.04	-0.95	-0.86	-0.77	-0.69	-0.61	-0.54	-0.47	-0.40	-0.34	-0.27	-0.21	-0.15	-0.10	-0.04	0.02	0.07
1.5	-1.21	-1.11	-1.02	-0.93	-0.85	-0.77	-0.69	-0.61	-0.54	-0.47	-0.41	-0.34	-0.28	-0.22	-0.17	-0.11	-0.06
1.6	-1.38	-1.29	-1.19	-1.10	-1.01	-0.93	-0.84	-0.77	-0.69	-0.62	-0.55	-0.48	-0.42	-0.36	-0.30	-0.24	-0.18
1.7	-1.56	-1.46	-1.37	-1.27	-1.18	-1.09	-1.01	-0.93	-0.85	-0.77	-0.70	-0.63	-0.56	-0.50	-0.44	-0.38	-0.32
1.8	-1.75	-1.65	-1.55	-1.45	-1.36	-1.27	-1.18	-1.09	-1.01	-0.93	-0.86	-0.78	-0.71	-0.65	-0.58	-0.52	-0.46
1.9	-1.86	-1.75	-1.65	-1.56	-1.46	-1.37	-1.28	-1.19	-1.11	-1.03	-0.95	-0.88	-0.81	-0.74	-0.68	-0.61	-0.55
2.0	-1.90	-1.80	-1.70	-1.60	-1.51	-1.42	-1.33	-1.24	-1.16	-1.08	-1.00	-0.93	-0.86	-0.79	-0.72	-0.66	-0.60
2.1	-1.96	-1.85	-1.75	-1.66	-1.56	-1.47	-1.38	-1.29	-1.21	-1.13	-1.05	-0.98	-0.91	-0.84	-0.78	-0.72	-0.66
2.2	-2.10	-2.00	-1.89	-1.79	-1.70	-1.60	-1.51	-1.42	-1.34	-1.26	-1.18	-1.10	-1.03	-0.96	-0.90	-0.83	-0.77
2.3	-2.28	-2.17	-2.06	-1.96	-1.86	-1.77	-1.67	-1.58	-1.49	-1.41	-1.33	-1.25	-1.17	-1.10	-1.03	-0.97	-0.90
2.4	-2.47	-2.36	-2.25	-2.14	-2.04	-1.94	-1.85	-1.75	-1.66	-1.57	-1.49	-1.41	-1.33	-1.26	-1.19	-1.12	-1.05
2.5	-2.67	-2.56	-2.45	-2.34	-2.24	-2.14	-2.04	-1.94	-1.85	-1.76	-1.67	-1.58	-1.50	-1.43	-1.35	-1.28	-1.21
2.6	-2.90	-2.79	-2.67	-2.56	-2.45	-2.35	-2.25	-2.15	-2.05	-1.96	-1.86	-1.78	-1.69	-1.61	-1.53	-1.46	-1.39
2.7	-3.15	-3.03	-2.91	-2.80	-2.69	-2.58	-2.47	-2.37	-2.27	-2.17	-2.08	-1.98	-1.90	-1.81	-1.73	-1.65	-1.57
2.8	-3.42	-3.30	-3.18	-3.06	-2.94	-2.83	-2.72	-2.61	-2.51	-2.41	-2.31	-2.21	-2.12	-2.03	-1.94	-1.86	-1.78
2.9	-3.72	-3.59	-3.46	-3.34	-3.22	-3.10	-2.99	-2.88	-2.77	-2.66	-2.56	-2.46	-2.36	-2.27	-2.17	-2.09	-2.00
3.0	-4.04	-3.90	-3.77	-3.64	-3.52	-3.40	-3.28	-3.16	-3.05	-2.94	-2.83	-2.73	-2.62	-2.52	-2.43	-2.33	-2.25

Source: D.M. Boore [written comm., 2003].

TABLE A22 Values of $\log S_a$ ($T_n = 0.1$ sec; g) for the Tabulated Version of the Atkinson and Boore ENA NEHRP B-C Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-0.08	0.00	0.08	0.15	0.22	0.28	0.35	0.41	0.46	0.52	0.58	0.63	0.69	0.74	0.79	0.84	0.90
1.1	-0.22	-0.14	-0.06	0.02	0.09	0.16	0.22	0.29	0.35	0.41	0.46	0.52	0.58	0.63	0.68	0.74	0.79
1.2	-0.37	-0.28	-0.20	-0.12	-0.04	0.03	0.10	0.16	0.23	0.29	0.35	0.41	0.46	0.52	0.57	0.63	0.68
1.3	-0.52	-0.43	-0.34	-0.26	-0.18	-0.10	-0.03	0.04	0.10	0.17	0.23	0.29	0.35	0.40	0.46	0.51	0.57
1.4	-0.68	-0.58	-0.49	-0.41	-0.32	-0.24	-0.17	-0.09	-0.02	0.04	0.11	0.17	0.23	0.29	0.34	0.40	0.45
1.5	-0.83	-0.74	-0.64	-0.55	-0.47	-0.39	-0.31	-0.23	-0.16	-0.09	-0.02	0.04	0.10	0.16	0.22	0.28	0.33
1.6	-1.00	-0.90	-0.80	-0.71	-0.62	-0.54	-0.45	-0.37	-0.30	-0.23	-0.16	-0.09	-0.03	0.04	0.10	0.15	0.21
1.7	-1.16	-1.06	-0.96	-0.87	-0.78	-0.69	-0.61	-0.52	-0.45	-0.37	-0.30	-0.23	-0.16	-0.10	-0.04	0.02	0.08
1.8	-1.33	-1.23	-1.13	-1.04	-0.94	-0.85	-0.77	-0.68	-0.60	-0.52	-0.45	-0.38	-0.31	-0.24	-0.18	-0.11	-0.05
1.9	-1.43	-1.33	-1.23	-1.13	-1.04	-0.95	-0.86	-0.77	-0.69	-0.61	-0.54	-0.46	-0.39	-0.33	-0.26	-0.20	-0.14
2.0	-1.46	-1.36	-1.26	-1.17	-1.08	-0.98	-0.90	-0.81	-0.73	-0.65	-0.58	-0.50	-0.43	-0.37	-0.30	-0.24	-0.18
2.1	-1.51	-1.41	-1.31	-1.21	-1.12	-1.03	-0.94	-0.86	-0.78	-0.70	-0.63	-0.55	-0.49	-0.42	-0.36	-0.30	-0.24
2.2	-1.64	-1.54	-1.44	-1.35	-1.25	-1.16	-1.07	-0.99	-0.91	-0.83	-0.75	-0.68	-0.61	-0.54	-0.48	-0.41	-0.35
2.3	-1.81	-1.71	-1.61	-1.51	-1.42	-1.32	-1.23	-1.15	-1.06	-0.98	-0.90	-0.83	-0.76	-0.69	-0.62	-0.56	-0.50
2.4	-2.00	-1.90	-1.80	-1.70	-1.60	-1.51	-1.42	-1.33	-1.25	-1.16	-1.08	-1.00	-0.93	-0.86	-0.79	-0.73	-0.66
2.5	-2.23	-2.12	-2.02	-1.92	-1.82	-1.73	-1.63	-1.54	-1.46	-1.37	-1.29	-1.21	-1.13	-1.06	-0.99	-0.92	-0.86
2.6	-2.48	-2.38	-2.28	-2.17	-2.08	-1.98	-1.88	-1.79	-1.70	-1.61	-1.53	-1.44	-1.37	-1.29	-1.22	-1.15	-1.08
2.7	-2.78	-2.68	-2.57	-2.47	-2.37	-2.27	-2.17	-2.07	-1.98	-1.89	-1.80	-1.72	-1.63	-1.55	-1.48	-1.40	-1.33
2.8	-3.13	-3.02	-2.91	-2.80	-2.70	-2.59	-2.49	-2.39	-2.30	-2.20	-2.11	-2.02	-1.93	-1.85	-1.77	-1.69	-1.61
2.9	-3.51	-3.39	-3.28	-3.17	-3.06	-2.95	-2.84	-2.74	-2.63	-2.53	-2.43	-2.34	-2.25	-2.16	-2.07	-1.98	-1.90
3.0	-3.91	-3.79	-3.66	-3.54	-3.43	-3.31	-3.20	-3.09	-2.98	-2.87	-2.76	-2.66	-2.56	-2.47	-2.37	-2.28	-2.19

Source: D.M. Boore [written comm., 2003].

TABLE A23 Values of $\log S_a$ ($T_n = 0.2$ sec; g) for the Tabulated Version of the Atkinson and Boore ENA NEHRP B-C Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-0.37	-0.26	-0.17	-0.08	0.01	0.08	0.16	0.23	0.29	0.36	0.42	0.48	0.54	0.60	0.65	0.71	0.76
1.1	-0.49	-0.39	-0.29	-0.20	-0.12	-0.04	0.04	0.11	0.18	0.25	0.31	0.37	0.43	0.49	0.55	0.60	0.66
1.2	-0.63	-0.52	-0.42	-0.33	-0.24	-0.16	-0.08	-0.01	0.07	0.13	0.20	0.26	0.32	0.38	0.44	0.50	0.55
1.3	-0.77	-0.66	-0.56	-0.46	-0.37	-0.29	-0.21	-0.13	-0.05	0.02	0.08	0.15	0.21	0.27	0.33	0.39	0.44
1.4	-0.91	-0.80	-0.70	-0.60	-0.51	-0.42	-0.33	-0.25	-0.18	-0.11	-0.04	0.03	0.10	0.16	0.22	0.28	0.33
1.5	-1.05	-0.95	-0.84	-0.74	-0.65	-0.55	-0.47	-0.38	-0.31	-0.23	-0.16	-0.09	-0.02	0.04	0.10	0.16	0.22
1.6	-1.20	-1.09	-0.99	-0.89	-0.79	-0.69	-0.60	-0.52	-0.44	-0.36	-0.29	-0.21	-0.15	-0.08	-0.02	0.04	0.10
1.7	-1.36	-1.25	-1.14	-1.03	-0.94	-0.84	-0.75	-0.66	-0.58	-0.49	-0.42	-0.34	-0.27	-0.21	-0.14	-0.08	-0.02
1.8	-1.52	-1.40	-1.29	-1.19	-1.09	-0.99	-0.90	-0.81	-0.72	-0.64	-0.56	-0.48	-0.41	-0.34	-0.27	-0.21	-0.15
1.9	-1.60	-1.49	-1.38	-1.27	-1.17	-1.07	-0.98	-0.89	-0.80	-0.71	-0.63	-0.56	-0.48	-0.41	-0.34	-0.28	-0.22
2.0	-1.62	-1.51	-1.40	-1.29	-1.19	-1.09	-1.00	-0.91	-0.82	-0.74	-0.66	-0.58	-0.51	-0.44	-0.37	-0.31	-0.25
2.1	-1.64	-1.53	-1.42	-1.32	-1.22	-1.12	-1.03	-0.94	-0.85	-0.77	-0.69	-0.61	-0.54	-0.47	-0.41	-0.34	-0.28
2.2	-1.75	-1.64	-1.53	-1.42	-1.32	-1.23	-1.13	-1.04	-0.95	-0.87	-0.79	-0.71	-0.64	-0.57	-0.50	-0.44	-0.37
2.3	-1.89	-1.77	-1.66	-1.56	-1.46	-1.36	-1.26	-1.17	-1.08	-0.99	-0.91	-0.83	-0.76	-0.69	-0.62	-0.55	-0.49
2.4	-2.04	-1.93	-1.82	-1.71	-1.61	-1.50	-1.41	-1.31	-1.22	-1.14	-1.05	-0.97	-0.89	-0.82	-0.75	-0.68	-0.62
2.5	-2.22	-2.10	-1.99	-1.88	-1.78	-1.68	-1.58	-1.48	-1.39	-1.30	-1.21	-1.13	-1.05	-0.98	-0.90	-0.84	-0.77
2.6	-2.42	-2.30	-2.19	-2.08	-1.97	-1.87	-1.77	-1.67	-1.58	-1.49	-1.40	-1.32	-1.24	-1.16	-1.08	-1.01	-0.94
2.7	-2.65	-2.53	-2.42	-2.31	-2.20	-2.10	-2.00	-1.90	-1.80	-1.71	-1.62	-1.53	-1.45	-1.37	-1.29	-1.22	-1.15
2.8	-2.92	-2.80	-2.69	-2.58	-2.47	-2.36	-2.26	-2.16	-2.06	-1.97	-1.88	-1.79	-1.70	-1.62	-1.54	-1.46	-1.39
2.9	-3.24	-3.12	-3.00	-2.89	-2.78	-2.67	-2.57	-2.47	-2.37	-2.27	-2.18	-2.08	-1.99	-1.91	-1.82	-1.75	-1.67
3.0	-3.61	-3.49	-3.37	-3.26	-3.14	-3.03	-2.93	-2.82	-2.72	-2.62	-2.52	-2.43	-2.33	-2.24	-2.15	-2.07	-1.99

