DRAFT

PEER site-specific ground motions for Oakland: record selection notes

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1. Location

These site-specific ground motions were selected to be representative of the hazard at the site of the I880 viaduct in Oakland, California. The viaduct runs from near the intersection of Center and 3rd Streets to Market and 5th Streets[1]. Those locations are noted in Figure 1 below. For the hazard analysis used here, a location of 37.803N x 122.287W was used, and this location is labeled "Oakland site" in Figure 1.

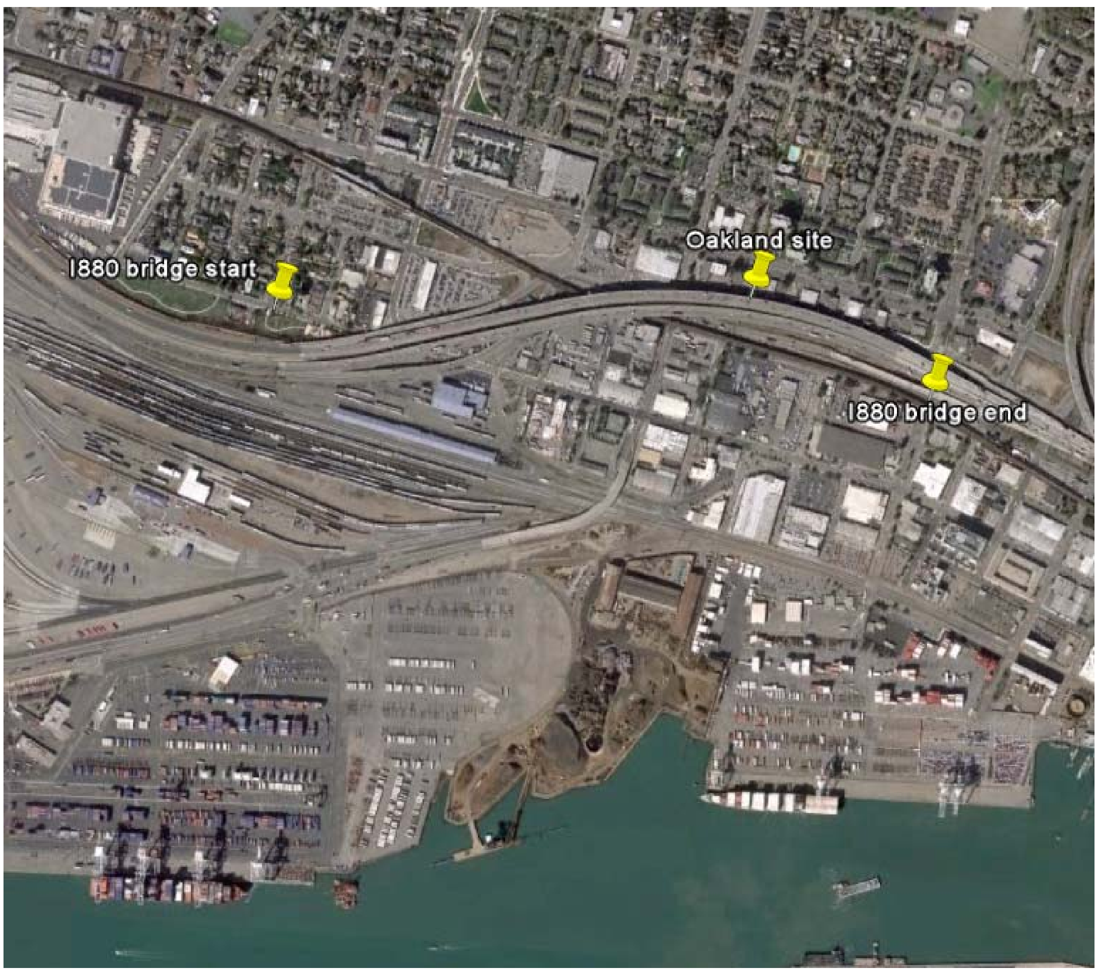

Figure 1: Location of I880 bridge viaduct

[1] Locations, including associated latitudes and longitudes, were taken from

2. Background: Calculations and data from the 2002 PEER Testbeds report

Data from the 2002 PEER Testbeds record selection for this bridge performed by Somerville (2002) were utilized to determine site conditions and initial selection parameters. Key information from this 2002 report is summarized here. The bridge is located on soil classified as Sc ("soft rock") by the Uniform Building Code. Ground motions were selected under the assumption that the NEHRP side class is C or D. The 2002 hazard analysis calculations showed that spectral accelerations at 1 second were caused primarily by earthquakes with magnitudes of 6.6 to 7, on the nearby Hayward fault (these observations are confirmed in the new hazard analysis below). The ground motions selected for in 2002 were chosen to have distances of less than 10 km, and magnitudes from 5.5 to 6.2 (for the "50% in 50 years" case) and magnitudes greater than 6.6 (for the "10% in 50 years" and "2% in 50 years" cases). The ground motions were taken exclusively from strike slip earthquake recordings. It is stated that "Some of the selected recordings contain strong forward rupture directivity pulses, but others do not." All ground motions were rotated to the strike-normal and strike-parallel orientations. Ten ground motions were provided at each hazard level.

