



Background Document

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PACT Beta Test Overview: Example Buildings, Sites, and Ground Motions

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Background Documentation

FEMA P-58 Background Documents are a series of reports documenting the technical background and source information for key aspects of the FEMA P-58 methodology and its implementation. These reports were developed over the course of the 10-year ATC-58/ATC-58-1 Projects funded under FEMA Contracts EMW-2001-RP-0056 and HSFEHQ-06-D-1105.

Background Documents were developed by consultants, serving at various levels within the project hierarchy, reporting the results of: (1) decisions on technical development protocols; (2) focused studies on the development of key aspects of the methodology; (3) documentation of recommended procedures; and (4) collection of available data for the development of structural and nonstructural fragilities. They were initially intended to serve as a record of the technical state-of-knowledge at the time they were produced, and as resources for the development of the eventual project reports. As such, they represent a snapshot in time, and may, or may not, match the technical content, recommended procedures, or data incorporated into the final methodology and its implementation.

This Background Document is intended for the purpose of providing supplemental knowledge to users of the FEMA P-58 methodology. Information contained herein has not been independently verified for accuracy as a stand-alone document, and may have been superseded in its final implementation within the methodology. Users of information in this document assume all liability arising from such use.

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1.1 Overview of Example Buildings, Sites, and Ground Motions Selected for Beta Testing

1.1.1 Introduction and Overview

For the purpose of Beta testing the ATC-58 Methodology and the PACT Beta version software, three buildings at three sites were selected. This report briefly summarizes the buildings, the site information, and the ground motions selected for use in Beta testing.

1.1.2 Overview of Buildings, Sites, and Ground Motion Hazard Analyses

Table 1-1 summarizes the three buildings, and their respective sites, that were used in the Beta testing examples. This table shows the building description and occupancy as well as the site description, which includes seismic design category, site class and soil shear wave velocity, and the latitude and longitude coordinates of the site.

Table 1-1 Summary of Buildings and Sites

Building				Site Information					
Index	Description	Fund. Period, T_1 [s]	Occupancy	City	Seismic Design Category	Site Class	$V_{s,30}$ [m/s]	Latitude	Long.
A	8-story steel perimeter SMF	3.55	Laboratory	Sacramento	D_{min}	C	537	38.582	-121.494
B	8-story RC perimeter SMF	1.13	Office	Los Angeles	D_{max}	D	259	33.996	-118.162
C	2-story masonry wall	0.13	Residential	Los Angeles	D_{max}	D	537	33.996	-118.162

Site hazard was evaluated for the eight intensity levels suggested by the ATC-58 Methodology. These intensity levels were computed using an approximate 2% in 50 year ground motion intensity (based on the seismic design category of the site and the approximate location) and an approximate estimate of the median collapse capacity (based on previous research using these three buildings). For each of the eight intensity levels, the ground motion hazard analyses and hazard deaggregation analyses were completed by Nico Luco of the US Geological Survey (USGS). Table 1-2 through Table 1-4 present the ground motion hazard analysis and deaggregation analysis results for these three sites. The analyses were based on the fundamental period of each building (shown previously in Table 1-1) and the results include the mean annual frequency of exceedance (MAF) of each intensity level, as well as the dominant contributing magnitude (M), site-to-

source distance (R), and epsilon value (ϵ) for each intensity level. The MAF is used as direct input into PACT and the M/R/ ϵ values are used to inform the ground motion selection and scaling.

Table 1-2 Summary of Hazard and Deaggregation Analyses for Building A (8-story steel SMF)

Intensity Level	Sa (T_1)	MAF	Mean M	Mean R	Mean ϵ
Sa_min	0.014	2.04E-02	--	--	--
Intensity 1	0.022	9.22E-03	7.1	113	1.1
Intensity 2	0.038	2.65E-03	7.4	120	1.5
Intensity 3	0.055	9.51E-04	7.5	128	1.7
Intensity 4	0.071	4.21E-04	7.7	135	1.9
Intensity 5	0.087	2.09E-04	7.8	142	2.0
Intensity 6	0.103	1.08E-04	7.9	149	2.1
Intensity 7	0.120	5.83E-05	8.0	156	2.2
Intensity 8	0.136	3.25E-05	8.1	161	2.3
Sa_max	0.144	2.47E-05	--	--	--

Table 1-3 Summary of Hazard and Deaggregation Analyses for Building B (4-story RC SMF)

