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Site-Response Maps for the Los Angeles Region Based on Earthquake Ground Motions

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Abstract.--Ground-motion records from aftershocks of the 1994 Northridge earthquake and main-shock records from the 1971 San Fernando, 1987 Whittier Narrows, 1991 Sierra Madre, and 1994 Northridge earthquakes are used to estimate site response in the urban Los Angeles, California, area. Two frequency bands are considered, 0.5-1.5 Hz and 2.0-6.0 Hz. Instrument characteristics prevented going to lower frequencies, and frequencies above 6.0 Hz are less important to the building inventory. Site response determined at the instrumented locations is associated with the surficial geology and contoured to produce a continuous spatial estimation of site response. The maps in this report are preliminary and will evolve as more data become available and more analysis is done.

INTRODUCTION

Site response, or the site specific amplification of ground motion as a function of frequency, is a fundamental component of earthquake hazard assessment. Site response is also a desired component of any regional seismic hazard map. Previous site response studies in Los Angeles include Campbell (1976), who showed that damage during the 1933 Long Beach earthquake was greater for sites on unconsolidated soils than at sites on consolidated soils, for a given distance from the Newport-Inglewood fault zone. Rogers and others (1979) calculated site response in Long Beach using spectral ratios of Nevada Test Site (NTS) nuclear events. They found amplification factors as high as 11 in the frequency band from 0.16 to 5.0 Hz for alluvium-to-rock ratios. This work was continued by Rogers and others (1980 ,1984, 1985) to include additional sites in the Los Angeles area. They confirmed that low strain records from NTS nuclear events gave similar site response estimates as strong-motion records from the 1971 San Fernando earthquake. Their results show elevated site response at frequencies greater than 2.0 Hz with increased mean void ratio in the near-surface layers, unconsolidated sediment thickness, and depth to basement rock. At frequencies less than 2.0 Hz, the most significant factors were reported to be thickness of Quaternary sediments and the depth to basement. The 1994 Northridge earthquake greatly increased the available ground-motion data for the urban Los Angeles area from which site-response estimates can be made. Recordings of this earthquake and its aftershocks have also greatly increased our understanding of the variability in site response over widely different length scales; from one city block to across entire sedimentary basins. In addition, instrument deployment for the Northridge earthquake targeted several specific areas of severe damage and compared them with low or nondamaged areas. This expanded data set has led to the feasibility of creating site-response maps for the Los Angeles area.

DATA

The data for this study are recorded earthquake ground motions. We use both aftershock and main-shock records to increase the size of our database. Deployment of portable digital recorders after the 1994 Northridge earthquake yielded an extensive collection of aftershock records for a wide variety of surficial geologic units (Meremonte, 1996; Glassmoyer, 1996). Figure 1 shows the distribution of portable recorders and table 1 gives their locations. Over 1,300 records from 61 sources and 87 sites are utilized. The main-shock records are SMA-1 strong motion accelerograms for the four events: 1971 San Fernando (M6.6), 1987 Whittier Narrows (M5.8), 1991 Sierra Madre (M5.8), and 1994 Northridge (M6.7). These records are available for 223 sites and give coverage to the south and west not represented in the Northridge aftershock data set. These records come from four primary sources: U.S. Geological Survey, California Strong Motion Instrumentation Program, University of Southern California, and Los Angeles Department of Water and Power (Porcella and others, 1994; Shakal and others, 1994, 1995; Trifunac and others, 1994). The main-shock station locations are shown on figure 2 and listed in table 2.

