BellBendCOLPEm Resource

From: Sgarro, Rocco R [rrsgarro@pplweb.com]
Sent: Wednesday, August 26, 2009 1:56 PM
To: Canova, Michael
Cc: 'j freels'; Kirkwood, Jon K; Woodring, Kathryn L; 'Yox, Michael J'
Subject: Response to RAI Set 37
Attachments: BNP-2009-244.pdf

Mike,

Attached please find an advance copy of our response to RAI set 37 for your use.

Please advise if you have any questions.

Rocky

R. R. Sgarro
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August 26, 2009

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Washington, DC 20555-0001

BELL BEND NUCLEAR POWER PLANT
RESPONSE TO RAI No. 37 AND
SCHEDULE INFORMATION
BNP-2009-244 Docket No. 52-039

References: 1) M. Canova (NRC) to R. Sgarro (PPL Bell Bend, LLC), Bell Bend COLA – Request for Information No. 37 (RAI No. 37) – SEB1 -2659, 2660, 2661, e-mail dated July 27, 2009

The purpose of this letter is to respond to the request for additional information (RAI) identified in the referenced NRC correspondence to PPL Bell Bend, LLC (PPL). This RAI addresses Seismic System Analysis, Seismic Subsystem Analysis, and Seismic Design Parameters as discussed in Chapter 2 of the Final Safety Analysis Report (FSAR) and submitted in Part 2 of the Bell Bend Nuclear Power Plant Combined License Application (COLA).

The enclosure provides our response to RAI No. 37 questions, including schedule information relating to those questions which require additional time for a response. This RAI response includes COLA text changes which will be incorporated into a future revision of the COLA.

The future COLA update represents a new regulatory commitment.

If you have any questions, please contact the undersigned at 570.802.8102.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on August 26, 2009

Respectfully,

Rocco R Sgarro

Rocco R. Sgarro

RRS/kw

Enclosure: As stated

cc: (w/o Enclosures)

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Enclosure 1

Response to NRC Request for Additional Information No. 37
Bell Bend Nuclear Power Plant

03.07.01-1

The Final Safety Analysis Report (FSAR) for the Bell Bend Nuclear Power Plant (BBNPP) states that the Ground Motion Response Spectra (GMRS) for the BBNPP site does not fall within that postulated in the U.S. EPR design certification (DC) application. To address this, in the BBNPP FSAR Section 3.7.1.1.1 (Design Ground Motion Response Spectra) on page 3-33, it states that in addition to the Certified Seismic Design Response Spectra (CSDRS) anchored at 0.30g peak ground acceleration (PGA) for the generic soil profiles defined in the U.S. EPR FSAR, the design of the BBNPP shall consider the GMRS as a design motion in combination with the site specific soil profiles.

1) What is the meaning of the phrase "shall consider" and how will the GMRS discussed in BBNPP FSAR Section 3.7.1 be used in the design of the BBNPP? In your response, please address both U.S EPR and site-specific seismic Category I structures, systems and components (SSCs).
2) On page 3-33 it also states that the horizontal Safe Shutdown Earthquake (SSE) for the Bell Bend site is defined as the envelope of the GMRS and the 0.1g European Utility Requirements (EUR) based CSDRS curves. If this is the horizontal SSE, explain why it is not used as the basis for the confirmatory analysis of the Nuclear Island (NI) Common Basemat structures, Emergency Power Generating Buildings (EPGB), Essential Service Water Buildings (ESWB), and site-specific seismic Category I structures at the Bell Bend site.

Response

A response to this question will be provided by 2/17/2010.

03.07.01-2

In FSAR Section 3.7.1.1 (Design Ground Motion) on page 3-31 it states the BBNPP site specific reactor coolant system (RCS) seismic loads are confirmed to be within the U.S. EPR Design Certification RCS seismic loads envelope. The applicant is requested to provide the specific steps that were used to develop the loads for this comparison and provide the results of the comparison for the locations identified on page 3-31 of the FSAR. Indicate in your response whether the load comparison was done with the results of the simplified RCS model included in the NI common basemat structures model or if the load comparison was done with the detailed seismic model of the RCS. Also indicate if a load comparison was done between the BBNPP simplified RCS model results and the BBNPP detailed RCS model results and whether these results are comparable. Provide examples of this comparison in your response. If such a comparison was not done provide justification for not doing so.

Response

A response to this question will be provided by 10/21/2009.

03.07.01-3

FSAR Section 3.7.1.1.1 (Design Ground Motion Response Spectra), starting on page 3-35, describes the site specific analysis for the NI Common Basemat Structures. However, details relating to the development of seismic design parameters were not provided. With regard to this analysis, the applicant is requested to provide the following information:

1) A description of the development of the ground motion input time histories that were used in the analysis and how they meet SRP Acceptance Criteria 1.B of SRP Section 3.7.1.

Response

The ground motion input time histories meet the requirement prescribed in Approach 2 of the Acceptance Criteria 1.B of SRP Section 3.7.1. The time increment is 0.005 seconds and a Nyquist frequency of 100 Hz (1/(2*0.005)) equal to the maximum frequency of interest. The total duration is greater than the minimum of 20 seconds. The 5 percent damped response spectrum of the time history calculated at 100 points per frequency decade, uniformly spaced over the log frequency scale from 0.1 Hz to 100 Hz, do not fall more than 10 percent below the target response spectrum and do not exceed the target response spectrum by more than 30 percent and no more than nine adjacent frequency points fall below the target response spectrum.

2) A comparison of the response spectra of the input time histories to the GMRS. Demonstrate how the response spectra of the input time histories meet Approach 1 or Approach 2 of NUREG-0800, Standard Review Plan (SRP) Acceptance Criteria 1.B of SRP Section 3.7.1.

Response

Figures 1-1 through 1-3 show the comparison of the 5 percent damped response spectrum of the input time histories, and the 90 percent, 100 percent, and 130 percent target response spectra. This comparison demonstrates that the 5 percent damped response spectra of the time histories does not drop more than 10 percent below the target response spectra, and does not exceed the target response spectra by more than 30 percent which is consistent with NUREG-0800 Acceptance Criteria 1.B..

Table 1-1 and Table 1-2 show the comparison of the response spectra of the input time history and the target response spectra for the horizontal and vertical direction. No more than nine adjacent frequency points fall below the target response spectra.

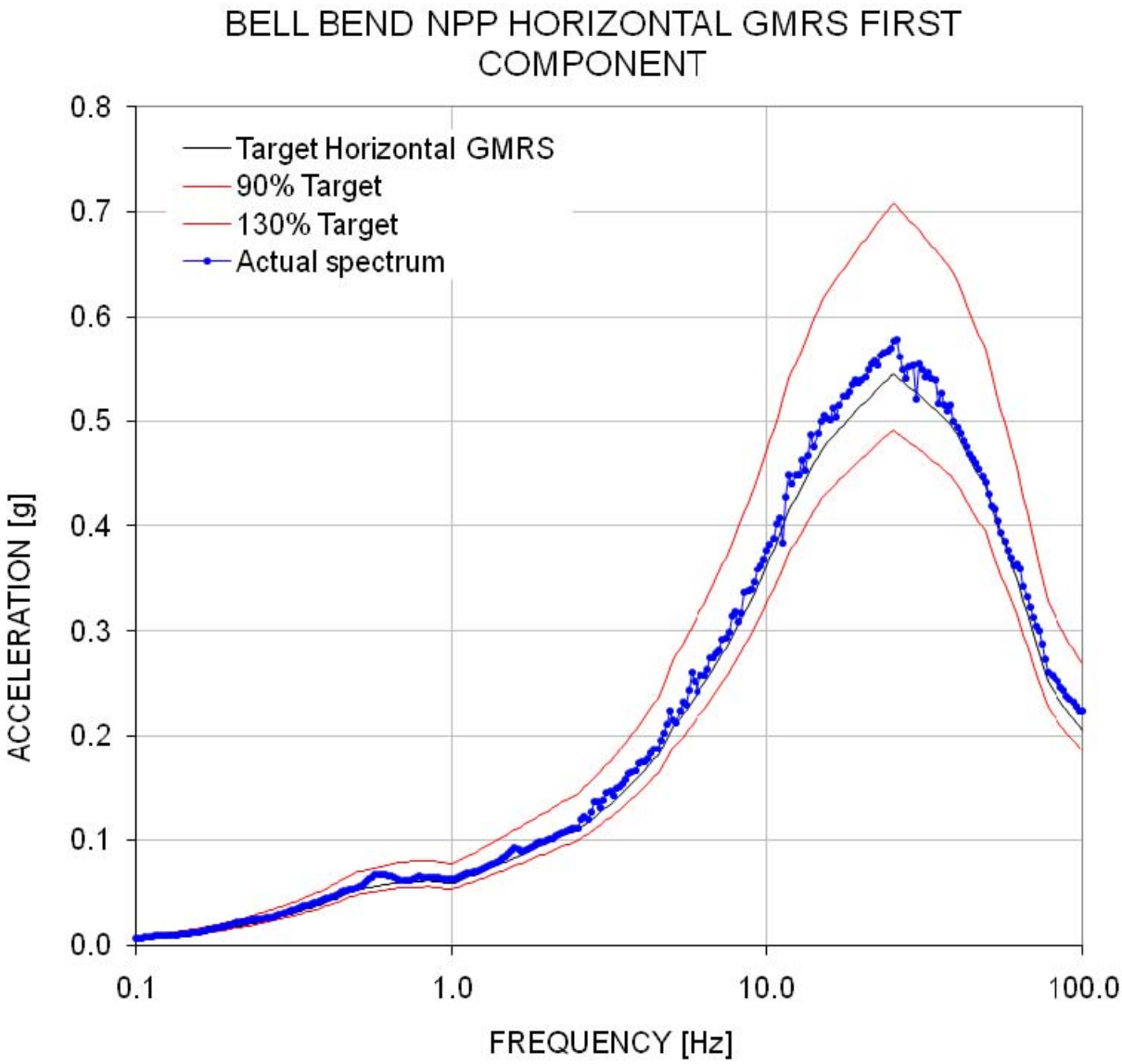


FIGURE 1-1

RESPONSE SPECTRA COMPUTED FROM THE TIME HISTORY AND TARGET GMRS IN ONE OF THE HORIZONTAL DIRECTIONS

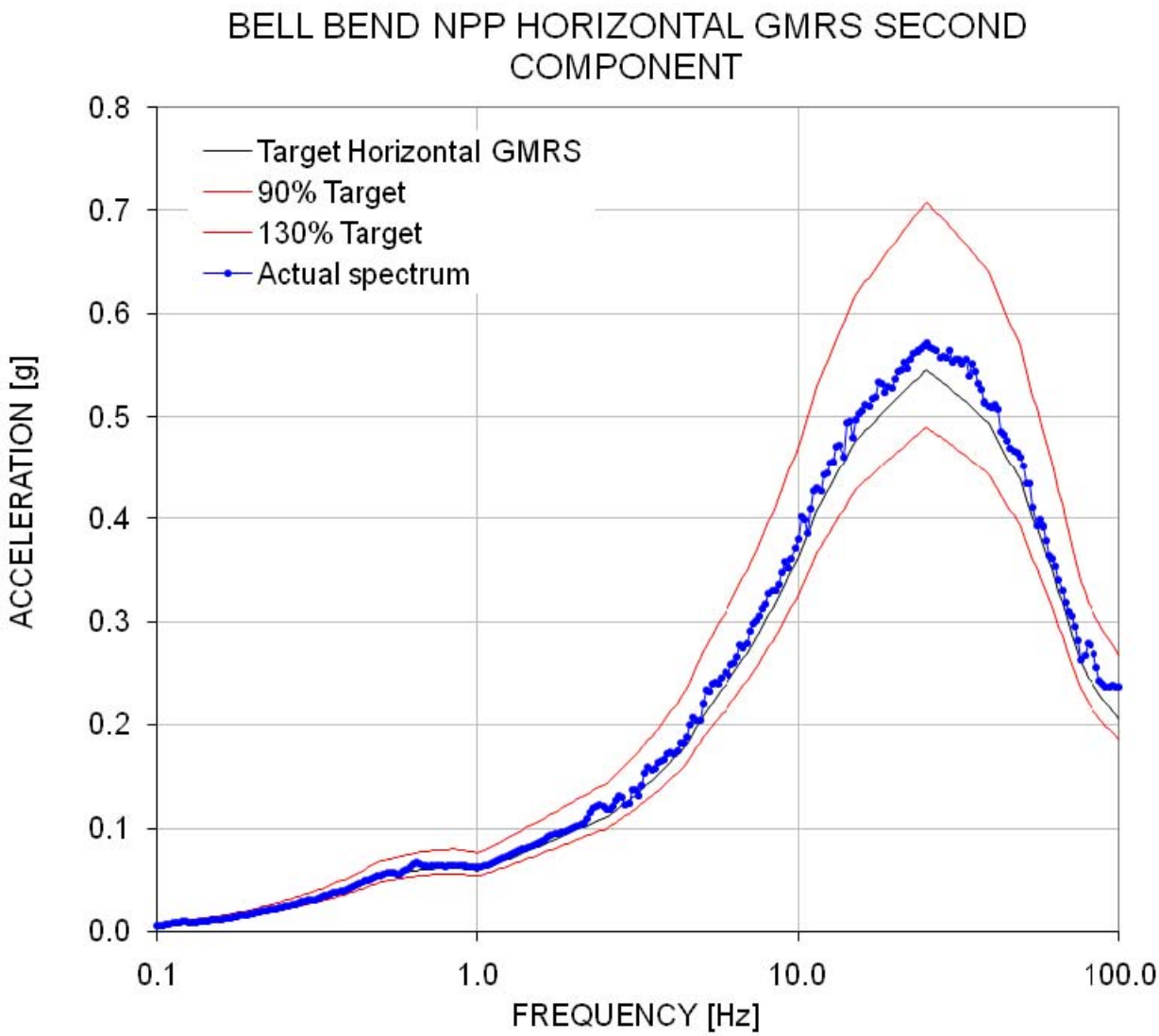


FIGURE 1-2

RESPONSE SPECTRA COMPUTED FROM THE TIME HISTORY AND TARGET GMRS IN ONE OF THE HORIZONTAL DIRECTIONS

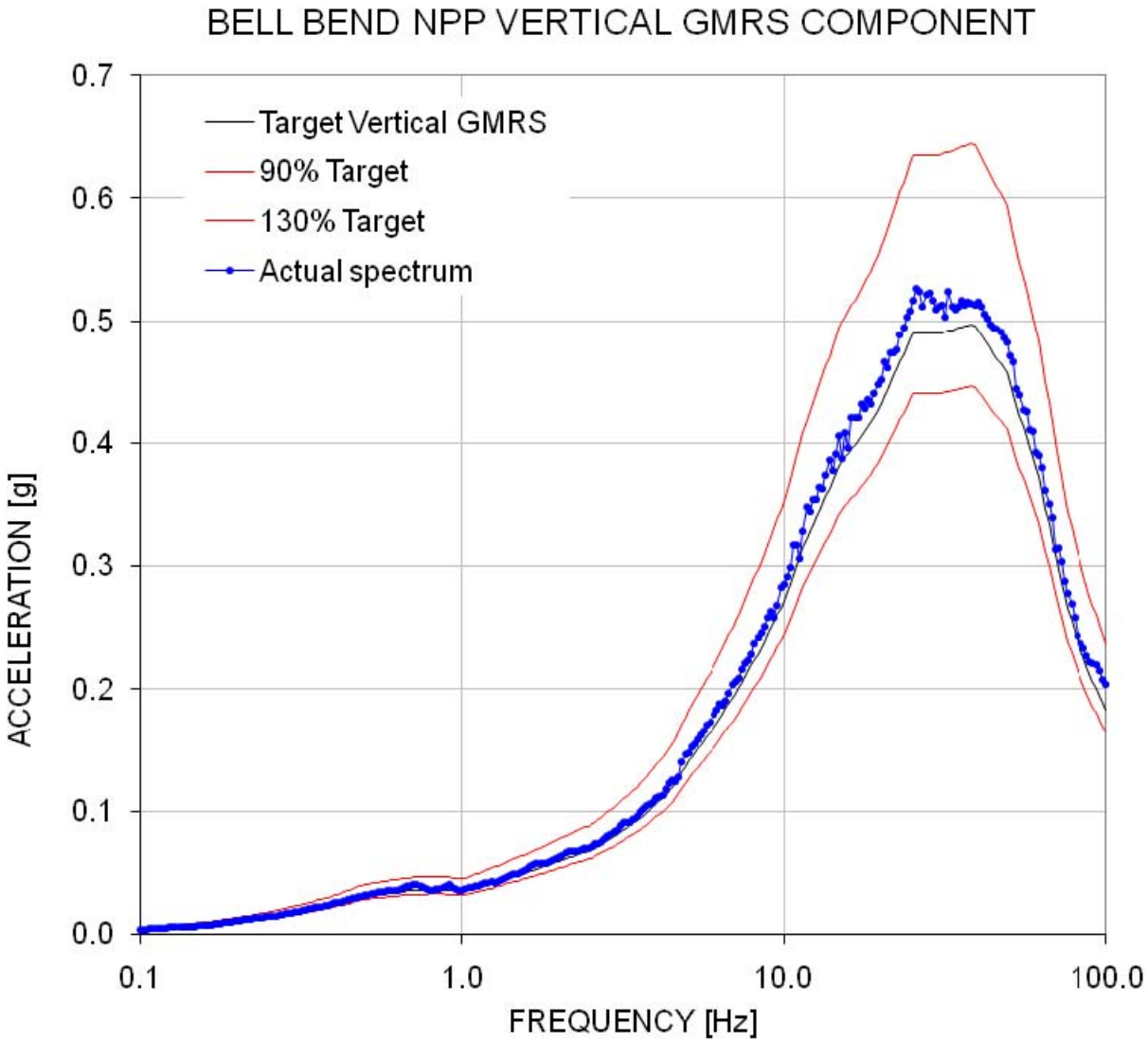


FIGURE 1-3

RESPONSE SPECTRA COMPUTED FROM THE TIME HISTORY AND TARGET GMRS IN THE VERTICAL DIRECTIONS

TABLE 1-1

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE HORIZONTAL DIRECTION

FREQUENCY (HZ)	HORIZONTAL FIRS ACCELERATION (G)	FIRST HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)	SECOND HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0056	0.0059	5.54	0.0059	5.71
0.102	0.0058	0.0061	5.50	0.0062	6.53
0.105	0.0061	0.0064	6.12	0.0065	7.27
0.107	0.0063	0.0067	6.35	0.0069	8.73
0.110	0.0065	0.0069	5.96	0.0076	16.21
0.112	0.0068	0.0075	10.72	0.0083	22.03
0.115	0.0071	0.0082	15.25	0.0089	25.71
0.118	0.0074	0.0086	17.12	0.0093	26.90
0.120	0.0077	0.0089	16.34	0.0096	25.49
0.123	0.0080	0.0090	12.69	0.0097	21.36
0.126	0.0083	0.0088	6.52	0.0096	15.34
0.129	0.0086	0.0087	1.51	0.0095	10.36
0.132	0.0089	0.0089	0.11	0.0095	6.29
0.135	0.0092	0.0092	-0.11	0.0098	6.49
0.138	0.0096	0.0096	0.52	0.0101	5.96
0.141	0.0099	0.0101	1.11	0.0105	6.04
0.145	0.0103	0.0104	1.17	0.0109	5.83
0.148	0.0107	0.0107	0.56	0.0112	4.78
0.151	0.0111	0.0111	0.36	0.0116	4.96
0.155	0.0115	0.0115	0.44	0.0121	5.05
0.159	0.0119	0.0119	0.34	0.0124	4.37
0.162	0.0123	0.0125	1.62	0.0129	4.21
0.166	0.0128	0.0131	2.66	0.0134	5.09
0.170	0.0132	0.0138	4.16	0.0139	5.15
0.174	0.0137	0.0144	5.48	0.0143	4.61
0.178	0.0142	0.0152	6.99	0.0149	4.87
0.182	0.0147	0.0158	7.98	0.0154	5.18
0.186	0.0152	0.0167	9.76	0.0160	5.54
0.191	0.0157	0.0175	11.46	0.0167	6.50
0.195	0.0163	0.0184	13.04	0.0174	7.20

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.200	0.0168	0.0192	13.90	0.0180	7.19
0.204	0.0174	0.0200	14.52	0.0187	7.58
0.209	0.0180	0.0208	15.52	0.0194	7.90
0.214	0.0186	0.0214	15.40	0.0201	8.13
0.219	0.0192	0.0221	15.34	0.0207	7.82
0.224	0.0198	0.0227	14.55	0.0214	8.29
0.229	0.0204	0.0232	13.46	0.0220	7.59
0.234	0.0211	0.0236	12.00	0.0226	7.26
0.240	0.0218	0.0241	10.79	0.0232	6.48
0.246	0.0225	0.0245	8.90	0.0237	5.61
0.251	0.0232	0.0248	6.77	0.0244	4.96
0.257	0.0239	0.0252	5.26	0.0251	4.93
0.263	0.0247	0.0258	4.62	0.0259	5.03
0.269	0.0254	0.0264	3.90	0.0265	4.41
0.275	0.0261	0.0273	4.40	0.0277	5.97
0.282	0.0269	0.0282	4.72	0.0286	6.43
0.288	0.0277	0.0292	5.52	0.0295	6.35
0.295	0.0285	0.0305	6.84	0.0302	5.86
0.302	0.0294	0.0316	7.73	0.0307	4.50
0.309	0.0302	0.0326	7.94	0.0315	4.14
0.316	0.0311	0.0333	7.14	0.0327	4.98
0.324	0.0320	0.0343	7.15	0.0339	5.68
0.331	0.0329	0.0356	8.01	0.0349	5.86
0.339	0.0339	0.0364	7.65	0.0357	5.58
0.347	0.0348	0.0370	6.33	0.0366	5.15
0.355	0.0357	0.0381	6.55	0.0373	4.51
0.363	0.0367	0.0393	6.92	0.0382	3.95
0.372	0.0377	0.0404	7.21	0.0391	3.66
0.380	0.0387	0.0416	7.25	0.0402	3.79
0.389	0.0398	0.0426	7.01	0.0415	4.22
0.398	0.0409	0.0436	6.63	0.0429	4.89
0.407	0.0420	0.0446	6.16	0.0443	5.50
0.417	0.0432	0.0459	6.21	0.0457	5.88
0.427	0.0443	0.0470	6.09	0.0470	5.98
0.437	0.0455	0.0482	6.12	0.0480	5.70

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.447	0.0466	0.0495	6.11	0.0490	5.12
0.457	0.0479	0.0505	5.56	0.0500	4.47
0.468	0.0491	0.0515	4.85	0.0510	3.83
0.479	0.0504	0.0523	3.83	0.0521	3.41
0.490	0.0517	0.0531	2.69	0.0534	3.33
0.501	0.0530	0.0540	1.95	0.0549	3.59
0.513	0.0535	0.0552	3.18	0.0560	4.73
0.525	0.0540	0.0572	5.89	0.0566	4.89
0.537	0.0545	0.0595	9.18	0.0567	4.06
0.550	0.0550	0.0619	12.58	0.0564	2.54
0.562	0.0555	0.0644	15.93	0.0561	1.08
0.575	0.0561	0.0662	18.10	0.0563	0.43
0.589	0.0566	0.0671	18.58	0.0580	2.44
0.603	0.0572	0.0672	17.49	0.0605	5.83
0.617	0.0577	0.0666	15.44	0.0634	9.88
0.631	0.0583	0.0658	12.91	0.0657	12.72
0.646	0.0588	0.0649	10.29	0.0666	13.21
0.661	0.0594	0.0639	7.63	0.0661	11.25
0.676	0.0599	0.0628	4.98	0.0649	8.42
0.692	0.0600	0.0616	2.65	0.0639	6.43
0.708	0.0602	0.0607	0.81	0.0635	5.48
0.724	0.0604	0.0606	0.35	0.0640	5.96
0.741	0.0605	0.0615	1.59	0.0645	6.53
0.759	0.0607	0.0630	3.80	0.0643	5.90
0.776	0.0609	0.0643	5.62	0.0639	4.98
0.794	0.0611	0.0647	5.96	0.0634	3.78
0.813	0.0612	0.0644	5.13	0.0640	4.59
0.832	0.0614	0.0639	4.12	0.0643	4.77
0.851	0.0616	0.0639	3.78	0.0638	3.62
0.871	0.0612	0.0641	4.72	0.0642	4.92
0.891	0.0608	0.0641	5.44	0.0643	5.69
0.912	0.0604	0.0636	5.33	0.0637	5.48
0.933	0.0600	0.0629	4.90	0.0630	5.00
0.955	0.0596	0.0625	4.85	0.0625	4.83
0.977	0.0592	0.0623	5.25	0.0623	5.25

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
1.000	0.0588	0.0624	6.05	0.0625	6.29
1.023	0.0599	0.0629	4.98	0.0631	5.33
1.047	0.0610	0.0640	4.94	0.0640	4.87
1.072	0.0621	0.0654	5.31	0.0650	4.60
1.097	0.0633	0.0666	5.29	0.0660	4.27
1.122	0.0644	0.0676	4.93	0.0671	4.11
1.148	0.0656	0.0687	4.71	0.0683	4.04
1.175	0.0668	0.0696	4.08	0.0697	4.31
1.202	0.0681	0.0698	2.50	0.0714	4.92
1.230	0.0693	0.0706	1.88	0.0735	6.01
1.259	0.0706	0.0719	1.86	0.0752	6.44
1.288	0.0719	0.0731	1.67	0.0766	6.45
1.318	0.0733	0.0746	1.88	0.0778	6.20
1.349	0.0746	0.0767	2.79	0.0788	5.62
1.380	0.0760	0.0785	3.33	0.0798	5.00
1.413	0.0772	0.0796	3.12	0.0809	4.86
1.445	0.0784	0.0820	4.53	0.0822	4.87
1.479	0.0797	0.0833	4.54	0.0835	4.83
1.514	0.0810	0.0866	6.88	0.0847	4.64
1.549	0.0823	0.0896	8.85	0.0861	4.67
1.585	0.0836	0.0915	9.45	0.0876	4.81
1.622	0.0850	0.0905	6.54	0.0894	5.21
1.660	0.0864	0.0886	2.63	0.0919	6.45
1.698	0.0877	0.0894	1.91	0.0943	7.42
1.738	0.0892	0.0901	1.02	0.0951	6.68
1.778	0.0905	0.0916	1.26	0.0954	5.47
1.820	0.0918	0.0938	2.22	0.0958	4.42
1.862	0.0931	0.0961	3.18	0.0967	3.89
1.906	0.0944	0.0974	3.15	0.0974	3.19
1.950	0.0958	0.0984	2.75	0.0988	3.21
1.995	0.0971	0.0992	2.16	0.1016	4.57
2.042	0.0985	0.1000	1.51	0.1030	4.51
2.089	0.0999	0.1011	1.20	0.1037	3.76
2.138	0.1014	0.1035	2.15	0.1055	4.11
2.188	0.1028	0.1054	2.56	0.1102	7.18

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
2.239	0.1041	0.1067	2.43	0.1157	11.10
2.291	0.1054	0.1076	2.16	0.1197	13.59
2.344	0.1066	0.1097	2.89	0.1218	14.23
2.399	0.1078	0.1112	3.10	0.1228	13.88
2.455	0.1091	0.1111	1.88	0.1220	11.80
2.512	0.1106	0.1107	0.17	0.1185	7.17
2.570	0.1127	0.1190	5.57	0.1179	4.58
2.630	0.1150	0.1220	6.09	0.1215	5.72
2.692	0.1172	0.1186	1.16	0.1268	8.12
2.754	0.1196	0.1264	5.70	0.1321	10.46
2.818	0.1219	0.1353	10.97	0.1308	7.28
2.884	0.1243	0.1357	9.11	0.1235	-0.67
2.951	0.1268	0.1298	2.35	0.1244	-1.90
3.020	0.1293	0.1367	5.72	0.1376	6.43
3.090	0.1319	0.1447	9.76	0.1368	3.74
3.162	0.1345	0.1462	8.69	0.1315	-2.20
3.236	0.1371	0.1422	3.67	0.1424	3.84
3.311	0.1398	0.1486	6.24	0.1535	9.77
3.389	0.1426	0.1508	5.75	0.1593	11.68
3.467	0.1454	0.1530	5.18	0.1559	7.16
3.548	0.1483	0.1573	6.05	0.1583	6.70
3.631	0.1513	0.1625	7.41	0.1644	8.65
3.715	0.1544	0.1647	6.68	0.1648	6.76
3.802	0.1575	0.1663	5.59	0.1673	6.26
3.891	0.1607	0.1732	7.81	0.1721	7.15
3.981	0.1639	0.1738	6.05	0.1738	6.02
4.074	0.1672	0.1737	3.89	0.1720	2.86
4.169	0.1706	0.1771	3.79	0.1749	2.51
4.266	0.1740	0.1829	5.09	0.1830	5.18
4.365	0.1775	0.1862	4.89	0.1830	3.08
4.467	0.1811	0.1875	3.49	0.1880	3.79
4.571	0.1857	0.1960	5.52	0.1997	7.51
4.677	0.1915	0.2026	5.80	0.2079	8.59
4.786	0.1974	0.2105	6.65	0.2039	3.32
4.898	0.2035	0.2230	9.59	0.2048	0.67