The report states that "The ground motion time histories have not been scaled, because a unique period for use in scaling has not been identified. Once a period has been identified, a scaling factor should be found for the strike normal component using the strike normal response spectral value." Uniform hazard spectra were provided for each of the three exceedance probabilities of interest, and these would be used as the targets for ground motion scaling.

3. Hazard analysis

To characterize seismic hazard at the site (37.803N, 122.287W), the 2008 USGS hazard maps and interactive deaggregations tools[2] were used. The assumed site conditions were Vs30 = 360 m/s (i.e., the NEHRP site class C/D boundary). Uniform hazard spectra were obtained, along with the mean magnitude/ distance/ε values associated with occurrence of each spectral value. This information is summarized in Table 1 through Table 3 for probabilities of exceedance of 2%, 10% and 50% in 50 years. These uniform hazard spectra are plotted in Figure 2.

[2] http://eqint.cr.usgs.gov/deaggint/2008/

Table 1: Uniform hazard spectrum and mean deaggregation values of distance, magnitude and ε for the Oakland site, with a 2% probability of exceedance in 50 years.

Period (s)	Sa (g)	R (km)	M	ε
0.0	0.94	8.8	6.78	1.70
0.1	1.78	8.4	6.73	1.76
0.2	2.20	8.4	6.77	1.74
0.3	2.13	8.5	6.81	1.73
1.0	1.14	9.9	7.00	1.74
2.0	0.60	13.4	7.20	1.74
5.0	0.22	16.0	7.43	1.64

Table 2: Uniform hazard spectrum and mean deaggregation values of distance, magnitude and ε for the Oakland site, with a 10% probability of exceedance in 50 years.

Period (s)	Sa (g)	R (km)	M	ε
0.0	0.60	10.1	6.80	1.05
0.1	1.11	10.0	6.75	1.10
0.2	1.38	10.0	6.78	1.10
0.3	1.32	10.2	6.82	1.09
1.0	0.67	11.8	7.00	1.09
2.0	0.34	15.6	7.15	1.09
5.0	0.12	16.9	7.31	1.01

Table 3: Uniform hazard spectrum and mean deaggregation values of distance, magnitude and ε for the Oakland site, with a 50% probability of exceedance in 50 years.

Period (s)	Sa (g)	R (km)	M	ε
0.0	0.27	15.1	6.79	0.00
0.1	0.48	15.0	6.73	0.10
0.2	0.60	15.7	6.76	0.11
0.3	0.56	16.2	6.80	0.10
1.0	0.26	19.3	6.96	0.04
2.0	0.12	24.2	7.06	0.02
5.0	0.04	24.2	7.13	-0.02

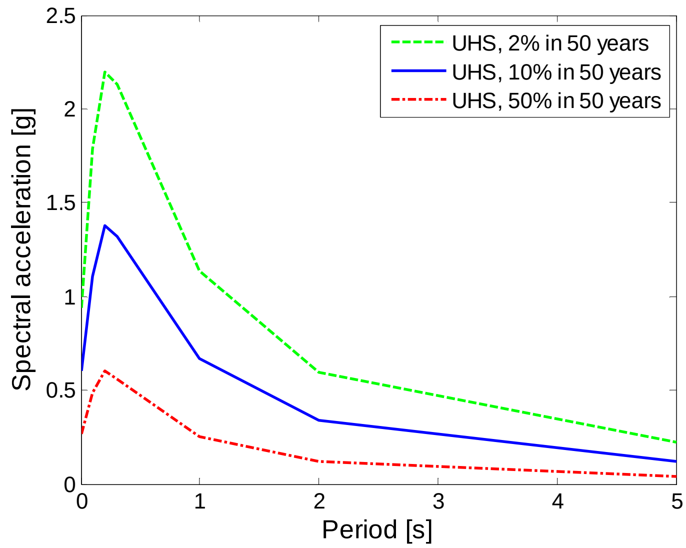

Figure 2: Uniform hazard spectra for the Oakland site.

The mean deaggregation values in Table 1 through Table 3 provide some idea as to the causal earthquakes causing occurrence of these spectral values. More complete information is only available, however, by looking at a complete deaggregation plot for a given period and spectral amplitude. Figure 3 and Figure 4 show the deaggregation plots for *Sa* values exceeded with 2% probability in 50 years at periods of 0.1 and 1 seconds, respectively. We see that at 0.1s, the almost all occurrences of Sa(0.1s)= 1.78g are caused by earthquakes on the Hayward fault at 7km, having magnitudes of approximately 7. For reference, a map of the Oakland site is shown in Figure 6, noting the Hayward fault approximately 7 km away. Looking back to Table 1, the mean magnitude of 6.73 corresponds to these large Hayward fault events, and the mean distance of 8.4 km corresponds to the Hayward fault distance (it is larger than 7 km because some ground motions are caused on portions of the Hayward fault not occurring on this closest segment, and also because this is the mean distance of all events, and includes some events on the more distant San Andreas fault). At a period of 1 second, shown in Figure 4, we see that the contribution from the San Andreas fault has gotten larger. That contribution continues to grow as the period gets larger (as seen in the increasing mean magnitude values with increasing period in Table 1).