Source: D.M. Boore [written comm., 2003].

TABLE A24 Values of $\log S_a$ ($T_n = 0.3$ sec; g) for the Tabulated Version of the Atkinson and Boore ENA NEHRP B-C Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-0.63	-0.51	-0.40	-0.29	-0.20	-0.11	-0.02	0.06	0.14	0.21	0.28	0.35	0.41	0.47	0.53	0.59	0.65
1.1	-0.75	-0.63	-0.52	-0.41	-0.32	-0.22	-0.13	-0.05	0.03	0.10	0.17	0.24	0.30	0.37	0.43	0.49	0.54
1.2	-0.87	-0.75	-0.64	-0.54	-0.44	-0.34	-0.25	-0.17	-0.09	-0.01	0.06	0.13	0.20	0.26	0.32	0.38	0.44
1.3	-1.00	-0.88	-0.77	-0.66	-0.56	-0.47	-0.37	-0.29	-0.21	-0.13	-0.05	0.02	0.08	0.15	0.21	0.27	0.33
1.4	-1.14	-1.02	-0.90	-0.79	-0.69	-0.59	-0.50	-0.41	-0.33	-0.25	-0.17	-0.10	-0.03	0.04	0.10	0.16	0.22
1.5	-1.28	-1.15	-1.04	-0.93	-0.82	-0.72	-0.63	-0.54	-0.45	-0.37	-0.29	-0.22	-0.15	-0.08	-0.01	0.05	0.11
1.6	-1.42	-1.30	-1.18	-1.07	-0.96	-0.86	-0.76	-0.67	-0.58	-0.49	-0.41	-0.34	-0.27	-0.20	-0.13	-0.07	0.00
1.7	-1.57	-1.44	-1.33	-1.21	-1.10	-1.00	-0.90	-0.80	-0.71	-0.63	-0.54	-0.46	-0.39	-0.32	-0.25	-0.18	-0.12
1.8	-1.72	-1.59	-1.47	-1.36	-1.25	-1.14	-1.04	-0.94	-0.85	-0.76	-0.68	-0.60	-0.52	-0.45	-0.38	-0.31	-0.24
1.9	-1.80	-1.67	-1.55	-1.44	-1.33	-1.22	-1.12	-1.02	-0.92	-0.83	-0.75	-0.67	-0.59	-0.51	-0.44	-0.37	-0.31
2.0	-1.81	-1.69	-1.57	-1.45	-1.34	-1.23	-1.13	-1.03	-0.94	-0.85	-0.77	-0.68	-0.61	-0.53	-0.46	-0.40	-0.33
2.1	-1.83	-1.70	-1.58	-1.47	-1.36	-1.25	-1.15	-1.05	-0.96	-0.87	-0.79	-0.71	-0.63	-0.56	-0.49	-0.42	-0.36
2.2	-1.92	-1.80	-1.68	-1.56	-1.45	-1.35	-1.24	-1.15	-1.05	-0.96	-0.88	-0.80	-0.72	-0.64	-0.57	-0.51	-0.44
2.3	-2.05	-1.92	-1.80	-1.68	-1.57	-1.46	-1.36	-1.26	-1.17	-1.07	-0.99	-0.90	-0.82	-0.75	-0.68	-0.61	-0.54
2.4	-2.18	-2.05	-1.93	-1.82	-1.70	-1.60	-1.49	-1.39	-1.29	-1.20	-1.11	-1.03	-0.95	-0.87	-0.79	-0.72	-0.66
2.5	-2.33	-2.21	-2.08	-1.97	-1.85	-1.74	-1.64	-1.54	-1.44	-1.34	-1.25	-1.17	-1.08	-1.00	-0.93	-0.86	-0.79
2.6	-2.51	-2.38	-2.26	-2.14	-2.03	-1.91	-1.81	-1.70	-1.60	-1.51	-1.42	-1.33	-1.24	-1.16	-1.08	-1.01	-0.94
2.7	-2.71	-2.58	-2.46	-2.34	-2.22	-2.11	-2.00	-1.90	-1.80	-1.70	-1.60	-1.51	-1.43	-1.34	-1.26	-1.19	-1.11
2.8	-2.94	-2.81	-2.68	-2.57	-2.45	-2.34	-2.23	-2.12	-2.02	-1.92	-1.82	-1.73	-1.64	-1.55	-1.47	-1.39	-1.32
2.9	-3.21	-3.08	-2.95	-2.83	-2.71	-2.60	-2.49	-2.38	-2.28	-2.18	-2.08	-1.98	-1.89	-1.80	-1.72	-1.64	-1.56
3.0	-3.52	-3.39	-3.27	-3.14	-3.03	-2.91	-2.80	-2.69	-2.58	-2.48	-2.38	-2.28	-2.19	-2.10	-2.01	-1.92	-1.84

Source: D.M. Boore [written comm., 2003].

TABLE A25 Values of $\log S_a$ ($T_n = 0.5$ sec; g) for the Tabulated Version of the Atkinson and Boore ENA NEHRP B-C Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-1.08	-0.94	-0.80	-0.68	-0.56	-0.45	-0.34	-0.24	-0.15	-0.06	0.02	0.10	0.18	0.25	0.32	0.39	0.45
1.1	-1.18	-1.04	-0.91	-0.79	-0.67	-0.56	-0.45	-0.35	-0.26	-0.17	-0.08	0.00	0.07	0.15	0.22	0.28	0.35
1.2	-1.29	-1.15	-1.03	-0.90	-0.78	-0.67	-0.57	-0.47	-0.37	-0.28	-0.19	-0.11	-0.04	0.04	0.11	0.18	0.24
1.3	-1.41	-1.27	-1.14	-1.02	-0.90	-0.79	-0.68	-0.58	-0.48	-0.39	-0.31	-0.22	-0.14	-0.07	0.00	0.07	0.14
1.4	-1.53	-1.40	-1.27	-1.14	-1.03	-0.91	-0.80	-0.70	-0.60	-0.51	-0.42	-0.34	-0.26	-0.18	-0.11	-0.04	0.03
1.5	-1.66	-1.53	-1.40	-1.27	-1.15	-1.04	-0.93	-0.82	-0.72	-0.63	-0.54	-0.45	-0.37	-0.29	-0.22	-0.15	-0.08
1.6	-1.80	-1.66	-1.53	-1.40	-1.28	-1.17	-1.05	-0.95	-0.85	-0.75	-0.66	-0.57	-0.49	-0.41	-0.33	-0.26	-0.19
1.7	-1.94	-1.80	-1.67	-1.54	-1.42	-1.30	-1.19	-1.08	-0.97	-0.87	-0.78	-0.69	-0.61	-0.53	-0.45	-0.38	-0.31
1.8	-2.08	-1.94	-1.81	-1.68	-1.56	-1.44	-1.32	-1.21	-1.11	-1.01	-0.91	-0.82	-0.73	-0.65	-0.57	-0.49	-0.42
1.9	-2.15	-2.01	-1.88	-1.75	-1.63	-1.51	-1.39	-1.28	-1.17	-1.07	-0.97	-0.88	-0.79	-0.71	-0.63	-0.56	-0.49
2.0	-2.16	-2.02	-1.89	-1.76	-1.64	-1.52	-1.40	-1.29	-1.18	-1.08	-0.99	-0.89	-0.81	-0.72	-0.65	-0.57	-0.50
2.1	-2.17	-2.03	-1.90	-1.77	-1.65	-1.53	-1.41	-1.30	-1.20	-1.10	-1.00	-0.91	-0.82	-0.74	-0.66	-0.59	-0.52
2.2	-2.25	-2.12	-1.98	-1.85	-1.73	-1.61	-1.50	-1.39	-1.28	-1.18	-1.08	-0.99	-0.90	-0.82	-0.74	-0.66	-0.59
2.3	-2.36	-2.22	-2.09	-1.96	-1.83	-1.71	-1.60	-1.49	-1.38	-1.28	-1.18	-1.08	-0.99	-0.91	-0.83	-0.75	-0.68
2.4	-2.48	-2.34	-2.20	-2.08	-1.95	-1.83	-1.71	-1.60	-1.49	-1.38	-1.28	-1.19	-1.10	-1.01	-0.93	-0.85	-0.78
2.5	-2.61	-2.47	-2.33	-2.20	-2.08	-1.96	-1.84	-1.72	-1.61	-1.51	-1.41	-1.31	-1.22	-1.13	-1.05	-0.97	-0.89
2.6	-2.76	-2.62	-2.48	-2.35	-2.22	-2.10	-1.98	-1.87	-1.75	-1.65	-1.54	-1.44	-1.35	-1.26	-1.17	-1.09	-1.02
2.7	-2.92	-2.78	-2.65	-2.51	-2.39	-2.26	-2.14	-2.03	-1.91	-1.80	-1.70	-1.60	-1.50	-1.41	-1.32	-1.24	-1.16
2.8	-3.11	-2.97	-2.84	-2.70	-2.58	-2.45	-2.33	-2.21	-2.10	-1.99	-1.88	-1.78	-1.68	-1.59	-1.50	-1.41	-1.33
2.9	-3.33	-3.19	-3.05	-2.92	-2.79	-2.67	-2.54	-2.43	-2.31	-2.20	-2.09	-1.99	-1.89	-1.79	-1.70	-1.61	-1.53
3.0	-3.59	-3.44	-3.31	-3.17	-3.04	-2.92	-2.79	-2.67	-2.56	-2.44	-2.33	-2.23	-2.13	-2.03	-1.93	-1.84	-1.76

Source: D.M. Boore [written comm., 2003].

