APPENDIX

This document and appended files provide supporting information related to the site amplification model and NEHRP site factors presented in the main paper. The supplemental materials include the following:

- Sections A.1 and A.2 describe elements of model development related to the interpretation of simulations (A.1) and establishing the additive f_3 parameter used in Equation 3 (A.2).
- Table A1 provides the previous and current NEHRP site factors.
- A spreadsheet file providing the model coefficients and a Matlab™ script for applying the proposed site amplification model.

A.1 NONLINEAR MODEL PARAMETERS FROM SIMULATION RESULTS

Nonlinear site amplification models can be derived on the basis of one-dimensional (1-D) equivalent-linear ground response simulations, which were undertaken by Walling et al. (2008) for the NGA-West1 project (WEA08) and Kamei et al. (2014) for the NGA-West2 project (KEA14). The nonlinearity in these relations is driven by the shear modulus reduction and damping versus shear strain relations. Both studies used judgment-driven modulus reduction and damping curves known as the peninsular range curves (PEN) and curves presented by EPRI (1993). We considered the more recent results of KEA14 for the present study.

The KEA14 results are presented as period-dependent nonlinear amplification models for a discrete number of mean V_{S30} values (six derived from the PEN nonlinear curves, four from EPRI). The resulting KEA14 model uses the function for site amplification from WEA08, which has a similar structure to Equation 3 but which is considerably more complex such that the coefficients' physical meaning is not the same as the f_1, f_2, and f_3 parameters in Equation 3. Accordingly, as shown in Figures A1 and A2, we use the KEA14 equations to compute site amplifications and then fit the computed points using Equation 3. Because the KEA14 function has a closed-form expression for the equivalent of the f_3 parameter that is V_{S30}-dependent, we apply that function in advance so that the fitting process matches f_1 and f_2 for a constrained value of f_3. Table 1 shows the resulting f_2 values for the discrete V_{S30} values and various periods.

Values of nonlinear parameter f_2 from simulations are shown in Figure 2 along with non-regional empirical results from the main paper and the proposed model. As noted in the main paper, the simulation-based slopes are comparable to the data-based slopes, except for PSA at $T = 0.5 - 3.0$ s where the data exhibits more nonlinearity than is evident from the simulations.

A.2 EVALUATION OF ADDITIVE ACCELERATION f_3 FOR NONLINEAR MODEL

Additive acceleration f_3 in Equation 3 has the purpose of producing saturation of site amplification for input motion amplitudes with $PGA_r \ll f_3$. In the section of the main paper titled "Stage 1 analysis of nonlinear site response," f_3 was fixed at 0.1 g for