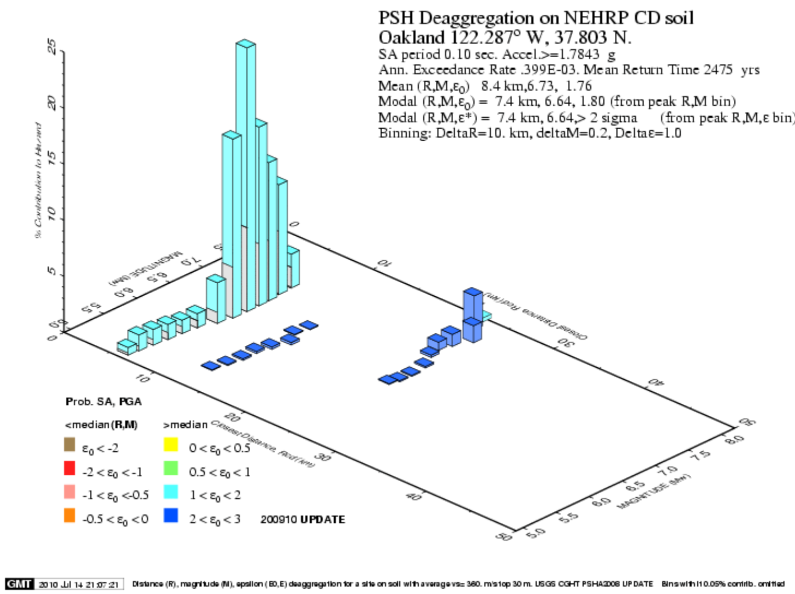

Figure 3: Deaggregation plot for Sa(0.1s) exceeded with 2% probability in 50 years The largest contribution is from the Hayward fault at 7 km, with a small contribution from M>7 earthquakes on the San Andreas fault.

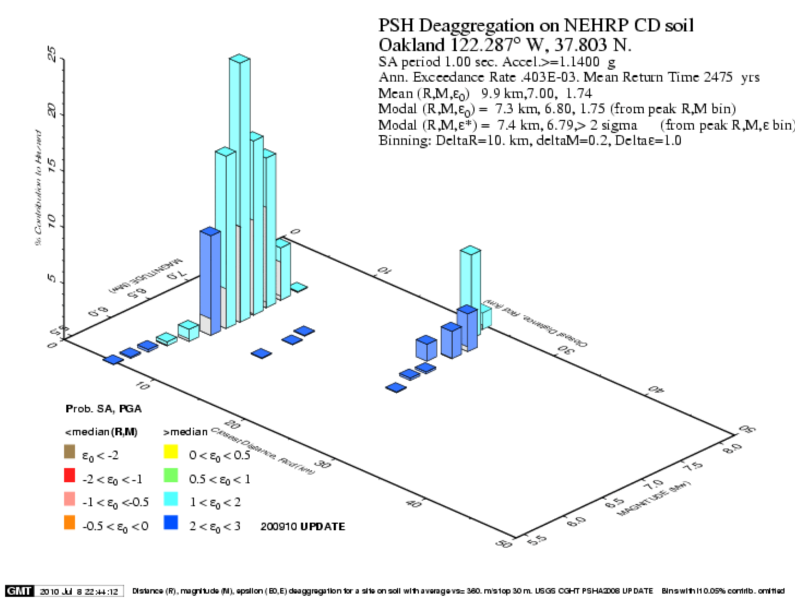

Figure 4: Deaggregation plot for Sa(1s) exceeded with 2% probability in 50 years. The largest contribution is from the Hayward fault at 7 km, with some contribution from M>7 earthquakes on the San Andreas fault.

Looking at the other hazard levels, we see that the mean distances increase and mean magnitudes and ε's decrease as the probability of exceedance increases from 2% to 10% and 50% in 50 years. This is expected, as at these lower ground motion intensity levels one does not need such an extreme event (i.e., close distance, large magnitude, and large ε) to achieve the given Sa level. At the 50% in 50 year level especially, larger-distance events contribute significantly to the hazard.

This variation in causal sources with period is one reason why the uniform hazard spectrum cannot be interpreted as the response spectrum associated with any single ground motion (Reiter 1990; Beyer and Bommer 2007). Also, note that the mean ε values in Table 1 are typically about 1.7, indicating that these spectral values are associated with ground motions having spectra 1.7 standard deviations larger than the mean predicted (logarithmic) spectra associated with the causal earthquake. Any single ground motion is unlikely to be this much larger than mean at all periods, providing a second reason why these uniform hazard spectra should not be interpreted as the spectra of individual ground motions that might be seen at this Oakland site (Baker and Cornell 2006). To help illustrate this, the uniform hazard spectra are re-plotted in Figure 2, along with median predicted spectrum (i.e., the exponential of the mean predicted logarithmic spectrum) for a magnitude 7 earthquake at a distance of 10 km. This is the dominant causal earthquake for occurence of Sa(1s)= 1.14g, the 2% in 50 year hazard value from Table 1, but the amplitude of this spectrum is dramatically lower than the 2% in 50 year spectrum. In fact, it is only slightly larger than the 50% in 50 years spectrum.