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
5.012	0.2095	0.2157	2.96	0.2213	5.62
5.129	0.2133	0.2123	-0.45	0.2340	9.71
5.248	0.2172	0.2241	3.18	0.2330	7.28
5.370	0.2211	0.2322	5.03	0.2404	8.73
5.495	0.2251	0.2293	1.87	0.2409	7.00
5.623	0.2292	0.2438	6.40	0.2401	4.75
5.754	0.2333	0.2597	11.31	0.2453	5.14
5.889	0.2376	0.2515	5.85	0.2507	5.53
6.026	0.2419	0.2424	0.24	0.2482	2.63
6.166	0.2463	0.2579	4.75	0.2584	4.95
6.310	0.2507	0.2570	2.52	0.2608	4.02
6.457	0.2553	0.2639	3.40	0.2663	4.31
6.607	0.2599	0.2746	5.67	0.2775	6.78
6.761	0.2646	0.2746	3.78	0.2755	4.13
6.918	0.2694	0.2788	3.48	0.2796	3.78
7.080	0.2743	0.2821	2.86	0.2914	6.25
7.244	0.2792	0.2914	4.37	0.2983	6.84
7.413	0.2843	0.2933	3.17	0.3013	5.98
7.586	0.2896	0.2982	2.97	0.3057	5.56
7.763	0.2951	0.3141	6.45	0.3122	5.80
7.943	0.3007	0.3190	6.08	0.3165	5.26
8.128	0.3064	0.3078	0.47	0.3275	6.90
8.318	0.3122	0.3173	1.65	0.3305	5.87
8.511	0.3181	0.3364	5.76	0.3309	4.03
8.710	0.3241	0.3386	4.47	0.3367	3.88
8.913	0.3303	0.3389	2.62	0.3484	5.48
9.120	0.3365	0.3467	3.02	0.3577	6.30
9.333	0.3429	0.3587	4.59	0.3528	2.88
9.550	0.3494	0.3625	3.75	0.3605	3.18
9.772	0.3561	0.3680	3.35	0.3707	4.10
10.000	0.3628	0.3757	3.56	0.3801	4.76
10.233	0.3699	0.3819	3.24	0.4022	8.71
10.471	0.3772	0.3882	2.92	0.3991	5.81
10.715	0.3846	0.4013	4.34	0.3860	0.36
10.965	0.3922	0.4070	3.78	0.4098	4.50

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
11.220	0.3999	0.3835	-4.09	0.4265	6.65
11.482	0.4077	0.4268	4.67	0.4290	5.23
11.749	0.4155	0.4482	7.87	0.4267	2.72
12.023	0.4208	0.4402	4.61	0.4434	5.36
12.303	0.4263	0.4480	5.10	0.4445	4.29
12.589	0.4318	0.4488	3.96	0.4549	5.35
12.883	0.4373	0.4625	5.75	0.4552	4.10
13.183	0.4430	0.4526	2.17	0.4711	6.34
13.490	0.4487	0.4671	4.11	0.4721	5.22
13.804	0.4545	0.4869	7.14	0.4605	1.32
14.125	0.4604	0.4751	3.19	0.4940	7.30
14.455	0.4663	0.4885	4.75	0.4961	6.38
14.791	0.4723	0.5001	5.87	0.4790	1.42
15.136	0.4762	0.5051	6.07	0.4963	4.21
15.488	0.4794	0.5019	4.68	0.5032	4.96
15.849	0.4827	0.5007	3.74	0.5053	4.68
16.218	0.4860	0.5123	5.42	0.5121	5.37
16.596	0.4892	0.5041	3.03	0.5106	4.36
16.983	0.4925	0.5143	4.41	0.5178	5.14
17.378	0.4959	0.5236	5.60	0.5183	4.53
17.783	0.4992	0.5239	4.93	0.5327	6.71
18.197	0.5026	0.5278	5.00	0.5323	5.90
18.621	0.5060	0.5347	5.67	0.5228	3.31
19.055	0.5092	0.5384	5.72	0.5294	3.95
19.499	0.5122	0.5366	4.76	0.5274	2.96
19.953	0.5152	0.5392	4.65	0.5369	4.20
20.418	0.5183	0.5415	4.49	0.5434	4.86
20.893	0.5213	0.5494	5.39	0.5452	4.59
21.380	0.5243	0.5547	5.80	0.5524	5.34
21.878	0.5274	0.5566	5.54	0.5466	3.63
22.387	0.5305	0.5534	4.32	0.5553	4.67
22.909	0.5336	0.5632	5.53	0.5606	5.04
23.442	0.5368	0.5657	5.38	0.5634	4.96
23.989	0.5399	0.5669	5.00	0.5659	4.81
24.547	0.5431	0.5704	5.02	0.5687	4.72

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
25.119	0.5451	0.5768	5.82	0.5714	4.83
25.704	0.5425	0.5785	6.64	0.5671	4.52
26.303	0.5400	0.5613	3.94	0.5650	4.62
26.916	0.5375	0.5487	2.08	0.5639	4.91
27.542	0.5350	0.5398	0.90	0.5574	4.19
28.184	0.5325	0.5521	3.68	0.5578	4.76
28.841	0.5300	0.5537	4.47	0.5574	5.16
29.512	0.5275	0.5212	-1.20	0.5642	6.95
30.200	0.5251	0.5540	5.52	0.5518	5.08
30.903	0.5223	0.5488	5.07	0.5558	6.40
31.623	0.5195	0.5424	4.41	0.5560	7.03
32.360	0.5167	0.5467	5.81	0.5511	6.66
33.113	0.5139	0.5403	5.14	0.5549	7.97
33.885	0.5111	0.5396	5.58	0.5388	5.43
34.674	0.5083	0.5157	1.45	0.5515	8.50
35.482	0.5056	0.5267	4.19	0.5434	7.48
36.308	0.5028	0.5147	2.37	0.5314	5.68
37.154	0.5001	0.5095	1.87	0.5257	5.12
38.019	0.4974	0.5146	3.46	0.5137	3.28
38.905	0.4935	0.4993	1.18	0.5099	3.33
39.811	0.4876	0.4936	1.24	0.5088	4.35
40.738	0.4818	0.4881	1.31	0.5108	6.03
41.687	0.4761	0.4816	1.16	0.5077	6.64
42.658	0.4704	0.4756	1.10	0.4853	3.17
43.652	0.4649	0.4689	0.86	0.4820	3.69
44.669	0.4593	0.4636	0.93	0.4760	3.64
45.709	0.4539	0.4591	1.14	0.4689	3.31
46.774	0.4485	0.4538	1.18	0.4669	4.10
47.863	0.4432	0.4475	0.98	0.4643	4.76
48.978	0.4378	0.4414	0.83	0.4605	5.20
50.119	0.4281	0.4306	0.59	0.4518	5.55
51.287	0.4186	0.4193	0.18	0.4344	3.77
52.481	0.4093	0.4158	1.60	0.4341	6.06
53.704	0.4003	0.4049	1.15	0.4103	2.51
54.954	0.3914	0.3930	0.40	0.3930	0.42

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
56.235	0.3827	0.3852	0.64	0.3995	4.38
57.544	0.3742	0.3765	0.61	0.3924	4.85
58.885	0.3660	0.3686	0.73	0.3782	3.35
60.256	0.3579	0.3627	1.37	0.3638	1.65
61.660	0.3499	0.3637	3.92	0.3606	3.05
63.096	0.3397	0.3592	5.72	0.3542	4.26
64.566	0.3288	0.3431	4.36	0.3406	3.60
66.070	0.3182	0.3331	4.70	0.3304	3.85
67.609	0.3079	0.3228	4.84	0.3188	3.54
69.184	0.2980	0.3121	4.73	0.3093	3.80
70.795	0.2883	0.3043	5.52	0.3062	6.19
72.444	0.2790	0.2995	7.34	0.2955	5.89
74.132	0.2700	0.2867	6.18	0.2823	4.54
75.858	0.2613	0.2728	4.38	0.2628	0.57
77.625	0.2529	0.2608	3.12	0.2681	6.01
79.433	0.2460	0.2572	4.56	0.2787	13.30
81.284	0.2417	0.2543	5.18	0.2770	14.59
83.177	0.2375	0.2518	5.99	0.2689	13.22
85.114	0.2334	0.2458	5.31	0.2553	9.39
87.097	0.2294	0.2428	5.86	0.2429	5.89
89.126	0.2254	0.2383	5.72	0.2390	6.05
91.202	0.2215	0.2354	6.27	0.2367	6.87
93.326	0.2176	0.2324	6.78	0.2374	9.07
95.500	0.2139	0.2278	6.51	0.2376	11.10
97.724	0.2102	0.2233	6.25	0.2374	12.96
100.000	0.2065	0.2243	8.61	0.2367	14.64

TABLE 1-2

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE VERTICAL DIRECTION

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0032	0.0035	7.81
0.102	0.0033	0.0037	9.91
0.105	0.0035	0.0039	10.95
0.107	0.0036	0.0041	12.98
0.110	0.0038	0.0045	18.04
0.112	0.0039	0.0048	21.63
0.115	0.0041	0.0050	22.98
0.118	0.0043	0.0052	22.01
0.120	0.0044	0.0053	18.92
0.123	0.0046	0.0053	14.47
0.126	0.0048	0.0053	10.79
0.129	0.0050	0.0054	7.78
0.132	0.0052	0.0056	7.51
0.135	0.0054	0.0057	6.51
0.138	0.0056	0.0059	5.56
0.141	0.0058	0.0060	4.15
0.145	0.0060	0.0062	3.67
0.148	0.0062	0.0064	3.22
0.151	0.0065	0.0067	3.26
0.155	0.0067	0.0069	3.14
0.159	0.0069	0.0072	3.46
0.162	0.0072	0.0074	3.62
0.166	0.0074	0.0077	4.04
0.170	0.0077	0.0081	4.68
0.174	0.0080	0.0084	5.78
0.178	0.0082	0.0088	6.68
0.182	0.0085	0.0091	6.69
0.186	0.0088	0.0095	7.37
0.191	0.0091	0.0099	8.11
0.195	0.0094	0.0102	8.37
0.200	0.0098	0.0107	9.01

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.204	0.0101	0.0111	9.40
0.209	0.0104	0.0115	9.87
0.214	0.0108	0.0119	10.48
0.219	0.0111	0.0123	10.59
0.224	0.0115	0.0128	11.13
0.229	0.0119	0.0131	10.10
0.234	0.0123	0.0134	9.30
0.240	0.0127	0.0137	8.45
0.246	0.0131	0.0140	7.11
0.251	0.0135	0.0143	5.55
0.257	0.0140	0.0146	4.95
0.263	0.0144	0.0151	4.87
0.269	0.0148	0.0156	5.27
0.275	0.0152	0.0161	5.45
0.282	0.0157	0.0165	5.11
0.288	0.0161	0.0169	4.78
0.295	0.0166	0.0175	5.67
0.302	0.0171	0.0181	5.91
0.309	0.0176	0.0187	6.49
0.316	0.0181	0.0194	7.02
0.324	0.0186	0.0199	7.15
0.331	0.0191	0.0204	6.69
0.339	0.0197	0.0208	5.69
0.347	0.0202	0.0214	5.89
0.355	0.0208	0.0219	5.63
0.363	0.0213	0.0224	5.11
0.372	0.0219	0.0229	4.61
0.380	0.0225	0.0237	4.97
0.389	0.0232	0.0243	5.05
0.398	0.0238	0.0250	5.21
0.407	0.0245	0.0257	5.07
0.417	0.0251	0.0261	4.06
0.427	0.0258	0.0267	3.53
0.437	0.0265	0.0276	4.31
0.447	0.0272	0.0284	4.64
0.457	0.0279	0.0291	4.45

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.468	0.0286	0.0297	3.74
0.479	0.0293	0.0303	3.27
0.490	0.0301	0.0309	2.72
0.501	0.0308	0.0316	2.40
0.513	0.0311	0.0322	3.57
0.525	0.0314	0.0329	4.74
0.537	0.0317	0.0335	5.64
0.550	0.0320	0.0340	6.21
0.562	0.0323	0.0344	6.34
0.575	0.0326	0.0346	6.13
0.589	0.0330	0.0348	5.71
0.603	0.0333	0.0350	5.29
0.617	0.0336	0.0353	5.03
0.631	0.0339	0.0358	5.57
0.646	0.0342	0.0365	6.69
0.661	0.0346	0.0375	8.39
0.676	0.0348	0.0386	10.71
0.692	0.0349	0.0396	13.43
0.708	0.0350	0.0403	15.11
0.724	0.0351	0.0403	14.87
0.741	0.0352	0.0397	12.75
0.759	0.0353	0.0385	8.92
0.776	0.0354	0.0370	4.60
0.794	0.0355	0.0360	1.44
0.813	0.0356	0.0358	0.53
0.832	0.0357	0.0362	1.54
0.851	0.0358	0.0372	3.91
0.871	0.0356	0.0377	5.96
0.891	0.0354	0.0395	11.63
0.912	0.0351	0.0398	13.21
0.933	0.0349	0.0384	10.17
0.955	0.0347	0.0365	5.34
0.977	0.0344	0.0353	2.58
1.000	0.0342	0.0355	3.89
1.023	0.0349	0.0365	4.67
1.047	0.0356	0.0375	5.26

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
1.072	0.0363	0.0384	5.84
1.097	0.0370	0.0390	5.32
1.122	0.0377	0.0396	4.93
1.148	0.0385	0.0404	5.04
1.175	0.0393	0.0413	5.22
1.202	0.0401	0.0421	5.19
1.230	0.0409	0.0423	3.50
1.259	0.0417	0.0421	0.96
1.288	0.0425	0.0423	-0.52
1.318	0.0433	0.0435	0.30
1.349	0.0442	0.0451	2.10
1.380	0.0451	0.0469	4.04
1.413	0.0459	0.0482	5.19
1.445	0.0467	0.0489	4.72
1.479	0.0475	0.0492	3.62
1.514	0.0483	0.0498	3.17
1.549	0.0492	0.0511	3.87
1.585	0.0500	0.0526	5.10
1.622	0.0509	0.0546	7.31
1.660	0.0518	0.0566	9.37
1.698	0.0527	0.0573	8.65
1.738	0.0536	0.0571	6.53
1.778	0.0545	0.0574	5.34
1.820	0.0554	0.0578	4.48
1.862	0.0563	0.0586	4.25
1.906	0.0571	0.0597	4.41
1.950	0.0581	0.0608	4.72
1.995	0.0590	0.0619	4.95
2.042	0.0599	0.0637	6.24
2.089	0.0609	0.0658	8.07
2.138	0.0618	0.0670	8.33
2.188	0.0628	0.0670	6.57
2.239	0.0637	0.0671	5.30
2.291	0.0646	0.0679	5.09
2.344	0.0654	0.0689	5.33
2.399	0.0663	0.0695	4.74

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
2.455	0.0672	0.0693	3.17
2.512	0.0682	0.0707	3.65
2.570	0.0697	0.0731	4.95
2.630	0.0712	0.0740	3.91
2.692	0.0727	0.0752	3.49
2.754	0.0743	0.0778	4.81
2.818	0.0759	0.0798	5.17
2.884	0.0775	0.0813	4.93
2.951	0.0792	0.0828	4.65
3.020	0.0809	0.0850	5.14
3.090	0.0826	0.0882	6.83
3.162	0.0844	0.0905	7.24
3.236	0.0862	0.0911	5.64
3.311	0.0881	0.0910	3.38
3.389	0.0900	0.0933	3.77
3.467	0.0919	0.0960	4.47
3.548	0.0939	0.0993	5.77
3.631	0.0961	0.1019	6.11
3.715	0.0983	0.1045	6.24
3.802	0.1007	0.1054	4.71
3.891	0.1030	0.1065	3.39
3.981	0.1055	0.1107	4.95
4.074	0.1080	0.1115	3.23
4.169	0.1105	0.1135	2.70
4.266	0.1131	0.1185	4.71
4.365	0.1158	0.1229	6.12
4.467	0.1186	0.1250	5.43
4.571	0.1221	0.1244	1.88
4.677	0.1265	0.1283	1.39
4.786	0.1311	0.1396	6.52
4.898	0.1358	0.1462	7.67
5.012	0.1405	0.1480	5.32
5.129	0.1437	0.1519	5.69
5.248	0.1469	0.1543	5.01
5.370	0.1503	0.1583	5.33
5.495	0.1536	0.1627	5.87

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
5.623	0.1571	0.1662	5.79
5.754	0.1607	0.1706	6.20
5.889	0.1643	0.1736	5.69
6.026	0.1680	0.1796	6.91
6.166	0.1718	0.1825	6.21
6.310	0.1757	0.1877	6.88
6.457	0.1796	0.1869	4.06
6.607	0.1837	0.1903	3.61
6.761	0.1878	0.1968	4.79
6.918	0.1921	0.2036	5.99
7.080	0.1964	0.2066	5.19
7.244	0.2008	0.2086	3.84
7.413	0.2054	0.2157	5.03
7.586	0.2099	0.2214	5.48
7.763	0.2145	0.2242	4.54
7.943	0.2191	0.2292	4.60
8.128	0.2239	0.2366	5.69
8.318	0.2287	0.2418	5.73
8.511	0.2337	0.2452	4.93
8.710	0.2388	0.2505	4.89
8.913	0.2440	0.2579	5.72
9.120	0.2493	0.2630	5.50
9.333	0.2547	0.2586	1.53
9.550	0.2602	0.2683	3.10
9.772	0.2658	0.2824	6.23
10.000	0.2716	0.2848	4.87
10.233	0.2784	0.2907	4.44
10.471	0.2853	0.2992	4.86
10.715	0.2924	0.3168	8.34
10.965	0.2997	0.3177	6.00
11.220	0.3071	0.3066	-0.18
11.482	0.3148	0.3284	4.34
11.749	0.3224	0.3477	7.87
12.023	0.3277	0.3438	4.91
12.303	0.3332	0.3547	6.44
12.589	0.3388	0.3544	4.61

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
12.883	0.3444	0.3635	5.55
13.183	0.3502	0.3621	3.41
13.490	0.3560	0.3736	4.94
13.804	0.3620	0.3857	6.57
14.125	0.3680	0.3777	2.64
14.455	0.3741	0.3914	4.61
14.791	0.3804	0.4057	6.67
15.136	0.3845	0.3879	0.88
15.488	0.3879	0.4077	5.10
15.849	0.3913	0.3964	1.29
16.218	0.3948	0.4204	6.48
16.596	0.3983	0.4200	5.44
16.983	0.4019	0.4205	4.64
17.378	0.4054	0.4322	6.60
17.783	0.4090	0.4282	4.69
18.197	0.4127	0.4349	5.39
18.621	0.4163	0.4311	3.55
19.055	0.4207	0.4402	4.63
19.499	0.4261	0.4475	5.02
19.953	0.4316	0.4518	4.68
20.418	0.4371	0.4654	6.48
20.893	0.4427	0.4607	4.06
21.380	0.4484	0.4732	5.53
21.878	0.4542	0.4739	4.34
22.387	0.4600	0.4755	3.36
22.909	0.4659	0.4878	4.70
23.442	0.4719	0.4940	4.69
23.989	0.4779	0.5025	5.15
24.547	0.4841	0.5079	4.92
25.119	0.4890	0.5162	5.57
25.704	0.4890	0.5263	7.63
26.303	0.4891	0.5243	7.21
26.916	0.4891	0.5118	4.65
27.542	0.4891	0.5213	6.59
28.184	0.4891	0.5229	6.91
28.841	0.4892	0.5168	5.65

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
29.512	0.4892	0.5097	4.20
30.200	0.4892	0.5120	4.67
30.903	0.4897	0.5126	4.67
31.623	0.4905	0.5036	2.66
32.360	0.4912	0.5234	6.55
33.113	0.4920	0.5110	3.86
33.885	0.4928	0.5086	3.21
34.674	0.4935	0.5120	3.74
35.482	0.4943	0.5170	4.59
36.308	0.4950	0.5124	3.52
37.154	0.4958	0.5151	3.91
38.019	0.4965	0.5146	3.63
38.905	0.4955	0.5128	3.48
39.811	0.4916	0.5153	4.83
40.738	0.4877	0.5117	4.91
41.687	0.4839	0.5054	4.46
42.658	0.4801	0.5022	4.62
43.652	0.4763	0.4972	4.40
44.669	0.4725	0.4942	4.59
45.709	0.4688	0.4926	5.08
46.774	0.4651	0.4901	5.39
47.863	0.4614	0.4859	5.31
48.978	0.4576	0.4818	5.30
50.119	0.4482	0.4715	5.20
51.287	0.4390	0.4659	6.13
52.481	0.4300	0.4439	3.22
53.704	0.4212	0.4384	4.08
54.954	0.4126	0.4267	3.43
56.235	0.4041	0.4253	5.24
57.544	0.3958	0.4103	3.65
58.885	0.3877	0.4100	5.74
60.256	0.3798	0.3919	3.20
61.660	0.3720	0.3894	4.67
63.096	0.3600	0.3803	5.65
64.566	0.3466	0.3620	4.47
66.070	0.3336	0.3507	5.13

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
67.609	0.3211	0.3390	5.55
69.184	0.3091	0.3137	1.49
70.795	0.2976	0.3150	5.85
72.444	0.2864	0.3039	6.08
74.132	0.2757	0.2879	4.41
75.858	0.2654	0.2775	4.57
77.625	0.2555	0.2691	5.33
79.433	0.2466	0.2578	4.51
81.284	0.2394	0.2428	1.42
83.177	0.2323	0.2376	2.26
85.114	0.2255	0.2339	3.72
87.097	0.2188	0.2278	4.07
89.126	0.2124	0.2219	4.49
91.202	0.2061	0.2211	7.24
93.326	0.2001	0.2197	9.80
95.500	0.1942	0.2153	10.86
97.724	0.1885	0.2072	9.95
100.000	0.1829	0.2035	11.28

3) A description of how the strain-compatible soil profiles were generated including information on (a) the computer code used to develop the results, (b) the assumed material degradation models used in the calculations for each soil layer of the base-case profile, (c) how randomized parameters were selected for each soil layer, (d) the correlation model used between layers and its appropriateness for application to the Bell Bend site, and (e) plots of low strain velocities for each of the soil profiles used in the site response analyses.

Response

Regulatory Guide (RG) 1.208 was followed for the development of the Probabilistic Seismic Hazard Assessment (PSHA). Method 2B has been applied for the site amplification analysis. The steps used to develop the strain compatible soil profiles were performed according to the following procedure:

De-aggregation of the PSHA results is performed to obtain the relative contribution to the total hazard for each magnitude and distance pair. Based on de-aggregation, controlling earthquakes are obtained in terms of earthquake magnitudes and distances.

Strain-compatible soil/rock parameters, shear modulus (G) and damping (ξ), are the "de-aggregated weighted" average of shear modulus and the average of damping versus depth, respectively.

The site amplification analysis has been conducted according to RG 1.208 and following Method 2-B from NUREG-6728. For the site amplification analysis, 60 random soil profiles were generated to consider the variability of different parameters (shear wave velocity, damping, and layer thickness) with respect to the best estimate profile.

For each single controlling event, the strain compatible shear modulus matrix can be expressed as:

$$G_{nm} = \begin{bmatrix} G_{11} & \cdots & G_{1m} \\ \vdots & \ddots & \vdots \\ G_{n1} & \cdots & G_{nm} \end{bmatrix} \quad (1)$$

Where m = number of random profiles (60) and
n = number of material layers in a random profile.

The mean (μ_{Gk}) and standard deviation (σ_{Gk}) of shear modulus for the kth layer are calculated as:

$$\mu_{Gk} = mean\{G_{k1}, G_{k2}, \ldots, G_{km}\} \quad (2)$$

$$\sigma_{Gk} = STDEV\{G_{k1}, G_{k2}, \ldots, G_{km}\} \quad (3)$$

Considering six controlling events for a probability exceedance of 10^{-4}, the high-frequency and low-frequency best estimate of shear modulus for the kth layer is expressed as:

$$G_k^{HF} = \sum_i \mu_{Gk_i}^{HF} W_i^{HF} \quad (4)$$

Where HF_i = Events of 10^{-4}HF-DEH, 10^{-4}HF-DEM, 10^{-4}HF-DEL;

W_i^{HF} = De – aggregation coefficient for high frequency controlling events

and,

$$G_k^{LF} = \sum_i \mu_{Gk_i}^{LF} W_i^{LF} \quad (5)$$

Where LF_i = Events of 10^{-4}LF-DEH, 10^{-4}LF-DEM, 10^{-4}LF-DEL;

W_i^{LF} = De – aggregation coefficient for low frequency controlling events

The best estimate of shear modulus for the kth layer is expressed as:

$$G_k^{BE} = \frac{G_k^{HF} + G_k^{LF}}{2} \quad (6)$$

The standard deviation of the best estimate (σ_{Gk}^{BE}) for the kth layer is obtained with an equivalent approach:

$$\sigma_{Gk}^{HF} = \sum_i \sigma_{Gk_i}^{LF} W_i^{HF} \quad (7)$$

$$\sigma_{Gk}^{LF} = \sum_i \sigma_{Gk_i}^{LF} W_i^{LF} \quad (8)$$

$$\sigma_{Gk}^{BE} = max \begin{Bmatrix} \sigma_{Gk}^{HF} \\ \sigma_{Gk}^{LF} \end{Bmatrix} \quad (9)$$

The same procedure is used to obtain the best estimate of damping (ξ_{Gk}^{BE}) and standard deviation of best estimate ($\sigma_{\xi k}^{BE}$) for the kth layer.

According to NUREG-0800 (Section 3.7.2), for cases with multiple site response calculations, lower and upper bounds of strain compatible parameters need to meet these conditions:

1. The best estimate properties are determined from the mean of the resulting properties (as defined above) and the upper bound and lower bound values selected from the ± 1 sigma values.

2. The COV for shear modulus should not be less than 0.5.

   Therefore:

$$COV_{MIN} = 0.5 = \frac{\sigma}{BE}$$

   The lower bound estimate would then be:

$$G_{LB} = min(G_{BE} - \sigma_1\ G_{BE} - 0.5G_{BE} = 0.5G_{BE})$$

The upper bound:

$$G_{UB} = max(G_{BE} + \sigma_1\ G_{BE} + 0.5G_{BE} = 1.5G_{BE})$$

However, an alternate bounding criterion, based on discussions with the groups performing the SSI analysis, is used:

$$G_{LB} = min\left(G_{BE} - \sigma_1\ \frac{G_{BE}}{1.5}\right)$$

$$G_{UB} = max(G_{BE} + \sigma_1\ 1.5G_{BE})$$

3. The lower bound shear modulus should not be less than the static value used in the settlement analysis (G_{static}).

4. The upper bound shear modulus should not be less than the best estimate shear modulus defined at low strain and determined from the geophysical testing program (G_{max}).

5. The soil damping should not exceed 15 percent.

To fulfill the requirements, the upper and lower bounds of strain compatible parameters for the kth layer can be expressed as:

$$G_k^{UB} = max\begin{Bmatrix} G_k^{BE} + \sigma_{Gk}^{BE} \\ 1.5G_k^{BE} \\ G_{max} \end{Bmatrix} \tag{10}$$

$$G_k^{LB} = max\left\{ min\begin{Bmatrix} G_k^{BE} - \sigma_{Gk}^{BE} \\ 0.667G_k^{BE} \end{Bmatrix} \atop G_{static} \right\} \tag{11}$$

$$\zeta_k^{UB} = min\begin{Bmatrix} \zeta_k^{BE} - \sigma_{\zeta k}^{BE} \\ 0.15 \end{Bmatrix} \tag{12}$$

$$\zeta_k^{LB} = min\begin{Bmatrix} \zeta_k^{BE} + \sigma_{\zeta k}^{BE} \\ 0.15 \end{Bmatrix} \tag{13}$$

(a) The program Shake07 is used to develop the results. The program is a modified version of the original codes (Schnabel 1972). The modified version is fully verified.

(b) The building facilities in the Nuclear Island (NI) are sitting on top of a concrete fill with an average thickness of 10 feet. The fill is placed directly on top of the Mahantango formation, which consists of extremely dense Devonian shale. The Mahantango formation features high shear-wave velocities larger than 6800 feet per second (fps). FSAR Figure 2.5-165 provides a shear wave velocity profile. This is the only soil layer identified for analysis under the NI. The material degradation model for this layer considers that the damping value and the ratio of shear modulus to maximum shear modulus (G/G_{max}) will remain unchanged during ground motion. Such consideration is adequate given the nature of the rock.