TABLE A26 Values of $\log S_a$ ($T_n = 1.0$ sec; g) for the Tabulated Version of the Atkinson and Boore ENA NEHRP B-C Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-1.78	-1.63	-1.48	-1.34	-1.20	-1.07	-0.94	-0.82	-0.71	-0.59	-0.49	-0.39	-0.29	-0.20	-0.11	-0.02	0.06
1.1	-1.88	-1.73	-1.58	-1.43	-1.30	-1.17	-1.05	-0.93	-0.81	-0.70	-0.59	-0.49	-0.40	-0.30	-0.21	-0.13	-0.04
1.2	-1.98	-1.82	-1.68	-1.54	-1.41	-1.28	-1.15	-1.03	-0.92	-0.81	-0.70	-0.60	-0.50	-0.41	-0.32	-0.23	-0.15
1.3	-2.08	-1.93	-1.78	-1.65	-1.51	-1.39	-1.26	-1.14	-1.03	-0.92	-0.81	-0.71	-0.61	-0.51	-0.42	-0.34	-0.25
1.4	-2.19	-2.04	-1.89	-1.76	-1.63	-1.50	-1.38	-1.26	-1.14	-1.03	-0.92	-0.82	-0.72	-0.62	-0.53	-0.44	-0.36
1.5	-2.31	-2.15	-2.01	-1.87	-1.74	-1.62	-1.49	-1.37	-1.26	-1.14	-1.03	-0.93	-0.83	-0.73	-0.64	-0.55	-0.47
1.6	-2.43	-2.27	-2.13	-1.99	-1.86	-1.74	-1.61	-1.49	-1.37	-1.26	-1.15	-1.04	-0.94	-0.84	-0.75	-0.66	-0.57
1.7	-2.55	-2.40	-2.25	-2.12	-1.99	-1.86	-1.74	-1.61	-1.50	-1.38	-1.27	-1.16	-1.06	-0.96	-0.86	-0.77	-0.69
1.8	-2.69	-2.53	-2.39	-2.25	-2.12	-1.99	-1.86	-1.74	-1.62	-1.50	-1.39	-1.28	-1.18	-1.08	-0.98	-0.89	-0.80
1.9	-2.75	-2.59	-2.45	-2.31	-2.18	-2.05	-1.93	-1.80	-1.68	-1.57	-1.45	-1.34	-1.23	-1.13	-1.04	-0.94	-0.85
2.0	-2.75	-2.60	-2.45	-2.32	-2.19	-2.06	-1.93	-1.81	-1.69	-1.57	-1.46	-1.35	-1.24	-1.14	-1.04	-0.95	-0.86
2.1	-2.76	-2.61	-2.46	-2.32	-2.19	-2.06	-1.94	-1.82	-1.70	-1.58	-1.47	-1.36	-1.25	-1.15	-1.06	-0.96	-0.88
2.2	-2.84	-2.68	-2.53	-2.40	-2.26	-2.14	-2.01	-1.89	-1.77	-1.65	-1.54	-1.43	-1.32	-1.22	-1.12	-1.03	-0.94
2.3	-2.93	-2.77	-2.62	-2.49	-2.35	-2.22	-2.10	-1.97	-1.85	-1.73	-1.62	-1.51	-1.40	-1.30	-1.20	-1.11	-1.02
2.4	-3.03	-2.87	-2.72	-2.58	-2.45	-2.32	-2.19	-2.07	-1.95	-1.83	-1.71	-1.60	-1.49	-1.39	-1.29	-1.19	-1.10
2.5	-3.13	-2.98	-2.83	-2.69	-2.56	-2.43	-2.30	-2.17	-2.05	-1.93	-1.81	-1.70	-1.59	-1.48	-1.38	-1.28	-1.19
2.6	-3.25	-3.10	-2.95	-2.81	-2.67	-2.54	-2.42	-2.29	-2.16	-2.04	-1.92	-1.81	-1.70	-1.59	-1.49	-1.39	-1.30
2.7	-3.39	-3.23	-3.08	-2.94	-2.81	-2.67	-2.55	-2.42	-2.29	-2.17	-2.05	-1.93	-1.82	-1.71	-1.61	-1.51	-1.41
2.8	-3.54	-3.38	-3.23	-3.09	-2.95	-2.82	-2.69	-2.56	-2.44	-2.31	-2.19	-2.07	-1.96	-1.85	-1.74	-1.64	-1.54
2.9	-3.71	-3.55	-3.40	-3.26	-3.12	-2.99	-2.86	-2.73	-2.60	-2.48	-2.35	-2.23	-2.12	-2.00	-1.90	-1.79	-1.69
3.0	-3.90	-3.74	-3.59	-3.45	-3.31	-3.18	-3.05	-2.92	-2.79	-2.66	-2.54	-2.42	-2.30	-2.19	-2.08	-1.97	-1.87

Source: D.M. Boore [written comm., 2003].

TABLE A27 Values of $\log S_a$ ($T_n = 2.0$ sec; g) for the Tabulated Version of the Atkinson and Boore ENA NEHRP B-C Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-2.37	-2.23	-2.10	-1.96	-1.82	-1.69	-1.56	-1.43	-1.31	-1.19	-1.08	-0.97	-0.86	-0.76	-0.65	-0.55	-0.45
1.1	-2.53	-2.37	-2.21	-2.07	-1.92	-1.79	-1.66	-1.53	-1.41	-1.30	-1.18	-1.07	-0.97	-0.86	-0.76	-0.66	-0.56
1.2	-2.66	-2.48	-2.32	-2.17	-2.02	-1.89	-1.76	-1.64	-1.52	-1.40	-1.29	-1.18	-1.07	-0.96	-0.86	-0.76	-0.66
1.3	-2.77	-2.59	-2.42	-2.27	-2.12	-1.99	-1.86	-1.74	-1.62	-1.51	-1.39	-1.28	-1.17	-1.07	-0.96	-0.86	-0.76
1.4	-2.88	-2.69	-2.52	-2.37	-2.23	-2.09	-1.97	-1.85	-1.73	-1.61	-1.50	-1.39	-1.28	-1.17	-1.07	-0.97	-0.87
1.5	-2.98	-2.80	-2.63	-2.47	-2.33	-2.20	-2.08	-1.95	-1.84	-1.72	-1.61	-1.50	-1.39	-1.28	-1.18	-1.07	-0.97
1.6	-3.09	-2.91	-2.74	-2.58	-2.44	-2.31	-2.19	-2.07	-1.95	-1.83	-1.72	-1.61	-1.50	-1.39	-1.29	-1.18	-1.08
1.7	-3.21	-3.02	-2.85	-2.70	-2.56	-2.42	-2.30	-2.18	-2.06	-1.95	-1.83	-1.72	-1.61	-1.50	-1.40	-1.29	-1.19
1.8	-3.33	-3.14	-2.97	-2.81	-2.67	-2.54	-2.42	-2.30	-2.18	-2.07	-1.95	-1.84	-1.73	-1.62	-1.51	-1.40	-1.30
1.9	-3.39	-3.20	-3.03	-2.87	-2.73	-2.60	-2.48	-2.36	-2.24	-2.12	-2.01	-1.89	-1.78	-1.67	-1.56	-1.46	-1.35
2.0	-3.39	-3.20	-3.03	-2.88	-2.74	-2.60	-2.48	-2.36	-2.24	-2.13	-2.01	-1.90	-1.79	-1.68	-1.57	-1.46	-1.36
2.1	-3.40	-3.21	-3.04	-2.88	-2.74	-2.61	-2.49	-2.37	-2.25	-2.13	-2.02	-1.90	-1.79	-1.68	-1.57	-1.47	-1.37
2.2	-3.47	-3.27	-3.10	-2.95	-2.80	-2.67	-2.55	-2.43	-2.31	-2.19	-2.08	-1.97	-1.85	-1.74	-1.63	-1.53	-1.42
2.3	-3.54	-3.35	-3.18	-3.02	-2.88	-2.75	-2.62	-2.50	-2.38	-2.27	-2.15	-2.04	-1.93	-1.81	-1.70	-1.60	-1.49
2.4	-3.63	-3.44	-3.26	-3.11	-2.96	-2.83	-2.71	-2.58	-2.47	-2.35	-2.23	-2.12	-2.00	-1.89	-1.78	-1.67	-1.57
2.5	-3.72	-3.53	-3.35	-3.20	-3.05	-2.92	-2.79	-2.67	-2.55	-2.44	-2.32	-2.20	-2.09	-1.97	-1.86	-1.75	-1.65
2.6	-3.82	-3.63	-3.45	-3.29	-3.15	-3.02	-2.89	-2.77	-2.65	-2.53	-2.41	-2.30	-2.18	-2.07	-1.95	-1.84	-1.73
2.7	-3.94	-3.74	-3.56	-3.40	-3.26	-3.12	-3.00	-2.88	-2.75	-2.64	-2.52	-2.40	-2.28	-2.17	-2.05	-1.94	-1.83
2.8	-4.06	-3.86	-3.68	-3.52	-3.38	-3.24	-3.12	-2.99	-2.87	-2.75	-2.63	-2.51	-2.39	-2.28	-2.16	-2.05	-1.94
2.9	-4.19	-3.99	-3.82	-3.66	-3.51	-3.38	-3.25	-3.12	-3.00	-2.88	-2.76	-2.64	-2.52	-2.40	-2.28	-2.17	-2.06
3.0	-4.35	-4.15	-3.97	-3.80	-3.66	-3.52	-3.40	-3.27	-3.15	-3.03	-2.91	-2.78	-2.66	-2.54	-2.43	-2.31	-2.19

Source: D.M. Boore [written comm., 2003].