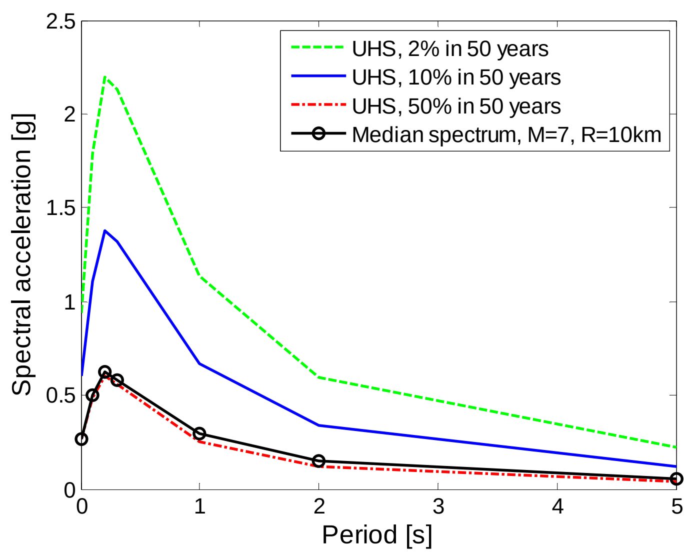

Figure 5: Uniform hazard spectra for the Oakland site, compared to the median predicted spectrum for an M = 7, R= 10 km event (Campbell and Bozorgnia 2008).

Despite the limitations of uniform hazard spectra discussed above, ground motions selected and scaled to approximately match these uniform hazard spectra have the advantage that their amplitude at any given period has approximately the same probability of exceedance; this is a useful property when one desires to use a single set of ground motions to analyze structures sensitive to excitation at differing periods, and one wants the ground motions to be comparably "intense" in their excitation of each building. These uniform hazard spectra will thus be used as target spectra for the selection of site-specific ground motions.

Figure 6: Oakland site. The pushpin marks the site location and the Hayward fault is shown in the upper right portion of the map, approximately 7 km from the site.

4. Ground motion library

All ground motions and associated metadata were obtained from the PEER NGA Project ground motion library (Chiou et al. 2008). This library, available online at *http://peer.berkeley.edu/nga*, contains 3551 multi-component ground motions from 173 earthquakes. The earthquakes, ranging in magnitude from 4.3 to 7.9, are primarily from shallow crustal earthquakes observed in seismically active regions of the world. The NGA project made a significant effort to carefully process these ground motion recordings (including filtering, baseline correcting, and verification of metadata such as associated source-site-distances and near surface site conditions).

5. Ground motion selection

With the above hazard and site information, ground motions were selected to represent the hazard at the site. The following criteria and procedures were used for selection:

- Forty three-component ground motions were selected at each hazard level.

- The selected ground motions were rotated from their as-recorded orientations to strike-normal and strike-parallel orientations.
- Ground motions were selected based on their close match to the target spectrum over a range of periods between 0 and 5 seconds.
- The ground motions have been amplitude scaled to match their target spectrum as closely as possible. (In the selection and scaling operation, mismatch is computed as the sum of squared differences between the logarithm of the scaled ground motion's geometric mean spectrum and the logarithm of the target spectrum.) All three components of the ground motion were scaled by the same factor. No ground motions were scaled by more than a factor of 8. The mean scale factors of the selected ground motions were 3.8, 2.5 and 1.5 at the 2%, 10% and 50% in 50 years hazard levels, respectively.
- Ground motions were selected to have magnitudes between 5.9 and 7.3, to approximately match the magnitudes of causal earthquakes identified in the hazard calculations above.
- Ground motions were selected to have closest distances to the fault rupture of between 0 and 20 km for the 2% and 10% in 50 years hazard levels. At the 50% in 50 years hazard level, ground motions were selected to have closest distances to the fault rupture of between 0 and 30 km. These limits were chosen to be approximately consistent with the hazard deaggregation results above.
- Ground motions were selected to have Vs30 values less than 550 m/s, to approximately represent the site conditions at the location of interest.
- No ground motions were selected from dam abutments, or from instruments located above the first floor of a structure.
- No restriction was put on the mechanism of the earthquake associated with the ground motion.
- No restriction was put on the number of ground motions selected from a single earthquake, although some ground motions were omitted manually if the initial selection identified two ground motions in close proximity to each other.
- The site of interest is close enough to the Hayward fault to potentially experience directivity effects, so some selected ground motions have velocity pulses in the fault-normal component of the recording. The selected sets for the 2%, 10% and 50% in 50 years hazard levels have 19, 16 and 7 pulses, respectively. The pulses were identified using the procedure of Baker (2007), and have a variety of pulse periods between 1 and 7 seconds. The fraction of pulse-like motions is approximately consistent with what might be expected at a site of this type (Shahi and Baker 2010), but an exact comparison is not possible because hazard analysis used here does not explicitly account for directivity effects, and even if it did the fraction of pulses expected would

vary with the period of interest. This characterization nonetheless provides an approximate representation of potential directivity effects at the site.