(c) The random parameters (shear-wave velocity, layer thickness, hysterical damping) were generated based on best-estimate data obtained from site-specific investigation along with proper probabilistic models. The site-specific investigation included subsurface explorations, geophysical survey, and laboratory testing. The subsurface exploration program featured a number of in-situ borings to determine the geological conditions, the elevation of groundwater level, and sampling of specimens. Some boreholes were selected to perform geophysical survey by seismic down-hole and PS suspension logging tests to establish the best estimate compressional-wave, shear-wave profile along with the uncertainties of the site. During subsurface explorations, soil/rock specimens were collected and transported to the laboratory for element testing. The testing program included index property tests, resonant column tests, and triaxial tests to determine the index properties and engineering properties (hysterical damping, strain-dependent dynamic nonlinear material properties and strength parameters) of the materials. According to the results of the site-specific investigation, the best estimate data of each soil layer are determined.

To accommodate the variability in the layer thickness, shear-wave velocity and strain-dependent dynamic nonlinear material property, a Monte-Carlo procedure was used to generate 60 sets of parameters for each layer. The generation of random parameters was based on proper probabilistic models and predetermined, site-specific best estimate data. FSAR Section 2.5.2.5.1.3 (Site Properties Representing Uncertainties and Correlations) provides a description of the randomization process followed for the site amplification analysis.

(d) Variation in shear-wave velocities is characterized by the log-normal distribution. The correlation coefficients between shear wave velocities in adjacent layers were determined using United States Geological Survey (USGS) empirical relationships. The correlation among layers features a first-order auto-regressive model with a coefficient correlation (ρ) that depends on depth and distance of mid-points of adjacent layers (Toro, 1996). The randomly generated thicknesses of layer were computed assuming a normal distribution using the coefficient of variation of 0.10 to 0.15 for thickness of each layer. For consistency with the site-specific data, the generated ln-velocities and the generated thicknesses were truncated at ±2s according to the recommendations of Toro (Toro, 1996).

(e) FSAR Figure 2.5-165 provides the low strain P and S wave velocity profiles of the best estimate. FSAR Figure 3.7-14 provides the lower and upper bound profiles.

4) A description of the SSI analyses performed including a description of the computer codes, seismic models, how embedment effects were considered, modeling assumptions, and properties of the backfill incorporated into the analyses.

Response
A response to this question will be provided by 10/21/2009.

5) FSAR 3.7.1, Page 3-30, states that Tables 3.7-1 and 3.7-2 presents the seismic input ground motion utilized in the seismic design of the seismic Category I structural components. These two tables appear to provide the best estimate (BE) and lower bound (LB) soil modeling characteristics. The statement needs to be corrected and the appropriate tables added to the FSAR.

Response
A response to this question will be provided by 10/21/2009.

COLA Impact

No changes to the COLA are required due to this RAI response.

03.07.01-4

In FSAR Section 3.7.1.1 on page 3-35, it states that the ground motion for the soil-structure interaction (SSI) analysis of the EPGB and ESWB are based on the foundation input response spectra (FIRS) developed by the site response analysis that accounts for structure-soil-structure interaction (SSSI) effects due to the influence of the NI. However, details relating to the development of the seismic design parameters were not provided and it is not clear whether they meet the acceptance criteria of SRP Section 3.7.1 and SRP 3.7.2.

1) Describe in detail the process used to develop the FIRS and indicate if the FIRS were developed in a probabilistic manner. State if the site profiles used in the calculations were based on the geologic outcrop at the foundation elevation of each structure.

Response

The procedure documented in Regulatory Guide (RG) 1.208 (pp 17-18) is followed to develop the Foundation Input Response Spectra (FIRS). In this procedure, the site-specific Uniform Hazard Response Spectra (UHRS) are the product of the UHRS multiplied by the mean site amplification function. The UHRS and mean site amplification function are generated with the use of a Probabilistic Seismic Hazard Analysis (PSHA) and 60 random site response calculations, respectively. Therefore, the FIRS are developed in a probabilistic manner.

The soil layers above the foundation level are removed from the soil column to obtain the truncated soil column surface response. Based on the technical guideline NUREG-6728 (pp 6-20, 6-21), the conventional approach to develop the site-specific FIRS involves convolutional analysis, either equivalent-linear or fully nonlinear. In the convolutional analysis, uncertainty in dynamic material properties is generally accommodated through a Monte Carlo approach using randomly generated properties with statistically used distributions. Uncertainties in soil properties and model deficiencies of the convolutional analysis are accommodated by either smoothly enveloping the deterministic variations or selecting a fractile level, generally the mean. According to the guideline, the approach using randomized material properties is preferred since the conservatism is quantified, provided the parameter distributions reflect a realistic assessment of how well the base case profile and non-linear properties are known and vary over the site. Since the component of model uncertainty in the convolutional analysis is currently un-quantified, it is not possible to add it explicitly; however, it is expected to be very small based on validation exercises of the entire model (Appendix D, NUREG-6728). As a result, the possible double counting of site variability may be largely offset by neglecting the deficiencies in the convolutional formulation. Regarding the development of the control motions used in the convolutional analysis, mean, high, and low percentile magnitudes from de-aggregation for each design earthquake are used to scale spectral shape to the rock Uniform Hazard Spectra (UHS); the resulting controlling motions are used to develop weighted mean transfer function for each design earthquake.

The procedure documented in the NUREG-6728, considering uncertainties of material properties and model deficiencies, was followed to develop the FIRS. Section 2.5.2.6 of the FSAR describes the process for development of vertical spectra by scaling the horizontal spectra by a frequency-dependent vertical-to-horizontal (V/H) factor.

The FIRS for each building in the power block area was developed independently to accommodate a specific soil column. A figure is provided for each of the facilities as follows:

- Figure 1-1 – General plan view and building nomenclature
- Figure 1-2 – Soil profile underneath the Nuclear Island (NI)
- Figure 1-3 – Soil profile underneath 3URB (ESWB)
- Figure 1-4 – Soil profile underneath 4URB (ESWB)
- Figure 1-5 – Soil profile underneath 3UBP and 4UBP (EPBG)
- Figure 1-6 – Soil profile underneath 1URB and 2URB (ESWB)
- Figure 1-7 – Soil profile underneath 1UBP and 2UBP

Table 1-1 summarizes the criteria to develop the FIRS for each of the facilities.

TABLE 1-1

SUMMARY OF CRITERIA USED FOR DEVELOPMENT OF FIRS

FACILITY	BASE LEVEL (FT)		FOUNDATION MATERIAL	EMBEDMENT CONSIDERED	FIRS CRITERIA
	DEPTH	EL.			
NI	0	638	C-MF	No	Outcropping ground motion at base after excavation
3URB	22	652	Fill	Yes	Equivalent outcropping motion at foundation level
4URB	22	652	Fill	Yes	Equivalent outcropping motion at foundation level
3UBP	5	669	Fill	No	Surface structure, outcropping ground motion at foundation level
4UBP	5	669	Fill	No	Surface structure, outcropping ground motion at foundation level
1URB	22	652	C-MF	Yes	Equivalent outcropping motion at foundation level
2URB	22	652	C-MF	Yes	Equivalent outcropping motion at foundation level
1UBP	5	669	C-MF	No	Surface structure, outcropping ground motion at foundation level
2UBP	5	669	C-MF	No	Surface structure, outcropping ground motion at foundation level

C-MF: Concrete fill over Mahantango Formation

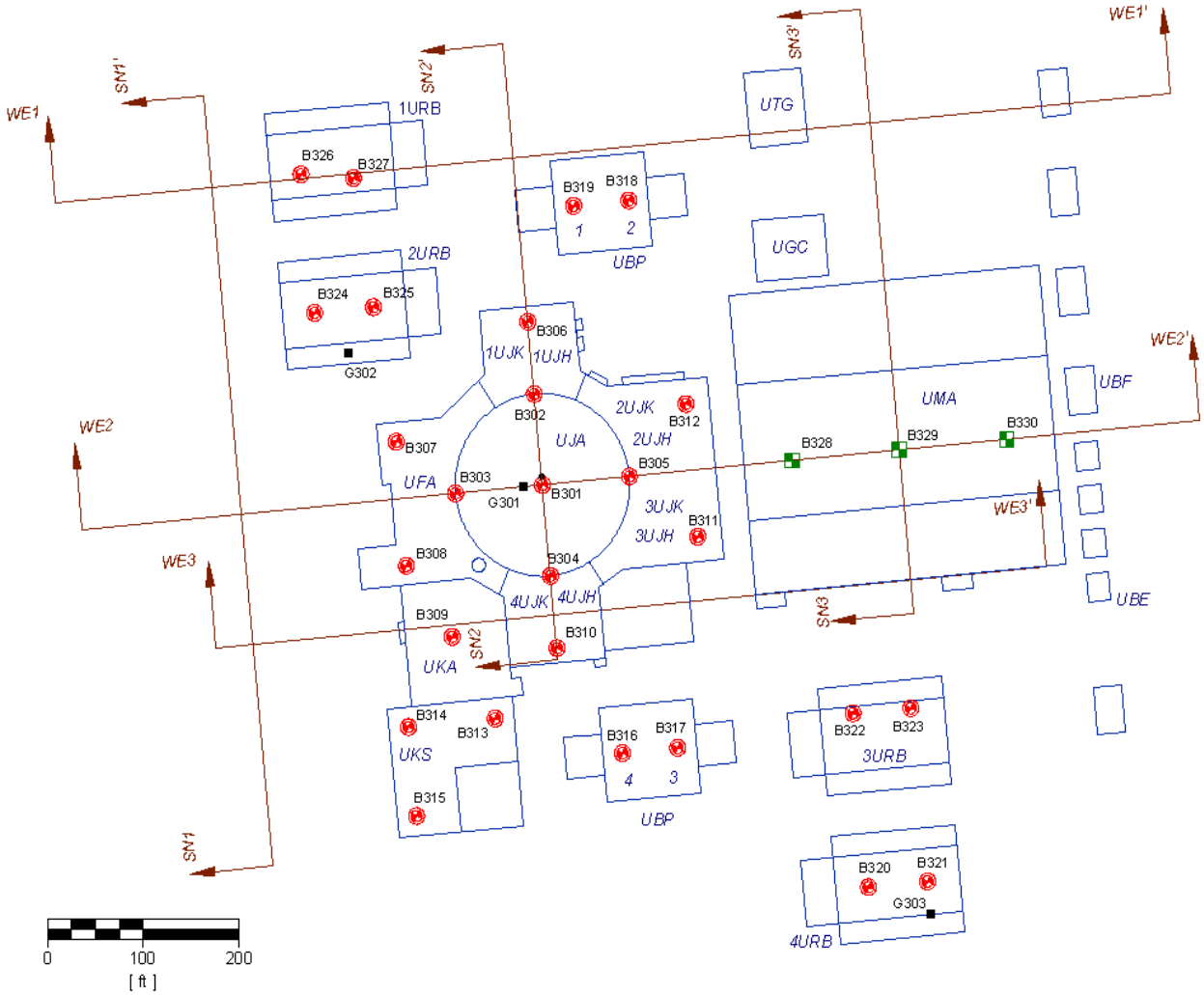


FIGURE 1-1

GENERAL PLAN VIEW AND BUILDING NOMENCLATURE

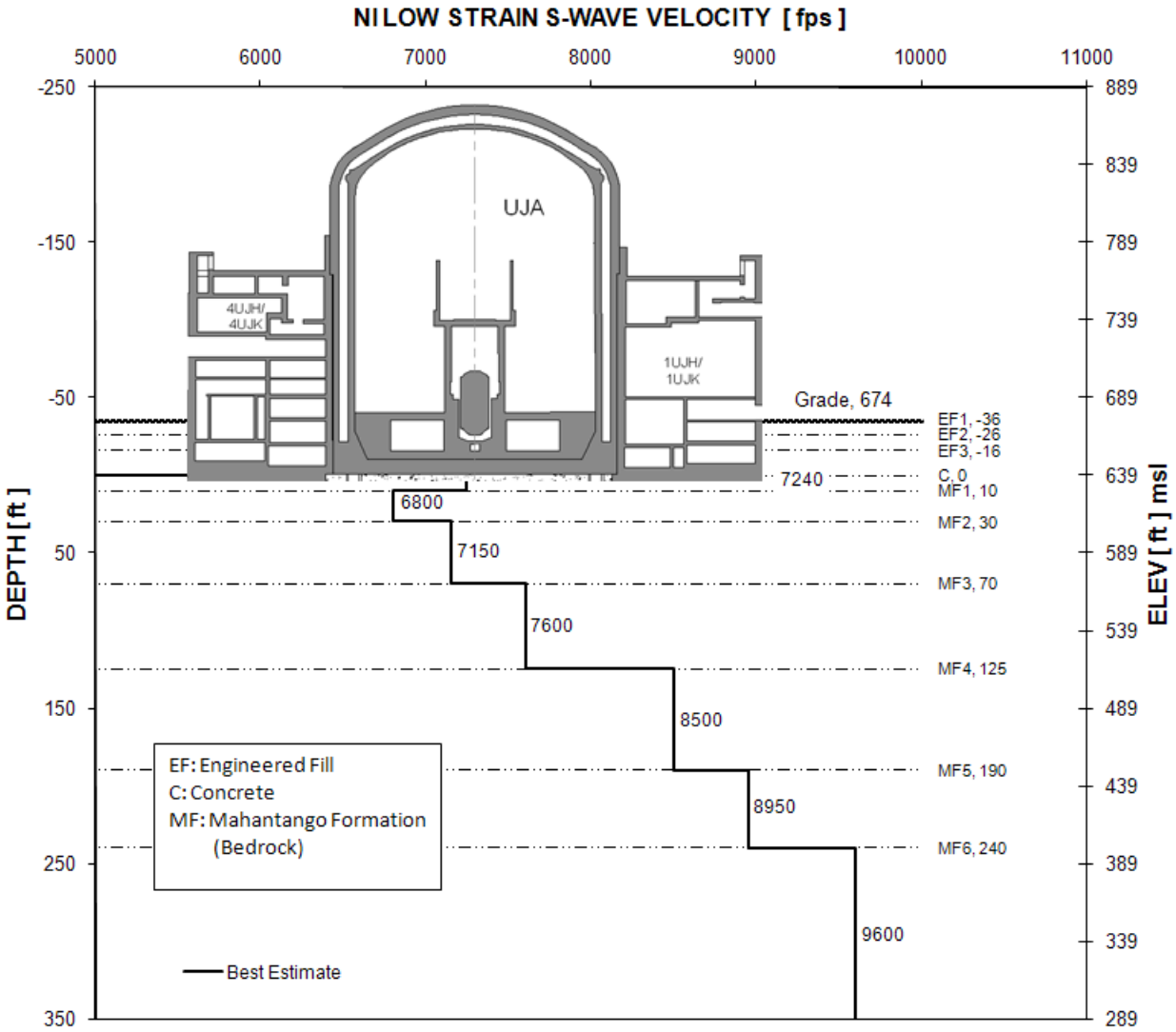


FIGURE 1-2

SOIL PROFILE UNDERNEATH THE NUCLEAR ISLAND (NI)

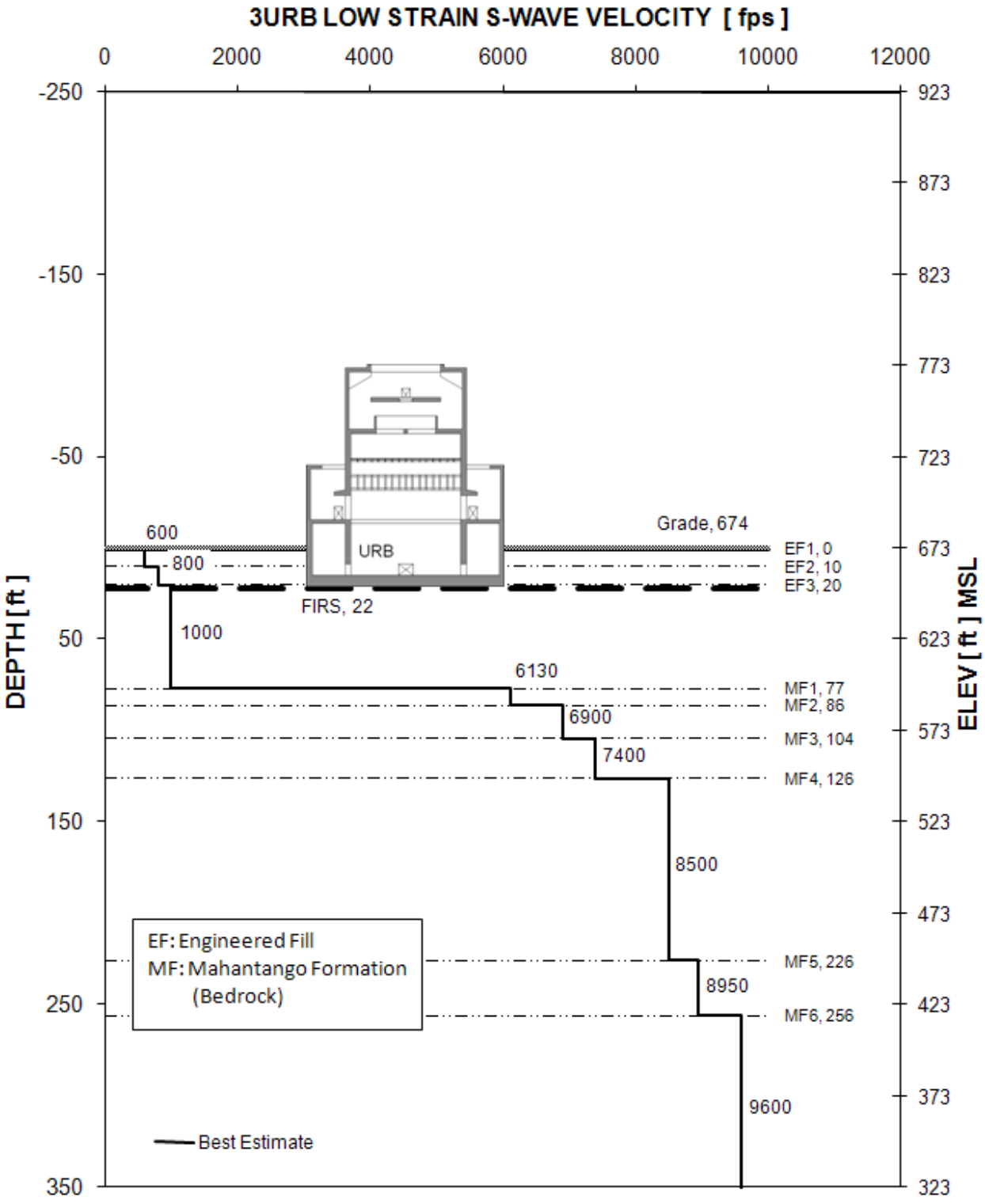


FIGURE 1-3

SOIL PROFILE UNDERNEATH 3URB (ESWB)

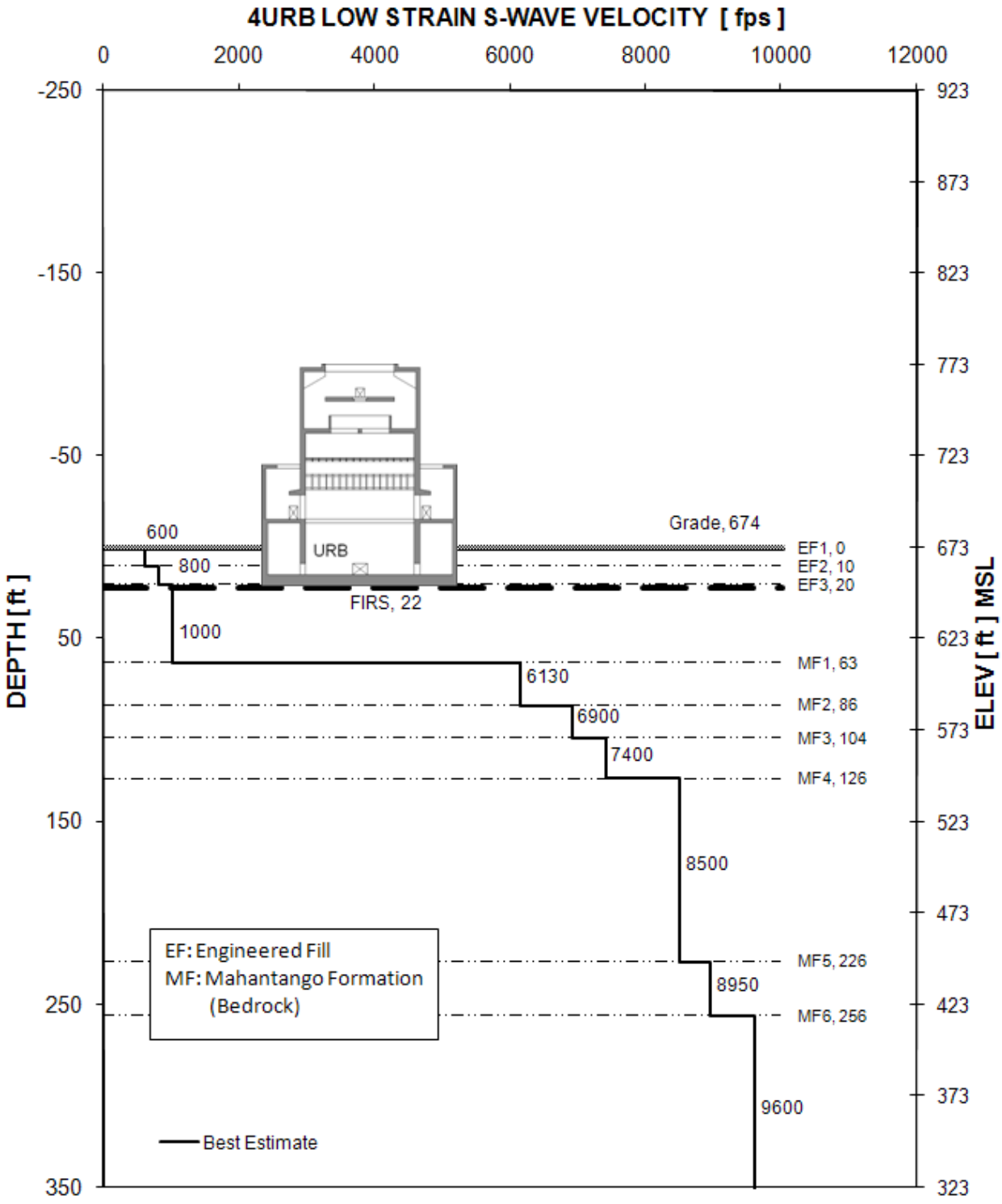


FIGURE 1-4

SOIL PROFILE UNDERNEATH 4URB (ESWB)

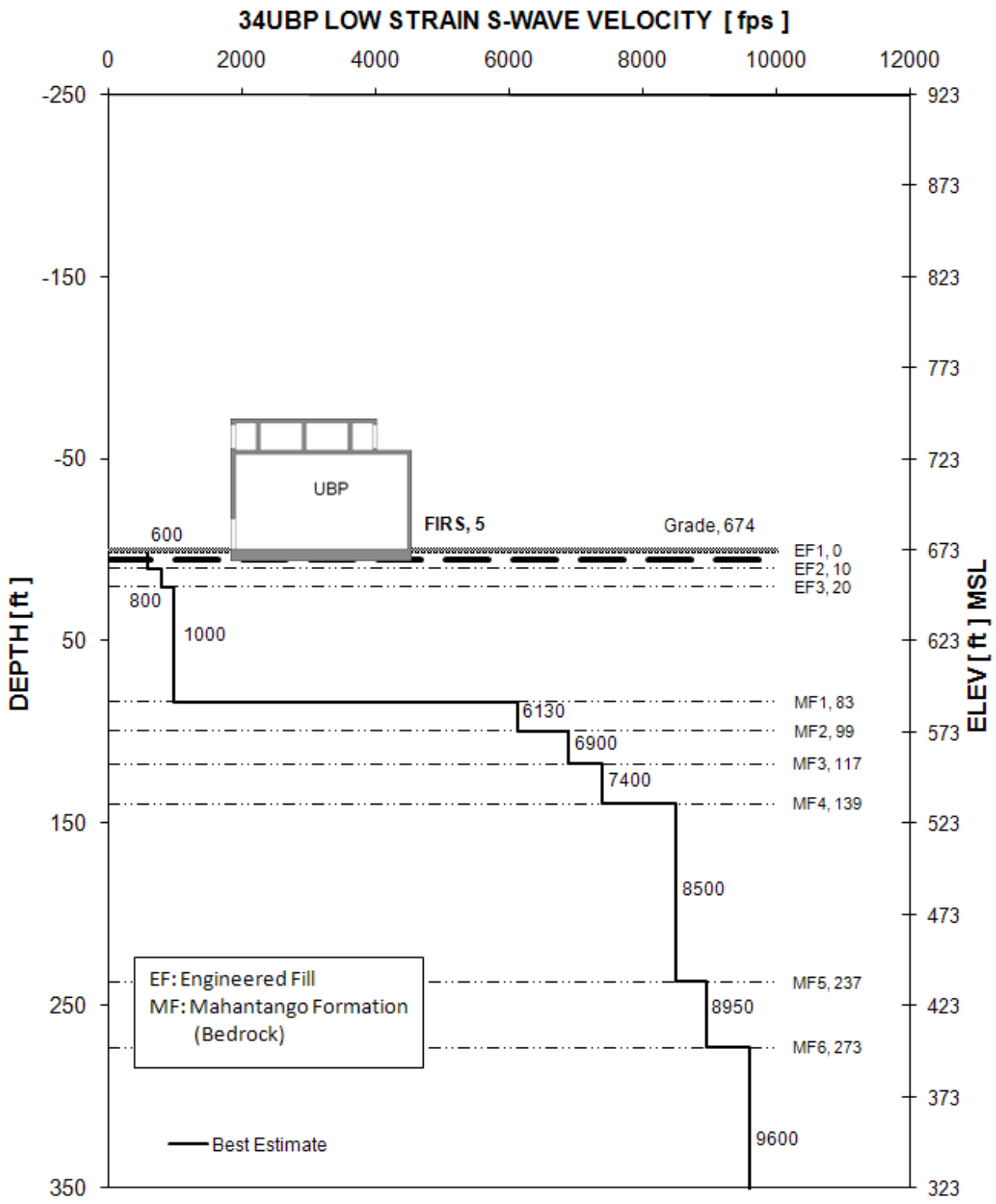


FIGURE 1-5

SOIL PROFILE UNDERNEATH 3UBP AND 4UBP (EPBG)

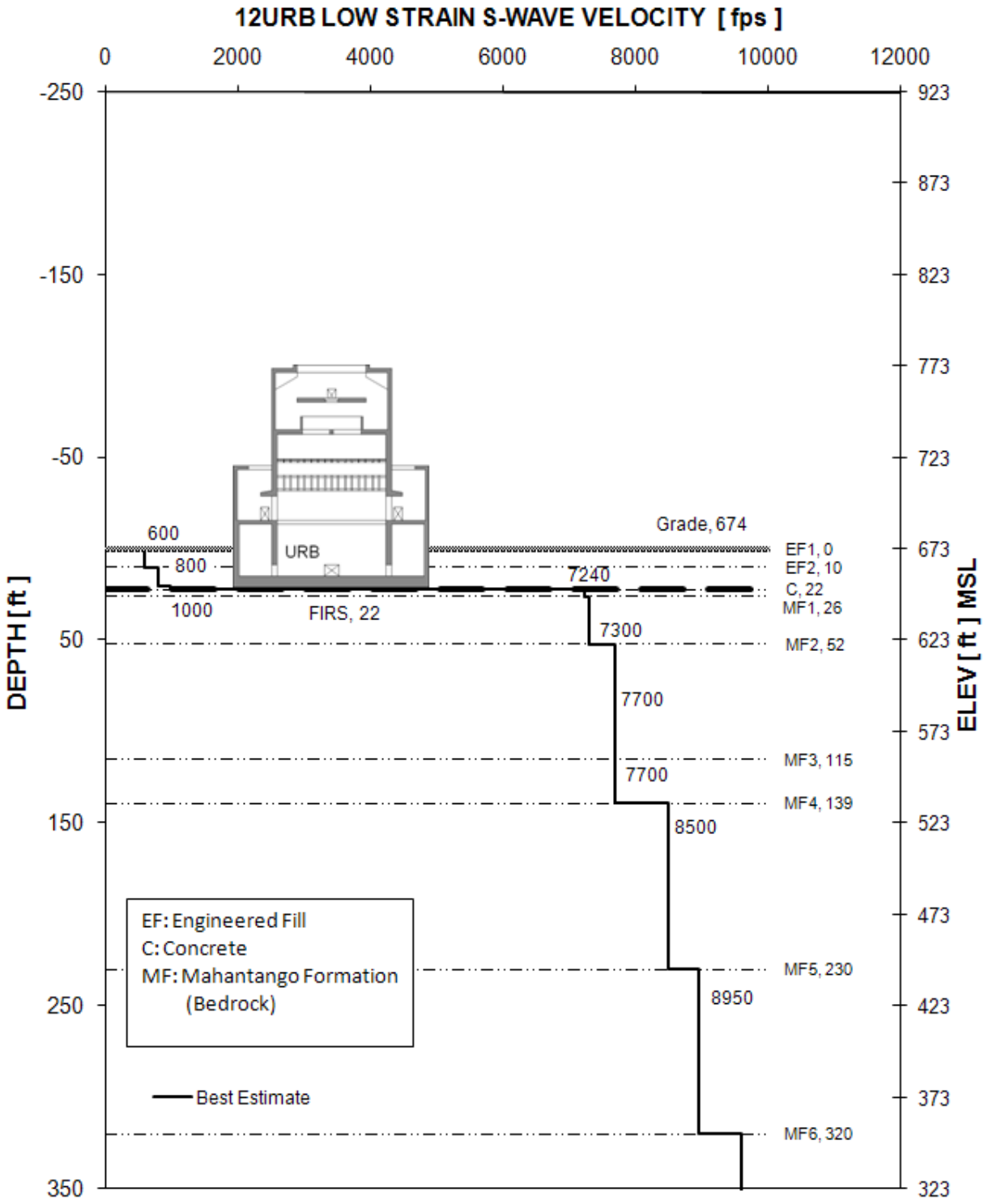


FIGURE 1-6

SOIL PROFILE UNDERNEATH 1URB AND 2URB (ESWB)