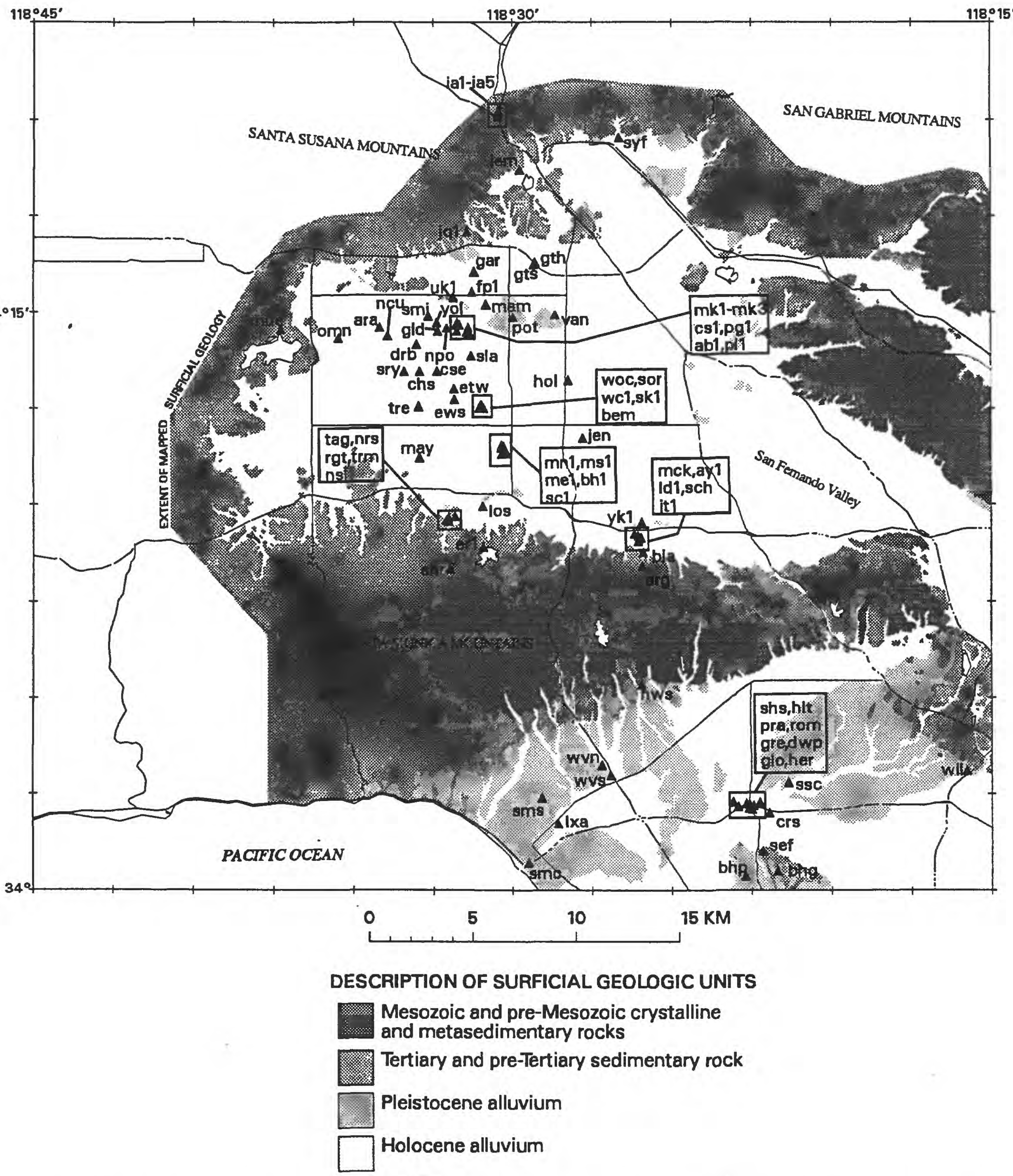

FIGURE 1. Aftershock station locations, indicated by triangles and listed in table 1, used in the determination of site response. Surficial geology is from Tinsley and Fumal (1985).