TABLE A28 Coefficients for the Campbell ENA Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}
PGA	0.0305	0.633	-0.0427	-1.591	-0.00428	0.000483	0.683	0.416	1.140	-0.873	1.030	-0.0860	0.414
0.02	1.3535	0.630	-0.0404	-1.787	-0.00388	0.000497	1.020	0.363	0.851	-0.715	1.030	-0.0860	0.414
0.03	1.1860	0.622	-0.0362	-1.691	-0.00367	0.000501	0.922	0.376	0.759	-0.922	1.030	-0.0860	0.414
0.05	0.3736	0.616	-0.0353	-1.469	-0.00378	0.000500	0.630	0.423	0.771	-1.239	1.042	-0.0838	0.443
0.075	-0.0395	0.615	-0.0353	-1.383	-0.00421	0.000486	0.491	0.463	0.955	-1.349	1.052	-0.0838	0.453
0.10	-0.1475	0.613	-0.0353	-1.369	-0.00454	0.000460	0.484	0.467	1.096	-1.284	1.059	-0.0838	0.460
0.15	-0.1901	0.616	-0.0478	-1.368	-0.00473	0.000393	0.461	0.478	1.239	-1.079	1.068	-0.0838	0.469
0.20	-0.4328	0.617	-0.0586	-1.320	-0.00460	0.000337	0.399	0.493	1.250	-0.928	1.077	-0.0838	0.478
0.30	-0.6906	0.609	-0.0786	-1.280	-0.00414	0.000263	0.349	0.502	1.241	-0.753	1.081	-0.0838	0.482
0.50	-0.5907	0.534	-0.1379	-1.216	-0.00341	0.000194	0.318	0.503	1.166	-0.606	1.098	-0.0824	0.508
0.75	-0.5429	0.480	-0.1806	-1.184	-0.00288	0.000160	0.304	0.504	1.110	-0.526	1.105	-0.0806	0.528
1.0	-0.6104	0.451	-0.2090	-1.158	-0.00255	0.000141	0.299	0.503	1.067	-0.482	1.110	-0.0793	0.543
1.5	-0.9666	0.441	-0.2405	-1.135	-0.00213	0.000119	0.304	0.500	1.029	-0.438	1.099	-0.0771	0.547
2.0	-1.4306	0.459	-0.2552	-1.124	-0.00187	0.000103	0.310	0.499	1.015	-0.417	1.093	-0.0758	0.551
3.0	-2.2331	0.492	-0.2646	-1.121	-0.00154	0.000084	0.310	0.499	1.014	-0.393	1.090	-0.0737	0.562
4.0	-2.7975	0.507	-0.2738	-1.119	-0.00135	0.000074	0.294	0.506	1.018	-0.386	1.092	-0.0722	0.575

Adapted from: Campbell, K.W. (2001). "Development of semi-empirical attenuation relationships for CEUS." U.S. Geological Survey, Award 01HQGR0011, final report; and Campbell, K.W. (2003d). "Prediction of strong ground motion using the hybrid empirical method and its use in the development of ground motion (attenuation) relations in eastern North America," *Bulletin of the Seismological Society of America*, 93, 1012–1033.

TABLE A29 Values of log PGA (g) for the Tabulated Version of the Frankel *et al.* ENA Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-0.44	-0.36	-0.29	-0.21	-0.14	-0.07	0.00	0.06	0.12	0.19	0.25	0.31	0.37	0.43	0.49	0.54	0.60
1.1	-0.57	-0.49	-0.41	-0.33	-0.26	-0.19	-0.12	-0.05	0.01	0.07	0.14	0.20	0.26	0.32	0.38	0.43	0.49
1.2	-0.70	-0.62	-0.53	-0.46	-0.38	-0.31	-0.24	-0.17	-0.10	-0.04	0.02	0.08	0.14	0.20	0.26	0.32	0.38
1.3	-0.84	-0.75	-0.66	-0.58	-0.51	-0.43	-0.36	-0.29	-0.22	-0.16	-0.10	-0.03	0.03	0.09	0.15	0.21	0.27
1.4	-0.98	-0.89	-0.80	-0.72	-0.64	-0.56	-0.49	-0.42	-0.35	-0.28	-0.22	-0.15	-0.09	-0.03	0.03	0.09	0.15
1.5	-1.13	-1.03	-0.94	-0.86	-0.78	-0.70	-0.62	-0.55	-0.48	-0.41	-0.34	-0.28	-0.22	-0.15	-0.09	-0.03	0.03
1.6	-1.28	-1.19	-1.09	-1.01	-0.92	-0.84	-0.76	-0.69	-0.61	-0.54	-0.48	-0.41	-0.35	-0.28	-0.22	-0.16	-0.10
1.7	-1.44	-1.35	-1.25	-1.16	-1.07	-0.99	-0.91	-0.83	-0.76	-0.69	-0.62	-0.55	-0.48	-0.42	-0.35	-0.29	-0.23
1.8	-1.61	-1.51	-1.42	-1.33	-1.24	-1.15	-1.07	-0.99	-0.91	-0.83	-0.76	-0.69	-0.63	-0.56	-0.50	-0.43	-0.37
1.9	-1.74	-1.64	-1.54	-1.44	-1.35	-1.26	-1.18	-1.10	-1.02	-0.94	-0.86	-0.79	-0.72	-0.65	-0.59	-0.53	-0.46
2.0	-1.83	-1.73	-1.63	-1.53	-1.43	-1.34	-1.25	-1.17	-1.09	-1.01	-0.93	-0.86	-0.78	-0.71	-0.65	-0.58	-0.52
2.1	-1.93	-1.83	-1.72	-1.62	-1.53	-1.43	-1.34	-1.25	-1.17	-1.09	-1.01	-0.93	-0.86	-0.78	-0.71	-0.65	-0.58
2.2	-2.09	-1.98	-1.87	-1.77	-1.67	-1.58	-1.48	-1.39	-1.30	-1.22	-1.14	-1.06	-0.98	-0.91	-0.83	-0.77	-0.70
2.3	-2.26	-2.15	-2.04	-1.94	-1.84	-1.74	-1.64	-1.55	-1.46	-1.37	-1.29	-1.20	-1.12	-1.05	-0.97	-0.90	-0.83
2.4	-2.45	-2.34	-2.23	-2.12	-2.01	-1.91	-1.81	-1.72	-1.62	-1.53	-1.45	-1.36	-1.28	-1.20	-1.12	-1.05	-0.98
2.5	-2.66	-2.54	-2.42	-2.31	-2.20	-2.10	-2.00	-1.90	-1.80	-1.71	-1.62	-1.53	-1.45	-1.36	-1.28	-1.21	-1.13
2.6	-2.88	-2.75	-2.63	-2.52	-2.41	-2.30	-2.19	-2.09	-1.99	-1.90	-1.80	-1.71	-1.62	-1.54	-1.46	-1.38	-1.30
2.7	-3.11	-2.98	-2.86	-2.74	-2.62	-2.51	-2.40	-2.30	-2.19	-2.09	-2.00	-1.90	-1.81	-1.72	-1.64	-1.56	-1.48
2.8	-3.37	-3.23	-3.10	-2.97	-2.85	-2.73	-2.62	-2.51	-2.41	-2.30	-2.20	-2.10	-2.01	-1.92	-1.83	-1.74	-1.66
2.9	-3.65	-3.50	-3.36	-3.22	-3.09	-2.97	-2.85	-2.74	-2.63	-2.52	-2.42	-2.31	-2.22	-2.12	-2.03	-1.94	-1.85
3.0	-3.94	-3.78	-3.63	-3.49	-3.35	-3.22	-3.10	-2.98	-2.86	-2.75	-2.64	-2.53	-2.43	-2.33	-2.23	-2.14	-2.05

Adapted from: Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E., Dickman, N., Hanson, S. and Hopper, M. (1996). "National seismic hazard maps: documentation June 1996," U.S. Geological Survey, Open-File Rept. 96-532.

TABLE A30 Values of $\log S_a$ ($T_n = 0.1$ sec; g) for the Tabulated Version of the Frankel *et al.* ENA Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-0.14	-0.05	0.03	0.11	0.19	0.26	0.33	0.40	0.47	0.54	0.60	0.66	0.72	0.78	0.84	0.90	0.96
1.1	-0.26	-0.17	-0.08	0.00	0.07	0.15	0.22	0.29	0.36	0.43	0.49	0.55	0.62	0.68	0.74	0.80	0.86
1.2	-0.38	-0.29	-0.20	-0.12	-0.04	0.03	0.11	0.18	0.25	0.31	0.38	0.44	0.51	0.57	0.63	0.69	0.75
1.3	-0.50	-0.41	-0.33	-0.24	-0.16	-0.09	-0.01	0.06	0.13	0.20	0.27	0.33	0.39	0.46	0.52	0.58	0.64
1.4	-0.63	-0.54	-0.45	-0.37	-0.29	-0.21	-0.13	-0.06	0.01	0.08	0.15	0.21	0.28	0.34	0.40	0.46	0.52
1.5	-0.77	-0.68	-0.59	-0.50	-0.42	-0.34	-0.26	-0.18	-0.11	-0.04	0.03	0.09	0.16	0.22	0.28	0.35	0.41
1.6	-0.91	-0.82	-0.73	-0.64	-0.55	-0.47	-0.39	-0.32	-0.24	-0.17	-0.10	-0.03	0.03	0.10	0.16	0.22	0.28
1.7	-1.06	-0.97	-0.87	-0.78	-0.70	-0.61	-0.53	-0.45	-0.38	-0.30	-0.23	-0.16	-0.10	-0.03	0.03	0.10	0.16
1.8	-1.22	-1.12	-1.03	-0.94	-0.85	-0.76	-0.68	-0.60	-0.52	-0.45	-0.37	-0.30	-0.23	-0.17	-0.10	-0.04	0.02
1.9	-1.33	-1.24	-1.14	-1.05	-0.96	-0.87	-0.79	-0.70	-0.62	-0.54	-0.47	-0.40	-0.33	-0.26	-0.19	-0.13	-0.06
2.0	-1.41	-1.31	-1.22	-1.12	-1.03	-0.94	-0.86	-0.77	-0.69	-0.61	-0.53	-0.46	-0.39	-0.32	-0.25	-0.18	-0.12
2.1	-1.51	-1.41	-1.31	-1.21	-1.12	-1.03	-0.94	-0.85	-0.77	-0.69	-0.61	-0.53	-0.46	-0.39	-0.32	-0.25	-0.18
2.2	-1.66	-1.56	-1.46	-1.36	-1.27	-1.18	-1.09	-1.00	-0.91	-0.83	-0.75	-0.67	-0.59	-0.52	-0.44	-0.37	-0.31
2.3	-1.84	-1.74	-1.64	-1.54	-1.45	-1.35	-1.26	-1.17	-1.08	-0.99	-0.91	-0.83	-0.75	-0.67	-0.60	-0.53	-0.46
2.4	-2.05	-1.94	-1.84	-1.74	-1.64	-1.55	-1.45	-1.36	-1.27	-1.18	-1.10	-1.01	-0.93	-0.85	-0.78	-0.70	-0.63
2.5	-2.28	-2.17	-2.07	-1.97	-1.87	-1.77	-1.68	-1.58	-1.49	-1.40	-1.31	-1.22	-1.14	-1.06	-0.98	-0.91	-0.83
2.6	-2.55	-2.44	-2.33	-2.23	-2.13	-2.03	-1.93	-1.83	-1.74	-1.64	-1.55	-1.46	-1.38	-1.29	-1.21	-1.13	-1.06
2.7	-2.85	-2.73	-2.62	-2.51	-2.41	-2.31	-2.20	-2.10	-2.01	-1.91	-1.82	-1.72	-1.63	-1.55	-1.46	-1.38	-1.30
2.8	-3.18	-3.06	-2.94	-2.82	-2.71	-2.60	-2.49	-2.39	-2.29	-2.19	-2.09	-1.99	-1.90	-1.81	-1.72	-1.64	-1.56
2.9	-3.53	-3.39	-3.26	-3.14	-3.02	-2.90	-2.78	-2.67	-2.57	-2.46	-2.36	-2.26	-2.16	-2.07	-1.97	-1.88	-1.80
3.0	-3.88	-3.73	-3.59	-3.45	-3.32	-3.19	-3.07	-2.95	-2.83	-2.72	-2.61	-2.51	-2.40	-2.31	-2.21	-2.12	-2.03

Adapted from: Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E., Dickman, N., Hanson, S. and Hopper, M. (1996). "National seismic hazard maps: documentation June 1996," U.S. Geological Survey, Open-File Rept. 96-532.