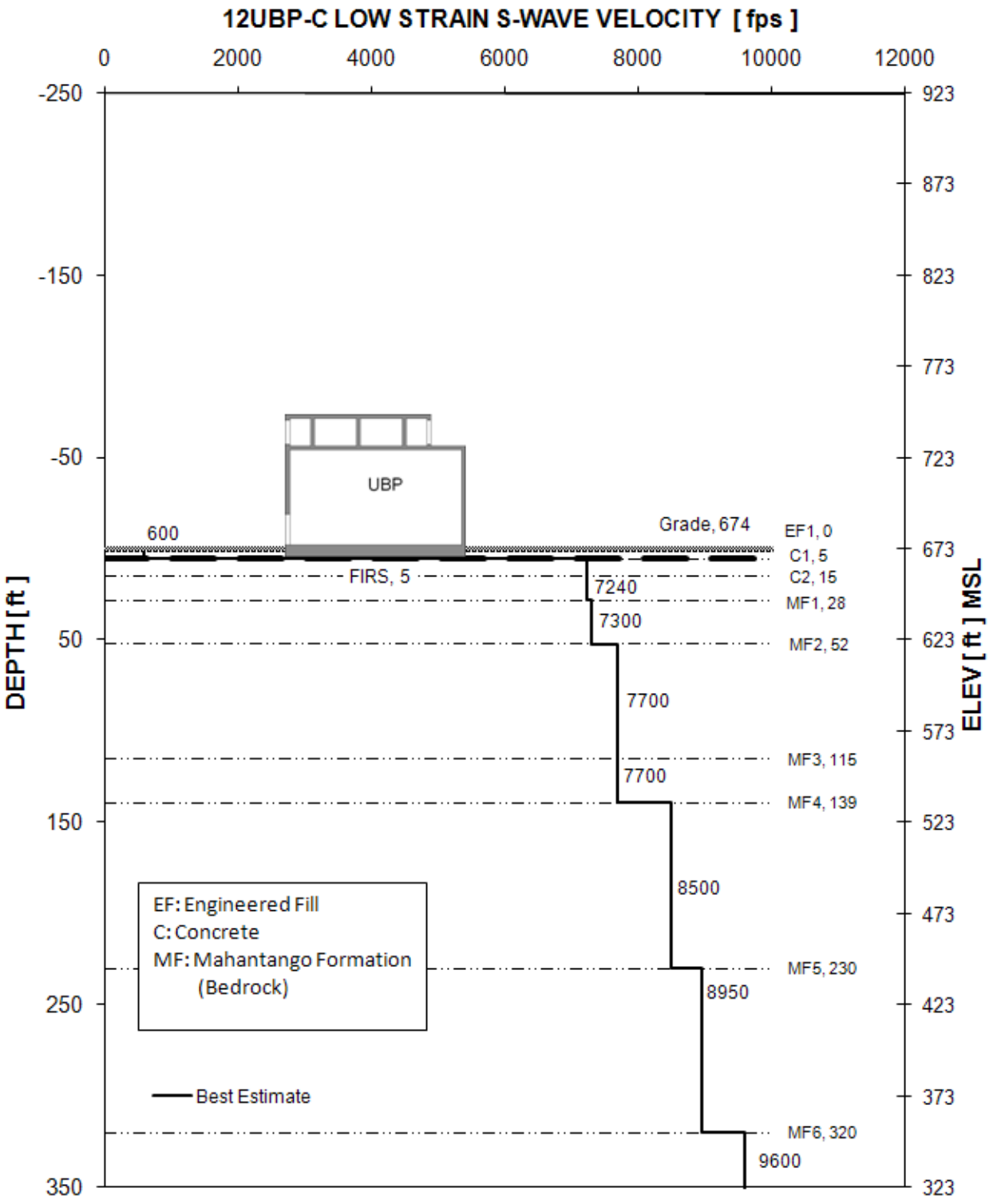


FIGURE 1-7

SOIL PROFILE UNDERNEATH 1UBP AND 2UBP (EPBG)

2) Describe how the SSSI effects are determined and subsequently used to modify the FIRS for the EPGB and ESWB.

Response
A response to this question will be provided by 11/18/2009.

3) Describe the ground motion input time histories that were used in the SSI analysis and how they meet SRP Acceptance Criteria 1.B of SRP Section 3.7.1. In addition, provide a comparison of the response spectra of the input time histories to the FIRS for each of the structures and demonstrate how the response spectra of the input time histories meet Approach 1 or Approach 2 of SRP Acceptance Criteria 1.B of SRP Section 3.7.1.

Response
Figures 1-8 through 1-22 show the comparison of the 5% damped response spectrum of the input time histories, and 90%, 100% and 130% of the target response spectra for five structures (3URB, 4URB, 12URB, 12UBP, 34UBP). The comparison demonstrates that the 5% damped response spectra of the time histories do not fall more than 10% below the target response spectra, and do not exceed the target response spectra by more than 30%.

Tables 1-2 through 1-11 show the comparison of the response spectra of the input time history and the target response spectra for the horizontal and vertical direction for each structure. This data demonstrate that no more than 9 adjacent frequency points fall below the target response spectra.

The two horizontal time histories and the vertical input time history have a time increment of 0.005s and a Nyquist frequency of 100 Hz (1/(2*0.005)) equal to the maximum frequency of interest, and their total durations are greater than 20s.

Finally, the correlation coefficients among the three time histories for each structure are less than 0.16 prescribed by the SRP. The correlation coefficients for each structure are given in Table 1-12.

TABLE 1-2

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE HORIZONTAL DIRECTION FOR 3URB

FREQUENCY (HZ)	HORIZONTAL FIRS ACCELERATION (G)	FIRST HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)	SECOND HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0058	0.0065	12.59	0.0061	5.52
0.102	0.0060	0.0067	11.79	0.0065	8.14
0.105	0.0063	0.0069	10.38	0.0069	9.58
0.107	0.0065	0.0071	8.92	0.0072	10.15
0.110	0.0068	0.0072	7.26	0.0074	10.07
0.112	0.0070	0.0074	6.13	0.0078	10.84
0.115	0.0073	0.0077	5.22	0.0081	10.71
0.118	0.0076	0.0079	4.62	0.0083	9.78
0.120	0.0079	0.0082	4.46	0.0085	8.41
0.123	0.0082	0.0085	4.17	0.0087	6.37
0.126	0.0085	0.0091	7.55	0.0088	4.01
0.129	0.0088	0.0098	11.25	0.0092	4.66
0.132	0.0091	0.0105	14.57	0.0097	6.02
0.135	0.0095	0.0111	17.30	0.0101	6.01
0.138	0.0098	0.0117	18.92	0.0104	5.29
0.141	0.0102	0.0122	19.29	0.0112	9.70
0.145	0.0106	0.0125	17.94	0.0119	12.46
0.148	0.0110	0.0127	15.38	0.0125	13.83
0.151	0.0114	0.0127	11.39	0.0129	12.97
0.155	0.0118	0.0124	4.90	0.0130	9.71
0.159	0.0123	0.0121	-1.79	0.0129	4.64
0.162	0.0128	0.0126	-0.86	0.0132	3.61
0.166	0.0132	0.0131	-0.83	0.0139	5.14
0.170	0.0137	0.0140	2.04	0.0145	5.77
0.174	0.0142	0.0147	3.59	0.0150	5.70
0.178	0.0147	0.0153	3.60	0.0158	6.99
0.182	0.0153	0.0162	5.95	0.0164	6.93
0.186	0.0159	0.0173	8.83	0.0168	5.74
0.191	0.0164	0.0181	9.92	0.0169	2.92
0.195	0.0170	0.0187	9.74	0.0167	-1.82
0.200	0.0177	0.0195	10.30	0.0178	0.96
0.204	0.0183	0.0199	8.73	0.0194	5.62
0.209	0.0189	0.0199	5.18	0.0210	10.89

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.214	0.0196	0.0199	1.89	0.0223	14.07
0.219	0.0202	0.0196	-3.12	0.0230	14.12
0.224	0.0209	0.0222	6.23	0.0232	11.03
0.229	0.0215	0.0240	11.37	0.0227	5.57
0.234	0.0223	0.0252	13.17	0.0221	-0.67
0.240	0.0230	0.0251	9.13	0.0238	3.35
0.246	0.0237	0.0250	5.22	0.0246	3.71
0.251	0.0245	0.0257	4.65	0.0269	9.58
0.257	0.0253	0.0260	2.49	0.0280	10.66
0.263	0.0261	0.0260	-0.34	0.0284	8.62
0.269	0.0269	0.0264	-1.97	0.0288	7.06
0.275	0.0277	0.0272	-1.84	0.0297	7.29
0.282	0.0285	0.0285	-0.07	0.0305	6.76
0.288	0.0294	0.0302	2.62	0.0316	7.66
0.295	0.0303	0.0317	4.56	0.0332	9.75
0.302	0.0312	0.0328	5.16	0.0343	9.85
0.309	0.0321	0.0339	5.61	0.0354	10.18
0.316	0.0331	0.0348	5.35	0.0364	9.98
0.324	0.0341	0.0361	5.96	0.0378	10.89
0.331	0.0351	0.0388	10.72	0.0392	11.63
0.339	0.0361	0.0405	12.25	0.0400	10.81
0.347	0.0371	0.0396	6.71	0.0404	8.70
0.355	0.0382	0.0402	5.23	0.0405	5.99
0.363	0.0393	0.0431	9.66	0.0406	3.28
0.372	0.0405	0.0456	12.73	0.0423	4.52
0.380	0.0416	0.0481	15.67	0.0438	5.14
0.389	0.0428	0.0501	16.95	0.0448	4.60
0.398	0.0441	0.0505	14.62	0.0455	3.34
0.407	0.0453	0.0502	10.74	0.0464	2.34
0.417	0.0467	0.0501	7.40	0.0478	2.51
0.427	0.0479	0.0506	5.66	0.0499	4.15
0.437	0.0492	0.0517	5.12	0.0521	5.87
0.447	0.0505	0.0530	4.77	0.0536	6.07
0.457	0.0519	0.0541	4.20	0.0558	7.53
0.468	0.0533	0.0563	5.66	0.0564	5.74
0.479	0.0548	0.0576	5.19	0.0563	2.81
0.490	0.0562	0.0585	4.07	0.0587	4.45
0.501	0.0577	0.0597	3.50	0.0601	4.23
0.513	0.0584	0.0605	3.47	0.0610	4.40
0.525	0.0592	0.0621	4.87	0.0612	3.41

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.537	0.0600	0.0630	5.12	0.0603	0.50
0.550	0.0607	0.0632	4.00	0.0613	0.92
0.562	0.0615	0.0629	2.19	0.0625	1.54
0.575	0.0623	0.0629	0.91	0.0631	1.22
0.589	0.0631	0.0645	2.17	0.0637	0.93
0.603	0.0640	0.0673	5.27	0.0646	1.03
0.617	0.0648	0.0705	8.77	0.0653	0.77
0.631	0.0656	0.0732	11.53	0.0657	0.03
0.646	0.0665	0.0737	10.81	0.0687	3.37
0.661	0.0674	0.0727	7.97	0.0695	3.15
0.676	0.0681	0.0748	9.79	0.0687	0.78
0.692	0.0687	0.0758	10.31	0.0693	0.86
0.708	0.0692	0.0743	7.31	0.0706	1.95
0.724	0.0698	0.0751	7.60	0.0700	0.29
0.741	0.0703	0.0736	4.71	0.0695	-1.15
0.759	0.0709	0.0718	1.34	0.0711	0.35
0.776	0.0715	0.0763	6.84	0.0744	4.17
0.794	0.0720	0.0760	5.51	0.0761	5.60
0.813	0.0726	0.0797	9.85	0.0753	3.76
0.832	0.0732	0.0813	11.04	0.0763	4.21
0.851	0.0737	0.0823	11.64	0.0814	10.44
0.871	0.0742	0.0812	9.43	0.0859	15.76
0.891	0.0747	0.0784	4.99	0.0892	19.42
0.912	0.0752	0.0789	4.95	0.0897	19.36
0.933	0.0757	0.0807	6.73	0.0908	20.01
0.955	0.0761	0.0794	4.30	0.0931	22.24
0.977	0.0766	0.0776	1.34	0.0928	21.12
1.000	0.0771	0.0810	5.02	0.0877	13.80
1.023	0.0796	0.0881	10.73	0.0823	3.42
1.047	0.0822	0.0944	14.86	0.0854	3.92
1.072	0.0849	0.0974	14.76	0.0939	10.61
1.097	0.0876	0.0966	10.30	0.0992	13.25
1.122	0.0905	0.0950	5.02	0.1000	10.54
1.148	0.0934	0.0963	3.15	0.1039	11.26
1.175	0.0964	0.0998	3.47	0.0999	3.61
1.202	0.0996	0.1047	5.13	0.1087	9.15
1.230	0.1028	0.1076	4.65	0.1087	5.72
1.259	0.1061	0.1086	2.36	0.1095	3.16
1.288	0.1096	0.1128	2.94	0.1126	2.78
1.318	0.1131	0.1187	4.95	0.1182	4.51

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
1.349	0.1168	0.1196	2.36	0.1256	7.53
1.380	0.1211	0.1189	-1.82	0.1307	7.95
1.413	0.1277	0.1296	1.50	0.1347	5.44
1.445	0.1347	0.1345	-0.13	0.1421	5.46
1.479	0.1421	0.1466	3.15	0.1546	8.79
1.514	0.1499	0.1628	8.61	0.1657	10.54
1.549	0.1581	0.1792	13.37	0.1661	5.09
1.585	0.1667	0.1929	15.72	0.1605	-3.71
1.622	0.1758	0.1970	12.05	0.1823	3.66
1.660	0.1855	0.1949	5.07	0.2041	10.04
1.698	0.1956	0.2040	4.28	0.2172	11.03
1.738	0.2063	0.2290	10.96	0.2238	8.45
1.778	0.2175	0.2333	7.27	0.2255	3.69
1.820	0.2291	0.2451	6.98	0.2302	0.47
1.862	0.2414	0.2572	6.56	0.2468	2.27
1.906	0.2543	0.2720	6.97	0.2484	-2.32
1.950	0.2679	0.3019	12.68	0.2826	5.49
1.995	0.2822	0.3172	12.40	0.3093	9.59
2.042	0.2973	0.3111	4.66	0.3118	4.89
2.089	0.3132	0.3147	0.49	0.3182	1.59
2.138	0.3300	0.3485	5.62	0.3575	8.35
2.188	0.3476	0.3659	5.25	0.3753	7.95
2.239	0.3603	0.3798	5.40	0.3632	0.81
2.291	0.3679	0.3907	6.18	0.3850	4.65
2.344	0.3757	0.4041	7.57	0.4182	11.32
2.399	0.3836	0.4266	11.19	0.4267	11.21
2.455	0.3917	0.4357	11.21	0.4094	4.50
2.512	0.3987	0.4193	5.16	0.4073	2.14
2.570	0.4007	0.3979	-0.70	0.4192	4.60
2.630	0.4028	0.4262	5.82	0.4427	9.92
2.692	0.4048	0.4355	7.58	0.4552	12.44
2.754	0.4069	0.4244	4.31	0.4521	11.12
2.818	0.4089	0.4250	3.94	0.4386	7.25
2.884	0.4110	0.4632	12.70	0.4313	4.95
2.951	0.4131	0.4521	9.44	0.4343	5.13
3.020	0.4152	0.4311	3.82	0.4471	7.69
3.090	0.4173	0.4326	3.66	0.4498	7.80
3.162	0.4194	0.4386	4.58	0.4394	4.77
3.236	0.4215	0.4423	4.93	0.4351	3.23
3.311	0.4237	0.4507	6.39	0.4451	5.05

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
3.389	0.4258	0.4469	4.96	0.4750	11.56
3.467	0.4280	0.4420	3.29	0.4579	6.99
3.548	0.4301	0.4531	5.33	0.4305	0.09
3.631	0.4209	0.4538	7.81	0.4059	-3.57
3.715	0.4096	0.4335	5.85	0.4100	0.09
3.802	0.3986	0.4319	8.35	0.4438	11.34
3.891	0.3879	0.4195	8.14	0.4363	12.47
3.981	0.3775	0.4002	6.03	0.3913	3.66
4.074	0.3674	0.3762	2.40	0.3903	6.24
4.169	0.3575	0.3773	5.54	0.3854	7.80
4.266	0.3479	0.3649	4.89	0.3668	5.44
4.365	0.3386	0.3547	4.78	0.3654	7.92
4.467	0.3295	0.3422	3.85	0.3476	5.51
4.571	0.3245	0.3517	8.40	0.3360	3.55
4.677	0.3236	0.3480	7.56	0.3359	3.82
4.786	0.3227	0.3331	3.21	0.3406	5.54
4.898	0.3218	0.3249	0.96	0.3390	5.35
5.012	0.3218	0.3389	5.31	0.3343	3.87
5.129	0.3298	0.3531	7.06	0.3420	3.68
5.248	0.3380	0.3578	5.84	0.3474	2.77
5.370	0.3464	0.3649	5.34	0.3535	2.05
5.495	0.3551	0.3745	5.47	0.3573	0.63
5.623	0.3639	0.3805	4.57	0.3875	6.48
5.754	0.3729	0.3843	3.03	0.4017	7.72
5.889	0.3822	0.3983	4.21	0.4029	5.40
6.026	0.3917	0.4140	5.69	0.4098	4.61
6.166	0.4015	0.4197	4.55	0.4221	5.14
6.310	0.4115	0.4289	4.25	0.4305	4.62
6.457	0.4217	0.4428	4.99	0.4403	4.42
6.607	0.4322	0.4443	2.81	0.4610	6.68
6.761	0.4429	0.4597	3.79	0.4693	5.95
6.918	0.4540	0.4923	8.45	0.4502	-0.82
7.080	0.4653	0.4938	6.14	0.4794	3.03
7.244	0.4768	0.4797	0.60	0.5058	6.07
7.413	0.4887	0.5138	5.15	0.5029	2.92
7.586	0.4953	0.5260	6.19	0.4950	-0.07
7.763	0.4964	0.5209	4.93	0.5320	7.17
7.943	0.4975	0.5209	4.70	0.5309	6.71
8.128	0.4987	0.5320	6.68	0.5044	1.16
8.318	0.4998	0.5288	5.81	0.5200	4.05

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
8.511	0.5009	0.5197	3.77	0.5321	6.23
8.710	0.5020	0.5233	4.25	0.5322	6.01
8.913	0.5031	0.5292	5.20	0.5176	2.88
9.120	0.5042	0.5354	6.19	0.5095	1.05
9.333	0.5053	0.5310	5.08	0.5155	2.02
9.550	0.5065	0.5329	5.21	0.5156	1.81
9.772	0.5076	0.5214	2.71	0.5155	1.56
10.000	0.5087	0.5347	5.12	0.5159	1.41
10.233	0.5130	0.5331	3.91	0.5270	2.73
10.471	0.5173	0.5408	4.53	0.5253	1.54
10.715	0.5217	0.5689	9.05	0.5416	3.81
10.965	0.5261	0.5568	5.84	0.5391	2.47
11.220	0.5306	0.5672	6.91	0.5390	1.59
11.482	0.5351	0.5643	5.47	0.5450	1.85
11.749	0.5393	0.5734	6.32	0.5574	3.35
12.023	0.5415	0.5671	4.72	0.5512	1.79
12.303	0.5437	0.5829	7.20	0.5605	3.10
12.589	0.5459	0.5787	6.00	0.5449	-0.18
12.883	0.5481	0.5878	7.23	0.5488	0.12
13.183	0.5503	0.5860	6.48	0.5599	1.74
13.490	0.5526	0.5805	5.06	0.5593	1.22
13.804	0.5548	0.5748	3.61	0.5624	1.37
14.125	0.5570	0.5866	5.31	0.5563	-0.14
14.455	0.5593	0.5862	4.81	0.5659	1.19
14.791	0.5616	0.5833	3.88	0.5706	1.61
15.136	0.5638	0.5974	5.95	0.6118	8.51
15.488	0.5661	0.5941	4.93	0.5928	4.70
15.849	0.5685	0.6020	5.91	0.5881	3.46
16.218	0.5708	0.5999	5.11	0.6056	6.10
16.596	0.5731	0.5980	4.34	0.6119	6.78
16.983	0.5754	0.6037	4.91	0.6018	4.59
17.378	0.5778	0.6100	5.57	0.5992	3.70
17.783	0.5802	0.5971	2.92	0.6148	5.98
18.197	0.5825	0.6168	5.89	0.6046	3.79
18.621	0.5849	0.6058	3.57	0.6127	4.75
19.055	0.5853	0.6158	5.21	0.6050	3.35
19.499	0.5830	0.6125	5.05	0.6087	4.40
19.953	0.5807	0.6084	4.76	0.6063	4.41
20.418	0.5784	0.6098	5.43	0.6046	4.54
20.893	0.5761	0.6022	4.53	0.5941	3.12

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
21.380	0.5738	0.6000	4.57	0.6002	4.60
21.878	0.5715	0.5989	4.79	0.5946	4.03
22.387	0.5693	0.5974	4.94	0.5922	4.03
22.909	0.5670	0.5937	4.71	0.5877	3.65
23.442	0.5647	0.5913	4.70	0.5900	4.47
23.989	0.5625	0.5885	4.62	0.5870	4.36
24.547	0.5603	0.5852	4.44	0.5872	4.81
25.119	0.5571	0.5886	5.66	0.5797	4.05
25.704	0.5504	0.5809	5.53	0.5704	3.63
26.303	0.5438	0.5621	3.38	0.5753	5.80
26.916	0.5372	0.5638	4.95	0.5606	4.35
27.542	0.5307	0.5623	5.95	0.5552	4.61
28.184	0.5243	0.5430	3.57	0.5396	2.92
28.841	0.5180	0.5403	4.30	0.5390	4.04
29.512	0.5118	0.5411	5.74	0.5281	3.19
30.200	0.5056	0.5309	5.01	0.5329	5.39
30.903	0.4993	0.5233	4.80	0.5215	4.45
31.623	0.4930	0.5166	4.77	0.5079	3.01
32.360	0.4868	0.5068	4.10	0.4861	-0.16
33.113	0.4807	0.5045	4.95	0.4941	2.79
33.885	0.4747	0.4976	4.82	0.4790	0.90
34.674	0.4687	0.4921	4.99	0.4778	1.94
35.482	0.4628	0.4864	5.09	0.4852	4.83
36.308	0.4570	0.4772	4.41	0.4684	2.50
37.154	0.4513	0.4642	2.87	0.4703	4.23
38.019	0.4456	0.4625	3.79	0.4630	3.90
38.905	0.4384	0.4529	3.31	0.4555	3.89
39.811	0.4288	0.4479	4.45	0.4507	5.10
40.738	0.4195	0.4418	5.32	0.4200	0.12
41.687	0.4103	0.4277	4.23	0.4100	-0.08
42.658	0.4013	0.4208	4.84	0.3966	-1.18
43.652	0.3926	0.4107	4.61	0.3879	-1.20
44.669	0.3840	0.4030	4.96	0.3788	-1.35
45.709	0.3756	0.3941	4.92	0.3670	-2.29
46.774	0.3674	0.3866	5.23	0.3616	-1.57
47.863	0.3594	0.3771	4.92	0.3565	-0.80
48.978	0.3516	0.3710	5.53	0.3634	3.36
50.119	0.3446	0.3623	5.14	0.3556	3.21
51.287	0.3377	0.3582	6.06	0.3438	1.79
52.481	0.3310	0.3421	3.34	0.3397	2.63

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
53.704	0.3244	0.3389	4.45	0.3319	2.30
54.954	0.3180	0.3353	5.44	0.3305	3.94
56.235	0.3116	0.3255	4.44	0.3252	4.34
57.544	0.3055	0.3238	6.02	0.3172	3.85
58.885	0.2994	0.3088	3.16	0.3212	7.28
60.256	0.2934	0.3082	5.02	0.3093	5.43
61.660	0.2876	0.3012	4.74	0.3020	5.00
63.096	0.2823	0.2940	4.16	0.2921	3.49
64.566	0.2773	0.2879	3.84	0.2828	1.98
66.070	0.2724	0.2831	3.92	0.2799	2.77
67.609	0.2675	0.2779	3.87	0.2810	5.03
69.184	0.2628	0.2743	4.38	0.2762	5.09
70.795	0.2581	0.2629	1.84	0.2661	3.10
72.444	0.2536	0.2536	0.02	0.2659	4.89
74.132	0.2491	0.2531	1.63	0.2638	5.93
75.858	0.2446	0.2575	5.26	0.2631	7.53
77.625	0.2403	0.2593	7.89	0.2655	10.47
79.433	0.2366	0.2464	4.15	0.2655	12.23
81.284	0.2340	0.2425	3.64	0.2608	11.46
83.177	0.2314	0.2387	3.18	0.2634	13.86
85.114	0.2288	0.2349	2.68	0.2638	15.28
87.097	0.2263	0.2332	3.06	0.2570	13.59
89.126	0.2237	0.2318	3.58	0.2552	14.07
91.202	0.2213	0.2333	5.42	0.2595	17.29
93.326	0.2188	0.2471	12.94	0.2596	18.64
95.500	0.2164	0.2473	14.29	0.2545	17.60
97.724	0.2140	0.2382	11.31	0.2452	14.57
100.000	0.2116	0.2278	7.65	0.2365	11.78

TABLE 1-3

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE VERTICAL DIRECTION FOR 3URB

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0032	0.0037	5.71
0.102	0.0033	0.0038	5.51
0.105	0.0034	0.0040	4.76
0.107	0.0035	0.0041	3.82
0.110	0.0037	0.0043	4.67
0.112	0.0038	0.0045	7.08
0.115	0.0040	0.0048	9.09
0.118	0.0041	0.0050	10.28
0.120	0.0043	0.0053	10.95
0.123	0.0044	0.0055	11.16
0.126	0.0046	0.0057	10.33
0.129	0.0048	0.0058	9.40
0.132	0.0050	0.0060	7.97
0.135	0.0052	0.0061	6.81
0.138	0.0053	0.0063	6.23
0.141	0.0056	0.0065	5.19
0.145	0.0058	0.0067	4.38
0.148	0.0060	0.0069	4.37
0.151	0.0062	0.0072	4.06
0.155	0.0064	0.0074	3.92
0.159	0.0067	0.0078	5.13
0.162	0.0069	0.0083	8.45
0.166	0.0072	0.0089	11.53
0.170	0.0075	0.0094	13.77
0.174	0.0077	0.0099	15.13
0.178	0.0080	0.0103	15.26
0.182	0.0083	0.0107	15.14
0.186	0.0086	0.0112	17.10
0.191	0.0090	0.0116	16.58
0.195	0.0093	0.0117	13.55
0.200	0.0096	0.0117	9.06
0.204	0.0100	0.0119	6.65
0.209	0.0103	0.0121	5.32
0.214	0.0107	0.0122	2.87
0.219	0.0110	0.0122	0.00
0.224	0.0114	0.0125	-1.27