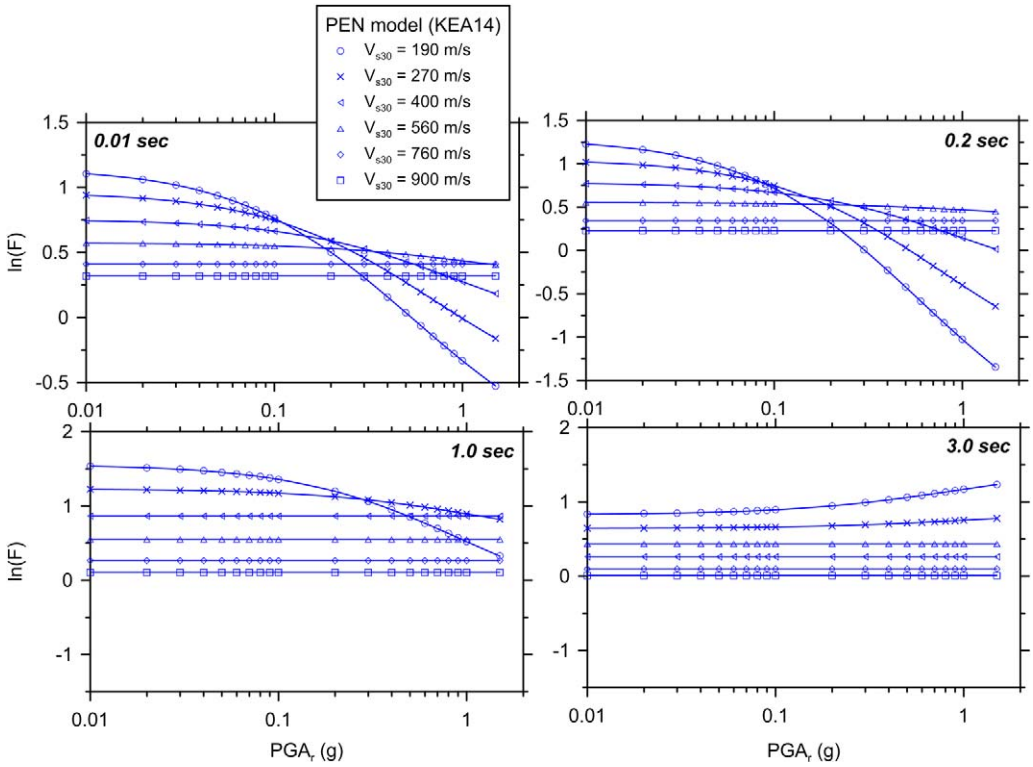

Figure A1. Site amplification as function of V_{S30}, period, and PGA_r from simulation-based model of KEA14; PEN modulus reduction and damping curves. The symbols in the plots are computed site amplifications from the KEA14 model, and the lines are our fits to those amplifications using Equation 3.

the regression of other parameters (f_1 and f_2) because the three coefficients cannot be reliably computed simultaneously.

The fixed value of $f_3 = 0.1\ g$ was selected by repeating regressions using Equation 3 with variable fixed values of f_3 and finding the value that minimizes dispersion for data in the V_{S30} bins of <200 and $200 - 310$ m/s. These analyses utilize the same global data set considered in other Stage 1 analyses from the main paper. Figure A3 shows the resulting values of f_3, which do not exhibit trends with period. Note that values of f_3 implied from the simulation-based model of KEA14 are also shown in Figure A3. There are substantial variations between the simulation- and data-based results, with the data-based values being smaller. The large values of f_3 from simulations at long periods essentially force the model to be nearly linear for smaller values of PGA_r. While we also see relatively linear conditions at long periods, we find the data is adequately fit for such conditions with smaller values of f_3 and small values of slope parameter f_2.

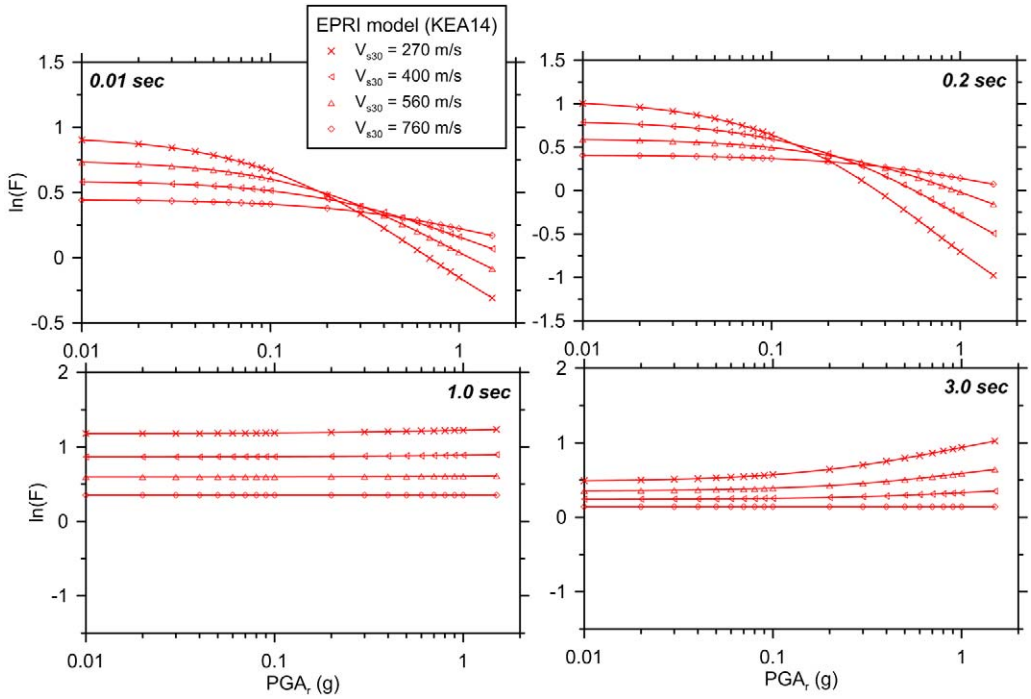

Figure A2. Same as Figure A1, but using EPRI modulus reduction and damping curves.