The above criteria are a compromise between the desire to have ground motions whose properties closely matched the target properties identified above, and the limitations of the finite number of recorded strong ground motions available for use. The restrictions above result in 172 ground motions being available at the 2% and 10% in 50 years hazard levels, out of 3551 total ground motions in the NGA library. At the 50% in 50 years hazard level, there are 303 available ground motions because of the increased range of acceptable distances used in that case.

Response spectra of the selected ground motions are shown Figure 7, Figure 8 and Figure 9. The selected motions in general have a close match to the target, but there is variability around the target spectra due to the inherent "bumpiness" of real ground motions. The geometric means of the selected spectra generally match closely to the target spectra. An exception is at periods greater than 2.5 seconds for the 2% in 50 years hazard level, where the selected motions are slightly lower on average than the target spectrum; this is in part because those spectral values are partially driven by different events than the spectral values at shorter periods, as discussed above, so recorded ground motions tend not to have the shape of this enveloped uniform hazard spectrum. The discrepancy in this case is unavoidable given the currently available ground motion library, unless one is willing to relax the selection criteria listed above.

Additional summary data, as well as the time histories of the ground motions, are provided online at http://peer.berkeley.edu/transportation/gm_peer_transportation.html.

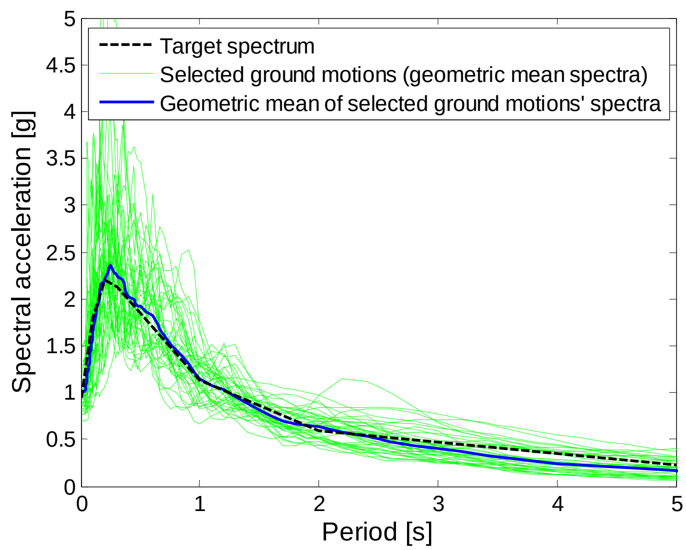

Figure 7: Target uniform hazard spectrum at the 2% in 50 years hazard level, and the response spectra of the selected ground motions.

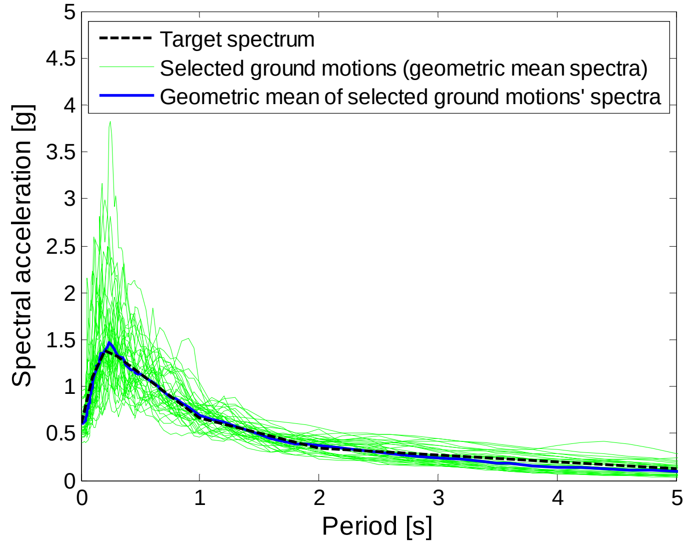

Figure 8: Target uniform hazard spectrum at the 10% in 50 years hazard level, and the response spectra of the selected ground motions.