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.229	0.0118	0.0129	-1.38
0.234	0.0121	0.0134	-0.30
0.240	0.0125	0.0142	1.58
0.246	0.0129	0.0150	4.52
0.251	0.0134	0.0161	8.08
0.257	0.0138	0.0171	11.81
0.263	0.0142	0.0182	15.18
0.269	0.0147	0.0192	17.74
0.275	0.0151	0.0200	18.95
0.282	0.0156	0.0206	19.16
0.288	0.0160	0.0211	18.37
0.295	0.0165	0.0214	16.68
0.302	0.0170	0.0216	14.56
0.309	0.0175	0.0219	12.28
0.316	0.0180	0.0221	10.07
0.324	0.0186	0.0224	8.23
0.331	0.0191	0.0226	6.39
0.339	0.0197	0.0229	4.76
0.347	0.0203	0.0235	4.44
0.355	0.0208	0.0241	4.23
0.363	0.0214	0.0252	5.80
0.372	0.0220	0.0261	6.57
0.380	0.0227	0.0270	7.23
0.389	0.0233	0.0280	7.95
0.398	0.0240	0.0280	4.91
0.407	0.0247	0.0283	3.28
0.417	0.0254	0.0296	4.82
0.427	0.0261	0.0301	3.73
0.437	0.0268	0.0314	5.44
0.447	0.0275	0.0321	4.87
0.457	0.0283	0.0331	5.47
0.468	0.0291	0.0352	9.01
0.479	0.0298	0.0381	14.75
0.490	0.0307	0.0411	20.75
0.501	0.0315	0.0415	18.71
0.513	0.0319	0.0396	11.72
0.525	0.0323	0.0376	4.80
0.537	0.0327	0.0379	4.18
0.550	0.0331	0.0411	11.60
0.562	0.0336	0.0432	15.88
0.575	0.0340	0.0402	6.49
0.589	0.0344	0.0385	0.68
0.603	0.0349	0.0399	2.92
0.617	0.0353	0.0411	4.76

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.631	0.0358	0.0422	5.98
0.646	0.0363	0.0431	7.02
0.661	0.0367	0.0435	6.59
0.676	0.0372	0.0431	4.41
0.692	0.0374	0.0437	4.93
0.708	0.0377	0.0447	6.46
0.724	0.0380	0.0453	7.24
0.741	0.0383	0.0455	6.83
0.759	0.0386	0.0451	4.91
0.776	0.0390	0.0440	1.55
0.794	0.0393	0.0423	-3.14
0.813	0.0396	0.0444	0.96
0.832	0.0399	0.0475	7.15
0.851	0.0402	0.0503	12.51
0.871	0.0405	0.0504	12.01
0.891	0.0407	0.0455	0.55
0.912	0.0410	0.0439	-3.56
0.933	0.0412	0.0450	-1.77
0.955	0.0415	0.0456	-1.02
0.977	0.0418	0.0464	-0.06
1.000	0.0420	0.0480	2.81
1.023	0.0435	0.0493	2.01
1.047	0.0449	0.0500	0.14
1.072	0.0464	0.0544	5.35
1.097	0.0480	0.0571	7.03
1.122	0.0497	0.0574	4.04
1.148	0.0513	0.0584	2.37
1.175	0.0531	0.0611	3.53
1.202	0.0549	0.0638	4.57
1.230	0.0568	0.0635	0.62
1.259	0.0587	0.0658	0.97
1.288	0.0607	0.0665	-1.35
1.318	0.0627	0.0730	4.81
1.349	0.0649	0.0828	14.89
1.380	0.0673	0.0865	15.58
1.413	0.0711	0.0827	4.62
1.445	0.0751	0.0803	-3.76
1.479	0.0793	0.0848	-3.73
1.514	0.0838	0.0912	-2.03
1.549	0.0885	0.1012	2.98
1.585	0.0934	0.1113	7.22
1.622	0.0987	0.1152	5.07
1.660	0.1042	0.1218	5.20
1.698	0.1100	0.1205	-1.43

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
1.738	0.1162	0.1322	2.35
1.778	0.1227	0.1452	6.52
1.820	0.1294	0.1472	2.36
1.862	0.1366	0.1444	-4.85
1.906	0.1441	0.1614	0.81
1.950	0.1521	0.1792	6.08
1.995	0.1604	0.1849	3.74
2.042	0.1693	0.2137	13.61
2.089	0.1786	0.2317	16.73
2.138	0.1885	0.2356	12.52
2.188	0.1989	0.2363	6.93
2.239	0.2065	0.2407	4.95
2.291	0.2112	0.2533	7.95
2.344	0.2160	0.2701	12.51
2.399	0.2210	0.2804	14.22
2.455	0.2260	0.2701	7.53
2.512	0.2305	0.2619	2.27
2.570	0.2320	0.2706	4.98
2.630	0.2336	0.2642	1.81
2.692	0.2352	0.2743	4.99
2.754	0.2367	0.2822	7.28
2.818	0.2383	0.3086	16.54
2.884	0.2399	0.3101	16.32
2.951	0.2416	0.2880	7.31
3.020	0.2432	0.2810	3.98
3.090	0.2449	0.2695	-0.94
3.162	0.2465	0.2548	-6.96
3.236	0.2482	0.2728	-1.06
3.311	0.2498	0.2904	4.60
3.389	0.2515	0.2933	4.95
3.467	0.2532	0.2946	4.71
3.548	0.2550	0.2956	4.34
3.631	0.2502	0.2913	4.76
3.715	0.2444	0.2867	5.59
3.802	0.2386	0.2739	3.30
3.891	0.2330	0.2576	-0.49
3.981	0.2275	0.2606	3.09
4.074	0.2222	0.2612	5.82
4.169	0.2169	0.2539	5.35
4.266	0.2118	0.2437	3.54
4.365	0.2068	0.2366	2.95
4.467	0.2020	0.2362	5.24
4.571	0.1998	0.2295	3.38
4.677	0.2002	0.2296	3.21

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
4.786	0.2007	0.2330	4.48
4.898	0.2012	0.2228	-0.31
5.012	0.2022	0.2382	6.00
5.129	0.2081	0.2604	12.61
5.248	0.2142	0.2564	7.69
5.370	0.2205	0.2525	3.06
5.495	0.2270	0.2634	4.42
5.623	0.2337	0.2731	5.18
5.754	0.2405	0.2860	7.02
5.889	0.2476	0.2894	5.18
6.026	0.2549	0.2808	-0.82
6.166	0.2623	0.2974	2.03
6.310	0.2700	0.3125	4.15
6.457	0.2780	0.3180	2.95
6.607	0.2861	0.3379	6.30
6.761	0.2945	0.3444	5.25
6.918	0.3032	0.3471	3.06
7.080	0.3121	0.3625	4.54
7.244	0.3212	0.3811	6.78
7.413	0.3306	0.3835	4.40
7.586	0.3363	0.3729	-0.22
7.763	0.3380	0.3972	5.77
7.943	0.3396	0.3901	3.36
8.128	0.3413	0.3960	4.43
8.318	0.3429	0.3985	4.58
8.511	0.3446	0.3973	3.76
8.710	0.3463	0.4018	4.41
8.913	0.3480	0.4050	4.75
9.120	0.3497	0.4023	3.53
9.333	0.3514	0.4020	2.96
9.550	0.3531	0.4014	2.30
9.772	0.3548	0.4197	6.46
10.000	0.3566	0.4142	4.54
10.233	0.3616	0.3975	-1.06
10.471	0.3667	0.4221	3.58
10.715	0.3719	0.4216	2.03
10.965	0.3771	0.4344	3.66
11.220	0.3825	0.4334	1.99
11.482	0.3879	0.4489	4.17
11.749	0.3931	0.4490	2.79
12.023	0.3963	0.4571	3.81
12.303	0.3996	0.4672	5.23
12.589	0.4028	0.4567	2.03
12.883	0.4062	0.4631	2.62

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
13.183	0.4095	0.4776	4.96
13.490	0.4128	0.4779	4.19
13.804	0.4162	0.4970	7.46
14.125	0.4197	0.4831	3.60
14.455	0.4231	0.4879	3.79
14.791	0.4266	0.4697	-0.91
15.136	0.4296	0.5037	5.52
15.488	0.4324	0.5056	5.23
15.849	0.4353	0.4917	1.66
16.218	0.4382	0.5119	5.14
16.596	0.4411	0.5078	3.61
16.983	0.4440	0.5110	3.57
17.378	0.4470	0.5051	1.69
17.783	0.4500	0.5229	4.59
18.197	0.4530	0.5201	3.34
18.621	0.4560	0.5215	2.93
19.055	0.4584	0.5306	4.17
19.499	0.4599	0.5309	3.90
19.953	0.4614	0.5312	3.60
20.418	0.4630	0.5357	4.14
20.893	0.4645	0.5433	5.27
21.380	0.4661	0.5442	5.08
21.878	0.4676	0.5432	4.55
22.387	0.4692	0.5378	3.17
22.909	0.4707	0.5419	3.60
23.442	0.4723	0.5457	3.99
23.989	0.4739	0.5474	3.96
24.547	0.4755	0.5483	3.78
25.119	0.4762	0.5552	4.94
25.704	0.4735	0.5361	1.89
26.303	0.4709	0.5470	4.54
26.916	0.4683	0.5289	1.64
27.542	0.4657	0.5262	1.69
28.184	0.4631	0.5179	0.65
28.841	0.4606	0.5199	1.60
29.512	0.4580	0.5163	1.46
30.200	0.4555	0.5126	1.29
30.903	0.4531	0.5111	1.53
31.623	0.4508	0.5149	2.81
32.360	0.4485	0.5100	2.36
33.113	0.4462	0.5203	4.95
33.885	0.4439	0.5121	3.83
34.674	0.4416	0.4973	1.35
35.482	0.4394	0.5132	5.12

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
36.308	0.4371	0.5047	3.91
37.154	0.4349	0.5026	4.02
38.019	0.4327	0.4990	3.80
38.905	0.4286	0.4932	3.56
39.811	0.4217	0.4885	4.24
40.738	0.4149	0.4808	4.28
41.687	0.4082	0.4743	4.58
42.658	0.4016	0.4655	4.32
43.652	0.3952	0.4618	5.18
44.669	0.3888	0.4527	4.79
45.709	0.3825	0.4443	4.54
46.774	0.3763	0.4361	4.29
47.863	0.3703	0.4277	3.95
48.978	0.3642	0.4198	3.72
50.119	0.3572	0.4105	3.43
51.287	0.3503	0.4053	4.13
52.481	0.3435	0.3958	3.71
53.704	0.3368	0.3878	3.61
54.954	0.3303	0.3828	4.31
56.235	0.3239	0.3723	3.45
57.544	0.3176	0.3642	3.19
58.885	0.3115	0.3606	4.18
60.256	0.3055	0.3559	4.86
61.660	0.2995	0.3462	4.04
63.096	0.2930	0.3384	3.97
64.566	0.2862	0.3305	3.94
66.070	0.2795	0.3230	4.00
67.609	0.2731	0.3153	3.91
69.184	0.2667	0.3074	3.71
70.795	0.2606	0.3013	4.09
72.444	0.2545	0.2917	3.13
74.132	0.2486	0.2855	3.35
75.858	0.2429	0.2811	4.15
77.625	0.2372	0.2703	2.53
79.433	0.2318	0.2548	-1.08
81.284	0.2265	0.2552	1.39
83.177	0.2214	0.2475	0.60
85.114	0.2164	0.2401	-0.13
87.097	0.2115	0.2330	-0.83
89.126	0.2067	0.2296	-0.03
91.202	0.2020	0.2277	1.44
93.326	0.1974	0.2235	1.88
95.500	0.1930	0.2200	2.59
97.724	0.1886	0.2168	3.44

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
100.000	0.1843	0.2146	4.80

TABLE 1-4

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE HORIZONTAL DIRECTION FOR 4URB

FREQUENCY (HZ)	HORIZONTAL FIRS ACCELERATION (G)	FIRST HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)	SECOND HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0057	0.0062	8.77	0.0063	10.53
0.102	0.0059	0.0063	5.56	0.0067	13.32
0.105	0.0062	0.0064	3.08	0.0071	14.75
0.107	0.0064	0.0066	2.96	0.0073	14.02
0.110	0.0067	0.0069	3.00	0.0075	12.74
0.112	0.0070	0.0072	3.45	0.0077	11.08
0.115	0.0072	0.0075	4.29	0.0080	10.24
0.118	0.0075	0.0080	5.72	0.0082	9.18
0.120	0.0078	0.0084	7.16	0.0084	7.42
0.123	0.0081	0.0088	8.35	0.0086	6.14
0.126	0.0085	0.0092	9.09	0.0090	6.49
0.129	0.0088	0.0096	9.10	0.0094	7.39
0.132	0.0091	0.0099	8.00	0.0098	7.68
0.135	0.0095	0.0101	6.87	0.0102	7.51
0.138	0.0098	0.0102	3.78	0.0105	6.84
0.141	0.0102	0.0104	2.16	0.0109	7.17
0.145	0.0105	0.0111	5.60	0.0113	7.21
0.148	0.0109	0.0117	7.04	0.0117	6.95
0.151	0.0114	0.0120	5.81	0.0120	6.08
0.155	0.0118	0.0124	5.19	0.0124	5.61
0.159	0.0122	0.0127	4.18	0.0129	5.98
0.162	0.0127	0.0130	2.61	0.0134	6.17
0.166	0.0131	0.0132	0.61	0.0139	5.71
0.170	0.0136	0.0135	-1.17	0.0142	4.55
0.174	0.0141	0.0138	-2.55	0.0149	5.37
0.178	0.0147	0.0142	-3.07	0.0154	5.25
0.182	0.0152	0.0149	-2.50	0.0165	8.14
0.186	0.0158	0.0157	-0.95	0.0176	11.14
0.191	0.0164	0.0166	1.46	0.0186	13.42
0.195	0.0170	0.0177	4.17	0.0195	14.63
0.200	0.0177	0.0188	6.63	0.0202	14.28
0.204	0.0183	0.0198	7.86	0.0205	11.84
0.209	0.0189	0.0204	7.72	0.0205	8.57
0.214	0.0195	0.0205	4.87	0.0209	6.86
0.219	0.0202	0.0212	5.21	0.0216	7.05
0.224	0.0208	0.0217	4.18	0.0229	10.05

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.229	0.0215	0.0225	4.89	0.0245	14.21
0.234	0.0222	0.0227	2.48	0.0253	14.36
0.240	0.0229	0.0225	-1.75	0.0263	14.87
0.246	0.0236	0.0243	2.88	0.0264	11.91
0.251	0.0244	0.0263	7.96	0.0256	5.09
0.257	0.0251	0.0272	8.40	0.0268	6.76
0.263	0.0259	0.0275	5.98	0.0279	7.84
0.269	0.0267	0.0274	2.66	0.0286	7.12
0.275	0.0275	0.0277	0.73	0.0288	4.95
0.282	0.0283	0.0288	1.77	0.0296	4.52
0.288	0.0292	0.0307	5.45	0.0309	5.97
0.295	0.0300	0.0329	9.59	0.0322	7.40
0.302	0.0309	0.0348	12.68	0.0336	8.51
0.309	0.0318	0.0357	12.12	0.0348	9.30
0.316	0.0328	0.0344	4.94	0.0359	9.33
0.324	0.0338	0.0354	4.83	0.0365	7.90
0.331	0.0348	0.0365	4.95	0.0365	4.89
0.339	0.0358	0.0372	3.97	0.0364	1.87
0.347	0.0368	0.0402	9.21	0.0368	0.14
0.355	0.0379	0.0413	9.09	0.0365	-3.51
0.363	0.0389	0.0405	3.98	0.0420	7.86
0.372	0.0401	0.0411	2.72	0.0451	12.66
0.380	0.0412	0.0425	3.15	0.0463	12.33
0.389	0.0424	0.0444	4.69	0.0496	16.99
0.398	0.0436	0.0460	5.41	0.0503	15.29
0.407	0.0449	0.0473	5.39	0.0493	9.88
0.417	0.0462	0.0485	5.03	0.0488	5.76
0.427	0.0474	0.0497	4.79	0.0509	7.25
0.437	0.0487	0.0511	4.86	0.0518	6.22
0.447	0.0501	0.0528	5.41	0.0535	6.91
0.457	0.0515	0.0548	6.55	0.0559	8.69
0.468	0.0529	0.0571	7.96	0.0562	6.34
0.479	0.0543	0.0594	9.43	0.0570	4.93
0.490	0.0558	0.0617	10.42	0.0595	6.52
0.501	0.0573	0.0633	10.44	0.0607	5.95
0.513	0.0579	0.0642	10.79	0.0613	5.80
0.525	0.0586	0.0643	9.76	0.0615	5.02
0.537	0.0593	0.0637	7.52	0.0604	1.94
0.550	0.0600	0.0629	4.89	0.0594	-0.87
0.562	0.0607	0.0622	2.52	0.0610	0.49
0.575	0.0614	0.0675	9.97	0.0616	0.36
0.589	0.0621	0.0694	11.76	0.0616	-0.82

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.603	0.0628	0.0661	5.26	0.0627	-0.16
0.617	0.0635	0.0668	5.13	0.0640	0.80
0.631	0.0643	0.0662	3.04	0.0640	-0.47
0.646	0.0650	0.0702	7.94	0.0678	4.28
0.661	0.0657	0.0722	9.83	0.0698	6.24
0.676	0.0664	0.0723	8.81	0.0714	7.47
0.692	0.0669	0.0727	8.73	0.0717	7.13
0.708	0.0674	0.0720	6.90	0.0701	4.01
0.724	0.0679	0.0702	3.49	0.0674	-0.74
0.741	0.0684	0.0743	8.66	0.0689	0.79
0.759	0.0688	0.0788	14.48	0.0722	4.84
0.776	0.0693	0.0786	13.28	0.0774	11.57
0.794	0.0698	0.0776	11.08	0.0809	15.81
0.813	0.0703	0.0770	9.53	0.0786	11.77
0.832	0.0708	0.0747	5.51	0.0744	4.97
0.851	0.0714	0.0747	4.63	0.0720	0.90
0.871	0.0716	0.0757	5.81	0.0713	-0.38
0.891	0.0718	0.0769	7.13	0.0729	1.62
0.912	0.0719	0.0800	11.22	0.0743	3.29
0.933	0.0721	0.0817	13.21	0.0747	3.58
0.955	0.0723	0.0785	8.48	0.0763	5.46
0.977	0.0725	0.0749	3.28	0.0759	4.72
1.000	0.0727	0.0766	5.39	0.0735	1.07
1.023	0.0748	0.0823	10.08	0.0741	-0.94
1.047	0.0769	0.0886	15.15	0.0760	-1.24
1.072	0.0791	0.0930	17.54	0.0798	0.90
1.097	0.0813	0.0921	13.27	0.0865	6.39
1.122	0.0837	0.0878	5.00	0.0879	5.12
1.148	0.0860	0.0862	0.17	0.0818	-4.94
1.175	0.0885	0.0888	0.36	0.0910	2.80
1.202	0.0910	0.0960	5.48	0.0973	6.87
1.230	0.0936	0.1027	9.69	0.1000	6.81
1.259	0.0963	0.1063	10.42	0.1013	5.20
1.288	0.0990	0.1079	8.96	0.1027	3.77
1.318	0.1018	0.1070	5.10	0.1063	4.36
1.349	0.1047	0.1042	-0.53	0.1090	4.04
1.380	0.1080	0.1234	14.35	0.1120	3.76
1.413	0.1123	0.1336	18.99	0.1177	4.85
1.445	0.1168	0.1284	9.99	0.1269	8.70
1.479	0.1215	0.1203	-0.91	0.1403	15.55
1.514	0.1263	0.1353	7.11	0.1492	18.11
1.549	0.1314	0.1478	12.49	0.1505	14.56

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
1.585	0.1366	0.1548	13.27	0.1436	5.12
1.622	0.1421	0.1558	9.63	0.1448	1.91
1.660	0.1478	0.1551	4.95	0.1531	3.58
1.698	0.1537	0.1633	6.26	0.1561	1.54
1.738	0.1599	0.1879	17.49	0.1597	-0.10
1.778	0.1671	0.1933	15.64	0.1740	4.11
1.820	0.1751	0.1894	8.17	0.1848	5.57
1.862	0.1834	0.1892	3.18	0.1818	-0.86
1.906	0.1921	0.2012	4.74	0.2031	5.74
1.950	0.2012	0.2198	9.25	0.2289	13.77
1.995	0.2108	0.2304	9.30	0.2395	13.61
2.042	0.2208	0.2281	3.30	0.2282	3.34
2.089	0.2313	0.2254	-2.54	0.2407	4.05
2.138	0.2423	0.2485	2.56	0.2725	12.45
2.188	0.2538	0.2777	9.41	0.2849	12.26
2.239	0.2668	0.3128	17.25	0.2778	4.12
2.291	0.2814	0.3364	19.55	0.2800	-0.49
2.344	0.2967	0.3350	12.90	0.3182	7.24
2.399	0.3130	0.3261	4.21	0.3341	6.76
2.455	0.3301	0.3374	2.22	0.3473	5.23
2.512	0.3460	0.3841	11.01	0.3486	0.75
2.570	0.3545	0.4195	18.36	0.3709	4.64
2.630	0.3631	0.4254	17.14	0.4079	12.32
2.692	0.3720	0.4017	7.97	0.4339	16.63
2.754	0.3811	0.4018	5.44	0.4378	14.88
2.818	0.3904	0.3960	1.43	0.4240	8.61
2.884	0.3999	0.4200	5.02	0.4208	5.23
2.951	0.4097	0.3935	-3.94	0.4461	8.89
3.020	0.4197	0.4532	7.98	0.4848	15.51
3.090	0.4300	0.4902	14.01	0.4951	15.15
3.162	0.4405	0.4877	10.73	0.4622	4.94
3.236	0.4512	0.4760	5.49	0.4933	9.33
3.311	0.4623	0.4626	0.08	0.4809	4.03
3.389	0.4736	0.4993	5.44	0.5046	6.56
3.467	0.4851	0.5171	6.60	0.5197	7.12
3.548	0.4970	0.5096	2.55	0.4925	-0.91
3.631	0.4875	0.5013	2.84	0.4895	0.41
3.715	0.4740	0.4804	1.35	0.4882	2.99
3.802	0.4609	0.4924	6.85	0.5188	12.57
3.891	0.4481	0.4731	5.58	0.5183	15.66
3.981	0.4357	0.4594	5.43	0.4671	7.22
4.074	0.4236	0.4489	5.95	0.4151	-2.01

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
4.169	0.4119	0.4434	7.65	0.4235	2.80
4.266	0.4005	0.4174	4.21	0.4201	4.88
4.365	0.3894	0.3873	-0.54	0.4063	4.33
4.467	0.3786	0.3888	2.68	0.3821	0.91
4.571	0.3724	0.3942	5.85	0.4083	9.63
4.677	0.3707	0.3912	5.53	0.4055	9.37
4.786	0.3691	0.3854	4.42	0.3734	1.16
4.898	0.3675	0.3831	4.24	0.3853	4.84
5.012	0.3666	0.3844	4.87	0.3897	6.30
5.129	0.3719	0.3931	5.71	0.3902	4.93
5.248	0.3773	0.3972	5.26	0.3946	4.58
5.370	0.3828	0.4013	4.83	0.4028	5.21
5.495	0.3884	0.4077	4.98	0.4097	5.49
5.623	0.3941	0.4141	5.09	0.4127	4.73
5.754	0.3998	0.4233	5.86	0.4162	4.09
5.889	0.4057	0.4266	5.16	0.4256	4.91
6.026	0.4116	0.4371	6.20	0.4327	5.13
6.166	0.4176	0.4400	5.38	0.4383	4.96
6.310	0.4237	0.4424	4.43	0.4429	4.55
6.457	0.4298	0.4507	4.85	0.4491	4.48
6.607	0.4361	0.4451	2.05	0.4659	6.83
6.761	0.4425	0.4584	3.60	0.4700	6.22
6.918	0.4489	0.4830	7.60	0.4504	0.34
7.080	0.4555	0.4824	5.91	0.4753	4.36
7.244	0.4621	0.4603	-0.40	0.4904	6.12
7.413	0.4689	0.4942	5.41	0.4898	4.47
7.586	0.4766	0.5045	5.87	0.4716	-1.04
7.763	0.4854	0.5093	4.94	0.5216	7.46
7.943	0.4943	0.5173	4.66	0.5297	7.16
8.128	0.5034	0.5369	6.65	0.5134	1.99
8.318	0.5127	0.5421	5.74	0.5347	4.29
8.511	0.5221	0.5420	3.82	0.5534	6.00
8.710	0.5317	0.5515	3.72	0.5617	5.65
8.913	0.5415	0.5728	5.78	0.5744	6.07
9.120	0.5515	0.5853	6.13	0.5829	5.71
9.333	0.5616	0.5854	4.24	0.5750	2.39
9.550	0.5720	0.5947	3.97	0.5935	3.77
9.772	0.5825	0.6203	6.50	0.6061	4.06
10.000	0.5932	0.6235	5.11	0.6139	3.48
10.233	0.5946	0.6253	5.16	0.6230	4.78
10.471	0.5960	0.6257	4.99	0.6220	4.37
10.715	0.5974	0.6479	8.46	0.6401	7.16

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
10.965	0.5988	0.6333	5.77	0.6284	4.94
11.220	0.6001	0.6045	0.72	0.6297	4.93
11.482	0.6015	0.6318	5.02	0.6309	4.88
11.749	0.6033	0.6428	6.55	0.6424	6.48
12.023	0.6079	0.6371	4.80	0.6400	5.27
12.303	0.6126	0.6535	6.67	0.6543	6.82
12.589	0.6173	0.6547	6.05	0.6527	5.74
12.883	0.6220	0.6553	5.35	0.6568	5.59
13.183	0.6268	0.6779	8.15	0.6595	5.21
13.490	0.6316	0.6633	5.00	0.6671	5.61
13.804	0.6365	0.6552	2.94	0.6763	6.26
14.125	0.6414	0.6504	1.41	0.6777	5.66
14.455	0.6463	0.6571	1.66	0.6859	6.13
14.791	0.6513	0.6621	1.67	0.6650	2.10
15.136	0.6538	0.6684	2.23	0.6860	4.93
15.488	0.6555	0.6689	2.05	0.6882	4.99
15.849	0.6572	0.6688	1.77	0.6961	5.93
16.218	0.6589	0.6714	1.91	0.7061	7.17
16.596	0.6606	0.6820	3.24	0.6836	3.48
16.983	0.6623	0.6806	2.76	0.6954	5.00
17.378	0.6640	0.6863	3.36	0.6991	5.28
17.783	0.6657	0.7021	5.46	0.6856	2.98
18.197	0.6675	0.7031	5.34	0.7065	5.85
18.621	0.6692	0.6990	4.45	0.6963	4.06
19.055	0.6700	0.7028	4.90	0.7036	5.02
19.499	0.6694	0.6967	4.09	0.7013	4.78
19.953	0.6688	0.6958	4.04	0.7004	4.73
20.418	0.6682	0.6962	4.18	0.7009	4.89
20.893	0.6676	0.7007	4.95	0.6920	3.66
21.380	0.6670	0.7023	5.29	0.7034	5.46
21.878	0.6665	0.6967	4.53	0.6973	4.63
22.387	0.6659	0.7015	5.35	0.7017	5.39
22.909	0.6653	0.7003	5.26	0.6987	5.01
23.442	0.6647	0.6950	4.56	0.7012	5.49
23.989	0.6641	0.6980	5.09	0.7027	5.81
24.547	0.6636	0.6882	3.71	0.6985	5.27
25.119	0.6617	0.6899	4.25	0.6935	4.80
25.704	0.6551	0.6614	0.96	0.6800	3.80
26.303	0.6486	0.6648	2.50	0.6787	4.63
26.916	0.6422	0.6709	4.48	0.6756	5.20
27.542	0.6358	0.6490	2.08	0.6770	6.49
28.184	0.6294	0.6614	5.09	0.6534	3.80