TABLE A31 Values of $\log S_a$ ($T_n = 0.2$ sec; g) for the Tabulated Version of the Frankel *et al.* ENA Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-0.35	-0.25	-0.15	-0.06	0.02	0.10	0.18	0.25	0.32	0.39	0.46	0.53	0.59	0.65	0.72	0.78	0.84
1.1	-0.46	-0.36	-0.26	-0.17	-0.09	-0.01	0.07	0.14	0.22	0.29	0.35	0.42	0.48	0.55	0.61	0.67	0.73
1.2	-0.57	-0.47	-0.38	-0.29	-0.20	-0.12	-0.04	0.03	0.11	0.18	0.25	0.31	0.38	0.44	0.50	0.56	0.63
1.3	-0.69	-0.59	-0.49	-0.40	-0.32	-0.23	-0.15	-0.08	0.00	0.07	0.14	0.20	0.27	0.33	0.40	0.46	0.52
1.4	-0.81	-0.71	-0.61	-0.52	-0.44	-0.35	-0.27	-0.19	-0.12	-0.05	0.02	0.09	0.16	0.22	0.29	0.35	0.41
1.5	-0.94	-0.84	-0.74	-0.65	-0.56	-0.47	-0.39	-0.31	-0.24	-0.16	-0.09	-0.02	0.04	0.11	0.17	0.24	0.30
1.6	-1.07	-0.97	-0.87	-0.77	-0.69	-0.60	-0.52	-0.44	-0.36	-0.28	-0.21	-0.14	-0.07	-0.01	0.06	0.12	0.18
1.7	-1.21	-1.10	-1.00	-0.91	-0.82	-0.73	-0.65	-0.56	-0.49	-0.41	-0.34	-0.27	-0.20	-0.13	-0.06	0.00	0.06
1.8	-1.35	-1.25	-1.15	-1.05	-0.96	-0.87	-0.78	-0.70	-0.62	-0.54	-0.47	-0.39	-0.32	-0.25	-0.19	-0.12	-0.06
1.9	-1.45	-1.34	-1.24	-1.14	-1.05	-0.96	-0.87	-0.79	-0.70	-0.63	-0.55	-0.47	-0.40	-0.33	-0.26	-0.20	-0.13
2.0	-1.51	-1.40	-1.30	-1.20	-1.10	-1.01	-0.92	-0.84	-0.75	-0.67	-0.59	-0.52	-0.44	-0.37	-0.30	-0.24	-0.17
2.1	-1.58	-1.47	-1.37	-1.27	-1.17	-1.08	-0.99	-0.90	-0.81	-0.73	-0.65	-0.57	-0.50	-0.42	-0.35	-0.28	-0.22
2.2	-1.70	-1.59	-1.49	-1.39	-1.29	-1.20	-1.11	-1.02	-0.93	-0.84	-0.76	-0.68	-0.60	-0.53	-0.45	-0.38	-0.32
2.3	-1.85	-1.74	-1.64	-1.53	-1.44	-1.34	-1.25	-1.15	-1.06	-0.98	-0.89	-0.81	-0.73	-0.65	-0.58	-0.51	-0.44
2.4	-2.01	-1.90	-1.80	-1.70	-1.60	-1.50	-1.40	-1.31	-1.22	-1.13	-1.04	-0.96	-0.88	-0.80	-0.72	-0.65	-0.58
2.5	-2.20	-2.09	-1.98	-1.88	-1.78	-1.68	-1.58	-1.49	-1.39	-1.30	-1.22	-1.13	-1.04	-0.96	-0.88	-0.81	-0.73
2.6	-2.41	-2.30	-2.19	-2.09	-1.98	-1.88	-1.79	-1.69	-1.60	-1.50	-1.41	-1.32	-1.24	-1.15	-1.07	-0.99	-0.92
2.7	-2.65	-2.54	-2.43	-2.32	-2.22	-2.12	-2.02	-1.92	-1.83	-1.73	-1.64	-1.55	-1.46	-1.37	-1.29	-1.21	-1.13
2.8	-2.93	-2.82	-2.71	-2.60	-2.49	-2.39	-2.29	-2.19	-2.09	-1.99	-1.90	-1.80	-1.71	-1.62	-1.54	-1.45	-1.37
2.9	-3.26	-3.14	-3.02	-2.91	-2.80	-2.69	-2.59	-2.48	-2.38	-2.28	-2.18	-2.09	-1.99	-1.90	-1.81	-1.73	-1.64
3.0	-3.63	-3.50	-3.38	-3.26	-3.14	-3.03	-2.92	-2.81	-2.70	-2.59	-2.49	-2.39	-2.29	-2.19	-2.10	-2.01	-1.92

Adapted from: Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E., Dickman, N., Hanson, S. and Hopper, M. (1996). "National seismic hazard maps: documentation June 1996," U.S. Geological Survey, Open-File Rept. 96-532.

TABLE A32 Values of $\log S_a$ ($T_n = 0.3$ sec; g) for the Tabulated Version of the Frankel *et al.* ENA Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-0.53	-0.42	-0.31	-0.21	-0.12	-0.03	0.05	0.13	0.20	0.28	0.35	0.41	0.48	0.54	0.61	0.67	0.73
1.1	-0.64	-0.53	-0.42	-0.32	-0.23	-0.14	-0.06	0.02	0.10	0.17	0.24	0.31	0.38	0.44	0.50	0.57	0.63
1.2	-0.75	-0.64	-0.53	-0.43	-0.34	-0.25	-0.17	-0.09	-0.01	0.06	0.13	0.20	0.27	0.33	0.40	0.46	0.52
1.3	-0.86	-0.75	-0.64	-0.54	-0.45	-0.36	-0.28	-0.20	-0.12	-0.05	0.03	0.09	0.16	0.23	0.29	0.36	0.42
1.4	-0.98	-0.86	-0.76	-0.66	-0.57	-0.48	-0.39	-0.31	-0.23	-0.16	-0.09	-0.02	0.05	0.12	0.18	0.25	0.31
1.5	-1.10	-0.98	-0.88	-0.78	-0.68	-0.59	-0.51	-0.43	-0.35	-0.27	-0.20	-0.13	-0.06	0.01	0.07	0.14	0.20
1.6	-1.23	-1.11	-1.00	-0.90	-0.81	-0.72	-0.63	-0.55	-0.47	-0.39	-0.31	-0.24	-0.17	-0.11	-0.04	0.02	0.09
1.7	-1.36	-1.24	-1.13	-1.03	-0.93	-0.84	-0.75	-0.67	-0.59	-0.51	-0.44	-0.36	-0.29	-0.22	-0.16	-0.09	-0.03
1.8	-1.49	-1.37	-1.26	-1.16	-1.07	-0.97	-0.88	-0.80	-0.72	-0.64	-0.56	-0.49	-0.41	-0.34	-0.28	-0.21	-0.15
1.9	-1.58	-1.46	-1.35	-1.25	-1.15	-1.06	-0.97	-0.88	-0.80	-0.71	-0.64	-0.56	-0.49	-0.42	-0.35	-0.28	-0.21
2.0	-1.63	-1.51	-1.40	-1.30	-1.20	-1.10	-1.01	-0.92	-0.84	-0.75	-0.67	-0.60	-0.52	-0.45	-0.38	-0.31	-0.24
2.1	-1.69	-1.57	-1.46	-1.35	-1.25	-1.16	-1.06	-0.97	-0.89	-0.80	-0.72	-0.64	-0.56	-0.49	-0.42	-0.35	-0.28
2.2	-1.80	-1.68	-1.57	-1.46	-1.36	-1.26	-1.17	-1.08	-0.99	-0.90	-0.82	-0.74	-0.66	-0.58	-0.51	-0.44	-0.37
2.3	-1.93	-1.81	-1.70	-1.59	-1.49	-1.39	-1.29	-1.20	-1.11	-1.02	-0.94	-0.85	-0.77	-0.70	-0.62	-0.55	-0.48
2.4	-2.08	-1.96	-1.84	-1.73	-1.63	-1.53	-1.43	-1.34	-1.25	-1.16	-1.07	-0.99	-0.90	-0.82	-0.75	-0.67	-0.60
2.5	-2.24	-2.12	-2.00	-1.89	-1.79	-1.69	-1.59	-1.50	-1.40	-1.31	-1.22	-1.13	-1.05	-0.97	-0.89	-0.81	-0.74
2.6	-2.42	-2.30	-2.18	-2.08	-1.97	-1.87	-1.77	-1.67	-1.58	-1.48	-1.39	-1.30	-1.22	-1.13	-1.05	-0.97	-0.90
2.7	-2.63	-2.51	-2.39	-2.28	-2.18	-2.07	-1.97	-1.87	-1.78	-1.68	-1.59	-1.50	-1.41	-1.32	-1.24	-1.16	-1.08
2.8	-2.87	-2.75	-2.63	-2.52	-2.41	-2.31	-2.20	-2.11	-2.01	-1.91	-1.82	-1.72	-1.63	-1.54	-1.46	-1.37	-1.29
2.9	-3.15	-3.02	-2.91	-2.79	-2.68	-2.58	-2.47	-2.37	-2.27	-2.17	-2.08	-1.98	-1.89	-1.80	-1.71	-1.62	-1.54
3.0	-3.48	-3.35	-3.22	-3.11	-3.00	-2.89	-2.78	-2.67	-2.57	-2.47	-2.37	-2.27	-2.17	-2.08	-1.99	-1.90	-1.81

Adapted from: Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E., Dickman, N., Hanson, S. and Hopper, M. (1996). "National seismic hazard maps: documentation June 1996," U.S. Geological Survey, Open-File Rept. 96-532.