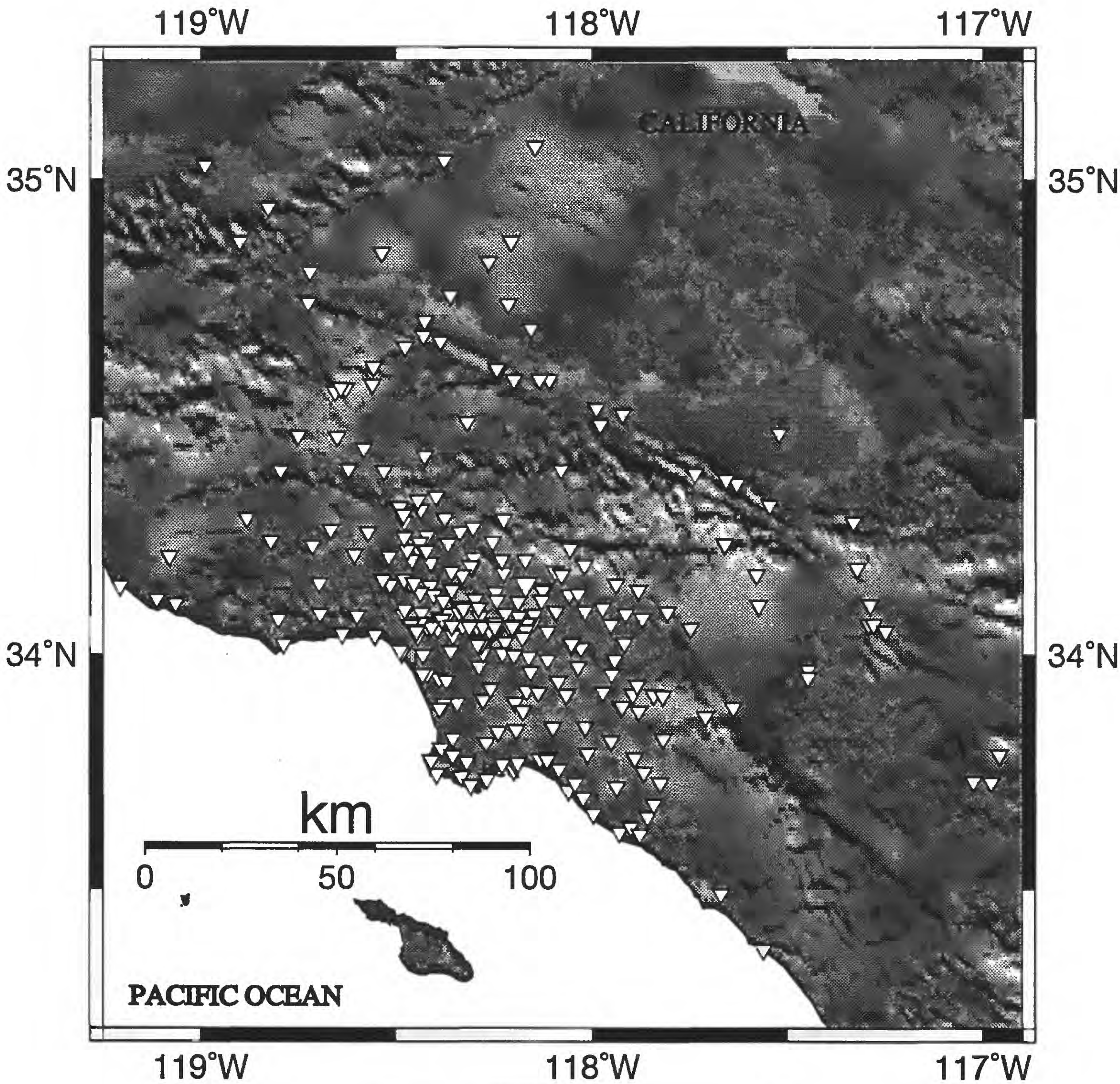

FIGURE 2. Strong-motion station locations, indicated by triangles and listed in table 2, used in the determination of site response.

METHOD

The method used to calculate site response is described in detail in two papers: Hartzell and others (1996) for the aftershock records, and Harmsen (1996) for the main-shock records. These two data sets present their own individual processing problems that are handled separately and described in the above papers. The general process, however, is relatively simple and is summarized here. The *S waves* from the above data records are first transformed to the frequency domain using a fast Fourier transform. Then, following Andrews (1986), the *S-wave* spectrum, U(f), for source i and site j is decomposed as

$$S_i(f) \cdot R_j(f) \cdot P_{ij}(f,r) = U_{ij}(f),$$

were S(f) is the source spectrum, R(f) is the site spectrum, P(f) is the path spectrum, f is frequency, and r is the source to station distance. General assumptions are made about the nature of P(f,r), including 1/r attenuation with distance and an elastic attenuation, Q(f). Incorporating these propagation path effects and taking the logarithm of both sides gives the linear expression

$$\log S_i(f_k) + \log R_j(f_k) = \log U'_{ij}(f_k),$$

where U′(f) is the path-corrected *S-wave* spectrum. Linear least squares analysis can then be used to solve for the best-fitting source and site terms. Averages are then taken over frequency bands of R(f) for each site to obtain the site amplification factors. Two frequency bands are selected, 0.5-1.5 Hz and 2.0-6.0 Hz, on the basis of the bandwidth of the available ground-motion data. Main-shock records with suspected nonlinear effects have been omitted from the analysis.

The aftershock and strong-motion data results must be normalized with respect to each other. In the above analysis, a reference site is selected to remove a fundamental degree of freedom in the problem. The site response at this reference site must be specified. To accomplish the normalization, we select a common reference site for both the aftershock and main-shock record analysis. We choose one of the most competent rock sites in our database and assume its amplification is approximately 1 at all frequencies. This site is the Encino Reservoir Dam, ER1 in the aftershock data set (table 1) and ERD in the main-shock data set (table 2). These two stations are separated by approximately 20 ft.

SPATIAL CONTINUATION OF SITE RESPONSE

Given the point determinations of site response at each of the recording sites, a method is needed to spatially continue these values to produce a map. Surficial geology and shallow *S-wave* velocity are logical means of interpolating and extrapolating our point values of site response. The correlation of larger ground motion with less competent surficial material and lower *S-wave* velocity has long been observed and used in studies of site response (Borcherdt, 1970, 1994; Boore and others, 1993, 1994; Joyner and Fumal, 1984; and Harmsen, 1996). In the work of Hartzell and others (1996) and Harmsen (1996), however, significant variations in site response are observed for the same mapped surficial geologic unit, particularly within the young basin sediments (factor of 2 in amplitude within a few hundred meters). These results reflect the fact that shallow *S-wave* velocities vary significantly within these sediments (Williams and others, 1996; Harmsen, 1996) and buried structures such as folds and mini-basins focus and defocus energy at the surface. Because of these variations in *S-wave* velocity and the sparseness of the *S-wave* data set, *S-wave* velocity is presently not a feasible means of spatially continuing our site amplification values. For this report we have chosen a compromise by calculating average site amplification values for Mesozoic and Tertiary rocks and Pleistocene and Holocene alluvium, as well as contouring the amplification values within the more spatially variable sedimentary basins. With minor corrections to the extent of the hard-rock units, we use the surficial geology of Tinsley and Fumal (1985).