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
28.841	0.6231	0.6566	5.36	0.6524	4.69
29.512	0.6169	0.6445	4.47	0.6463	4.77
30.200	0.6108	0.6392	4.65	0.6395	4.71
30.903	0.6019	0.6327	5.11	0.6328	5.13
31.623	0.5920	0.6196	4.65	0.6181	4.41
32.360	0.5824	0.6092	4.62	0.6014	3.26
33.113	0.5728	0.6036	5.36	0.6017	5.05
33.885	0.5635	0.5910	4.89	0.5941	5.44
34.674	0.5543	0.5862	5.76	0.5709	3.01
35.482	0.5452	0.5710	4.74	0.5828	6.90
36.308	0.5363	0.5616	4.73	0.5672	5.78
37.154	0.5275	0.5544	5.10	0.5638	6.87
38.019	0.5189	0.5449	5.01	0.5487	5.75
38.905	0.5097	0.5293	3.85	0.5375	5.45
39.811	0.4996	0.5193	3.96	0.5289	5.87
40.738	0.4896	0.5126	4.70	0.5191	6.03
41.687	0.4799	0.5057	5.38	0.5053	5.29
42.658	0.4703	0.4977	5.81	0.4951	5.27
43.652	0.4610	0.4869	5.63	0.4839	4.97
44.669	0.4518	0.4720	4.46	0.4701	4.04
45.709	0.4428	0.4631	4.57	0.4608	4.06
46.774	0.4340	0.4535	4.48	0.4524	4.24
47.863	0.4254	0.4440	4.38	0.4430	4.15
48.978	0.4169	0.4347	4.28	0.4337	4.03
50.119	0.4080	0.4244	4.03	0.4227	3.62
51.287	0.3993	0.4202	5.24	0.4156	4.11
52.481	0.3907	0.4023	2.97	0.4053	3.73
53.704	0.3824	0.3961	3.59	0.3969	3.80
54.954	0.3742	0.3922	4.80	0.3903	4.30
56.235	0.3662	0.3771	2.99	0.3736	2.04
57.544	0.3584	0.3727	4.01	0.3640	1.57
58.885	0.3507	0.3577	2.00	0.3576	1.98
60.256	0.3432	0.3481	1.43	0.3508	2.21
61.660	0.3359	0.3439	2.40	0.3498	4.15
63.096	0.3289	0.3378	2.70	0.3460	5.19
64.566	0.3222	0.3285	1.94	0.3412	5.87
66.070	0.3157	0.3224	2.13	0.3406	7.88
67.609	0.3093	0.3181	2.84	0.3373	9.06
69.184	0.3030	0.3146	3.84	0.3217	6.19
70.795	0.2968	0.3011	1.43	0.3152	6.19
72.444	0.2908	0.2887	-0.74	0.3062	5.31
74.132	0.2849	0.2879	1.03	0.2978	4.53

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
75.858	0.2791	0.2895	3.73	0.2895	3.71
77.625	0.2735	0.2827	3.37	0.2805	2.57
79.433	0.2687	0.2787	3.71	0.2760	2.72
81.284	0.2654	0.2792	5.20	0.2843	7.12
83.177	0.2622	0.2735	4.31	0.2839	8.28
85.114	0.2590	0.2680	3.44	0.2803	8.19
87.097	0.2559	0.2732	6.76	0.2775	8.44
89.126	0.2528	0.2778	9.89	0.2732	8.07
91.202	0.2498	0.2826	13.16	0.2706	8.33
93.326	0.2467	0.2771	12.32	0.2680	8.62
95.500	0.2438	0.2695	10.56	0.2724	11.75
97.724	0.2408	0.2653	10.18	0.2626	9.03
100.000	0.2379	0.2629	10.49	0.2587	8.74

TABLE 1-5

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE HORIZONTAL DIRECTION FOR 4URB

FREQUENCY (HZ)	HORIZONTAL FIRS ACCELERATION (G)	FIRST HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)	SECOND HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0057	0.0062	8.77	0.0063	10.53
0.102	0.0059	0.0063	5.56	0.0067	13.32
0.105	0.0062	0.0064	3.08	0.0071	14.75
0.107	0.0064	0.0066	2.96	0.0073	14.02
0.110	0.0067	0.0069	3.00	0.0075	12.74
0.112	0.0070	0.0072	3.45	0.0077	11.08
0.115	0.0072	0.0075	4.29	0.0080	10.24
0.118	0.0075	0.0080	5.72	0.0082	9.18
0.120	0.0078	0.0084	7.16	0.0084	7.42
0.123	0.0081	0.0088	8.35	0.0086	6.14
0.126	0.0085	0.0092	9.09	0.0090	6.49
0.129	0.0088	0.0096	9.10	0.0094	7.39
0.132	0.0091	0.0099	8.00	0.0098	7.68
0.135	0.0095	0.0101	6.87	0.0102	7.51
0.138	0.0098	0.0102	3.78	0.0105	6.84
0.141	0.0102	0.0104	2.16	0.0109	7.17
0.145	0.0105	0.0111	5.60	0.0113	7.21
0.148	0.0109	0.0117	7.04	0.0117	6.95
0.151	0.0114	0.0120	5.81	0.0120	6.08
0.155	0.0118	0.0124	5.19	0.0124	5.61
0.159	0.0122	0.0127	4.18	0.0129	5.98
0.162	0.0127	0.0130	2.61	0.0134	6.17
0.166	0.0131	0.0132	0.61	0.0139	5.71
0.170	0.0136	0.0135	-1.17	0.0142	4.55
0.174	0.0141	0.0138	-2.55	0.0149	5.37
0.178	0.0147	0.0142	-3.07	0.0154	5.25
0.182	0.0152	0.0149	-2.50	0.0165	8.14
0.186	0.0158	0.0157	-0.95	0.0176	11.14
0.191	0.0164	0.0166	1.46	0.0186	13.42
0.195	0.0170	0.0177	4.17	0.0195	14.63
0.200	0.0177	0.0188	6.63	0.0202	14.28
0.204	0.0183	0.0198	7.86	0.0205	11.84
0.209	0.0189	0.0204	7.72	0.0205	8.57
0.214	0.0195	0.0205	4.87	0.0209	6.86
0.219	0.0202	0.0212	5.21	0.0216	7.05
0.224	0.0208	0.0217	4.18	0.0229	10.05

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.229	0.0215	0.0225	4.89	0.0245	14.21
0.234	0.0222	0.0227	2.48	0.0253	14.36
0.240	0.0229	0.0225	-1.75	0.0263	14.87
0.246	0.0236	0.0243	2.88	0.0264	11.91
0.251	0.0244	0.0263	7.96	0.0256	5.09
0.257	0.0251	0.0272	8.40	0.0268	6.76
0.263	0.0259	0.0275	5.98	0.0279	7.84
0.269	0.0267	0.0274	2.66	0.0286	7.12
0.275	0.0275	0.0277	0.73	0.0288	4.95
0.282	0.0283	0.0288	1.77	0.0296	4.52
0.288	0.0292	0.0307	5.45	0.0309	5.97
0.295	0.0300	0.0329	9.59	0.0322	7.40
0.302	0.0309	0.0348	12.68	0.0336	8.51
0.309	0.0318	0.0357	12.12	0.0348	9.30
0.316	0.0328	0.0344	4.94	0.0359	9.33
0.324	0.0338	0.0354	4.83	0.0365	7.90
0.331	0.0348	0.0365	4.95	0.0365	4.89
0.339	0.0358	0.0372	3.97	0.0364	1.87
0.347	0.0368	0.0402	9.21	0.0368	0.14
0.355	0.0379	0.0413	9.09	0.0365	-3.51
0.363	0.0389	0.0405	3.98	0.0420	7.86
0.372	0.0401	0.0411	2.72	0.0451	12.66
0.380	0.0412	0.0425	3.15	0.0463	12.33
0.389	0.0424	0.0444	4.69	0.0496	16.99
0.398	0.0436	0.0460	5.41	0.0503	15.29
0.407	0.0449	0.0473	5.39	0.0493	9.88
0.417	0.0462	0.0485	5.03	0.0488	5.76
0.427	0.0474	0.0497	4.79	0.0509	7.25
0.437	0.0487	0.0511	4.86	0.0518	6.22
0.447	0.0501	0.0528	5.41	0.0535	6.91
0.457	0.0515	0.0548	6.55	0.0559	8.69
0.468	0.0529	0.0571	7.96	0.0562	6.34
0.479	0.0543	0.0594	9.43	0.0570	4.93
0.490	0.0558	0.0617	10.42	0.0595	6.52
0.501	0.0573	0.0633	10.44	0.0607	5.95
0.513	0.0579	0.0642	10.79	0.0613	5.80
0.525	0.0586	0.0643	9.76	0.0615	5.02
0.537	0.0593	0.0637	7.52	0.0604	1.94
0.550	0.0600	0.0629	4.89	0.0594	-0.87
0.562	0.0607	0.0622	2.52	0.0610	0.49
0.575	0.0614	0.0675	9.97	0.0616	0.36
0.589	0.0621	0.0694	11.76	0.0616	-0.82

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.603	0.0628	0.0661	5.26	0.0627	-0.16
0.617	0.0635	0.0668	5.13	0.0640	0.80
0.631	0.0643	0.0662	3.04	0.0640	-0.47
0.646	0.0650	0.0702	7.94	0.0678	4.28
0.661	0.0657	0.0722	9.83	0.0698	6.24
0.676	0.0664	0.0723	8.81	0.0714	7.47
0.692	0.0669	0.0727	8.73	0.0717	7.13
0.708	0.0674	0.0720	6.90	0.0701	4.01
0.724	0.0679	0.0702	3.49	0.0674	-0.74
0.741	0.0684	0.0743	8.66	0.0689	0.79
0.759	0.0688	0.0788	14.48	0.0722	4.84
0.776	0.0693	0.0786	13.28	0.0774	11.57
0.794	0.0698	0.0776	11.08	0.0809	15.81
0.813	0.0703	0.0770	9.53	0.0786	11.77
0.832	0.0708	0.0747	5.51	0.0744	4.97
0.851	0.0714	0.0747	4.63	0.0720	0.90
0.871	0.0716	0.0757	5.81	0.0713	-0.38
0.891	0.0718	0.0769	7.13	0.0729	1.62
0.912	0.0719	0.0800	11.22	0.0743	3.29
0.933	0.0721	0.0817	13.21	0.0747	3.58
0.955	0.0723	0.0785	8.48	0.0763	5.46
0.977	0.0725	0.0749	3.28	0.0759	4.72
1.000	0.0727	0.0766	5.39	0.0735	1.07
1.023	0.0748	0.0823	10.08	0.0741	-0.94
1.047	0.0769	0.0886	15.15	0.0760	-1.24
1.072	0.0791	0.0930	17.54	0.0798	0.90
1.097	0.0813	0.0921	13.27	0.0865	6.39
1.122	0.0837	0.0878	5.00	0.0879	5.12
1.148	0.0860	0.0862	0.17	0.0818	-4.94
1.175	0.0885	0.0888	0.36	0.0910	2.80
1.202	0.0910	0.0960	5.48	0.0973	6.87
1.230	0.0936	0.1027	9.69	0.1000	6.81
1.259	0.0963	0.1063	10.42	0.1013	5.20
1.288	0.0990	0.1079	8.96	0.1027	3.77
1.318	0.1018	0.1070	5.10	0.1063	4.36
1.349	0.1047	0.1042	-0.53	0.1090	4.04
1.380	0.1080	0.1234	14.35	0.1120	3.76
1.413	0.1123	0.1336	18.99	0.1177	4.85
1.445	0.1168	0.1284	9.99	0.1269	8.70
1.479	0.1215	0.1203	-0.91	0.1403	15.55
1.514	0.1263	0.1353	7.11	0.1492	18.11
1.549	0.1314	0.1478	12.49	0.1505	14.56

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
1.585	0.1366	0.1548	13.27	0.1436	5.12
1.622	0.1421	0.1558	9.63	0.1448	1.91
1.660	0.1478	0.1551	4.95	0.1531	3.58
1.698	0.1537	0.1633	6.26	0.1561	1.54
1.738	0.1599	0.1879	17.49	0.1597	-0.10
1.778	0.1671	0.1933	15.64	0.1740	4.11
1.820	0.1751	0.1894	8.17	0.1848	5.57
1.862	0.1834	0.1892	3.18	0.1818	-0.86
1.906	0.1921	0.2012	4.74	0.2031	5.74
1.950	0.2012	0.2198	9.25	0.2289	13.77
1.995	0.2108	0.2304	9.30	0.2395	13.61
2.042	0.2208	0.2281	3.30	0.2282	3.34
2.089	0.2313	0.2254	-2.54	0.2407	4.05
2.138	0.2423	0.2485	2.56	0.2725	12.45
2.188	0.2538	0.2777	9.41	0.2849	12.26
2.239	0.2668	0.3128	17.25	0.2778	4.12
2.291	0.2814	0.3364	19.55	0.2800	-0.49
2.344	0.2967	0.3350	12.90	0.3182	7.24
2.399	0.3130	0.3261	4.21	0.3341	6.76
2.455	0.3301	0.3374	2.22	0.3473	5.23
2.512	0.3460	0.3841	11.01	0.3486	0.75
2.570	0.3545	0.4195	18.36	0.3709	4.64
2.630	0.3631	0.4254	17.14	0.4079	12.32
2.692	0.3720	0.4017	7.97	0.4339	16.63
2.754	0.3811	0.4018	5.44	0.4378	14.88
2.818	0.3904	0.3960	1.43	0.4240	8.61
2.884	0.3999	0.4200	5.02	0.4208	5.23
2.951	0.4097	0.3935	-3.94	0.4461	8.89
3.020	0.4197	0.4532	7.98	0.4848	15.51
3.090	0.4300	0.4902	14.01	0.4951	15.15
3.162	0.4405	0.4877	10.73	0.4622	4.94
3.236	0.4512	0.4760	5.49	0.4933	9.33
3.311	0.4623	0.4626	0.08	0.4809	4.03
3.389	0.4736	0.4993	5.44	0.5046	6.56
3.467	0.4851	0.5171	6.60	0.5197	7.12
3.548	0.4970	0.5096	2.55	0.4925	-0.91
3.631	0.4875	0.5013	2.84	0.4895	0.41
3.715	0.4740	0.4804	1.35	0.4882	2.99
3.802	0.4609	0.4924	6.85	0.5188	12.57
3.891	0.4481	0.4731	5.58	0.5183	15.66
3.981	0.4357	0.4594	5.43	0.4671	7.22
4.074	0.4236	0.4489	5.95	0.4151	-2.01

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
4.169	0.4119	0.4434	7.65	0.4235	2.80
4.266	0.4005	0.4174	4.21	0.4201	4.88
4.365	0.3894	0.3873	-0.54	0.4063	4.33
4.467	0.3786	0.3888	2.68	0.3821	0.91
4.571	0.3724	0.3942	5.85	0.4083	9.63
4.677	0.3707	0.3912	5.53	0.4055	9.37
4.786	0.3691	0.3854	4.42	0.3734	1.16
4.898	0.3675	0.3831	4.24	0.3853	4.84
5.012	0.3666	0.3844	4.87	0.3897	6.30
5.129	0.3719	0.3931	5.71	0.3902	4.93
5.248	0.3773	0.3972	5.26	0.3946	4.58
5.370	0.3828	0.4013	4.83	0.4028	5.21
5.495	0.3884	0.4077	4.98	0.4097	5.49
5.623	0.3941	0.4141	5.09	0.4127	4.73
5.754	0.3998	0.4233	5.86	0.4162	4.09
5.889	0.4057	0.4266	5.16	0.4256	4.91
6.026	0.4116	0.4371	6.20	0.4327	5.13
6.166	0.4176	0.4400	5.38	0.4383	4.96
6.310	0.4237	0.4424	4.43	0.4429	4.55
6.457	0.4298	0.4507	4.85	0.4491	4.48
6.607	0.4361	0.4451	2.05	0.4659	6.83
6.761	0.4425	0.4584	3.60	0.4700	6.22
6.918	0.4489	0.4830	7.60	0.4504	0.34
7.080	0.4555	0.4824	5.91	0.4753	4.36
7.244	0.4621	0.4603	-0.40	0.4904	6.12
7.413	0.4689	0.4942	5.41	0.4898	4.47
7.586	0.4766	0.5045	5.87	0.4716	-1.04
7.763	0.4854	0.5093	4.94	0.5216	7.46
7.943	0.4943	0.5173	4.66	0.5297	7.16
8.128	0.5034	0.5369	6.65	0.5134	1.99
8.318	0.5127	0.5421	5.74	0.5347	4.29
8.511	0.5221	0.5420	3.82	0.5534	6.00
8.710	0.5317	0.5515	3.72	0.5617	5.65
8.913	0.5415	0.5728	5.78	0.5744	6.07
9.120	0.5515	0.5853	6.13	0.5829	5.71
9.333	0.5616	0.5854	4.24	0.5750	2.39
9.550	0.5720	0.5947	3.97	0.5935	3.77
9.772	0.5825	0.6203	6.50	0.6061	4.06
10.000	0.5932	0.6235	5.11	0.6139	3.48
10.233	0.5946	0.6253	5.16	0.6230	4.78
10.471	0.5960	0.6257	4.99	0.6220	4.37
10.715	0.5974	0.6479	8.46	0.6401	7.16

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
10.965	0.5988	0.6333	5.77	0.6284	4.94
11.220	0.6001	0.6045	0.72	0.6297	4.93
11.482	0.6015	0.6318	5.02	0.6309	4.88
11.749	0.6033	0.6428	6.55	0.6424	6.48
12.023	0.6079	0.6371	4.80	0.6400	5.27
12.303	0.6126	0.6535	6.67	0.6543	6.82
12.589	0.6173	0.6547	6.05	0.6527	5.74
12.883	0.6220	0.6553	5.35	0.6568	5.59
13.183	0.6268	0.6779	8.15	0.6595	5.21
13.490	0.6316	0.6633	5.00	0.6671	5.61
13.804	0.6365	0.6552	2.94	0.6763	6.26
14.125	0.6414	0.6504	1.41	0.6777	5.66
14.455	0.6463	0.6571	1.66	0.6859	6.13
14.791	0.6513	0.6621	1.67	0.6650	2.10
15.136	0.6538	0.6684	2.23	0.6860	4.93
15.488	0.6555	0.6689	2.05	0.6882	4.99
15.849	0.6572	0.6688	1.77	0.6961	5.93
16.218	0.6589	0.6714	1.91	0.7061	7.17
16.596	0.6606	0.6820	3.24	0.6836	3.48
16.983	0.6623	0.6806	2.76	0.6954	5.00
17.378	0.6640	0.6863	3.36	0.6991	5.28
17.783	0.6657	0.7021	5.46	0.6856	2.98
18.197	0.6675	0.7031	5.34	0.7065	5.85
18.621	0.6692	0.6990	4.45	0.6963	4.06
19.055	0.6700	0.7028	4.90	0.7036	5.02
19.499	0.6694	0.6967	4.09	0.7013	4.78
19.953	0.6688	0.6958	4.04	0.7004	4.73
20.418	0.6682	0.6962	4.18	0.7009	4.89
20.893	0.6676	0.7007	4.95	0.6920	3.66
21.380	0.6670	0.7023	5.29	0.7034	5.46
21.878	0.6665	0.6967	4.53	0.6973	4.63
22.387	0.6659	0.7015	5.35	0.7017	5.39
22.909	0.6653	0.7003	5.26	0.6987	5.01
23.442	0.6647	0.6950	4.56	0.7012	5.49
23.989	0.6641	0.6980	5.09	0.7027	5.81
24.547	0.6636	0.6882	3.71	0.6985	5.27
25.119	0.6617	0.6899	4.25	0.6935	4.80
25.704	0.6551	0.6614	0.96	0.6800	3.80
26.303	0.6486	0.6648	2.50	0.6787	4.63
26.916	0.6422	0.6709	4.48	0.6756	5.20
27.542	0.6358	0.6490	2.08	0.6770	6.49
28.184	0.6294	0.6614	5.09	0.6534	3.80

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
28.841	0.6231	0.6566	5.36	0.6524	4.69
29.512	0.6169	0.6445	4.47	0.6463	4.77
30.200	0.6108	0.6392	4.65	0.6395	4.71
30.903	0.6019	0.6327	5.11	0.6328	5.13
31.623	0.5920	0.6196	4.65	0.6181	4.41
32.360	0.5824	0.6092	4.62	0.6014	3.26
33.113	0.5728	0.6036	5.36	0.6017	5.05
33.885	0.5635	0.5910	4.89	0.5941	5.44
34.674	0.5543	0.5862	5.76	0.5709	3.01
35.482	0.5452	0.5710	4.74	0.5828	6.90
36.308	0.5363	0.5616	4.73	0.5672	5.78
37.154	0.5275	0.5544	5.10	0.5638	6.87
38.019	0.5189	0.5449	5.01	0.5487	5.75
38.905	0.5097	0.5293	3.85	0.5375	5.45
39.811	0.4996	0.5193	3.96	0.5289	5.87
40.738	0.4896	0.5126	4.70	0.5191	6.03
41.687	0.4799	0.5057	5.38	0.5053	5.29
42.658	0.4703	0.4977	5.81	0.4951	5.27
43.652	0.4610	0.4869	5.63	0.4839	4.97
44.669	0.4518	0.4720	4.46	0.4701	4.04
45.709	0.4428	0.4631	4.57	0.4608	4.06
46.774	0.4340	0.4535	4.48	0.4524	4.24
47.863	0.4254	0.4440	4.38	0.4430	4.15
48.978	0.4169	0.4347	4.28	0.4337	4.03
50.119	0.4080	0.4244	4.03	0.4227	3.62
51.287	0.3993	0.4202	5.24	0.4156	4.11
52.481	0.3907	0.4023	2.97	0.4053	3.73
53.704	0.3824	0.3961	3.59	0.3969	3.80
54.954	0.3742	0.3922	4.80	0.3903	4.30
56.235	0.3662	0.3771	2.99	0.3736	2.04
57.544	0.3584	0.3727	4.01	0.3640	1.57
58.885	0.3507	0.3577	2.00	0.3576	1.98
60.256	0.3432	0.3481	1.43	0.3508	2.21
61.660	0.3359	0.3439	2.40	0.3498	4.15
63.096	0.3289	0.3378	2.70	0.3460	5.19
64.566	0.3222	0.3285	1.94	0.3412	5.87
66.070	0.3157	0.3224	2.13	0.3406	7.88
67.609	0.3093	0.3181	2.84	0.3373	9.06
69.184	0.3030	0.3146	3.84	0.3217	6.19
70.795	0.2968	0.3011	1.43	0.3152	6.19
72.444	0.2908	0.2887	-0.74	0.3062	5.31
74.132	0.2849	0.2879	1.03	0.2978	4.53

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
75.858	0.2791	0.2895	3.73	0.2895	3.71
77.625	0.2735	0.2827	3.37	0.2805	2.57
79.433	0.2687	0.2787	3.71	0.2760	2.72
81.284	0.2654	0.2792	5.20	0.2843	7.12
83.177	0.2622	0.2735	4.31	0.2839	8.28
85.114	0.2590	0.2680	3.44	0.2803	8.19
87.097	0.2559	0.2732	6.76	0.2775	8.44
89.126	0.2528	0.2778	9.89	0.2732	8.07
91.202	0.2498	0.2826	13.16	0.2706	8.33
93.326	0.2467	0.2771	12.32	0.2680	8.62
95.500	0.2438	0.2695	10.56	0.2724	11.75
97.724	0.2408	0.2653	10.18	0.2626	9.03
100.000	0.2379	0.2629	10.49	0.2587	8.74

TABLE 1-6

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE HORIZONTAL DIRECTION FOR 12URB

FREQUENCY (HZ)	HORIZONTAL FIRS ACCELERATION (G)	FIRST HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)	SECOND HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0056	0.0057	2.32	0.0058	4.29
0.102	0.0058	0.0059	1.37	0.0062	6.01
0.105	0.0061	0.0061	0.66	0.0065	7.10
0.107	0.0063	0.0064	2.22	0.0068	7.94
0.110	0.0066	0.0067	2.90	0.0071	8.09
0.112	0.0068	0.0070	3.08	0.0073	7.78
0.115	0.0071	0.0073	2.68	0.0076	7.20
0.118	0.0074	0.0075	1.63	0.0078	6.24
0.120	0.0077	0.0077	0.13	0.0081	5.09
0.123	0.0080	0.0078	-1.88	0.0083	3.76
0.126	0.0083	0.0081	-2.29	0.0085	2.53
0.129	0.0086	0.0086	-0.12	0.0087	1.63
0.132	0.0089	0.0092	2.46	0.0090	0.90
0.135	0.0093	0.0098	5.51	0.0093	0.65
0.138	0.0096	0.0104	8.22	0.0097	0.73
0.141	0.0100	0.0111	10.92	0.0101	1.30
0.145	0.0103	0.0117	13.15	0.0106	2.42
0.148	0.0107	0.0123	14.71	0.0112	3.91
0.151	0.0112	0.0129	15.52	0.0118	5.83
0.155	0.0116	0.0136	17.91	0.0125	7.96
0.159	0.0120	0.0144	19.92	0.0132	10.08
0.162	0.0124	0.0151	21.56	0.0140	12.31
0.166	0.0129	0.0160	24.18	0.0147	14.39
0.170	0.0133	0.0167	25.73	0.0154	15.80
0.174	0.0138	0.0173	26.04	0.0160	16.36
0.178	0.0142	0.0180	26.46	0.0165	15.90
0.182	0.0147	0.0186	26.33	0.0168	14.29
0.186	0.0152	0.0190	24.80	0.0171	12.76
0.191	0.0157	0.0192	21.82	0.0173	10.11
0.195	0.0163	0.0191	17.71	0.0173	6.21
0.200	0.0168	0.0192	14.28	0.0175	3.87
0.204	0.0174	0.0192	10.24	0.0182	4.83
0.209	0.0179	0.0191	6.30	0.0187	4.18
0.214	0.0185	0.0192	3.83	0.0193	4.10

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.219	0.0191	0.0199	4.03	0.0202	5.44
0.224	0.0198	0.0210	6.38	0.0208	5.32
0.229	0.0204	0.0215	5.30	0.0213	4.66
0.234	0.0210	0.0241	14.54	0.0221	4.90
0.240	0.0217	0.0255	17.44	0.0228	4.88
0.246	0.0224	0.0261	16.49	0.0235	4.90
0.251	0.0232	0.0261	12.82	0.0243	5.05
0.257	0.0239	0.0258	7.82	0.0251	5.15
0.263	0.0246	0.0256	3.86	0.0260	5.32
0.269	0.0254	0.0262	3.23	0.0268	5.48
0.275	0.0261	0.0278	6.51	0.0275	5.21
0.282	0.0269	0.0303	12.69	0.0279	3.83
0.288	0.0277	0.0331	19.62	0.0280	1.01
0.295	0.0285	0.0355	24.60	0.0283	-0.67
0.302	0.0293	0.0368	25.32	0.0307	4.74
0.309	0.0302	0.0359	18.83	0.0320	5.96
0.316	0.0311	0.0333	6.95	0.0348	12.03
0.324	0.0320	0.0328	2.53	0.0377	17.77
0.331	0.0330	0.0344	4.28	0.0390	18.21
0.339	0.0339	0.0359	6.00	0.0387	14.21
0.347	0.0348	0.0371	6.64	0.0378	8.68
0.355	0.0357	0.0377	5.34	0.0375	4.90
0.363	0.0367	0.0385	4.93	0.0387	5.39
0.372	0.0377	0.0394	4.43	0.0411	8.91
0.380	0.0388	0.0404	4.28	0.0435	12.04
0.389	0.0398	0.0418	4.89	0.0443	11.24
0.398	0.0409	0.0435	6.20	0.0425	3.91
0.407	0.0421	0.0455	8.06	0.0429	2.04
0.417	0.0432	0.0476	10.18	0.0450	4.00
0.427	0.0444	0.0501	12.97	0.0464	4.67
0.437	0.0455	0.0525	15.41	0.0470	3.28
0.447	0.0467	0.0537	15.10	0.0470	0.75
0.457	0.0479	0.0540	12.68	0.0475	-0.75
0.468	0.0491	0.0535	8.86	0.0490	-0.26
0.479	0.0504	0.0529	5.00	0.0517	2.50
0.490	0.0517	0.0527	2.01	0.0543	5.05
0.501	0.0530	0.0535	0.98	0.0555	4.76
0.513	0.0535	0.0552	3.18	0.0558	4.40
0.525	0.0540	0.0566	4.91	0.0562	4.06
0.537	0.0545	0.0572	5.03	0.0573	5.21
0.550	0.0550	0.0583	5.96	0.0588	6.84