TABLE A33 Values of $\log S_a$ ($T_n = 0.5$ sec; g) for the Tabulated Version of the Frankel *et al.* ENA Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-0.87	-0.72	-0.58	-0.46	-0.35	-0.25	-0.16	-0.07	0.01	0.09	0.16	0.23	0.30	0.37	0.44	0.50	0.57
1.1	-0.97	-0.82	-0.69	-0.57	-0.46	-0.36	-0.27	-0.18	-0.10	-0.02	0.06	0.13	0.20	0.27	0.34	0.40	0.46
1.2	-1.07	-0.92	-0.79	-0.67	-0.57	-0.47	-0.37	-0.29	-0.20	-0.12	-0.05	0.03	0.10	0.16	0.23	0.30	0.36
1.3	-1.18	-1.03	-0.90	-0.78	-0.67	-0.57	-0.48	-0.39	-0.31	-0.23	-0.15	-0.08	-0.01	0.06	0.13	0.19	0.26
1.4	-1.29	-1.14	-1.01	-0.89	-0.79	-0.69	-0.59	-0.50	-0.42	-0.34	-0.26	-0.19	-0.12	-0.05	0.02	0.09	0.15
1.5	-1.40	-1.25	-1.12	-1.01	-0.90	-0.80	-0.70	-0.62	-0.53	-0.45	-0.37	-0.30	-0.23	-0.16	-0.09	-0.02	0.04
1.6	-1.52	-1.37	-1.24	-1.12	-1.02	-0.91	-0.82	-0.73	-0.65	-0.56	-0.49	-0.41	-0.34	-0.27	-0.20	-0.13	-0.07
1.7	-1.64	-1.49	-1.36	-1.24	-1.14	-1.03	-0.94	-0.85	-0.76	-0.68	-0.60	-0.53	-0.45	-0.38	-0.31	-0.24	-0.18
1.8	-1.77	-1.62	-1.49	-1.37	-1.26	-1.16	-1.06	-0.97	-0.89	-0.80	-0.72	-0.64	-0.57	-0.50	-0.43	-0.36	-0.29
1.9	-1.84	-1.70	-1.56	-1.45	-1.34	-1.23	-1.14	-1.04	-0.96	-0.87	-0.79	-0.71	-0.64	-0.56	-0.49	-0.42	-0.36
2.0	-1.88	-1.73	-1.60	-1.48	-1.37	-1.27	-1.17	-1.08	-0.99	-0.90	-0.82	-0.74	-0.66	-0.59	-0.52	-0.45	-0.38
2.1	-1.93	-1.78	-1.65	-1.53	-1.42	-1.31	-1.21	-1.12	-1.03	-0.94	-0.86	-0.78	-0.70	-0.62	-0.55	-0.48	-0.41
2.2	-2.03	-1.88	-1.74	-1.62	-1.51	-1.41	-1.31	-1.21	-1.12	-1.03	-0.94	-0.86	-0.78	-0.70	-0.63	-0.56	-0.49
2.3	-2.14	-1.99	-1.86	-1.74	-1.62	-1.52	-1.42	-1.32	-1.23	-1.14	-1.05	-0.96	-0.88	-0.80	-0.73	-0.65	-0.58
2.4	-2.27	-2.12	-1.98	-1.86	-1.75	-1.64	-1.54	-1.44	-1.34	-1.25	-1.16	-1.08	-0.99	-0.91	-0.83	-0.76	-0.68
2.5	-2.41	-2.26	-2.12	-2.00	-1.88	-1.77	-1.67	-1.57	-1.48	-1.38	-1.29	-1.20	-1.12	-1.04	-0.96	-0.88	-0.80
2.6	-2.56	-2.41	-2.27	-2.15	-2.04	-1.93	-1.82	-1.72	-1.63	-1.53	-1.44	-1.35	-1.26	-1.18	-1.09	-1.01	-0.94
2.7	-2.74	-2.59	-2.45	-2.32	-2.21	-2.10	-1.99	-1.89	-1.79	-1.70	-1.60	-1.51	-1.42	-1.34	-1.25	-1.17	-1.09
2.8	-2.94	-2.78	-2.65	-2.52	-2.40	-2.29	-2.19	-2.08	-1.98	-1.89	-1.79	-1.70	-1.61	-1.52	-1.43	-1.35	-1.26
2.9	-3.17	-3.01	-2.87	-2.75	-2.63	-2.52	-2.41	-2.31	-2.20	-2.11	-2.01	-1.91	-1.82	-1.73	-1.64	-1.55	-1.47
3.0	-3.43	-3.27	-3.13	-3.01	-2.89	-2.77	-2.67	-2.56	-2.46	-2.36	-2.26	-2.16	-2.07	-1.97	-1.88	-1.79	-1.70

Adapted from: Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E., Dickman, N., Hanson, S. and Hopper, M. (1996). "National seismic hazard maps: documentation June 1996," U.S. Geological Survey, Open-File Rept. 96-532.

TABLE A34 Values of $\log S_a$ ($T_n = 1.0$ sec; g) for the Tabulated Version of the Frankel *et al.* ENA Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-1.52	-1.31	-1.12	-0.95	-0.80	-0.66	-0.54	-0.43	-0.33	-0.24	-0.15	-0.07	0.01	0.08	0.16	0.23	0.29
1.1	-1.62	-1.41	-1.22	-1.05	-0.90	-0.77	-0.64	-0.54	-0.43	-0.34	-0.25	-0.17	-0.09	-0.02	0.05	0.12	0.19
1.2	-1.72	-1.51	-1.32	-1.15	-1.00	-0.87	-0.75	-0.64	-0.54	-0.45	-0.36	-0.28	-0.20	-0.12	-0.05	0.02	0.09
1.3	-1.82	-1.61	-1.42	-1.25	-1.11	-0.97	-0.85	-0.74	-0.64	-0.55	-0.46	-0.38	-0.30	-0.23	-0.15	-0.08	-0.01
1.4	-1.92	-1.71	-1.53	-1.36	-1.21	-1.08	-0.96	-0.85	-0.75	-0.66	-0.57	-0.49	-0.41	-0.33	-0.26	-0.19	-0.12
1.5	-2.03	-1.82	-1.63	-1.46	-1.32	-1.18	-1.06	-0.96	-0.86	-0.76	-0.68	-0.59	-0.51	-0.44	-0.36	-0.29	-0.22
1.6	-2.13	-1.92	-1.74	-1.57	-1.42	-1.29	-1.17	-1.07	-0.97	-0.87	-0.78	-0.70	-0.62	-0.54	-0.47	-0.40	-0.33
1.7	-2.24	-2.03	-1.85	-1.68	-1.53	-1.40	-1.29	-1.18	-1.08	-0.98	-0.90	-0.81	-0.73	-0.65	-0.58	-0.51	-0.44
1.8	-2.35	-2.15	-1.96	-1.80	-1.65	-1.52	-1.40	-1.29	-1.19	-1.10	-1.01	-0.92	-0.84	-0.77	-0.69	-0.62	-0.55
1.9	-2.42	-2.21	-2.02	-1.86	-1.71	-1.58	-1.46	-1.36	-1.26	-1.16	-1.07	-0.99	-0.90	-0.83	-0.75	-0.68	-0.61
2.0	-2.44	-2.24	-2.05	-1.88	-1.74	-1.61	-1.49	-1.38	-1.28	-1.18	-1.09	-1.01	-0.92	-0.84	-0.77	-0.69	-0.62
2.1	-2.47	-2.27	-2.08	-1.91	-1.77	-1.63	-1.52	-1.41	-1.31	-1.21	-1.12	-1.03	-0.95	-0.87	-0.79	-0.71	-0.64
2.2	-2.55	-2.35	-2.16	-1.99	-1.84	-1.71	-1.59	-1.48	-1.38	-1.29	-1.19	-1.10	-1.02	-0.94	-0.86	-0.78	-0.71
2.3	-2.65	-2.44	-2.25	-2.09	-1.94	-1.81	-1.69	-1.58	-1.47	-1.37	-1.28	-1.19	-1.11	-1.02	-0.94	-0.87	-0.79
2.4	-2.75	-2.55	-2.36	-2.19	-2.04	-1.91	-1.79	-1.68	-1.57	-1.47	-1.38	-1.29	-1.20	-1.12	-1.03	-0.96	-0.88
2.5	-2.87	-2.66	-2.47	-2.30	-2.15	-2.02	-1.90	-1.79	-1.68	-1.58	-1.49	-1.39	-1.30	-1.22	-1.14	-1.05	-0.98
2.6	-3.00	-2.79	-2.60	-2.43	-2.28	-2.14	-2.02	-1.91	-1.80	-1.70	-1.60	-1.51	-1.42	-1.33	-1.25	-1.16	-1.09
2.7	-3.14	-2.93	-2.74	-2.57	-2.41	-2.28	-2.16	-2.04	-1.94	-1.83	-1.74	-1.64	-1.55	-1.46	-1.37	-1.29	-1.21
2.8	-3.30	-3.08	-2.89	-2.72	-2.57	-2.43	-2.31	-2.20	-2.09	-1.98	-1.88	-1.79	-1.69	-1.60	-1.51	-1.43	-1.35
2.9	-3.47	-3.26	-3.07	-2.90	-2.74	-2.61	-2.48	-2.37	-2.26	-2.15	-2.05	-1.96	-1.86	-1.77	-1.68	-1.59	-1.50
3.0	-3.68	-3.46	-3.27	-3.10	-2.94	-2.81	-2.68	-2.56	-2.45	-2.35	-2.25	-2.15	-2.05	-1.95	-1.86	-1.77	-1.69

Adapted from: Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E., Dickman, N., Hanson, S. and Hopper, M. (1996). "National seismic hazard maps: documentation June 1996," U.S. Geological Survey, Open-File Rept. 96-532.

TABLE A35 Values of $\log S_a$ ($T_n = 2.0$ sec; g) for the Tabulated Version of the Frankel *et al.* ENA Model

$\log r_{hypo}$ (km)	Moment Magnitude, M_W																
	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2
1.0	-2.24	-2.03	-1.81	-1.60	-1.39	-1.20	-1.02	-0.87	-0.73	-0.61	-0.50	-0.40	-0.30	-0.21	-0.13	-0.05	0.02
1.1	-2.36	-2.14	-1.92	-1.70	-1.49	-1.30	-1.12	-0.97	-0.83	-0.71	-0.60	-0.50	-0.40	-0.32	-0.23	-0.16	-0.08
1.2	-2.47	-2.24	-2.02	-1.80	-1.59	-1.40	-1.22	-1.07	-0.93	-0.81	-0.70	-0.60	-0.51	-0.42	-0.34	-0.26	-0.18
1.3	-2.58	-2.35	-2.12	-1.90	-1.69	-1.50	-1.32	-1.17	-1.04	-0.91	-0.80	-0.70	-0.61	-0.52	-0.44	-0.36	-0.28
1.4	-2.69	-2.45	-2.22	-2.00	-1.79	-1.60	-1.43	-1.27	-1.14	-1.02	-0.91	-0.81	-0.71	-0.62	-0.54	-0.46	-0.39
1.5	-2.79	-2.55	-2.32	-2.10	-1.89	-1.70	-1.53	-1.38	-1.24	-1.12	-1.01	-0.91	-0.82	-0.73	-0.65	-0.57	-0.49
1.6	-2.90	-2.66	-2.42	-2.20	-1.99	-1.80	-1.63	-1.48	-1.35	-1.22	-1.12	-1.02	-0.92	-0.83	-0.75	-0.67	-0.60
1.7	-3.00	-2.76	-2.52	-2.30	-2.09	-1.90	-1.73	-1.58	-1.45	-1.33	-1.22	-1.12	-1.03	-0.94	-0.86	-0.78	-0.70
1.8	-3.11	-2.86	-2.63	-2.40	-2.19	-2.01	-1.84	-1.69	-1.56	-1.44	-1.33	-1.23	-1.14	-1.05	-0.96	-0.89	-0.81
1.9	-3.16	-2.92	-2.68	-2.45	-2.25	-2.06	-1.89	-1.75	-1.61	-1.49	-1.39	-1.29	-1.19	-1.10	-1.02	-0.94	-0.86
2.0	-3.18	-2.93	-2.69	-2.47	-2.26	-2.07	-1.90	-1.76	-1.63	-1.51	-1.40	-1.30	-1.20	-1.12	-1.03	-0.95	-0.87
2.1	-3.20	-2.95	-2.71	-2.48	-2.27	-2.09	-1.92	-1.77	-1.64	-1.52	-1.42	-1.32	-1.22	-1.13	-1.05	-0.97	-0.89
2.2	-3.26	-3.01	-2.77	-2.55	-2.34	-2.15	-1.99	-1.84	-1.71	-1.59	-1.48	-1.38	-1.28	-1.19	-1.11	-1.03	-0.95
2.3	-3.34	-3.09	-2.85	-2.62	-2.42	-2.23	-2.06	-1.91	-1.78	-1.66	-1.56	-1.45	-1.36	-1.27	-1.18	-1.10	-1.02
2.4	-3.43	-3.18	-2.94	-2.71	-2.50	-2.31	-2.15	-2.00	-1.87	-1.75	-1.64	-1.54	-1.44	-1.35	-1.26	-1.18	-1.10
2.5	-3.53	-3.27	-3.03	-2.80	-2.59	-2.40	-2.24	-2.09	-1.96	-1.84	-1.73	-1.62	-1.53	-1.44	-1.35	-1.26	-1.18
2.6	-3.64	-3.38	-3.13	-2.90	-2.69	-2.51	-2.34	-2.19	-2.06	-1.94	-1.83	-1.72	-1.62	-1.53	-1.44	-1.35	-1.27
2.7	-3.75	-3.49	-3.25	-3.02	-2.81	-2.62	-2.45	-2.30	-2.17	-2.04	-1.93	-1.83	-1.73	-1.63	-1.54	-1.46	-1.37
2.8	-3.88	-3.62	-3.37	-3.14	-2.93	-2.74	-2.57	-2.42	-2.29	-2.17	-2.05	-1.95	-1.85	-1.75	-1.66	-1.57	-1.48
2.9	-4.03	-3.76	-3.51	-3.28	-3.07	-2.88	-2.71	-2.56	-2.42	-2.30	-2.19	-2.08	-1.98	-1.88	-1.79	-1.70	-1.61
3.0	-4.19	-3.92	-3.67	-3.44	-3.23	-3.03	-2.86	-2.71	-2.58	-2.45	-2.34	-2.23	-2.13	-2.03	-1.93	-1.84	-1.75