Intensity Level	Sa (T_1)	MAF	Mean M	Mean R	Mean ϵ
Sa_min	0.04	1.13E-01	--	--	--
Intensity 1	0.16	2.52E-02	6.7	80	1.4
Intensity 2	0.39	4.71E-03	7	40	1.3
Intensity 3	0.61	1.56E-03	6.9	26	1.4
Intensity 4	0.84	6.56E-04	6.9	18	1.5
Intensity 5	1.07	3.23E-04	6.9	13	1.6
Intensity 6	1.30	1.71E-04	6.8	10	1.7
Intensity 7	1.53	9.94E-05	6.8	8	1.7
Intensity 8	1.76	5.74E-05	6.8	7	1.8
Sa_max	1.87	4.47E-05	--	--	--

1.1.3 Approach Taken for Selecting and Scaling Ground Motion Sets for Beta Testing

A set of ground motions was selected for each of the eight ground motion intensity levels. A total of 20 ground motions were selected for each intensity level, to facilitate sensitivity studies that look at using more than the 11 ground motions suggested in the ATC-58 Methodology. All ground

motions were selected from the PEER-NGA database (PEER 2010), which currently includes over 3,500 records. The ground motions were selected based on the following considerations:

Table 1-4 Summary of Hazard and Deaggregation Analyses for Building C (2-story masonry wall)

Intensity Level	Sa (T ₁)	MAF	Mean M	Mean R	Mean ϵ
Sa_min	0.05	1.53E-01	--	--	--
Intensity 1	0.19	3.59E-02	6.3	70	1.5
Intensity 2	0.47	8.56E-03	6.6	31	1
Intensity 3	0.75	3.50E-03	6.6	20	1
Intensity 4	1.02	1.77E-03	6.6	14	1.1
Intensity 5	1.30	1.00E-03	6.6	11	1.1
Intensity 6	1.58	6.05E-04	6.6	10	1.2
Intensity 7	1.86	3.81E-04	6.6	8	1.3
Intensity 8	2.14	2.49E-04	6.6	8	1.4
Sa_max	2.27	2.05E-04	--	--	--

Ground motions were selected to match the Conditional Mean Spectrum (CMS) (Baker 2011) which is one of the two allowable options in the ATC-58 Methodology. The CMS was matched on average and the variability in the acceleration spectra was not considered in the ground motion selection and scaling.

The motions were selected to match the CMS over the period range of interest ($0.2T_1$ to $2.5T_1$), as required in the ATC-58 Methodology.

To correct for any mismatch between the CMS and the target $Sa(T_1)$ value computed from hazard analysis, the selected record set is scaled such that the median $Sa(T_1)$ value matches the target $Sa(T_1)$ value.

The candidate motions were ranked based on the goodness-of-fit in the period range of interest (the sum of the squared errors between the ground motion Sa values and the target CMS Sa values). For each ground motion set created in the following sensitivity studies (e.g. set of 20, 11, or even 3 motions), the ground motions that best-fit the CMS were selected.

Before selecting the motions that best-fit the CMS, some of the ground motions in the PEER-NGA database were removed to ensure reasonable consistency between the selected ground motions and the site and source conditions. Table 1-5 summarizes both these checks and some other ground motion selection and scaling considerations (e.g. maximum allowable scale factor). For each building, the table also reports the number of ground

motions from the PEER-NGA database which pass the checks and are considered to be candidate records for selection (but this number does not consider the minimum scale factor).

All selections were based on the 5% damped geometric mean acceleration response spectral values.

Table 1-5 Summary of Ground Motion Selection Criteria for Each of the Three Example Buildings and Sites

Ground Motion Selection Parameter	Building		
	A	B	C
Earthquake magnitude	--	--	--
Targets	7.1-8.1	6.7-7.0	6.3-6.6
Minimum allowable	6.5	6.0	5.5
Maximum allowable	Inf.	Inf.	Inf.
Site-source distance [km]	--	--	--
Targets	131-161	7-80	8-70
Minimum allowable	20	0	0
Maximum allowable	Inf.	150	150
Vs30 [m/s]	--	--	--
Target	537	259	537
Minimum allowable	182	182	182
Maximum allowable	1524	1524	1524
Period range for matching CMS [s]	--	--	--
T_1	3.55	1.13	0.13
Minimum period ($0.2T_1$)	0.71	0.23	0.03
Maximum period ($2.5T_1$)	8.88	2.83	0.33
Max. usable frequency of record [Hz]	0.11	0.35	3.08
Faulting mechanism	Not constrained in selection.		
Maximum allowable scale factor	4	4	4
Numbers of motions available:	513	1529	2602

1.1.4 Documentation of Ground Motion Sets for Building A - 8-Story Steel Special Moment Frame Building

Ground motion sets were selected for Building A according to the requirements of Section 1.1.3. Table 1-6 summarizes the selected ground motions and scale factors for the 20 selected ground motions for each of the eight intensity levels. The ground motions are listed in ranked order (with respect to the goodness-of-fit, as described in Section 1.1.3). The first 11 records are used for the baseline PACT analyses; the full set of 20 records is only used in the sensitivity studies to quantify the effects of the numbers of ground motions used for the assessment.