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.562	0.0555	0.0586	5.44	0.0600	7.96
0.575	0.0561	0.0589	5.10	0.0602	7.40
0.589	0.0566	0.0597	5.51	0.0600	5.92
0.603	0.0572	0.0603	5.42	0.0607	6.23
0.617	0.0577	0.0613	6.31	0.0632	9.45
0.631	0.0583	0.0615	5.61	0.0662	13.68
0.646	0.0588	0.0606	3.09	0.0678	15.22
0.661	0.0594	0.0605	1.92	0.0669	12.65
0.676	0.0598	0.0609	1.72	0.0644	7.54
0.692	0.0600	0.0611	1.72	0.0630	4.90
0.708	0.0602	0.0606	0.71	0.0622	3.22
0.724	0.0604	0.0636	5.38	0.0610	0.96
0.741	0.0606	0.0663	9.53	0.0649	7.07
0.759	0.0608	0.0657	8.16	0.0639	5.09
0.776	0.0609	0.0660	8.29	0.0620	1.67
0.794	0.0611	0.0648	5.97	0.0618	1.18
0.813	0.0613	0.0655	6.90	0.0643	4.89
0.832	0.0615	0.0643	4.62	0.0698	13.55
0.851	0.0617	0.0634	2.77	0.0748	21.29
0.871	0.0613	0.0643	4.78	0.0746	21.60
0.891	0.0609	0.0661	8.42	0.0697	14.36
0.912	0.0605	0.0689	13.80	0.0634	4.81
0.933	0.0601	0.0699	16.29	0.0673	12.00
0.955	0.0597	0.0669	12.09	0.0684	14.57
0.977	0.0593	0.0628	5.90	0.0648	9.19
1.000	0.0589	0.0616	4.57	0.0587	-0.39
1.023	0.0600	0.0632	5.35	0.0607	1.23
1.047	0.0611	0.0659	7.79	0.0705	15.30
1.072	0.0622	0.0688	10.49	0.0779	25.11
1.097	0.0634	0.0689	8.71	0.0785	23.88
1.122	0.0646	0.0676	4.63	0.0749	15.98
1.148	0.0658	0.0684	3.95	0.0691	5.08
1.175	0.0670	0.0705	5.30	0.0686	2.34
1.202	0.0682	0.0714	4.70	0.0677	-0.85
1.230	0.0695	0.0725	4.36	0.0731	5.14
1.259	0.0708	0.0763	7.74	0.0766	8.18
1.288	0.0721	0.0830	15.15	0.0777	7.74
1.318	0.0734	0.0875	19.10	0.0791	7.65
1.349	0.0748	0.0870	16.30	0.0806	7.73
1.380	0.0762	0.0826	8.52	0.0809	6.26
1.413	0.0774	0.0813	5.10	0.0812	4.86

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
1.445	0.0787	0.0810	3.01	0.0864	9.83
1.479	0.0799	0.0819	2.41	0.0886	10.90
1.514	0.0812	0.0830	2.22	0.0887	9.18
1.549	0.0825	0.0896	8.60	0.0866	4.97
1.585	0.0839	0.0944	12.59	0.0837	-0.18
1.622	0.0852	0.0947	11.09	0.0898	5.40
1.660	0.0866	0.0989	14.16	0.0895	3.27
1.698	0.0880	0.0976	10.85	0.0901	2.33
1.738	0.0895	0.0958	7.12	0.0929	3.81
1.778	0.0908	0.0962	5.90	0.0955	5.20
1.820	0.0921	0.0965	4.78	0.0993	7.82
1.862	0.0934	0.0981	4.99	0.1035	10.79
1.906	0.0948	0.0964	1.67	0.0986	4.05
1.950	0.0962	0.0961	-0.10	0.1068	11.11
1.995	0.0975	0.0988	1.25	0.1114	14.24
2.042	0.0989	0.1042	5.32	0.1078	8.94
2.089	0.1004	0.1083	7.91	0.1055	5.09
2.138	0.1018	0.1102	8.21	0.1116	9.63
2.188	0.1033	0.1086	5.18	0.1144	10.77
2.239	0.1047	0.1115	6.56	0.1109	6.00
2.291	0.1059	0.1114	5.13	0.1113	5.08
2.344	0.1072	0.1122	4.69	0.1203	12.17
2.399	0.1085	0.1138	4.87	0.1224	12.78
2.455	0.1098	0.1127	2.62	0.1155	5.13
2.512	0.1114	0.1173	5.31	0.1147	2.99
2.570	0.1136	0.1212	6.69	0.1116	-1.77
2.630	0.1159	0.1264	9.06	0.1164	0.41
2.692	0.1183	0.1293	9.36	0.1195	1.07
2.754	0.1207	0.1309	8.49	0.1182	-2.06
2.818	0.1231	0.1315	6.83	0.1249	1.50
2.884	0.1256	0.1344	7.06	0.1320	5.08
2.951	0.1281	0.1346	5.07	0.1479	15.45
3.020	0.1307	0.1398	6.92	0.1619	23.85
3.090	0.1334	0.1483	11.22	0.1585	18.82
3.162	0.1361	0.1515	11.37	0.1428	4.94
3.236	0.1388	0.1539	10.86	0.1541	10.99
3.311	0.1416	0.1512	6.80	0.1486	4.95
3.389	0.1445	0.1528	5.74	0.1525	5.56
3.467	0.1474	0.1569	6.47	0.1540	4.46
3.548	0.1504	0.1573	4.60	0.1642	9.16
3.631	0.1536	0.1531	-0.33	0.1735	12.97

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
3.715	0.1569	0.1633	4.07	0.1709	8.88
3.802	0.1603	0.1719	7.23	0.1713	6.81
3.891	0.1638	0.1711	4.43	0.1824	11.33
3.981	0.1674	0.1805	7.87	0.1752	4.67
4.074	0.1710	0.1891	10.58	0.1820	6.45
4.169	0.1747	0.1887	8.01	0.1855	6.18
4.266	0.1785	0.1860	4.18	0.1897	6.25
4.365	0.1824	0.1836	0.68	0.2015	10.48
4.467	0.1863	0.1964	5.42	0.1980	6.28
4.571	0.1911	0.2071	8.34	0.1968	2.97
4.677	0.1970	0.2100	6.62	0.2048	3.98
4.786	0.2029	0.2131	5.01	0.2123	4.61
4.898	0.2091	0.2248	7.49	0.2195	4.95
5.012	0.2152	0.2262	5.10	0.2263	5.17
5.129	0.2191	0.2343	6.97	0.2311	5.48
5.248	0.2230	0.2369	6.22	0.2289	2.63
5.370	0.2270	0.2360	3.96	0.2385	5.07
5.495	0.2311	0.2437	5.48	0.2378	2.91
5.623	0.2352	0.2502	6.38	0.2499	6.25
5.754	0.2395	0.2599	8.54	0.2622	9.50
5.889	0.2438	0.2548	4.52	0.2569	5.40
6.026	0.2481	0.2632	6.07	0.2619	5.53
6.166	0.2526	0.2624	3.89	0.2653	5.03
6.310	0.2571	0.2716	5.62	0.2693	4.71
6.457	0.2618	0.2735	4.50	0.2742	4.77
6.607	0.2665	0.2759	3.55	0.2801	5.12
6.761	0.2712	0.2830	4.34	0.2875	5.99
6.918	0.2761	0.2954	6.98	0.2847	3.13
7.080	0.2811	0.2970	5.67	0.2946	4.80
7.244	0.2861	0.2824	-1.31	0.3063	7.04
7.413	0.2913	0.3060	5.06	0.3050	4.73
7.586	0.2960	0.3154	6.55	0.3085	4.21
7.763	0.3004	0.3125	4.02	0.3149	4.83
7.943	0.3049	0.3174	4.11	0.3232	6.01
8.128	0.3094	0.3279	6.00	0.3210	3.77
8.318	0.3139	0.3311	5.47	0.3258	3.79
8.511	0.3186	0.3306	3.78	0.3364	5.61
8.710	0.3233	0.3355	3.77	0.3418	5.73
8.913	0.3280	0.3512	7.07	0.3425	4.42
9.120	0.3329	0.3536	6.22	0.3526	5.93
9.333	0.3378	0.3386	0.25	0.3562	5.45

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
9.550	0.3428	0.3594	4.85	0.3616	5.47
9.772	0.3479	0.3766	8.26	0.3620	4.06
10.000	0.3530	0.3716	5.27	0.3713	5.18
10.233	0.3593	0.3872	7.78	0.3890	8.27
10.471	0.3657	0.3866	5.71	0.3875	5.96
10.715	0.3722	0.3879	4.21	0.3922	5.38
10.965	0.3788	0.3961	4.57	0.3960	4.52
11.220	0.3856	0.4101	6.37	0.4059	5.26
11.482	0.3924	0.4139	5.46	0.4128	5.20
11.749	0.3992	0.4148	3.92	0.4198	5.17
12.023	0.4037	0.4241	5.07	0.4251	5.30
12.303	0.4082	0.4372	7.11	0.4367	6.98
12.589	0.4128	0.4195	1.63	0.4339	5.11
12.883	0.4175	0.4295	2.89	0.4393	5.23
13.183	0.4222	0.4516	6.97	0.4379	3.73
13.490	0.4269	0.4477	4.86	0.4478	4.90
13.804	0.4317	0.4675	8.28	0.4569	5.83
14.125	0.4366	0.4449	1.90	0.4665	6.86
14.455	0.4415	0.4598	4.15	0.4679	5.98
14.791	0.4465	0.4739	6.13	0.4709	5.47
15.136	0.4505	0.4715	4.66	0.4789	6.32
15.488	0.4541	0.4763	4.88	0.4773	5.10
15.849	0.4578	0.4775	4.30	0.4718	3.05
16.218	0.4615	0.4853	5.17	0.4934	6.91
16.596	0.4652	0.4880	4.90	0.4849	4.23
16.983	0.4690	0.4923	4.96	0.4939	5.31
17.378	0.4728	0.4968	5.07	0.4959	4.89
17.783	0.4766	0.5027	5.46	0.5039	5.71
18.197	0.4805	0.5075	5.61	0.4960	3.21
18.621	0.4844	0.5046	4.16	0.5101	5.31
19.055	0.4880	0.5106	4.62	0.5139	5.31
19.499	0.4913	0.5125	4.32	0.5154	4.92
19.953	0.4945	0.5189	4.94	0.5192	4.99
20.418	0.4978	0.5212	4.70	0.5253	5.53
20.893	0.5010	0.5262	5.02	0.5217	4.11
21.380	0.5044	0.5289	4.88	0.5323	5.53
21.878	0.5077	0.5341	5.20	0.5314	4.67
22.387	0.5110	0.5348	4.66	0.5376	5.20
22.909	0.5144	0.5425	5.46	0.5366	4.32
23.442	0.5178	0.5473	5.70	0.5462	5.49
23.989	0.5212	0.5479	5.12	0.5478	5.11

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
24.547	0.5247	0.5522	5.24	0.5531	5.42
25.119	0.5268	0.5563	5.60	0.5493	4.26
25.704	0.5240	0.5525	5.45	0.5430	3.63
26.303	0.5211	0.5554	6.58	0.5511	5.76
26.916	0.5183	0.5484	5.80	0.5424	4.65
27.542	0.5155	0.5389	4.54	0.5457	5.86
28.184	0.5127	0.5450	6.30	0.5352	4.39
28.841	0.5100	0.5398	5.86	0.5364	5.18
29.512	0.5072	0.5389	6.24	0.5335	5.18
30.200	0.5045	0.5359	6.23	0.5290	4.87
30.903	0.5023	0.5352	6.55	0.5270	4.92
31.623	0.5004	0.5369	7.29	0.5230	4.51
32.360	0.4985	0.5327	6.85	0.5359	7.49
33.113	0.4966	0.5283	6.38	0.5117	3.03
33.885	0.4948	0.5329	7.71	0.5119	3.47
34.674	0.4929	0.5330	8.13	0.5275	7.03
35.482	0.4910	0.5298	7.90	0.5221	6.33
36.308	0.4891	0.5267	7.68	0.5147	5.23
37.154	0.4873	0.5262	7.98	0.5114	4.95
38.019	0.4854	0.5224	7.61	0.5096	4.98
38.905	0.4824	0.5189	7.56	0.5044	4.56
39.811	0.4774	0.5169	8.26	0.5041	5.58
40.738	0.4725	0.5117	8.31	0.4952	4.81
41.687	0.4676	0.4971	6.31	0.4914	5.09
42.658	0.4627	0.4918	6.28	0.4894	5.75
43.652	0.4580	0.4858	6.07	0.4852	5.96
44.669	0.4532	0.4829	6.56	0.4753	4.87
45.709	0.4485	0.4744	5.76	0.4737	5.62
46.774	0.4439	0.4794	8.00	0.4685	5.54
47.863	0.4393	0.4657	6.01	0.4646	5.75
48.978	0.4346	0.4641	6.81	0.4554	4.81
50.119	0.4246	0.4577	7.81	0.4451	4.84
51.287	0.4149	0.4573	10.24	0.4404	6.15
52.481	0.4053	0.4356	7.47	0.4241	4.62
53.704	0.3960	0.4216	6.44	0.4191	5.81
54.954	0.3870	0.3845	-0.63	0.4106	6.12
56.235	0.3781	0.3935	4.09	0.3979	5.23
57.544	0.3694	0.3899	5.55	0.3890	5.30
58.885	0.3609	0.3700	2.52	0.3805	5.42
60.256	0.3527	0.3738	5.99	0.3753	6.42
61.660	0.3446	0.3641	5.68	0.3633	5.44

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
63.096	0.3342	0.3533	5.71	0.3520	5.33
64.566	0.3232	0.3645	12.78	0.3397	5.11
66.070	0.3125	0.3497	11.91	0.3283	5.07
67.609	0.3021	0.3319	9.88	0.3176	5.13
69.184	0.2921	0.3164	8.32	0.3052	4.49
70.795	0.2824	0.3026	7.17	0.2971	5.20
72.444	0.2730	0.2925	7.13	0.2885	5.67
74.132	0.2640	0.2817	6.70	0.2795	5.87
75.858	0.2553	0.2876	12.67	0.2705	5.97
77.625	0.2468	0.2891	17.15	0.2608	5.66
79.433	0.2402	0.2808	16.89	0.2534	5.51
81.284	0.2367	0.2628	11.00	0.2480	4.76
83.177	0.2333	0.2520	8.02	0.2450	5.02
85.114	0.2299	0.2500	8.74	0.2407	4.68
87.097	0.2266	0.2513	10.90	0.2361	4.17
89.126	0.2234	0.2611	16.87	0.2346	5.02
91.202	0.2201	0.2575	16.99	0.2393	8.69
93.326	0.2170	0.2552	17.64	0.2449	12.88
95.500	0.2138	0.2468	15.43	0.2479	15.92
97.724	0.2107	0.2437	15.63	0.2398	13.81
100.000	0.2077	0.2369	14.07	0.2272	9.40

TABLE 1-7

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE VERTICAL DIRECTION FOR 12URB

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0032	0.0033	3.44
0.102	0.0033	0.0034	2.70
0.105	0.0035	0.0035	1.44
0.107	0.0036	0.0036	0.00
0.110	0.0038	0.0037	-2.12
0.112	0.0039	0.0039	-1.78
0.115	0.0041	0.0041	0.49
0.118	0.0043	0.0043	0.94
0.120	0.0045	0.0045	0.45
0.123	0.0046	0.0046	-0.65
0.126	0.0048	0.0049	0.83
0.129	0.0050	0.0053	5.98
0.132	0.0052	0.0057	9.21
0.135	0.0054	0.0060	10.17
0.138	0.0056	0.0061	9.09
0.141	0.0058	0.0063	8.06
0.145	0.0061	0.0065	7.44
0.148	0.0063	0.0067	7.17
0.151	0.0065	0.0069	6.44
0.155	0.0068	0.0072	6.80
0.159	0.0070	0.0075	6.98
0.162	0.0073	0.0076	4.67
0.166	0.0075	0.0078	3.19
0.170	0.0078	0.0081	4.25
0.174	0.0080	0.0084	4.36
0.178	0.0083	0.0086	3.38
0.182	0.0086	0.0091	6.65
0.186	0.0089	0.0098	10.85
0.191	0.0091	0.0104	13.68
0.195	0.0095	0.0108	14.39
0.200	0.0098	0.0111	13.42
0.204	0.0101	0.0114	13.08
0.209	0.0104	0.0117	12.38
0.214	0.0108	0.0121	11.99
0.219	0.0111	0.0123	10.43
0.224	0.0115	0.0125	8.45
0.229	0.0119	0.0127	6.66

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.234	0.0122	0.0129	5.72
0.240	0.0127	0.0133	5.22
0.246	0.0131	0.0138	5.74
0.251	0.0135	0.0145	7.12
0.257	0.0139	0.0151	8.69
0.263	0.0144	0.0159	10.66
0.269	0.0148	0.0166	12.45
0.275	0.0152	0.0172	13.08
0.282	0.0157	0.0176	12.65
0.288	0.0161	0.0180	11.55
0.295	0.0166	0.0182	9.71
0.302	0.0171	0.0184	7.73
0.309	0.0176	0.0187	6.21
0.316	0.0181	0.0191	5.37
0.324	0.0186	0.0196	5.16
0.331	0.0191	0.0201	5.22
0.339	0.0197	0.0208	5.59
0.347	0.0202	0.0214	5.98
0.355	0.0208	0.0218	4.81
0.363	0.0214	0.0224	4.82
0.372	0.0219	0.0233	6.06
0.380	0.0226	0.0245	8.51
0.389	0.0232	0.0256	10.62
0.398	0.0238	0.0266	11.84
0.407	0.0245	0.0276	12.87
0.417	0.0252	0.0287	14.23
0.427	0.0258	0.0290	12.36
0.437	0.0265	0.0287	8.50
0.447	0.0272	0.0290	6.62
0.457	0.0279	0.0292	4.66
0.468	0.0286	0.0299	4.51
0.479	0.0293	0.0312	6.44
0.490	0.0301	0.0324	7.74
0.501	0.0308	0.0335	8.76
0.513	0.0311	0.0329	5.72
0.525	0.0314	0.0329	4.65
0.537	0.0317	0.0339	6.81
0.550	0.0320	0.0364	13.59
0.562	0.0323	0.0382	18.16
0.575	0.0326	0.0371	13.63
0.589	0.0330	0.0365	10.71
0.603	0.0333	0.0338	1.74
0.617	0.0336	0.0352	4.73
0.631	0.0339	0.0360	6.25

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.646	0.0342	0.0368	7.45
0.661	0.0346	0.0374	8.13
0.676	0.0348	0.0372	6.66
0.692	0.0349	0.0366	4.84
0.708	0.0350	0.0361	2.97
0.724	0.0351	0.0357	1.71
0.741	0.0353	0.0350	-0.60
0.759	0.0354	0.0343	-3.08
0.776	0.0355	0.0347	-2.28
0.794	0.0356	0.0366	3.01
0.813	0.0357	0.0374	4.79
0.832	0.0358	0.0404	12.94
0.851	0.0359	0.0410	14.24
0.871	0.0357	0.0396	10.96
0.891	0.0355	0.0370	4.23
0.912	0.0352	0.0399	13.20
0.933	0.0350	0.0387	10.57
0.955	0.0348	0.0343	-1.32
0.977	0.0345	0.0362	4.89
1.000	0.0343	0.0381	11.05
1.023	0.0350	0.0394	12.49
1.047	0.0357	0.0406	13.65
1.072	0.0364	0.0430	18.27
1.097	0.0371	0.0432	16.46
1.122	0.0379	0.0410	8.40
1.148	0.0386	0.0405	4.82
1.175	0.0394	0.0410	4.01
1.202	0.0402	0.0421	4.83
1.230	0.0410	0.0419	2.37
1.259	0.0418	0.0437	4.53
1.288	0.0426	0.0449	5.47
1.318	0.0434	0.0458	5.32
1.349	0.0443	0.0469	5.85
1.380	0.0452	0.0493	9.17
1.413	0.0460	0.0483	5.13
1.445	0.0468	0.0498	6.41
1.479	0.0476	0.0526	10.40
1.514	0.0484	0.0555	14.62
1.549	0.0493	0.0561	13.81
1.585	0.0502	0.0527	4.98
1.622	0.0511	0.0523	2.35
1.660	0.0520	0.0525	1.06
1.698	0.0529	0.0509	-3.80
1.738	0.0538	0.0561	4.20

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
1.778	0.0547	0.0609	11.39
1.820	0.0556	0.0607	9.18
1.862	0.0565	0.0622	10.08
1.906	0.0574	0.0603	5.09
1.950	0.0583	0.0619	6.24
1.995	0.0592	0.0632	6.67
2.042	0.0602	0.0620	3.06
2.089	0.0611	0.0643	5.18
2.138	0.0621	0.0679	9.30
2.188	0.0631	0.0683	8.18
2.239	0.0641	0.0639	-0.22
2.291	0.0649	0.0682	5.02
2.344	0.0658	0.0727	10.42
2.399	0.0667	0.0752	12.69
2.455	0.0677	0.0715	5.72
2.512	0.0687	0.0704	2.47
2.570	0.0702	0.0738	5.11
2.630	0.0718	0.0774	7.82
2.692	0.0733	0.0773	5.43
2.754	0.0749	0.0769	2.63
2.818	0.0766	0.0787	2.79
2.884	0.0783	0.0846	8.06
2.951	0.0800	0.0861	7.70
3.020	0.0817	0.0848	3.72
3.090	0.0835	0.0873	4.47
3.162	0.0854	0.0910	6.57
3.236	0.0872	0.0917	5.15
3.311	0.0892	0.0938	5.17
3.389	0.0911	0.0947	4.00
3.467	0.0931	0.0986	5.95
3.548	0.0951	0.1034	8.66
3.631	0.0975	0.1050	7.72
3.715	0.1000	0.1023	2.30
3.802	0.1025	0.1124	9.68
3.891	0.1051	0.1131	7.68
3.981	0.1077	0.1120	3.95
4.074	0.1104	0.1182	7.00
4.169	0.1132	0.1219	7.66
4.266	0.1161	0.1217	4.85
4.365	0.1190	0.1236	3.87
4.467	0.1220	0.1287	5.47
4.571	0.1257	0.1368	8.81
4.677	0.1302	0.1402	7.71
4.786	0.1348	0.1421	5.41

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
4.898	0.1396	0.1459	4.54
5.012	0.1443	0.1534	6.30
5.129	0.1476	0.1629	10.38
5.248	0.1509	0.1641	8.74
5.370	0.1543	0.1746	13.15
5.495	0.1577	0.1810	14.75
5.623	0.1613	0.1676	3.95
5.754	0.1649	0.1769	7.32
5.889	0.1686	0.1768	4.90
6.026	0.1724	0.1871	8.56
6.166	0.1762	0.1882	6.81
6.310	0.1802	0.1910	5.99
6.457	0.1842	0.1957	6.21
6.607	0.1883	0.1994	5.85
6.761	0.1926	0.2035	5.70
6.918	0.1969	0.2038	3.50
7.080	0.2013	0.2106	4.61
7.244	0.2058	0.2204	7.11
7.413	0.2104	0.2200	4.54
7.586	0.2146	0.2207	2.80
7.763	0.2184	0.2295	5.07
7.943	0.2222	0.2327	4.73
8.128	0.2261	0.2375	5.05
8.318	0.2301	0.2423	5.31
8.511	0.2341	0.2434	3.96
8.710	0.2382	0.2489	4.48
8.913	0.2423	0.2553	5.35
9.120	0.2466	0.2601	5.48
9.333	0.2509	0.2577	2.73
9.550	0.2553	0.2616	2.48
9.772	0.2598	0.2794	7.56
10.000	0.2643	0.2772	4.87
10.233	0.2704	0.2612	-3.40
10.471	0.2766	0.2894	4.62
10.715	0.2830	0.2938	3.80
10.965	0.2895	0.3025	4.47
11.220	0.2962	0.3123	5.43
11.482	0.3030	0.3189	5.22
11.749	0.3098	0.3144	1.48
12.023	0.3144	0.3329	5.87
12.303	0.3191	0.3436	7.67
12.589	0.3239	0.3371	4.07
12.883	0.3288	0.3418	3.95
13.183	0.3337	0.3537	5.98

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
13.490	0.3387	0.3553	4.88
13.804	0.3438	0.3628	5.52
14.125	0.3490	0.3755	7.60
14.455	0.3542	0.3734	5.43
14.791	0.3595	0.3719	3.45
15.136	0.3636	0.3848	5.84
15.488	0.3673	0.3850	4.82
15.849	0.3711	0.3831	3.24
16.218	0.3749	0.3981	6.20
16.596	0.3787	0.4012	5.94
16.983	0.3826	0.4014	4.90
17.378	0.3865	0.3965	2.58
17.783	0.3905	0.4112	5.32
18.197	0.3945	0.4116	4.33
18.621	0.3985	0.4111	3.16
19.055	0.4032	0.4258	5.62
19.499	0.4086	0.4298	5.19
19.953	0.4142	0.4328	4.49
20.418	0.4198	0.4442	5.80
20.893	0.4255	0.4430	4.09
21.380	0.4313	0.4532	5.07
21.878	0.4372	0.4561	4.31
22.387	0.4431	0.4718	6.46
22.909	0.4492	0.4725	5.19
23.442	0.4553	0.4790	5.21
23.989	0.4615	0.4839	4.86
24.547	0.4678	0.4928	5.36
25.119	0.4727	0.4988	5.52
25.704	0.4724	0.5028	6.44
26.303	0.4720	0.4992	5.74
26.916	0.4717	0.4949	4.92
27.542	0.4714	0.4895	3.84
28.184	0.4710	0.4919	4.44
28.841	0.4707	0.4936	4.88
29.512	0.4703	0.4945	5.13
30.200	0.4700	0.4994	6.27
30.903	0.4710	0.4986	5.85
31.623	0.4725	0.4851	2.67
32.360	0.4740	0.4926	3.93
33.113	0.4755	0.5002	5.19
33.885	0.4770	0.5014	5.13
34.674	0.4785	0.5018	4.87
35.482	0.4800	0.5075	5.73
36.308	0.4815	0.5072	5.34

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
37.154	0.4830	0.5091	5.39
38.019	0.4846	0.5097	5.19
38.905	0.4843	0.5097	5.24
39.811	0.4813	0.5031	4.54
40.738	0.4782	0.5045	5.50
41.687	0.4752	0.4959	4.36
42.658	0.4722	0.4899	3.76
43.652	0.4692	0.4897	4.37
44.669	0.4662	0.4839	3.79
45.709	0.4633	0.4824	4.12
46.774	0.4603	0.4776	3.76
47.863	0.4574	0.4770	4.28
48.978	0.4543	0.4742	4.40
50.119	0.4446	0.4630	4.14
51.287	0.4351	0.4528	4.05
52.481	0.4258	0.4453	4.57
53.704	0.4168	0.4360	4.62
54.954	0.4079	0.4271	4.71
56.235	0.3992	0.4217	5.65
57.544	0.3907	0.4123	5.53
58.885	0.3824	0.4100	7.24
60.256	0.3742	0.3931	5.04
61.660	0.3662	0.3793	3.56
63.096	0.3542	0.3572	0.85
64.566	0.3406	0.3424	0.51
66.070	0.3276	0.3400	3.79
67.609	0.3151	0.3283	4.20
69.184	0.3030	0.3121	3.01
70.795	0.2915	0.3047	4.54
72.444	0.2803	0.2946	5.11
74.132	0.2696	0.2796	3.72
75.858	0.2593	0.2702	4.20
77.625	0.2494	0.2612	4.75
79.433	0.2409	0.2532	5.12
81.284	0.2345	0.2452	4.58
83.177	0.2282	0.2362	3.48
85.114	0.2222	0.2314	4.15
87.097	0.2163	0.2279	5.39
89.126	0.2105	0.2225	5.69
91.202	0.2049	0.2175	6.14
93.326	0.1995	0.2151	7.81
95.500	0.1942	0.2131	9.75
97.724	0.1890	0.2057	8.81
100.000	0.1840	0.2026	10.10

TABLE 1-8

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE HORIZONTAL DIRECTION FOR 1UBP & 2UBP

FREQUENCY (HZ)	HORIZONTAL FIRS ACCELERATION (G)	FIRST HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)	SECOND HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0056	0.0057	1.43	0.0056	0.00
0.102	0.0058	0.0060	3.26	0.0060	2.41
0.105	0.0061	0.0063	4.62	0.0062	2.64
0.107	0.0063	0.0067	6.19	0.0063	0.63
0.110	0.0066	0.0070	7.18	0.0068	3.21
0.112	0.0068	0.0074	8.22	0.0074	8.52
0.115	0.0071	0.0077	9.04	0.0078	9.75
0.118	0.0074	0.0081	9.50	0.0079	6.78
0.120	0.0077	0.0084	9.66	0.0080	4.44
0.123	0.0080	0.0087	9.54	0.0086	7.28
0.126	0.0083	0.0091	9.17	0.0091	9.53
0.129	0.0086	0.0094	8.72	0.0096	11.16
0.132	0.0089	0.0096	7.84	0.0100	11.98
0.135	0.0093	0.0099	6.70	0.0104	12.53
0.138	0.0096	0.0102	5.93	0.0108	12.28
0.141	0.0100	0.0106	5.81	0.0112	11.72
0.145	0.0103	0.0109	5.13	0.0115	10.93
0.148	0.0107	0.0112	4.56	0.0118	9.96
0.151	0.0112	0.0116	3.68	0.0122	8.97
0.155	0.0116	0.0122	5.71	0.0125	8.22
0.159	0.0120	0.0128	6.50	0.0129	7.42
0.162	0.0124	0.0133	6.67	0.0133	6.83
0.166	0.0129	0.0137	6.45	0.0137	6.53
0.170	0.0133	0.0142	6.46	0.0141	6.01
0.174	0.0138	0.0146	5.95	0.0146	6.25
0.178	0.0143	0.0150	5.40	0.0151	6.04
0.182	0.0148	0.0157	6.17	0.0155	5.22
0.186	0.0153	0.0164	7.67	0.0158	3.48
0.191	0.0158	0.0171	8.24	0.0159	0.82
0.195	0.0163	0.0179	9.55	0.0159	-2.39
0.200	0.0169	0.0186	10.07	0.0167	-1.36
0.204	0.0175	0.0192	9.78	0.0181	3.43