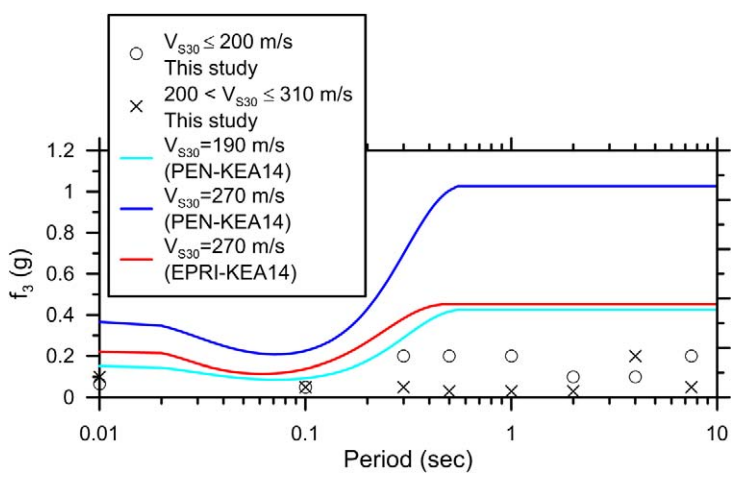

Figure A3. Variation of additive term f_3 in site amplification function with period from empirical data analysis (to minimize residuals) and from model of KEA14.

NEHRP COEFFICIENTS TABLE

Table A1. Previous and current site amplification factors F_a, F_v, and F_{PGA}. The current values are rounded to the nearest 0.1 for application in the NEHRP *Provisions*

F_a												
Site	$S_s < 0.25$		$S_s = 0.5$		$S_s = 0.75$		$S_s = 1.0$		$S_s = 1.25$		$S_s > 1.5$	
class	Current	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Previous
A	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	na
B	0.9	1.0	0.9	1.0	0.9	1.0	0.9	1.0	0.9	1.0	0.9	na
C	1.3	1.2	1.3	1.2	1.2	1.1	1.2	1.0	1.2	1.0	1.2	na
D	1.6	1.6	1.4	1.4	1.2	1.2	1.1	1.1	1.0	1.0	1.0	na
E	2.4	2.5	1.7	1.7	1.3	1.2	1.1	0.9	0.9	0.9	0.8	na

F_v												
Site	$S_1 < 0.1$		$S_1 = 0.2$		$S_1 = 0.3$		$S_1 = 0.4$		$S_1 = 0.5$		$S_1 > 0.6$	
class	Current	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Previous
A	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	na
B	0.8	1.0	0.8	1.0	0.8	1.0	0.8	1.0	0.8	1.0	0.8	na
C	1.5	1.7	1.5	1.6	1.5	1.5	1.5	1.4	1.5	1.3	1.4	na
D	2.4	2.4	2.2	2.0	2.0	1.8	1.9	1.6	1.8	1.5	1.7	na
E	4.2	3.5	3.3	3.2	2.8	2.8	2.4	2.4	2.2	2.4	2.0	na

F_{PGA}												
Site	PGA < 0.1		PGA = 0.2		PGA = 0.3		PGA = 0.4		PGA = 0.5		PGA > 0.6	
class	Current	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Previous
A	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	na
B	0.9	1.0	0.9	1.0	0.9	1.0	0.9	1.0	0.9	1.0	0.9	na
C	1.3	1.2	1.2	1.2	1.2	1.1	1.2	1.0	1.2	1.0	1.2	na
D	1.6	1.6	1.4	1.4	1.3	1.2	1.2	1.1	1.1	1.0	1.1	na
E	2.4	2.5	1.9	1.7	1.6	1.2	1.4	0.9	1.2	0.9	1.1	na