**Table 1-6 Documentation of Ground Motion Sets Selected for Building A
(8-story steel SMF)**

Intensity Level 1			Intensity Level 2			Intensity Level 3			Intensity Level 4		
Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor
1	1243	0.42	1	1215	0.80	1	1194	0.31	1	1194	0.39
2	1287	0.85	2	1194	0.21	2	1397	0.95	2	1500	0.46
3	1383	0.81	3	1382	1.48	3	1215	1.14	3	1189	0.98
4	1215	0.46	4	1397	0.67	4	1534	0.33	4	1360	2.22
5	1237	0.34	5	1823	1.23	5	1360	1.71	5	1397	1.23
6	1359	0.73	6	1243	0.75	6	1226	0.81	6	1356	1.30
7	1382	0.86	7	1534	0.23	7	1243	1.05	7	851	1.47
8	1223	0.52	8	1438	1.67	8	1223	1.28	8	1185	0.92
9	1823	0.71	9	1442	1.20	9	1237	0.83	9	1200	0.95
10	1224	0.58	10	1237	0.59	10	1189	0.75	10	1534	0.43
11	1155	0.34	11	1223	0.89	11	1500	0.36	11	1151	4.32
12	1438	0.97	12	1359	1.27	12	851	1.14	12	1442	2.23
13	1435	0.39	13	1226	0.57	13	1453	1.01	13	1226	1.06
14	1439	0.88	14	1287	1.48	14	1356	1.01	14	1272	3.23
15	1023	1.31	15	1453	0.71	15	838	0.76	15	1533	0.37
16	1299	1.25	16	1360	1.20	16	1199	0.67	16	1210	2.64
17	1397	0.39	17	1023	2.27	17	1213	0.71	17	1382	2.73
18	1534	0.13	18	1383	1.41	18	1241	1.52	18	1215	1.49
19	1430	0.38	19	1224	1.00	19	1533	0.29	19	1823	2.26
20	1763	1.86	20	1763	3.21	20	1224	1.43	20	1438	3.09

Intensity Level 5			Intensity Level 6			Intensity Level 7			Intensity Level 8		
Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor
1	1500	0.57	1	1500	0.67	1	1500	0.77	1	1500	0.88
2	1189	1.20	2	1189	1.42	2	1189	1.65	2	1189	1.87
3	1194	0.48	3	1185	1.35	3	1185	1.55	3	1185	1.77
4	1356	1.60	4	1356	1.90	4	1356	2.20	4	1200	1.84
5	1360	2.73	5	1200	1.40	5	1200	1.61	5	1356	2.50
6	1185	1.14	6	851	2.15	6	851	2.49	6	851	2.84
7	851	1.82	7	1360	3.22	7	1360	3.74	7	1790	4.39
8	1200	1.18	8	1194	0.58	8	1194	0.68	8	1544	1.49
9	1397	1.52	9	1170	4.83	9	1210	4.44	9	1360	4.25
10	1210	3.24	10	1210	3.84	10	1533	0.62	10	1552	1.50
11	1533	0.45	11	1533	0.54	11	1790	3.86	11	1533	0.71
12	1534	0.53	12	1397	1.80	12	1552	1.32	12	1194	0.77
13	1442	2.74	13	1272	4.71	13	1544	1.32	13	1482	0.73
14	1272	3.96	14	1542	0.55	14	1542	0.63	14	1532	1.10
15	1170	4.07	15	1442	3.25	15	1397	2.09	15	1477	0.75
16	1226	1.30	16	1534	0.62	16	1532	0.97	16	1542	0.72
17	1542	0.46	17	1213	1.35	17	1213	1.57	17	1826	1.73
18	1213	1.14	18	1226	1.53	18	1442	3.76	18	1238	0.80
19	838	1.21	19	1552	1.14	19	1482	0.65	19	1397	2.36
20	1382	3.36	20	838	1.43	20	1534	0.72	20	1213	1.78

1.1.5 Documentation of Ground Motion Sets for Building B - 4-Story Reinforced Concrete Special Moment Frame Building

Ground motion sets were selected for Building B according to the requirements of Section 1.1.3. Table 1-7 summarizes the selected ground

motions and scale factors for the 20 selected ground motions for each of the eight intensity levels.