Table 3 lists the average amplification values for the four ages (Mesozoic, Tertiary, Pleistocene, and Holocene) and for the two frequency bands 0.5-1.5 Hz and 2.0-6.0 Hz. Two different averages are given: (1) the geometric average of all sites within the indicated surficial geologic unit, and (2) the value predicted by a regression relationship between shallow *S-wave* velocity and site amplification obtained by Harmsen (1996). For the second case, we use the arithmetic average of the *S-wave* velocity in each geologic unit. Because of variability within a rock type and possible topographic amplification at some sites, the average Mesozoic values are not all 1. We therefore normalize the amplifications contoured on the maps and lists in tables 1, 2, and 3 so that the average Mesozoic values are 1. (The pre-normalization values for Mesozoic units are: 1.4 (2.0-6.0Hz, average #1), 1.9 (2.0-6.0Hz, average #2), 1.0 (0.5-1.5Hz, average #1), 1.3 (0.5-1.5Hz, average #2).)

Contouring of amplification values within the sedimentary basins is done using the inverse distance-weighted interpolation algorithm in the Arc/Info GIS software package. An interpolated value is a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. This weighted distance average cannot be greater than the highest or less than the lowest input. Therefore, it cannot create highs or lows if these extremes have not already been sampled. In this process all the Pleistocene and Holocene data points are contoured together, without distinction. After contouring, the Mesozoic and Tertiary units are layed down as masks over the contours. The result is discontinuous contours at the contacts of the sedimentary basins with the Mesozoic and Tertiary outcrops, reflecting the discontinuous change in material properties and amplification factors. In addition, some of the contours are given hachures to clarify the down-gradient direction.

ACCESSING DIGITAL FILES OF THE SITE-RESPONSE MAPS

Graphics files of the site-response maps are available to those who have the capability to plot large-format, color encapsulated-PostScript or HPGL2 files. The files can be accessed from anonymous FTP server greenwood (136.177.48.5).
The following sequence of commands should be executed on UNIX computers:

```
% ftp greenwood.cr.usgs.gov
Name: your_name@your_system.your_domain
ftp> dir
ftp> get INDEX
ftp> get README.FTP
ftp> get LISTING.TXT
ftp> cd pub
ftp> dir
ftp> cd open-file-reports
ftp> dir
ftp> cd ofr-96-0000
ftp> dir
ftp> binary
ftp> get file_name
ftp> quit
```

The text file INDEX contains a listing and short description of all publications in the /pub subdirectory, and README.FTP contains useful information on FTP file transfer. The text file LISTING.TXT is a long listing of files and the subdirectory structure below /pub. The site response map files are in subdirectory /pub/open-file-reports/ofr-96-0000.

Questions regarding digital database dissemination should be directed to the database manager:

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DISCLAIMER

The site-response maps have been approved for release and publication by the Director of the U.S. Geological Survey (USGS). However, the USGS reserves the right to revise these maps pursuant to further analysis and review. Furthermore, these maps are released on condition that neither the USGS nor the United States Government may be held liable for any damages resulting from their authorized or unauthorized use.

ACKNOWLEDGMENTS

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Table 1.–Aftershock station locations and amplification factors
[Asterisk (*) indicates poor data quality]