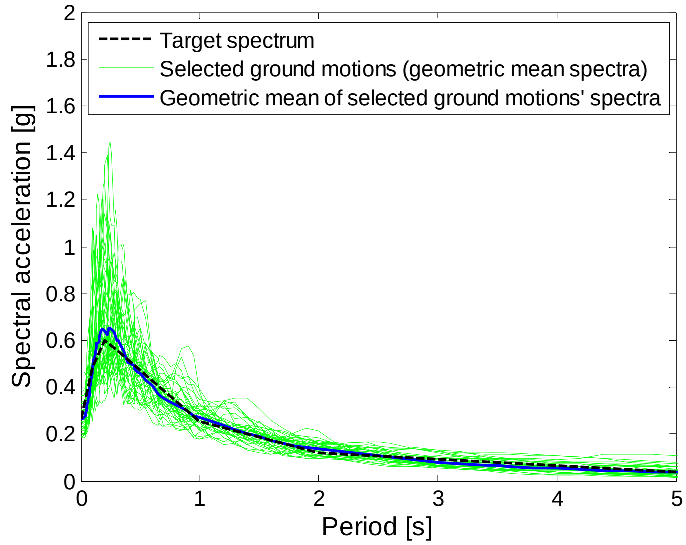

Figure 9: Target uniform hazard spectrum at the 50% in 50 years hazard level, and the response spectra of the selected ground motions.

Table 4: Ground motions selected for the 2% in 50 years hazard level.

Record number	NGA Record Sequence Number	Earthquake Name	Year	Station	Magnitude	Hypocentral Distance (km)	Closest Distance (km)	Preferred Vs30 (m/s)	FN Pulse	Pulse Period (s)
1	6	Imperial Valley-02	1940	El Centro Array #9	7.0	13.0	6.1	213	0	
2	159	Imperial Valley-06	1979	Agrarias	6.5	2.6	0.7	275	1	2.30
3	161	Imperial Valley-06	1979	Brawley Airport	6.5	43.2	10.4	209	1	4.03
4	165	Imperial Valley-06	1979	Chihuahua	6.5	18.9	7.3	275	0	
5	171	Imperial Valley-06	1979	EC Meloland Overpass FF	6.5	19.4	0.1	186	1	3.35
6	173	Imperial Valley-06	1979	El Centro Array #10	6.5	26.3	6.2	203	1	4.49
7	174	Imperial Valley-06	1979	El Centro Array #11	6.5	29.4	12.5	196	1	7.36
8	175	Imperial Valley-06	1979	El Centro Array #12	6.5	32.0	17.9	197	0	
9	178	Imperial Valley-06	1979	El Centro Array #3	6.5	28.7	12.9	163	1	5.24
10	179	Imperial Valley-06	1979	El Centro Array #4	6.5	27.1	7.1	209	1	4.61
11	180	Imperial Valley-06	1979	El Centro Array #5	6.5	27.8	4.0	206	1	4.05
12	181	Imperial Valley-06	1979	El Centro Array #6	6.5	27.5	1.4	203	1	3.84
13	183	Imperial Valley-06	1979	El Centro Array #8	6.5	28.1	3.9	206	1	5.39
14	184	Imperial Valley-06	1979	El Centro Differential Array	6.5	27.2	5.1	202	1	5.86
15	185	Imperial Valley-06	1979	Holtville Post Office	6.5	19.8	7.7	203	1	4.80
16	187	Imperial Valley-06	1979	Parachute Test Site	6.5	48.6	12.7	349	0	
17	266	Victoria, Mexico	1980	Chihuahua	6.3	36.7	19.0	275	0	
18	316	Westmorland	1981	Parachute Test Site	5.9	20.5	16.7	349	1	3.58
19	549	Chalfant Valley-02	1986	Bishop - LADWP South St	6.2	20.3	17.2	271	0	
20	718	Superstition Hills-01	1987	Wildlife Liquef. Array	6.2	24.8	17.6	207	0	
21	721	Superstition Hills-02	1987	El Centro Imp. Co. Cent	6.5	35.8	18.2	192	0	
22	728	Superstition Hills-02	1987	Westmorland Fire Sta	6.5	19.5	13.0	194	0	
23	768	Loma Prieta	1989	Gilroy Array #4	6.9	32.4	14.3	222	0	
24	802	Loma Prieta	1989	Saratoga - Aloha Ave	6.9	27.2	8.5	371	1	4.47
25	821	Erzican, Turkey	1992	Erzincan	6.7	9.0	4.4	275	1	2.65
26	949	Northridge-01	1994	Arleta - Nordhoff Fire Sta	6.7	11.1	8.7	298	0	
27	959	Northridge-01	1994	Canoga Park - Topanga Can	6.7	4.9	14.7	267	0	
28	982	Northridge-01	1994	Jensen Filter Plant	6.7	13.0	5.4	373	1	3.53
29	1042	Northridge-01	1994	N Hollywood - Coldwater Can	6.7	13.1	12.5	446	0	
30	1044	Northridge-01	1994	Newhall - Fire Sta	6.7	20.3	5.9	269	0	
31	1052	Northridge-01	1994	Pacoima Kagel Canyon	6.7	19.3	7.3	508	0	
32	1063	Northridge-01	1994	Rinaldi Receiving Sta	6.7	10.9	6.5	282	1	1.23
33	1082	Northridge-01	1994	Sun Valley - Roscoe Blvd	6.7	12.4	10.1	309	0	
34	1085	Northridge-01	1994	Sylmar - Converter Sta East	6.7	13.6	5.2	371	1	3.49
35	1116	Kobe, Japan	1995	Shin-Osaka	6.9	46.0	19.2	256	0	
36	1602	Duzce, Turkey	1999	Bolu	7.1	41.3	12.0	326	0	
37	1605	Duzce, Turkey	1999	Duzce	7.1	1.6	6.6	276	0	
38	2457	Chi-Chi, Taiwan-03	1999	CHY024	6.2	25.5	19.7	428	1	3.19
39	2734	Chi-Chi, Taiwan-04	1999	CHY074	6.2	10.1	6.2	553	0	
40	2739	Chi-Chi, Taiwan-04	1999	CHY080	6.2	14.5	12.5	553	0	

Table 5: Ground motions selected for the 10% in 50 years hazard level.