Table 1-7 Documentation of Ground Motion Sets Selected for Building B (4-story RC SMF)

Int. Level 1			Int. Level 2			Int. Level 3			Int. Level 4		
Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor
1	1063	0.14	1	1063	0.35	1	1063	0.56	1	1063	0.78
2	3268	0.68	2	1504	0.53	2	1504	0.85	2	1504	1.16
3	3253	3.30	3	1810	2.24	3	1810	3.55	3	1494	2.67
4	3456	2.69	4	1494	1.23	4	1268	5.03	4	334	3.02
5	796	0.80	5	1013	0.65	5	1494	1.96	5	1810	4.87
6	1268	1.29	6	722	1.57	6	1489	1.78	6	722	3.43
7	3247	4.66	7	1827	4.43	7	334	2.21	7	1268	6.88
8	1489	0.46	8	1546	1.08	8	1546	1.71	8	1013	1.44
9	289	0.57	9	1268	3.16	9	1827	7.02	9	1546	2.36
10	3427	4.94	10	1489	1.13	10	1013	1.04	10	1489	2.44
11	1009	0.60	11	334	1.38	11	3268	2.63	11	1178	2.84
12	719	1.10	12	1178	1.31	12	722	2.51	12	3268	3.61
13	988	0.55	13	3316	3.19	13	1009	2.35	13	1155	3.78
14	1810	0.91	14	1321	3.30	14	988	2.15	14	289	3.09
15	850	0.76	15	988	1.35	15	1178	2.07	15	1092	5.77
16	2605	3.76	16	1009	1.48	16	1321	5.24	16	756	4.99
17	2728	2.81	17	1057	2.36	17	289	2.24	17	1108	1.65
18	1321	1.35	18	1182	0.67	18	3316	5.08	18	1009	3.23
19	728	0.46	19	3268	1.66	19	1182	1.08	19	1182	1.46
20	1375	2.90	20	289	1.41	20	719	4.29	20	988	2.95

Int. Level 5			Int. Level 6			Int. Level 7			Int. Level 8		
Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor	Rank	PEER-NGA ID	Scale Factor
1	1504	1.49	1	1063	1.19	1	1494	4.86	1	1494	5.58
2	1063	0.99	2	1504	1.79	2	334	5.46	2	334	6.27
3	1494	3.40	3	334	4.64	3	1504	2.11	3	1504	2.44
4	334	3.83	4	1494	4.12	4	1063	1.41	4	777	3.32
5	722	4.36	5	722	5.28	5	722	6.21	5	1063	1.61
6	1810	6.19	6	1155	5.83	6	1300	6.73	6	1108	3.45
7	1155	4.82	7	1108	2.55	7	1108	3.00	7	2461	6.13
8	1013	1.82	8	1300	5.71	8	777	2.88	8	285	6.44
9	756	6.34	9	2461	4.54	9	1421	6.69	9	900	4.95
10	1108	2.10	10	1278	6.67	10	2461	5.34	10	803	2.80
11	1546	2.99	11	777	2.45	11	285	5.61	11	1013	2.99
12	1421	4.69	12	1421	5.70	12	1013	2.59	12	1503	1.55
13	1178	3.61	13	289	4.76	13	900	4.29	13	289	6.43
14	1300	4.72	14	900	3.65	14	1546	4.27	14	1178	5.91
15	2461	3.75	15	1013	2.21	15	1178	5.15	15	1546	4.91
16	289	3.91	16	1546	3.63	16	289	5.59	16	1101	3.08
17	1489	3.10	17	1178	4.37	17	2650	6.28	17	1541	4.66
18	285	3.93	18	285	4.76	18	1182	2.66	18	1182	3.06
19	900	3.02	19	3265	5.98	19	1227	4.94	19	723	2.46
20	1278	5.49	20	3268	5.56	20	3268	6.54	20	1227	5.69

The ground motions are listed in ranked order (with respect to the goodness-of-fit, as described in Section 1.1.3). For Building B, some of the ground

motions of rank 12-20 were inadvertently used for the baseline analyses; this occurred when there were collapse cases in the analysis. When collapse cases occur at a given ground motion intensity level, there will naturally be fewer than 11 demand vectors used for the PACT analyses (e.g. if three cause collapse, then there would be only eight demand vectors used in the PACT analysis). Even so, in the example analysis for Building B, 11 demand vectors were still inadvertently used for intensity levels where some collapse cases occurred; fewer than 11 demand vectors were only utilized for the high intensity levels where more than nine of the 20 ground motions caused collapse. This is documented here only for clarity and repeatability of the Building B example; in baseline PACT assessments, only 11 ground motions will be available for analysis and this approach will not be taken.