Station Code	Latitude	Longitude	Amplification Factor 0.5 to 1.5Hz	Amplification Factor 2.0 to 6.0Hz
ab1	34.2417	-118.5244	3.18	2.19
ara	34.2437	-118.5698	2.06	1.64
arg	34.1405	-118.4320	2.75	2.20
ay1	34.1533	-118.4342	4.12	3.21
bem	34.2088	-118.5150	4.54	2.56
bh1	34.1888	-118.5058	4.18	1.94
bhg	34.0086	-118.3615	3.58	1.79
bhp	34.0064	-118.3782	2.61	1.32
bla	34.1465	-118.4315	4.29	3.42
chs	34.2247	-118.5488	4.16	2.60
crs	34.0338	-118.3656	4.04	4.01
cs1	34.2423	-118.5295	2.71	2.19
cse	34.2248	-118.5397	4.20	2.47
drb	34.2365	-118.5505	3.57	2.06
dwp	34.0383	-118.3706	2.65	1.73
er1	34.1488	-118.5154	ref.	ref.
etw	34.2172	-118.5307	4.08	2.22
ews	34.2127	-118.5305	3.71	3.57
fp1	34.2592	-118.5212	2.90	1.41
g1d	34.2422	-118.5395	3.48	2.81
gar	34.2677	-118.5200	3.78	3.15
glo	34.0358	-118.3763	3.56	3.06
gre	34.0370	-118.3738	3.54	3.35
gth	34.2717	-118.4880	2.74	2.77
gts	34.2708	-118.4887	3.39	3.18
her	34.0353	-118.3747	3.48	4.66
hlt	34.0366	-118.3819	2.48	2.07
hol	34.2208	-118.4707	2.93	3.09
hws	34.0893	-118.4325	1.62	1.44
ia1	34.3374	-118.5071	1.88	1.66
ia2	34.3359	-118.5075	1.47	2.43
ia3	34.3349	-118.5075	2.17	2.98
ia4	34.3350	-118.5076	*	2.24
ia5	34.3360	-118.5076	*	1.96
jem	34.3120	-118.4960	2.64	1.85
jen	34.1958	-118.4630	3.26	2.46
jq1	34.2850	-118.5240	3.09	2.01
jt1	34.1523	-118.4338	4.59	2.50
ld1	34.1527	-118.4327	4.17	2.67
los	34.1662	-118.5157	5.06	1.01
lxa	34.0293	-118.4761	3.35	1.80
mam	34.2535	-118.5137	1.93	1.83
may	34.1873	-118.5487	3.94	2.36
mck	34.1542	-118.4363	6.20	5.17
me1	34.1922	-118.5045	2.55	1.33

Station Code	**Latitude**	**Longitude**	**Amplification Factor 0.5 to 1.5Hz**	**Amplification Factor 2.0 to 6.0Hz**
mk1	34.2458	-118.5293	3.48	2.43
mk2	34.2448	-118.5280	4.39	3.07
mk3	34.2448	-118.5300	5.36	2.59
mn1	34.1927	-118.5058	3.54	1.32
ms1	34.1917	-118.5060	2.21	1.31
mue	34.2428	-118.6213	1.07	1.10
ncu	34.2400	-118.5655	2.61	1.59
npo	34.2435	-118.5347	3.64	1.86
nrs	34.1614	-118.5339	4.38	1.54
nsl	34.1617	-118.5303	2.97	1.28
omn	34.2392	-118.5912	3.01	2.56
pg1	34.2438	-118.5233	3.52	2.91
pl1	34.2415	-118.5228	2.76	2.03
pot	34.2482	-118.4998	2.51	2.08
pra	34.0378	-118.3777	3.13	3.08
rgt	34.1602	-118.5350	2.67	1.01
rom	34.0372	-118.3757	3.05	3.20
sc1	34.1890	-118.5028	2.82	1.74
sch	34.1510	-118.4342	4.95	5.44
sef	34.0173	-118.3690	4.77	2.71
shs	34.0385	-118.3844	2.05	1.34
sk1	34.2101	-118.5163	3.06	2.03
sla	34.2315	-118.5217	5.21	3.92
smc	34.0122	-118.4914	2.98	1.49
smi	34.2487	-118.5443	3.84	3.49
sms	34.0403	-118.4844	3.57	0.84
sor	34.2102	-118.5164	4.18	3.21
sry	34.2247	-118.5567	4.36	2.17
ssc	34.0467	-118.3556	1.98	0.88
syf	34.3260	-118.4440	1.94	1.83
tpc	34.0840	-118.5990	1.29	1.32
tre	34.2095	-118.5493	2.43	2.00
trm	34.1597	-118.5336	2.18	1.73
uk1	34.2567	-118.5312	2.15	1.04
van	34.2493	-118.4777	2.06	1.80
wc1	34.2088	-118.5173	2.94	2.25
wil	34.0518	-118.2628	1.99	1.11
woc	34.2089	-118.5174	6.51	2.49
wvn	34.0543	-118.4531	2.87	1.48
wvs	34.0499	-118.4485	1.99	0.92
yk1	34.1593	-118.4323	3.06	1.30
yol	34.2458	-118.5400	3.27	1.95

Table 2.–Main-shock station locations and amplification factors
[Asterisk (*) indicates poor data quality]