Record number	NGA Record Sequence Number	Earthquake Name	Year	Station	Magnitude	Hypocentral Distance (km)	Closest Distance (km)	Preferred Vs30 (m/s)	FN Pulse	Pulse Period (s)
1	6	Imperial Valley-02	1940	El Centro Array #9	7.0	13.0	6.1	213	0	
2	159	Imperial Valley-06	1979	Agrarias	6.5	2.6	0.7	275	1	2.30
3	161	Imperial Valley-06	1979	Brawley Airport	6.5	43.2	10.4	209	1	4.03
4	165	Imperial Valley-06	1979	Chihuahua	6.5	18.9	7.3	275	0	
5	173	Imperial Valley-06	1979	El Centro Array #10	6.5	26.3	6.2	203	1	4.49
6	174	Imperial Valley-06	1979	El Centro Array #11	6.5	29.4	12.5	196	1	7.36
7	175	Imperial Valley-06	1979	El Centro Array #12	6.5	32.0	17.9	197	0	
8	178	Imperial Valley-06	1979	El Centro Array #3	6.5	28.7	12.9	163	1	5.24
9	179	Imperial Valley-06	1979	El Centro Array #4	6.5	27.1	7.1	209	1	4.61
10	180	Imperial Valley-06	1979	El Centro Array #5	6.5	27.8	4.0	206	1	4.05
11	181	Imperial Valley-06	1979	El Centro Array #6	6.5	27.5	1.4	203	1	3.84
12	183	Imperial Valley-06	1979	El Centro Array #8	6.5	28.1	3.9	206	1	5.39
13	184	Imperial Valley-06	1979	El Centro Differential Array	6.5	27.2	5.1	202	1	5.86
14	185	Imperial Valley-06	1979	Holtville Post Office	6.5	19.8	7.7	203	1	4.80
15	187	Imperial Valley-06	1979	Parachute Test Site	6.5	48.6	12.7	349	0	
16	192	Imperial Valley-06	1979	Westmorland Fire Sta	6.5	52.8	15.3	194	0	
17	266	Victoria, Mexico	1980	Chihuahua	6.3	36.7	19.0	275	0	
18	316	Westmorland	1981	Parachute Test Site	5.9	20.5	16.7	349	1	3.58
19	549	Chalfant Valley-02	1986	Bishop - LADWP South St	6.2	20.3	17.2	271	0	
20	718	Superstition Hills-01	1987	Wildlife Liquef. Array	6.2	24.8	17.6	207	0	
21	721	Superstition Hills-02	1987	El Centro Imp. Co. Cent	6.5	35.8	18.2	192	0	
22	728	Superstition Hills-02	1987	Westmorland Fire Sta	6.5	19.5	13.0	194	0	
23	767	Loma Prieta	1989	Gilroy Array #3	6.9	31.4	12.8	350	0	
24	768	Loma Prieta	1989	Gilroy Array #4	6.9	32.4	14.3	222	0	
25	802	Loma Prieta	1989	Saratoga - Aloha Ave	6.9	27.2	8.5	371	1	4.47
26	949	Northridge-01	1994	Arleta - Nordhoff Fire Sta	6.7	11.1	8.7	298	0	
27	959	Northridge-01	1994	Canoga Park - Topanga Can	6.7	4.9	14.7	267	0	
28	982	Northridge-01	1994	Jensen Filter Plant	6.7	13.0	5.4	373	1	3.53
29	1004	Northridge-01	1994	LA - Sepulveda VA Hospital	6.7	8.5	8.4	380	0	
30	1042	Northridge-01	1994	N Hollywood - Coldwater Can	6.7	13.1	12.5	446	0	
31	1044	Northridge-01	1994	Newhall - Fire Sta	6.7	20.3	5.9	269	0	
32	1063	Northridge-01	1994	Rinaldi Receiving Sta	6.7	10.9	6.5	282	1	1.23
33	1082	Northridge-01	1994	Sun Valley - Roscoe Blvd	6.7	12.4	10.1	309	0	
34	1085	Northridge-01	1994	Sylmar - Converter Sta East	6.7	13.6	5.2	371	1	3.49
35	1602	Duzce, Turkey	1999	Bolu	7.1	41.3	12.0	326	0	
36	1605	Duzce, Turkey	1999	Duzce	7.1	1.6	6.6	276	0	
37	1611	Duzce, Turkey	1999	Lamont 1058	7.1	13.4	0.2	425	0	
38	2699	Chi-Chi, Taiwan-04	1999	CHY024	6.2	27.9	19.7	428	0	
39	2734	Chi-Chi, Taiwan-04	1999	CHY074	6.2	10.1	6.2	553	0	
40	2739	Chi-Chi, Taiwan-04	1999	CHY080	6.2	14.5	12.5	553	0	

Table 6: Ground motions selected for the 50% in 50 years hazard level.