Adapted from: Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E., Dickman, N., Hanson, S. and Hopper, M. (1996). "National seismic hazard maps: documentation June 1996," U.S. Geological Survey, Open-File Rept. 96-532.

TABLE A36 Coefficients for the Somerville *et al.* ENA Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	$\sigma_{\ln Y}$
Non-rifted Domain, Average Horizontal									
PGA	0.418	0.8080	0.0000	0.0651	-0.006010	-0.728	-0.301	6.0	0.587
0.04	1.099	0.8080	0.0000	0.0651	-0.006010	-0.728	-0.301	6.0	0.592
0.10	1.071	0.8080	0.0000	0.0651	-0.006010	-0.728	-0.301	6.0	0.595
0.20	0.978	0.8080	0.0000	0.0651	-0.006010	-0.728	-0.301	6.0	0.611
0.40	0.851	0.8080	-0.0518	0.0651	-0.005380	-0.728	-0.423	6.0	0.602
1.00	-0.139	0.8080	-0.1020	0.0651	-0.003980	-0.739	-0.659	6.0	0.693
2.00	-0.932	0.8080	-0.1400	0.0651	-0.003180	-0.754	-0.702	6.0	0.824
4.00	-2.080	0.8080	-0.1956	0.0651	-0.001560	-0.686	-0.762	6.0	0.909
Rifted Domain, Average Horizontal									
PGA	0.239	0.8050	0.0000	0.0861	-0.004980	-0.679	-0.477	6.0	0.587
0.04	0.926	0.8050	0.0000	0.0861	-0.004980	-0.679	-0.477	6.0	0.592
0.10	0.888	0.8050	0.0000	0.0861	-0.004980	-0.679	-0.477	6.0	0.595
0.20	0.793	0.8050	0.0000	0.0861	-0.004980	-0.679	-0.477	6.0	0.611
0.40	0.622	0.8050	-0.0518	0.0861	-0.004680	-0.664	-0.557	6.0	0.602
1.00	-0.307	0.8050	-0.1020	0.0861	-0.003620	-0.696	-0.755	6.0	0.693
2.00	-1.132	0.8050	-0.1400	0.0861	-0.002210	-0.728	-0.946	6.0	0.824
4.00	-2.282	0.8050	-0.1956	0.0861	-0.000381	-0.671	-1.059	6.0	0.909
Non-rifted Domain, Vertical									
PGA	-0.151	0.8535	0.0000	0.0905	-0.005360	-0.607	-0.490	6.0	0.618
0.04	0.518	0.8535	0.0000	0.0905	-0.005360	-0.607	-0.490	6.0	0.618
0.10	0.505	0.8535	0.0000	0.0905	-0.005360	-0.607	-0.490	6.0	0.622
0.20	0.536	0.8535	0.0000	0.0905	-0.005360	-0.607	-0.490	6.0	0.635
0.40	0.566	0.8535	0.0000	0.0905	-0.004800	-0.682	-0.698	6.0	0.680
1.00	-0.273	0.8535	-0.0115	0.0905	-0.004050	-0.781	-0.658	6.0	0.763
2.00	-1.314	0.8535	-0.0240	0.0905	-0.003480	-0.767	-0.570	6.0	0.858
4.00	-2.382	0.8535	-0.0565	0.0905	-0.002070	-0.712	-0.490	6.0	0.919
Rifted Domain, Vertical									
PGA	-0.530	0.9360	0.0000	0.0746	-0.004360	-0.500	-0.642	6.0	0.618
0.04	0.147	0.9360	0.0000	0.0746	-0.004360	-0.500	-0.642	6.0	0.618
0.10	0.122	0.9360	0.0000	0.0746	-0.004360	-0.500	-0.642	6.0	0.622
0.20	-0.050	0.9360	0.0000	0.0746	-0.004360	-0.500	-0.642	6.0	0.635
0.40	-0.222	0.9360	0.0000	0.0746	-0.003970	-0.512	-0.732	6.0	0.680
1.00	-1.030	0.9360	-0.0115	0.0746	-0.003570	-0.569	-0.708	6.0	0.763
2.00	-1.693	0.9360	-0.0240	0.0746	-0.002950	-0.705	-0.629	6.0	0.858
4.00	-2.430	0.9360	-0.0565	0.0746	-0.001520	-0.744	-0.614	6.0	0.919

Adapted from: Somerville, P., Collins, N., Abrahamson, N., Graves, R. and Saikia, C. (2001). "Ground motion attenuation relations for the central and eastern United States." U.S. Geological Survey, Award 99HQGR0098, final report.

TABLE A37 Coefficients for the Toro *et al.* ENA Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	c_7	$\sigma_{\ln Y}(M)$			$\sigma_{\ln Y}(r_{rup})$	
								M_W 5.0 m_{Lg} 5.0	M_W 5.5 m_{Lg} 6.0	M_W 8.0 m_{Lg} 7.5	<5 km	>20 km
Midcontinent Region, M_W												
PGA	2.20	0.81	0	-1.27	0.11	-0.0021	9.3	0.55	0.59	0.50	0.54	0.20
0.029	4.00	0.79	0	-1.57	-0.26	-0.0008	11.1	0.62	0.63	0.50	0.62	0.35
0.040	3.68	0.80	0	-1.46	-0.31	-0.0013	10.5	0.62	0.63	0.50	0.57	0.29
0.10	2.37	0.81	0	-1.10	0.08	-0.0040	8.3	0.59	0.61	0.50	0.50	0.17
0.20	1.73	0.84	0	-0.98	0.32	-0.0042	7.5	0.60	0.64	0.56	0.45	0.12
0.40	1.07	1.05	-0.10	-0.93	0.37	-0.0033	7.1	0.63	0.68	0.64	0.45	0.12
1.00	0.09	1.42	-0.20	-0.90	0.41	-0.0023	6.8	0.63	0.64	0.67	0.45	0.12
2.00	-0.74	1.86	-0.31	-0.92	0.46	-0.0017	6.9	0.61	0.62	0.66	0.45	0.12
Midcontinent Region, m_{Lg}												
PGA	2.07	1.20	0	-1.28	0.05	-0.0018	9.3	0.58	0.58	0.44	0.54	0.20
0.029	3.87	1.19	0	-1.58	-0.32	-0.0005	11.1	0.57	0.58	0.44	0.62	0.35
0.040	3.54	1.19	0	-1.46	-0.38	-0.0010	10.5	0.57	0.58	0.44	0.57	0.29
0.10	2.36	1.23	0	-1.12	0.07	-0.0043	8.5	0.54	0.57	0.44	0.50	0.17
0.20	1.60	1.24	0	-0.98	0.24	-0.0039	7.5	0.54	0.63	0.51	0.45	0.12
0.40	0.90	1.70	-0.26	-0.94	0.29	-0.0030	7.2	0.58	0.70	0.59	0.45	0.12
1.00	-0.12	2.05	-0.34	-0.90	0.31	-0.0019	6.8	0.62	0.81	0.61	0.45	0.12
2.00	-0.97	2.52	-0.47	-0.93	0.33	-0.0012	7.0	0.63	0.81	0.61	0.45	0.12
Gulf Coast Region, M_W												
PGA	2.91	0.92	0	-1.49	-0.12	-0.0014	10.9	0.55	0.59	0.50	0.48	0.30
0.029	4.81	0.91	0	-1.89	0.09	-0.0008	11.9	0.62	0.63	0.50	0.68	0.47
0.040	5.19	0.91	0	-1.96	-0.00	-0.0004	12.9	0.62	0.63	0.50	0.63	0.47
0.10	5.08	1.00	0	-1.87	-0.65	-0.0002	14.1	0.59	0.61	0.50	0.53	0.38
0.20	3.10	0.92	0	-1.34	-0.61	-0.0017	11.4	0.60	0.64	0.56	0.50	0.33
0.40	1.64	1.06	-0.08	-0.99	-0.28	-0.0036	8.9	0.63	0.68	0.64	0.50	0.34
1.00	0.24	1.31	-0.15	-0.79	-0.03	-0.0034	7.2	0.63	0.64	0.67	0.51	0.39
2.00	-0.81	1.72	-0.26	-0.74	0.03	-0.0025	6.6	0.61	0.62	0.66	0.54	0.39
Gulf Coast Region, m_{Lg}												
PGA	2.80	1.31	0	-1.49	-0.19	-0.0017	10.9	0.58	0.58	0.44	0.48	0.30
0.029	4.68	1.30	0	-1.89	0.01	-0.0005	11.9	0.57	0.58	0.44	0.68	0.47
0.040	5.08	1.29	0	-1.97	-0.07	-0.0000	12.9	0.57	0.58	0.44	0.63	0.47
0.10	4.65	1.30	0	-1.78	-0.63	-0.0000	13.8	0.54	0.57	0.44	0.53	0.38
0.20	3.00	1.31	0	-1.35	-0.68	-0.0014	11.4	0.54	0.63	0.51	0.50	0.33
0.40	1.49	1.74	-0.26	-1.00	-0.36	-0.0032	9.0	0.58	0.70	0.59	0.50	0.34
1.00	0.06	1.97	-0.32	-0.80	-0.12	-0.0030	7.3	0.62	0.81	0.61	0.51	0.39
2.00	-1.01	2.38	-0.42	-0.75	-0.08	-0.0032	6.8	0.63	0.81	0.61	0.54	0.39

Adapted from: Toro, G.R., Abrahamson, N.A. and Schneider, J.F. (1997). "Model of strong ground motions from earthquakes in central and eastern North America: best estimates and uncertainties." *Seismological Research Letters*, 68, 41–57.