Station Code	Latitude	Longitude	Amplification Factor 0.5 to 1.5Hz	Amplification Factor 2.0 to 6.0Hz
AHM	33.8170	-117.9510	2.03	1.50
ALF	34.0700	-118.1500	2.48	1.40
ALH	34.0850	-118.1490	2.66	1.36
ARA	34.1272	-118.0588	2.46	1.37
ARC	34.1300	-118.0360	2.06	1.94
BAD	33.8890	-117.9260	1.49	2.16
BAP	33.8470	-118.0180	2.11	2.39
BCC	34.0580	-118.4170	2.02	0.95
BCF	34.1850	-118.3080	2.18	1.75
BCY	34.2040	-118.3020	1.06	0.82
BGC	33.9650	-118.1580	2.81	1.65
BHA	34.0090	-118.3610	2.63	1.80
BHO	34.0800	-118.3900	1.44	0.77
BHR	34.0700	-118.4100	1.45	1.64
BHW	34.0667	-118.3893	1.94	1.69
BLD	34.2330	-117.6610	1.14	1.88
BPK	34.1000	-117.9740	1.29	0.92
BPM	34.1870	-118.3110	3.06	1.91
BRDG	34.1400	-118.1190	2.83	1.00
BREA	33.9163	-117.8963	1.77	2.07
BTS	34.2860	-118.2250	1.13	1.30
BWP	34.1680	-118.3320	3.76	3.20
CAS	33.8120	-118.2700	1.51	1.02
CBP	34.0870	-117.9150	1.79	1.05
CBS	34.1510	-118.6970	1.36	1.24
CCS	34.0780	-117.8710	1.99	1.19
CDA	33.8360	-118.2400	3.88	1.54
CND	33.9160	-117.8420	1.17	2.00
COM	33.8990	-118.1960	3.13	1.97
CPC	34.2120	-118.6010	2.91	2.42
CSB	34.0670	-118.1680	3.87	2.61
CTG	34.1400	-118.1300	2.54	2.03
CWH	34.2590	-118.5710	2.32	*
DFL	33.9130	-117.8190	1.81	2.82
DOW	33.9240	-118.1670	3.95	1.78
DUA	34.1500	-117.9400	0.80	0.96
DWY	33.9200	-118.1370	3.29	2.17
ECC	34.2590	-118.3360	1.77	0.84
ECP	34.1770	-118.0960	2.11	1.61
EMC	34.0930	-118.0190	2.76	1.55
ERD	34.1488	-118.5153	ref.	ref.
FGA	34.0555	-118.2565	2.45	1.56
FGR	34.0555	-118.2568	3.09	2.03
FGU	34.0500	-118.2600	2.76	1.47
FRM	34.0525	-118.2577	2.89	2.08

Station Code	Latitude	Longitude	Amplification Factor 0.5 to 1.5Hz	Amplification Factor 2.0 to 6.0Hz
FUL	33.8800	-117.8800	1.35	1.15
FVP	33.7190	-117.9370	2.77	1.54
FYP	33.8690	-117.7090	1.34	2.18
GDL	34.1333	-118.2472	5.13	2.28
GGS	33.7900	-118.0120	3.16	3.03
GLF	34.2000	-118.2310	1.25	2.88
GMC	34.1370	-117.8820	1.66	1.47
GPK	34.1180	-118.2990	2.59	1.64
GVR	34.0500	-118.1140	1.56	1.66
HACI	33.9900	-117.9425	1.51	1.12
HBW	33.7272	-118.0437	2.14	2.33
HIL	34.0400	-118.2600	2.84	0.86
HLC	34.0880	-118.3650	2.26	1.36
HNB	33.6620	-117.9970	1.68	1.16
IGU	33.9050	-118.2790	2.62	1.77
IRV	33.6820	-117.8420	2.66	2.88
JFP	34.3120	-118.4960	*	0.84
JFPG	34.3125	-118.4977	*	1.83
JPC	34.2000	-118.1700	1.26	1.09
KECK	34.1400	-118.1200	2.41	1.42
LADF	34.2947	-118.4788	2.27	0.66
LADN	34.2997	-118.4870	*	1.75
LAJ	34.0810	-118.1880	1.77	1.12
LAPU	34.0262	-117.9182	1.31	1.11
LAS	33.9290	-118.2600	2.74	1.95
LAW	33.8970	-118.3460	2.12	0.94
LBC	33.8810	-118.1770	5.06	2.39
LBH	33.7540	-118.2000	3.42	1.27
LBL	33.8400	-118.1940	3.65	1.97
LBM	33.9960	-118.1620	2.99	2.12
LBO	33.7680	-118.1960	2.34	0.77
LBR	33.7780	-118.1330	2.17	0.74
LBS	33.7830	-118.1120	3.31	1.20
LBU	33.7800	-118.1100	3.02	1.57
LCA	34.2380	-118.2540	1.81	1.37
LCN	34.0630	-118.4180	2.51	1.55
LCS	34.0620	-118.4160	2.42	1.07
LCT	34.0530	-118.1710	2.30	3.12
LCY	33.9450	-118.3718	1.88	0.88
LDH	34.0820	-118.2880	1.86	2.00
LDS	34.0880	-118.2220	1.76	1.29
LF1	34.1150	-118.2440	2.92	1.89
LF2	34.1130	-118.1890	1.80	1.57
LF3	34.0420	-118.5540	1.04	1.55
LF4	34.1460	-118.4130	2.98	4.13
LF5	34.1270	-118.4050	1.58	1.98
LF6	34.1320	-118.4400	2.61	1.85
LHA	33.9600	-117.9500	2.10	1.17
LHO	33.9210	-117.9730	2.30	1.51
LNC	33.9600	-118.4200	1.47	0.85