Record number	NGA Record Sequence Number	Earthquake Name	Year	Station	Magnitude	Hypocentral Distance (km)	Closest Distance (km)	Preferred Vs30 (m/s)	FN Pulse	Pulse Period (s)
1	6	Imperial Valley-02	1940	El Centro Array #9	7.0	13.0	6.1	213	0	
2	68	San Fernando	1971	LA - Hollywood Stor FF	6.6	39.5	22.8	316	0	
3	79	San Fernando	1971	Pasadena - CIT Athenaeum	6.6	42.8	25.5	415	0	
4	161	Imperial Valley-06	1979	Brawley Airport	6.5	43.2	10.4	209	1	4.03
5	162	Imperial Valley-06	1979	Calexico Fire Station	6.5	17.7	10.5	231	0	
6	163	Imperial Valley-06	1979	Calipatria Fire Station	6.5	57.1	24.6	206	0	
7	169	Imperial Valley-06	1979	Delta	6.5	33.7	22.0	275	0	
8	174	Imperial Valley-06	1979	El Centro Array #11	6.5	29.4	12.5	196	1	7.36
9	175	Imperial Valley-06	1979	El Centro Array #12	6.5	32.0	17.9	197	0	
10	179	Imperial Valley-06	1979	El Centro Array #4	6.5	27.1	7.1	209	1	4.61
11	183	Imperial Valley-06	1979	El Centro Array #8	6.5	28.1	3.9	206	1	5.39
12	184	Imperial Valley-06	1979	El Centro Differential Array	6.5	27.2	5.1	202	1	5.86
13	187	Imperial Valley-06	1979	Parachute Test Site	6.5	48.6	12.7	349	0	
14	302	Irpinia, Italy-02	1980	Rionero In Vulture	6.2	29.8	22.7	530	0	
15	549	Chalfant Valley-02	1986	Bishop - LADWP South St	6.2	20.3	17.2	271	0	
16	553	Chalfant Valley-02	1986	Long Valley Dam (Downst)	6.2	23.8	21.1	345	0	
17	718	Superstition Hills-01	1987	Wildlife Liquef. Array	6.2	24.8	17.6	207	0	
18	721	Superstition Hills-02	1987	El Centro Imp. Co. Cent	6.5	35.8	18.2	192	0	
19	728	Superstition Hills-02	1987	Westmorland Fire Sta	6.5	19.5	13.0	194	0	
20	754	Loma Prieta	1989	Coyote Lake Dam (Downst)	6.9	30.9	20.8	295	0	
21	767	Loma Prieta	1989	Gilroy Array #3	6.9	31.4	12.8	350	0	
22	768	Loma Prieta	1989	Gilroy Array #4	6.9	32.4	14.3	222	0	
23	802	Loma Prieta	1989	Saratoga - Aloha Ave	6.9	27.2	8.5	371	1	4.47
24	880	Landers	1992	Mission Creek Fault	7.3	32.9	27.0	345	0	
25	882	Landers	1992	North Palm Springs	7.3	32.3	26.8	345	0	
26	982	Northridge-01	1994	Jensen Filter Plant	6.7	13.0	5.4	373	1	3.53
27	985	Northridge-01	1994	LA - Baldwin Hills	6.7	28.2	29.9	297	0	
28	987	Northridge-01	1994	LA - Centinela St	6.7	25.4	28.3	235	0	
29	1004	Northridge-01	1994	LA - Sepulveda VA Hospital	6.7	8.5	8.4	380	0	
30	1008	Northridge-01	1994	LA - W 15th St	6.7	29.6	29.7	405	0	
31	1010	Northridge-01	1994	LA - Wadsworth VA Hospital S	6.7	19.6	23.6	414	0	
32	1042	Northridge-01	1994	N Hollywood - Coldwater Can	6.7	13.1	12.5	446	0	
33	1077	Northridge-01	1994	Santa Monica City Hall	6.7	22.5	26.5	336	0	
34	1082	Northridge-01	1994	Sun Valley - Roscoe Blvd	6.7	12.4	10.1	309	0	
35	1602	Duzce, Turkey	1999	Bolu	7.1	41.3	12.0	326	0	
36	2624	Chi-Chi, Taiwan-03	1999	TCU073	6.2	24.8	20.9	273	0	
37	2655	Chi-Chi, Taiwan-03	1999	TCU122	6.2	24.5	19.3	475	0	
38	2739	Chi-Chi, Taiwan-04	1999	CHY080	6.2	14.5	12.5	553	0	
39	2752	Chi-Chi, Taiwan-04	1999	CHY101	6.2	28.0	21.7	259	0	
40	2893	Chi-Chi, Taiwan-04	1999	TCU122	6.2	31.9	23.2	475	0	

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