1.1.6 Documentation of Ground Motion Sets for Building C - 2-Story Reinforced Masonry Building

Similarly to the previous building, ground motion sets were selected for Building B according to the requirements of Section 1.1.3. Table 1-8 summarizes the selected ground motions and scale factors for the 20 selected ground motions for each of the eight intensity levels. The ground motions are listed in ranked order (with respect to the goodness-of-fit, as described in Section 1.1.3).

**Table 1-8 Documentation of Ground Motion Sets Selected for Building C
(2-story masonry wall)**

Int. Level 1			Int. Level 2			Int. Level 3			Int. Level 4		
Rank	PEER- NGA ID	Scale Factor	Rank	PEER- NGA ID	Scale Factor	Rank	PEER- NGA ID	Scale Factor	Rank	PEER- NGA ID	Scale Factor
1	679	0.50	1	1028	2.68	1	1028	4.29	1	3266	4.53
2	2113	1.04	2	2113	2.55	2	3266	3.30	2	1011	3.00
3	1011	0.56	3	28	3.33	3	1011	2.19	3	679	2.67
4	1028	1.09	4	815	4.38	4	2113	4.08	4	1642	1.69
5	28	1.35	5	1011	1.37	5	679	1.95	5	668	2.96
6	1642	0.31	6	1642	0.78	6	1642	1.23	6	718	2.57
7	3266	0.84	7	2388	4.75	7	3219	4.28	7	633	2.69
8	2210	2.07	8	3266	2.06	8	1627	3.56	8	3221	2.88
9	815	1.77	9	1077	0.38	9	668	2.16	9	1016	2.24
10	456	0.47	10	679	1.22	10	718	1.88	10	456	2.49
11	668	0.55	11	456	1.13	11	456	1.82	11	68	1.81
12	3221	0.54	12	1161	1.05	12	633	1.96	12	1633	0.63
13	2388	1.93	13	611	0.70	13	3221	2.11	13	2943	2.19
14	3219	1.09	14	357	1.73	14	2948	4.20	14	1161	2.31
15	1627	0.90	15	1627	2.23	15	1016	1.64	15	611	1.55
16	2892	3.11	16	554	2.61	16	1161	1.69	16	1077	0.82
17	1016	0.41	17	3219	2.68	17	2940	4.85	17	139	1.16
18	2948	1.07	18	621	1.93	18	611	1.13	18	232	1.30
19	633	0.50	19	1832	3.07	19	68	1.33	19	954	1.80
20	2413	2.99	20	1598	3.90	20	1633	0.46	20	3212	3.31

Int. Level 5			Int. Level 6			Int. Level 7			Int. Level 8		
Rank	PEER- NGA ID	Scale Factor	Rank	PEER- NGA ID	Scale Factor	Rank	PEER- NGA ID	Scale Factor	Rank	PEER- NGA ID	Scale Factor
1	1011	3.83	1	1011	4.64	1	1011	5.45	1	679	5.56
2	679	3.39	2	679	4.12	2	1642	3.06	2	1642	3.52
3	1642	2.15	3	1642	2.60	3	679	4.84	3	456	5.20
4	668	3.77	4	668	4.57	4	668	5.37	4	68	3.79
5	456	3.17	5	456	3.86	5	1077	1.49	5	1016	4.69
6	718	3.28	6	718	3.98	6	456	4.52	6	718	5.38
7	1077	1.05	7	3221	4.47	7	68	3.29	7	1077	1.73
8	68	2.31	8	1016	3.47	8	514	3.25	8	633	5.62
9	1016	2.85	9	68	2.80	9	611	2.81	9	514	3.74
10	3221	3.68	10	633	4.16	10	1161	4.19	10	611	3.23
11	633	3.43	11	1077	1.28	11	3221	5.24	11	1161	4.82
12	1161	2.94	12	1161	3.56	12	1016	4.07	12	1633	1.32
13	611	1.97	13	611	2.39	13	595	4.05	13	595	4.67
14	357	4.81	14	514	2.77	14	718	4.69	14	232	2.72
15	514	2.29	15	1633	0.97	15	633	4.90	15	1487	2.59
16	1633	0.81	16	2943	3.38	16	1487	2.24	16	2943	4.57
17	2943	2.79	17	139	1.78	17	2943	3.97	17	139	2.40
18	139	1.46	18	595	3.45	18	1633	1.15	18	548	4.97
19	595	2.84	19	232	2.00	19	548	4.33	19	954	3.76
20	232	1.66	20	1487	1.91	20	139	2.09	20	317	4.03