Station Code	Latitude	Longitude	Amplification Factor 0.5 to 1.5Hz	Amplification Factor 2.0 to 6.0Hz
LND	33.8960	-118.3770	1.95	1.10
LNK	34.1400	-118.3600	1.24	1.09
LPS	34.0430	-118.2710	1.77	0.87
LSR	33.9760	-118.2890	2.95	2.03
LST	34.0450	-118.2980	2.16	1.19
LSU	34.0670	-118.2480	1.73	0.86
LTH	34.0590	-118.2460	2.07	1.10
LUH	34.0620	-118.1980	1.69	2.75
LURA	34.1408	-118.1205	2.85	*
LVS	34.0050	-118.2790	2.13	1.92
LWD	33.8460	-118.0990	4.67	2.14
LWE	34.1150	-118.3800	0.63	0.56
LWS	34.0900	-118.4350	1.32	0.96
MBF	33.8870	-118.3890	2.19	1.30
MBS	34.0010	-118.4310	1.85	1.08
MCN	34.0870	-118.6930	0.61	0.69
MHI	34.0600	-118.2130	2.89	1.54
MSB	34.0690	-118.4420	1.12	0.80
MSM	34.0860	-118.4820	1.01	0.75
MTL	33.9900	-118.1140	1.77	1.43
MTW	34.2240	-118.0570	0.85	1.17
MUDD	34.1410	-118.1200	2.89	1.19
NBC	33.6230	-117.9310	2.59	1.93
NBI	33.6340	-117.9020	2.41	2.00
NHS	34.1380	-118.3590	2.12	1.14
NHW	34.1940	-118.4120	2.75	1.97
NIHB	33.9160	-118.0650	1.76	0.96
NIHN	33.9170	-118.0650	1.59	1.16
NOR	34.0600	-118.3167	2.36	1.57
NPB	33.6180	-117.8780	1.67	1.28
NRG	34.2090	-118.5170	3.41	2.18
NWKN	33.9170	-118.0670	1.54	1.37
NWKS	33.9150	-118.0670	2.42	1.29
OBG	34.0370	-118.1780	2.92	2.91
OCR	33.9360	-117.8840	1.03	2.24
OLI	34.0472	-118.2538	2.60	2.00
OLM	34.0500	-118.2700	2.72	2.06
OLV	34.0472	-118.2600	2.81	1.61
ORC	34.1000	-118.3400	1.21	1.31
ORG	33.7800	-117.8900	1.84	1.34
PAN	34.2220	-118.4420	3.46	3.50
PAS	34.1390	-118.1210	2.16	0.91
PASA	34.1707	-118.0795	2.06	1.50
PCD	34.3340	-118.3960	1.45	1.21
PCDA	34.3340	-118.3967	*	3.08
PDQ	33.9603	-118.4322	2.62	0.91
PDR	33.9603	-118.4322	1.38	0.74
PEL	34.0900	-118.3400	2.96	1.74
PELB	34.0903	-118.3400	2.64	1.52
PHL	34.0228	-118.2830	2.22	1.20