TABLE A38 Coefficients for the Atkinson and Boore Subduction-Zone Model

T_n (s)	c_{1A}	c_{1C}	c_{1J}	c_2	c_3	c_4	c_5	c_6	c_9	c_{10}	c_{11}	$\sigma_{\ln Y}$
Interface Events												
PGA	6.887	6.424	7.230	0.081	-0.00474	0.0175	2.763	-0.414	0.437	0.553	0.668	0.530
0.04	6.621	5.987	7.023	0.162	-0.00640	0.0231	2.763	-0.414	0.345	0.461	0.461	0.599
0.10	6.399	5.756	6.793	0.227	-0.00661	0.0224	2.763	-0.414	0.345	0.530	0.461	0.622
0.20	6.134	5.849	6.539	0.285	-0.00645	0.0204	2.763	-0.414	0.345	0.622	0.576	0.645
0.40	5.814	5.756	5.941	0.340	-0.00541	0.0168	2.763	-0.414	0.299	0.852	0.875	0.668
1.0	4.937	5.020	5.020	0.310	-0.00253	0.0120	2.763	-0.414	0.230	0.691	1.266	0.783
2.0	5.044	5.365	4.928	0.165	0.00000	0.0052	2.763	-0.414	0.230	0.576	0.921	0.783
3.0	5.298	5.434	5.227	0.052	0.00000	0.0003	2.763	-0.414	0.230	0.576	0.829	0.829
Intraslab Events												
PGA	-0.109	-0.576	0.230	1.591	-0.00465	0.0260	0.693	-0.023	0.437	0.553	0.668	0.622
0.04	1.167	0.530	1.566	1.457	-0.00539	0.0294	0.693	-0.023	0.345	0.461	0.461	0.576
0.10	1.011	0.368	1.405	1.535	-0.00504	0.0249	0.693	-0.023	0.345	0.530	0.461	0.645
0.20	1.188	0.921	1.612	1.593	-0.00442	0.0132	0.693	-0.023	0.345	0.622	0.576	0.645
0.40	0.013	-0.023	0.161	1.779	-0.00410	0.0040	0.693	-0.023	0.299	0.852	0.875	0.645
1.0	-2.352	-2.257	-2.257	2.024	-0.00398	0.0030	0.693	-0.023	0.230	0.691	1.266	0.668
2.0	-5.509	-5.181	-5.618	2.294	-0.00272	0.0084	0.693	-0.023	0.230	0.576	0.921	0.691
3.0	-8.520	-8.381	-8.589	2.572	-0.00104	0.0142	0.693	-0.023	0.230	0.576	0.829	0.691

Adapted from: Atkinson, G.M. and Boore, D.M. (2003). "Empirical ground-motion relations for subduction zone earthquakes and their application to Cascadia and other regions" *Bulletin of the Seismological Society of America*, 93, 1703–1729.

TABLE A39 Coefficients for the Youngs *et al.* Subduction-Zone Model

T_n (s)	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}
Generic Rock											
PGA	0.2418	1.414	0	-2.552	0.00617	1.7818	0.554	0.3846	1.45	-0.1	0.650
0.075	1.5168	1.414	0	-2.707	0.00617	1.7818	0.554	0.3846	1.45	-0.1	0.650
0.1	1.4298	1.414	-0.0011	-2.655	0.00617	1.7818	0.554	0.3846	1.45	-0.1	0.650
0.2	0.9638	1.414	-0.0027	-2.528	0.00617	1.7818	0.554	0.3846	1.45	-0.1	0.650
0.3	0.4878	1.414	-0.0036	-2.454	0.00617	1.7818	0.554	0.3846	1.45	-0.1	0.650
0.4	0.1268	1.414	-0.0043	-2.401	0.00617	1.7818	0.554	0.3846	1.45	-0.1	0.650
0.5	-0.1582	1.414	-0.0048	-2.360	0.00617	1.7818	0.554	0.3846	1.45	-0.1	0.650
0.75	-0.9072	1.414	-0.0057	-2.286	0.00617	1.7818	0.554	0.3846	1.45	-0.1	0.650
1.0	-1.4942	1.414	-0.0064	-2.234	0.00617	1.7818	0.554	0.3846	1.45	-0.1	0.650
1.5	-2.3922	1.414	-0.0073	-2.160	0.00617	1.7818	0.554	0.3846	1.50	-0.1	0.700
2.0	-3.0862	1.414	-0.0080	-2.107	0.00617	1.7818	0.554	0.3846	1.55	-0.1	0.750
3.0	-4.2692	1.414	-0.0089	-2.033	0.00617	1.7818	0.554	0.3846	1.65	-0.1	0.850
Generic Soil											
PGA	-0.6687	1.438	0	-2.329	0.00648	1.097	0.617	0.3648	1.45	-0.1	0.650
0.075	1.7313	1.438	-0.0019	-2.697	0.00648	1.097	0.617	0.3648	1.45	-0.1	0.650
0.1	1.8473	1.438	-0.0019	-2.697	0.00648	1.097	0.617	0.3648	1.45	-0.1	0.650
0.2	0.8803	1.438	-0.0019	-2.464	0.00648	1.097	0.617	0.3648	1.45	-0.1	0.650
0.3	0.1243	1.438	-0.0020	-2.327	0.00648	1.097	0.617	0.3648	1.45	-0.1	0.650
0.4	-0.5247	1.438	-0.0020	-2.230	0.00648	1.097	0.617	0.3648	1.45	-0.1	0.650
0.5	-1.1067	1.438	-0.0035	-2.140	0.00648	1.097	0.617	0.3648	1.45	-0.1	0.650
0.75	-2.3727	1.438	-0.0048	-1.952	0.00648	1.097	0.617	0.3648	1.45	-0.1	0.650
1.0	-3.5387	1.438	-0.0066	-1.785	0.00648	1.097	0.617	0.3648	1.45	-0.1	0.650
1.5	-5.7697	1.438	-0.0114	-1.470	0.00648	1.097	0.617	0.3648	1.50	-0.1	0.700
2.0	-7.1017	1.438	-0.0164	-1.290	0.00648	1.097	0.617	0.3648	1.55	-0.1	0.750
3.0	-7.3407	1.438	-0.0221	-1.347	0.00648	1.097	0.617	0.3648	1.65	-0.1	0.850
4.0	-8.2867	1.438	-0.0235	-1.272	0.00648	1.097	0.617	0.3648	1.65	-0.1	0.850

Adapted from: Youngs, R.R., Chiou, S.J., Silva, W.J. and Humphrey, J.R. (1997). "Strong ground motion attenuation relationships for subduction zone earthquakes." *Seismological Research Letters*, 68, 58–73.

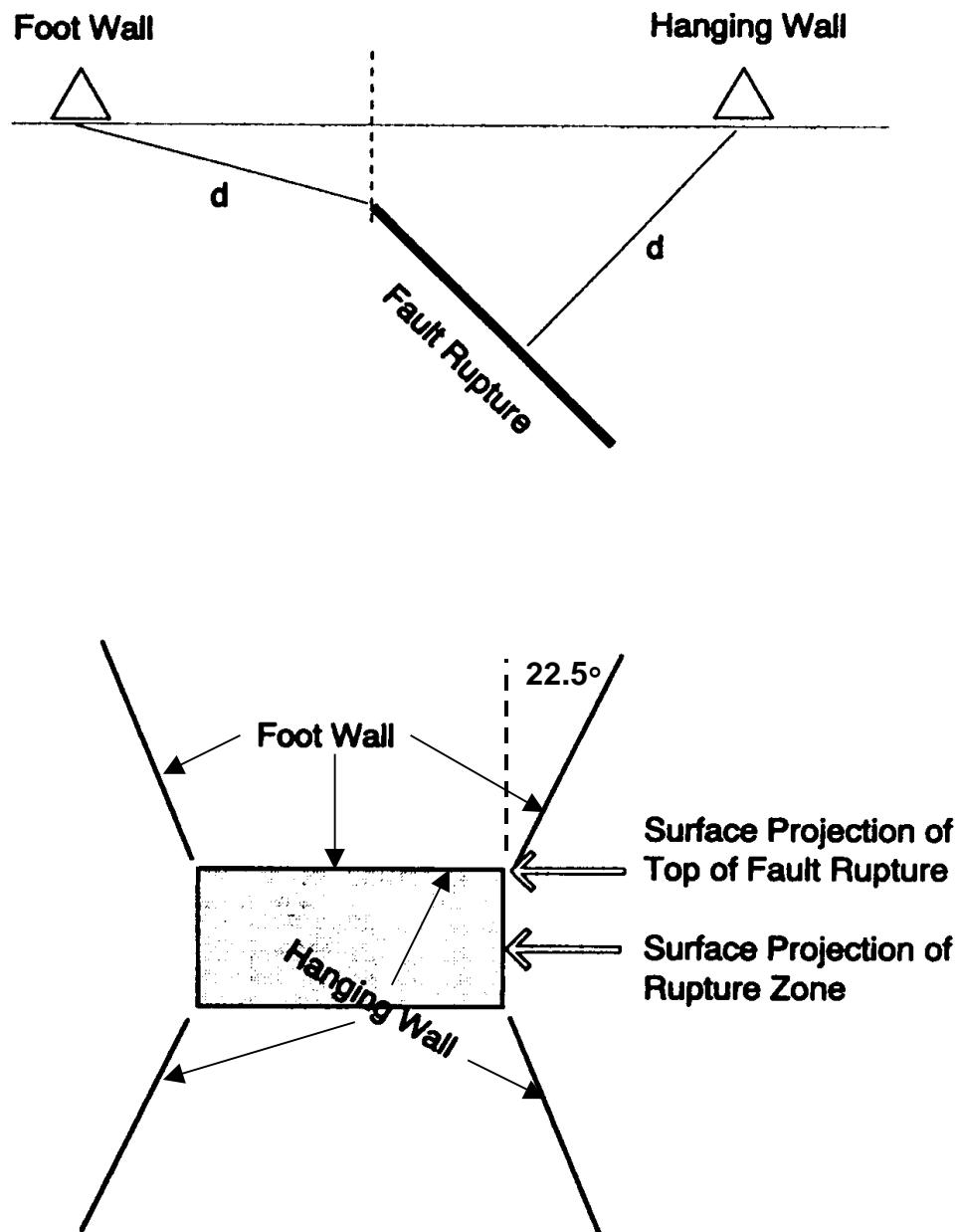


Figure A1: Definition of hanging wall and footwall for the Abrahamson and Silva [1997] ground motion relation. *Source:* Somerville, P. and Abrahamson, N. (1995). "Ground motion prediction for thrust earthquakes." *Proceedings, SMIP95 Seminar on Seismological and Engineering Implications of Recent Strong-Motion Data*, San Francisco, 11–23.