Station Code	Latitude	Longitude	Amplification Factor 0.5 to 1.5Hz	Amplification Factor 2.0 to 6.0Hz
PKC	34.2880	-118.3750	3.39	1.98
PMC	34.2510	-118.4200	2.71	2.47
PMN	34.0560	-117.7480	0.93	0.79
PSL	34.1490	-118.1710	0.82	0.94
PSM	34.1687	-118.0780	1.87	2.45
PSW	34.1360	-118.1270	1.55	1.42
PUR	34.0400	-118.4450	5.42	2.09
PVC	33.7460	-118.3960	0.88	0.70
PVE	33.8010	-118.3842	1.71	0.91
PVR	33.7720	-118.3190	3.69	1.83
RHE	33.7870	-118.3560	1.44	1.72
RIN	34.2810	-118.4790	*	1.75
ROB	34.0755	-118.3827	2.35	1.01
RPV	33.7400	-118.3340	1.52	0.90
RSE	34.1760	-118.3600	2.34	2.28
SBH	33.7570	-118.0840	2.62	2.45
SCC	34.0970	-118.4780	1.49	2.00
SCS1	34.3110	-118.4900	*	0.53
SCS2	34.3110	-118.4897	*	1.12
SCSE	34.2953	-118.4810	*	1.40
SFS	33.9440	-118.0870	2.23	2.25
SFY	34.2360	-118.4390	2.55	1.31
SGS	34.0920	-118.0930	2.54	1.59
SIX	34.0500	-118.2500	2.18	0.89
SMC	34.0050	-118.4850	1.91	1.06
SMI	34.2640	-118.6660	2.78	2.00
SMO	34.0110	-118.4900	3.57	2.14
SNM	34.1150	-118.1300	1.98	1.05
SNT	34.0972	-118.3312	2.22	1.10
SNV	34.2350	-118.3670	1.53	1.11
SOK	34.1540	-118.4650	2.70	1.76
SPP	33.7220	-118.3090	1.27	1.64
SRW	34.0280	-118.2230	2.91	1.20
SSA	34.2310	-118.7130	1.24	0.82
SSC	34.0470	-118.3550	2.10	1.45
SST	34.0972	-118.3293	2.47	1.49
SUN	34.2690	-118.3030	2.32	1.08
SVG	34.2210	-118.4220	2.85	1.80
SXH	34.0600	-118.3000	2.78	*
SYL	34.3060	-118.4370	2.30	1.74
SYLM	34.3260	-118.4440	*	1.93
TMI	33.7360	-118.2690	2.29	1.86
TOP	34.0840	-118.5990	0.79	1.18
TOR	33.8230	-118.3560	1.87	1.04
TUS	33.7278	-117.8245	1.83	2.30
UCA	34.0600	-118.4200	1.53	0.88
UCF	34.0600	-118.4100	1.08	1.37
UCLA	34.0680	-118.4390	2.11	1.48
VCS	34.0040	-118.2300	2.43	1.11
VCSS	34.0037	-118.2303	2.22	1.30

Station Code	Latitude	Longitude	Amplification Factor 0.5 to 1.5Hz	Amplification Factor 2.0 to 6.0Hz
VER	34.0225	-118.2925	1.21	0.86
VLA	34.0630	-118.4630	2.22	1.13
VLO	33.7770	-118.1150	1.74	1.37
VLOB	33.7767	-118.1147	1.79	1.18
VNA	34.1600	-118.4800	2.87	1.19
VNO	34.2000	-118.4600	2.70	0.86
VNT	34.1522	-118.4552	2.18	2.11
VNY	34.2210	-118.4710	3.35	1.89
VPS	33.8210	-117.8180	0.99	0.97
VRN	34.0000	-118.2000	3.05	1.92
VSP	34.2490	-118.4780	4.15	1.69
VWD	34.0500	-118.4490	2.23	1.25
VWDN	34.0540	-118.4530	2.38	1.53
VWDS	34.0500	-118.4480	2.66	1.80
WBV	34.0625	-118.3583	2.77	0.76
WCVA	34.0642	-117.9522	1.83	1.09
WHA	34.0153	-118.0287	1.21	0.84
WHB	33.9760	-118.0360	2.11	1.96
WIS	34.0520	-118.2630	1.52	0.84
WLB	34.0617	-118.3017	2.67	1.51
WLH	34.0600	-118.3000	2.41	1.24
WLR	34.0600	-118.2950	2.22	1.18
WLS	34.0600	-118.2800	2.32	0.83
WND	34.0200	-118.0530	1.53	1.83
WNDU	34.0250	-118.0530	1.57	1.24
WPB	34.0600	-118.2500	2.23	1.11
WTW	34.3600	-117.6300	0.77	1.24
WWS	34.3690	-117.6580	1.32	2.00

Table 3.--*Average amplification*

Average amplification factors* Short Period (2.0 to 6.0 Hz) (1)	SD(1)	(2)	Intermediate Period (0.5 to 1.5 Hz) (1)	SD(1)	(2)	Average *S-wave* velocity (m/s)	Surficial geologic unit
1.0	0.09	1.0	1.0	0.13	1.0	710	Mesozoic and pre-Mesozoic crystalline and metasedimentary rocks.
1.8	0.12	1.2	1.8	0.17	1.5	407	Tertiary and pre-Tertiary sedimentary rocks.
1.6	0.12	1.3	2.2	0.10	1.5	368	Pleistocene alluvium
1.9	0.11	1.3	2.2	0.16	1.7	321	Holocene alluvium

(1) Average amplification for all sites within the indicated surficial geologic unit.

(2) Amplification from regression relationship between *S-wave* velocity and site response using average *S-wave* velocities for the indicated geologic unit.

SD(1) Standard deviation for average (1).

*Normalized to 1.0 for Mesozoic units. (pre-normalization values for Mesozoic units: 1.4, short period (1); 1.9, short period (2); 1.0, intermediate period (1); 1.3, intermediate period (2))