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.209	0.0180	0.0197	9.26	0.0193	7.04
0.214	0.0186	0.0201	8.06	0.0202	8.54
0.219	0.0192	0.0205	6.45	0.0209	8.69
0.224	0.0198	0.0207	4.49	0.0215	8.63
0.229	0.0205	0.0211	3.13	0.0220	7.53
0.234	0.0211	0.0218	3.18	0.0223	5.55
0.240	0.0218	0.0225	3.40	0.0225	3.31
0.246	0.0225	0.0233	3.78	0.0228	1.38
0.251	0.0232	0.0242	4.53	0.0232	0.26
0.257	0.0239	0.0252	5.44	0.0239	-0.08
0.263	0.0246	0.0263	6.57	0.0247	0.20
0.269	0.0254	0.0274	7.84	0.0256	0.79
0.275	0.0261	0.0285	9.00	0.0263	0.80
0.282	0.0269	0.0294	9.34	0.0268	-0.45
0.288	0.0277	0.0301	8.60	0.0285	2.89
0.295	0.0285	0.0305	6.98	0.0297	4.35
0.302	0.0293	0.0311	6.00	0.0305	4.06
0.309	0.0302	0.0316	4.57	0.0313	3.64
0.316	0.0311	0.0319	2.60	0.0318	2.12
0.324	0.0320	0.0323	0.72	0.0322	0.53
0.331	0.0330	0.0328	-0.39	0.0327	-0.76
0.339	0.0339	0.0341	0.80	0.0343	1.30
0.347	0.0348	0.0361	3.85	0.0364	4.69
0.355	0.0357	0.0377	5.43	0.0372	4.03
0.363	0.0367	0.0387	5.36	0.0377	2.59
0.372	0.0377	0.0394	4.43	0.0392	3.79
0.380	0.0388	0.0405	4.51	0.0402	3.58
0.389	0.0398	0.0414	3.97	0.0408	2.41
0.398	0.0409	0.0420	2.64	0.0416	1.61
0.407	0.0421	0.0424	0.86	0.0428	1.78
0.417	0.0432	0.0443	2.38	0.0447	3.45
0.427	0.0444	0.0465	4.76	0.0468	5.52
0.437	0.0455	0.0482	5.94	0.0486	6.84
0.447	0.0467	0.0499	6.83	0.0501	7.37
0.457	0.0479	0.0510	6.47	0.0511	6.73
0.468	0.0491	0.0518	5.46	0.0519	5.70
0.479	0.0504	0.0529	5.02	0.0531	5.46
0.490	0.0517	0.0550	6.32	0.0545	5.42
0.501	0.0530	0.0575	8.56	0.0548	3.57
0.513	0.0535	0.0599	11.97	0.0544	1.81
0.525	0.0540	0.0613	13.62	0.0542	0.37

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.537	0.0545	0.0612	12.26	0.0545	-0.02
0.550	0.0550	0.0619	12.54	0.0555	0.91
0.562	0.0555	0.0624	12.33	0.0565	1.73
0.575	0.0561	0.0629	12.15	0.0571	1.82
0.589	0.0566	0.0645	13.99	0.0580	2.40
0.603	0.0572	0.0666	16.55	0.0602	5.27
0.617	0.0577	0.0669	15.93	0.0639	10.68
0.631	0.0583	0.0661	13.41	0.0677	16.19
0.646	0.0588	0.0645	9.64	0.0693	17.84
0.661	0.0594	0.0622	4.70	0.0685	15.33
0.676	0.0598	0.0624	4.26	0.0658	9.94
0.692	0.0600	0.0658	9.56	0.0636	5.88
0.708	0.0602	0.0652	8.35	0.0634	5.35
0.724	0.0604	0.0634	4.90	0.0641	6.09
0.741	0.0606	0.0628	3.75	0.0633	4.42
0.759	0.0608	0.0667	9.78	0.0644	5.94
0.776	0.0609	0.0670	9.99	0.0633	3.94
0.794	0.0611	0.0652	6.59	0.0630	3.09
0.813	0.0613	0.0658	7.36	0.0646	5.30
0.832	0.0615	0.0645	4.90	0.0690	12.21
0.851	0.0617	0.0632	2.51	0.0722	17.09
0.871	0.0613	0.0629	2.61	0.0694	13.22
0.891	0.0609	0.0646	6.01	0.0637	4.48
0.912	0.0605	0.0681	12.53	0.0631	4.23
0.933	0.0601	0.0684	13.86	0.0646	7.49
0.955	0.0597	0.0635	6.42	0.0629	5.38
0.977	0.0593	0.0595	0.40	0.0595	0.34
1.000	0.0589	0.0618	4.89	0.0620	5.30
1.023	0.0600	0.0670	11.62	0.0630	4.95
1.047	0.0611	0.0717	17.33	0.0624	2.14
1.072	0.0622	0.0739	18.69	0.0624	0.32
1.097	0.0634	0.0723	14.02	0.0675	6.53
1.122	0.0646	0.0678	4.96	0.0694	7.40
1.148	0.0658	0.0663	0.84	0.0748	13.78
1.175	0.0670	0.0674	0.66	0.0750	12.00
1.202	0.0682	0.0689	0.95	0.0701	2.77
1.230	0.0695	0.0706	1.64	0.0732	5.31
1.259	0.0708	0.0744	5.04	0.0727	2.74
1.288	0.0721	0.0807	11.89	0.0724	0.42
1.318	0.0734	0.0841	14.56	0.0742	1.08
1.349	0.0748	0.0821	9.77	0.0774	3.45

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
1.380	0.0762	0.0800	5.07	0.0807	6.00
1.413	0.0774	0.0890	15.05	0.0825	6.63
1.445	0.0787	0.0879	11.79	0.0828	5.29
1.479	0.0799	0.0811	1.49	0.0843	5.46
1.514	0.0812	0.0842	3.68	0.0865	6.51
1.549	0.0825	0.0903	9.39	0.0822	-0.42
1.585	0.0839	0.0946	12.76	0.0878	4.72
1.622	0.0852	0.0935	9.63	0.0941	10.39
1.660	0.0866	0.0926	6.89	0.0992	14.52
1.698	0.0880	0.0924	4.93	0.1012	14.92
1.738	0.0895	0.1000	11.74	0.1013	13.18
1.778	0.0908	0.0967	6.53	0.0993	9.32
1.820	0.0921	0.0956	3.82	0.0939	1.94
1.862	0.0934	0.0977	4.53	0.0984	5.29
1.906	0.0948	0.1041	9.84	0.0987	4.11
1.950	0.0962	0.1078	12.14	0.1051	9.34
1.995	0.0975	0.1028	5.37	0.1111	13.86
2.042	0.0989	0.1026	3.66	0.1110	12.16
2.089	0.1004	0.1020	1.57	0.1081	7.72
2.138	0.1018	0.1069	5.02	0.1066	4.65
2.188	0.1033	0.1107	7.14	0.1085	5.02
2.239	0.1047	0.1126	7.57	0.1074	2.65
2.291	0.1059	0.1101	3.96	0.1113	5.11
2.344	0.1072	0.1103	2.84	0.1208	12.70
2.399	0.1085	0.1139	4.93	0.1272	17.19
2.455	0.1098	0.1165	6.02	0.1158	5.45
2.512	0.1114	0.1201	7.89	0.1178	5.77
2.570	0.1136	0.1208	6.33	0.1200	5.64
2.630	0.1159	0.1201	3.63	0.1241	7.13
2.692	0.1182	0.1284	8.67	0.1243	5.22
2.754	0.1205	0.1375	14.06	0.1191	-1.22
2.818	0.1230	0.1385	12.68	0.1265	2.88
2.884	0.1254	0.1378	9.89	0.1369	9.19
2.951	0.1279	0.1394	9.01	0.1354	5.84
3.020	0.1305	0.1369	4.94	0.1365	4.64
3.090	0.1331	0.1342	0.80	0.1398	5.01
3.162	0.1358	0.1362	0.35	0.1461	7.63
3.236	0.1385	0.1449	4.67	0.1523	9.99
3.311	0.1412	0.1530	8.31	0.1484	5.07
3.389	0.1441	0.1564	8.54	0.1486	3.14
3.467	0.1470	0.1578	7.39	0.1549	5.41

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
3.548	0.1499	0.1518	1.25	0.1646	9.80
3.631	0.1530	0.1545	0.94	0.1797	17.42
3.715	0.1563	0.1609	2.98	0.1729	10.62
3.802	0.1596	0.1726	8.15	0.1747	9.49
3.891	0.1630	0.1772	8.72	0.1812	11.19
3.981	0.1664	0.1759	5.73	0.1742	4.65
4.074	0.1699	0.1727	1.61	0.1830	7.66
4.169	0.1735	0.1767	1.82	0.1876	8.12
4.266	0.1772	0.1850	4.37	0.1878	5.99
4.365	0.1810	0.1930	6.63	0.1982	9.54
4.467	0.1848	0.1919	3.85	0.1964	6.28
4.571	0.1895	0.2062	8.84	0.2034	7.36
4.677	0.1952	0.2122	8.71	0.2119	8.57
4.786	0.2011	0.2102	4.56	0.2098	4.35
4.898	0.2071	0.2245	8.37	0.2032	-1.91
5.012	0.2131	0.2197	3.11	0.2238	5.04
5.129	0.2170	0.2301	6.07	0.2280	5.07
5.248	0.2209	0.2336	5.76	0.2265	2.54
5.370	0.2249	0.2352	4.56	0.2414	7.32
5.495	0.2290	0.2385	4.15	0.2471	7.87
5.623	0.2332	0.2460	5.50	0.2420	3.77
5.754	0.2374	0.2540	6.98	0.2421	1.98
5.889	0.2417	0.2550	5.47	0.2531	4.69
6.026	0.2461	0.2648	7.60	0.2627	6.72
6.166	0.2506	0.2589	3.30	0.2645	5.53
6.310	0.2552	0.2694	5.60	0.2607	2.16
6.457	0.2598	0.2762	6.32	0.2690	3.55
6.607	0.2645	0.2715	2.65	0.2866	8.34
6.761	0.2693	0.2802	4.04	0.2868	6.50
6.918	0.2742	0.2977	8.57	0.2753	0.38
7.080	0.2792	0.2959	5.98	0.2913	4.34
7.244	0.2843	0.2963	4.24	0.3042	7.00
7.413	0.2895	0.3040	5.02	0.3036	4.90
7.586	0.2945	0.3111	5.63	0.3071	4.27
7.763	0.2995	0.3114	3.97	0.3135	4.67
7.943	0.3045	0.3181	4.47	0.3188	4.70
8.128	0.3097	0.3299	6.52	0.3248	4.89
8.318	0.3149	0.3327	5.67	0.3270	3.84
8.511	0.3202	0.3374	5.37	0.3390	5.87
8.710	0.3256	0.3414	4.86	0.3434	5.46
8.913	0.3311	0.3467	4.74	0.3478	5.04

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
9.120	0.3366	0.3579	6.32	0.3580	6.35
9.333	0.3423	0.3590	4.88	0.3540	3.41
9.550	0.3481	0.3657	5.05	0.3653	4.94
9.772	0.3539	0.3616	2.15	0.3681	4.00
10.000	0.3599	0.3700	2.80	0.3778	4.97
10.233	0.3657	0.3860	5.56	0.3940	7.75
10.471	0.3716	0.3842	3.40	0.3911	5.27
10.715	0.3775	0.3778	0.07	0.4002	6.01
10.965	0.3836	0.4001	4.30	0.4034	5.16
11.220	0.3897	0.4163	6.80	0.4100	5.21
11.482	0.3960	0.4159	5.03	0.4170	5.31
11.749	0.4021	0.4124	2.56	0.4271	6.20
12.023	0.4061	0.4274	5.23	0.4285	5.52
12.303	0.4101	0.4388	7.00	0.4384	6.90
12.589	0.4142	0.4199	1.36	0.4310	4.05
12.883	0.4183	0.4339	3.73	0.4351	4.00
13.183	0.4225	0.4463	5.65	0.4501	6.55
13.490	0.4267	0.4489	5.21	0.4493	5.31
13.804	0.4309	0.4585	6.41	0.4554	5.68
14.125	0.4352	0.4486	3.08	0.4552	4.61
14.455	0.4395	0.4513	2.68	0.4607	4.82
14.791	0.4438	0.4680	5.45	0.4588	3.38
15.136	0.4478	0.4680	4.52	0.4682	4.57
15.488	0.4515	0.4728	4.71	0.4758	5.38
15.849	0.4554	0.4826	5.97	0.4799	5.38
16.218	0.4592	0.4866	5.96	0.4791	4.32
16.596	0.4631	0.4817	4.03	0.4910	6.02
16.983	0.4670	0.4889	4.68	0.4909	5.11
17.378	0.4710	0.4982	5.78	0.4881	3.63
17.783	0.4749	0.4878	2.70	0.5037	6.06
18.197	0.4790	0.5060	5.64	0.4921	2.75
18.621	0.4830	0.4975	2.99	0.5095	5.48
19.055	0.4873	0.5106	4.78	0.5091	4.49
19.499	0.4918	0.5148	4.68	0.5163	5.00
19.953	0.4963	0.5175	4.28	0.5207	4.91
20.418	0.5009	0.5233	4.47	0.5310	6.03
20.893	0.5055	0.5305	4.94	0.5253	3.93
21.380	0.5102	0.5339	4.65	0.5391	5.67
21.878	0.5149	0.5372	4.34	0.5400	4.88
22.387	0.5196	0.5461	5.10	0.5462	5.12
22.909	0.5244	0.5556	5.96	0.5471	4.33

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
23.442	0.5292	0.5534	4.56	0.5585	5.54
23.989	0.5341	0.5595	4.75	0.5594	4.73
24.547	0.5391	0.5653	4.86	0.5670	5.19
25.119	0.5423	0.5737	5.80	0.5679	4.72
25.704	0.5388	0.5647	4.81	0.5637	4.62
26.303	0.5353	0.5689	6.28	0.5702	6.53
26.916	0.5318	0.5615	5.58	0.5607	5.43
27.542	0.5284	0.5288	0.07	0.5519	4.46
28.184	0.5250	0.5361	2.13	0.5498	4.73
28.841	0.5216	0.5351	2.60	0.5469	4.87
29.512	0.5182	0.5373	3.69	0.5418	4.56
30.200	0.5148	0.5341	3.74	0.5409	5.07
30.903	0.5131	0.5211	1.56	0.5389	5.04
31.623	0.5119	0.5328	4.07	0.5379	5.07
32.360	0.5108	0.5406	5.84	0.5488	7.45
33.113	0.5097	0.5333	4.63	0.5252	3.05
33.885	0.5085	0.5357	5.35	0.5262	3.47
34.674	0.5074	0.5345	5.34	0.5426	6.93
35.482	0.5063	0.5377	6.22	0.5393	6.52
36.308	0.5051	0.5351	5.93	0.5204	3.03
37.154	0.5040	0.5406	7.26	0.5311	5.37
38.019	0.5029	0.5399	7.37	0.5284	5.07
38.905	0.5000	0.5312	6.24	0.5244	4.87
39.811	0.4944	0.5202	5.21	0.5203	5.25
40.738	0.4888	0.5083	3.98	0.5129	4.93
41.687	0.4833	0.5013	3.73	0.5091	5.35
42.658	0.4778	0.5049	5.66	0.5010	4.85
43.652	0.4724	0.4857	2.82	0.4963	5.06
44.669	0.4671	0.4779	2.32	0.4915	5.22
45.709	0.4618	0.4777	3.45	0.4854	5.11
46.774	0.4566	0.4653	1.91	0.4802	5.17
47.863	0.4514	0.4581	1.47	0.4760	5.45
48.978	0.4461	0.4501	0.89	0.4713	5.64
50.119	0.4360	0.4350	-0.23	0.4608	5.68
51.287	0.4261	0.4267	0.13	0.4524	6.17
52.481	0.4165	0.4171	0.15	0.4411	5.92
53.704	0.4070	0.4155	2.09	0.4342	6.69
54.954	0.3978	0.4073	2.40	0.4189	5.31
56.235	0.3887	0.4119	5.96	0.4097	5.39
57.544	0.3799	0.4070	7.12	0.4007	5.48
58.885	0.3713	0.3942	6.17	0.3923	5.65

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
60.256	0.3629	0.3886	7.11	0.3876	6.83
61.660	0.3546	0.3781	6.61	0.3765	6.18
63.096	0.3442	0.3606	4.76	0.3640	5.76
64.566	0.3330	0.3544	6.41	0.3512	5.46
66.070	0.3222	0.3458	7.30	0.3391	5.23
67.609	0.3118	0.3369	8.06	0.3283	5.29
69.184	0.3017	0.3190	5.72	0.3181	5.42
70.795	0.2919	0.3324	13.87	0.3067	5.08
72.444	0.2825	0.3148	11.46	0.2958	4.72
74.132	0.2733	0.2936	7.42	0.2885	5.56
75.858	0.2644	0.2842	7.47	0.2849	7.73
77.625	0.2559	0.2777	8.55	0.2817	10.11
79.433	0.2491	0.2640	5.98	0.2677	7.45
81.284	0.2454	0.2564	4.48	0.2558	4.23
83.177	0.2417	0.2497	3.32	0.2530	4.65
85.114	0.2381	0.2556	7.34	0.2488	4.47
87.097	0.2346	0.2536	8.10	0.2457	4.75
89.126	0.2311	0.2550	10.37	0.2492	7.87
91.202	0.2276	0.2551	12.07	0.2501	9.87
93.326	0.2242	0.2555	13.97	0.2456	9.55
95.500	0.2209	0.2523	14.23	0.2421	9.61
97.724	0.2176	0.2500	14.92	0.2368	8.84
100.000	0.2143	0.2520	17.61	0.2325	8.50

TABLE 1-9

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE VERTICAL DIRECTION FOR 1UBP & 2UBP

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0032	0.0034	6.87
0.102	0.0033	0.0036	7.21
0.105	0.0035	0.0037	6.92
0.107	0.0036	0.0039	6.63
0.110	0.0038	0.0040	5.57
0.112	0.0039	0.0041	4.58
0.115	0.0041	0.0042	2.93
0.118	0.0043	0.0045	4.22
0.120	0.0045	0.0046	4.04
0.123	0.0046	0.0048	3.67
0.126	0.0048	0.0050	3.31
0.129	0.0050	0.0052	3.39
0.132	0.0052	0.0054	2.88
0.135	0.0054	0.0056	4.45
0.138	0.0056	0.0059	5.02
0.141	0.0058	0.0061	5.70
0.145	0.0060	0.0063	5.67
0.148	0.0062	0.0066	6.43
0.151	0.0065	0.0069	6.67
0.155	0.0067	0.0071	6.73
0.159	0.0069	0.0074	6.78
0.162	0.0072	0.0077	6.69
0.166	0.0074	0.0079	6.45
0.170	0.0077	0.0082	6.10
0.174	0.0080	0.0084	5.64
0.178	0.0083	0.0087	5.08
0.182	0.0086	0.0089	4.44
0.186	0.0089	0.0094	6.43
0.191	0.0092	0.0099	8.29
0.195	0.0095	0.0104	9.79
0.200	0.0098	0.0109	10.77
0.204	0.0102	0.0114	11.78
0.209	0.0105	0.0118	12.27
0.214	0.0109	0.0122	12.53
0.219	0.0112	0.0126	12.14
0.224	0.0116	0.0128	11.08
0.229	0.0119	0.0131	9.48
0.234	0.0123	0.0133	7.89

Frequency (Hz)	Vertical FIRS Acceleration (g)	Vertical Response Spectra Acceleration (g)	Difference (%)
0.240	0.0127	0.0135	6.07
0.246	0.0131	0.0137	4.66
0.251	0.0135	0.0140	3.85
0.257	0.0139	0.0144	3.52
0.263	0.0144	0.0149	3.83
0.269	0.0148	0.0154	4.47
0.275	0.0152	0.0160	5.13
0.282	0.0157	0.0165	5.50
0.288	0.0161	0.0170	5.46
0.295	0.0166	0.0174	5.19
0.302	0.0171	0.0179	4.63
0.309	0.0176	0.0183	4.27
0.316	0.0181	0.0188	4.09
0.324	0.0186	0.0194	4.41
0.331	0.0191	0.0201	5.22
0.339	0.0197	0.0209	6.20
0.347	0.0202	0.0216	6.97
0.355	0.0208	0.0223	7.31
0.363	0.0214	0.0229	7.21
0.372	0.0219	0.0239	9.12
0.380	0.0226	0.0250	10.82
0.389	0.0232	0.0259	11.65
0.398	0.0238	0.0268	12.47
0.407	0.0245	0.0275	12.34
0.417	0.0252	0.0281	11.80
0.427	0.0258	0.0287	11.31
0.437	0.0265	0.0290	9.67
0.447	0.0272	0.0290	6.81
0.457	0.0279	0.0293	4.95
0.468	0.0286	0.0304	6.37
0.479	0.0293	0.0326	11.21
0.490	0.0301	0.0354	17.51
0.501	0.0308	0.0369	19.72
0.513	0.0311	0.0370	18.76
0.525	0.0314	0.0354	12.60
0.537	0.0317	0.0335	5.55
0.550	0.0320	0.0336	4.81
0.562	0.0323	0.0361	11.60
0.575	0.0326	0.0390	19.52
0.589	0.0330	0.0396	20.12
0.603	0.0333	0.0356	7.13
0.617	0.0336	0.0353	5.06
0.631	0.0339	0.0370	9.06
0.646	0.0342	0.0377	10.25

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.661	0.0346	0.0387	12.01
0.676	0.0348	0.0392	12.43
0.692	0.0349	0.0388	10.94
0.708	0.0350	0.0380	8.45
0.724	0.0351	0.0372	5.98
0.741	0.0353	0.0369	4.62
0.759	0.0354	0.0362	2.52
0.776	0.0355	0.0357	0.68
0.794	0.0356	0.0390	9.67
0.813	0.0357	0.0406	13.77
0.832	0.0358	0.0413	15.34
0.851	0.0359	0.0413	15.05
0.871	0.0357	0.0375	4.99
0.891	0.0355	0.0343	-3.24
0.912	0.0352	0.0367	4.15
0.933	0.0350	0.0377	7.80
0.955	0.0348	0.0397	14.07
0.977	0.0345	0.0371	7.56
1.000	0.0343	0.0349	1.60
1.023	0.0350	0.0365	4.40
1.047	0.0357	0.0376	5.33
1.072	0.0364	0.0384	5.61
1.097	0.0371	0.0397	6.90
1.122	0.0379	0.0408	7.69
1.148	0.0386	0.0420	8.76
1.175	0.0394	0.0425	7.98
1.202	0.0402	0.0425	5.90
1.230	0.0410	0.0429	4.86
1.259	0.0418	0.0435	4.07
1.288	0.0426	0.0451	5.82
1.318	0.0434	0.0460	5.96
1.349	0.0443	0.0467	5.30
1.380	0.0452	0.0475	5.14
1.413	0.0460	0.0466	1.33
1.445	0.0468	0.0464	-0.79
1.479	0.0476	0.0480	0.84
1.514	0.0484	0.0509	5.04
1.549	0.0493	0.0534	8.22
1.585	0.0502	0.0573	14.23
1.622	0.0511	0.0602	17.86
1.660	0.0520	0.0580	11.62
1.698	0.0529	0.0556	5.12
1.738	0.0538	0.0555	3.12
1.778	0.0547	0.0579	5.90

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
1.820	0.0556	0.0628	13.06
1.862	0.0565	0.0635	12.50
1.906	0.0574	0.0603	5.14
1.950	0.0583	0.0642	10.05
1.995	0.0592	0.0629	6.21
2.042	0.0602	0.0643	6.85
2.089	0.0611	0.0633	3.45
2.138	0.0621	0.0680	9.45
2.188	0.0631	0.0692	9.63
2.239	0.0641	0.0672	4.98
2.291	0.0649	0.0637	-1.86
2.344	0.0658	0.0668	1.53
2.399	0.0667	0.0700	4.93
2.455	0.0677	0.0714	5.59
2.512	0.0687	0.0729	6.04
2.570	0.0702	0.0738	5.13
2.630	0.0717	0.0756	5.44
2.692	0.0733	0.0770	5.04
2.754	0.0749	0.0756	0.91
2.818	0.0765	0.0809	5.75
2.884	0.0782	0.0861	10.13
2.951	0.0799	0.0850	6.41
3.020	0.0816	0.0927	13.54
3.090	0.0834	0.0888	6.47
3.162	0.0852	0.0884	3.76
3.236	0.0870	0.0947	8.86
3.311	0.0889	0.0938	5.49
3.389	0.0909	0.0955	5.12
3.467	0.0928	0.0997	7.43
3.548	0.0949	0.1006	6.04
3.631	0.0971	0.1018	4.75
3.715	0.0995	0.0992	-0.37
3.802	0.1020	0.1118	9.66
3.891	0.1045	0.1109	6.15
3.981	0.1071	0.1106	3.28
4.074	0.1097	0.1218	10.98
4.169	0.1124	0.1262	12.20
4.266	0.1152	0.1224	6.24
4.365	0.1181	0.1296	9.79
4.467	0.1210	0.1288	6.46
4.571	0.1246	0.1302	4.49
4.677	0.1290	0.1360	5.44
4.786	0.1335	0.1423	6.60
4.898	0.1382	0.1432	3.58

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
5.012	0.1429	0.1512	5.81
5.129	0.1462	0.1601	9.55
5.248	0.1495	0.1601	7.09
5.370	0.1529	0.1704	11.45
5.495	0.1563	0.1748	11.83
5.623	0.1599	0.1671	4.52
5.754	0.1635	0.1795	9.81
5.889	0.1672	0.1768	5.74
6.026	0.1710	0.1914	11.96
6.166	0.1748	0.1875	7.27
6.310	0.1788	0.1766	-1.20
6.457	0.1828	0.1885	3.11
6.607	0.1870	0.1999	6.91
6.761	0.1912	0.2022	5.76
6.918	0.1955	0.2025	3.58
7.080	0.2000	0.2093	4.68
7.244	0.2045	0.2172	6.20
7.413	0.2091	0.2207	5.51
7.586	0.2135	0.2288	7.16
7.763	0.2177	0.2261	3.86
7.943	0.2220	0.2316	4.32
8.128	0.2263	0.2400	6.02
8.318	0.2308	0.2464	6.79
8.511	0.2353	0.2420	2.84
8.710	0.2399	0.2459	2.49
8.913	0.2446	0.2584	5.64
9.120	0.2494	0.2580	3.46
9.333	0.2543	0.2689	5.76
9.550	0.2593	0.2702	4.24
9.772	0.2643	0.2865	8.38
10.000	0.2695	0.2828	4.95
10.233	0.2752	0.2786	1.24
10.471	0.2811	0.2937	4.47
10.715	0.2871	0.2978	3.72
10.965	0.2932	0.3038	3.63
11.220	0.2994	0.3266	9.08
11.482	0.3058	0.3215	5.15
11.749	0.3120	0.3066	-1.76
12.023	0.3163	0.3350	5.92
12.303	0.3206	0.3459	7.89
12.589	0.3250	0.3431	5.56
12.883	0.3295	0.3393	2.97
13.183	0.3340	0.3583	7.29
13.490	0.3385	0.3558	5.10

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
13.804	0.3432	0.3666	6.84
14.125	0.3479	0.3718	6.87
14.455	0.3526	0.3704	5.05
14.791	0.3574	0.3488	-2.41
15.136	0.3615	0.3928	8.65
15.488	0.3653	0.3862	5.73
15.849	0.3692	0.3933	6.53
16.218	0.3731	0.3829	2.62
16.596	0.3770	0.3996	5.99
16.983	0.3810	0.4019	5.47
17.378	0.3851	0.3986	3.52
17.783	0.3892	0.4158	6.85
18.197	0.3933	0.4009	1.94
18.621	0.3974	0.4244	6.77
19.055	0.4026	0.4188	4.03
19.499	0.4091	0.4296	5.02
19.953	0.4157	0.4329	4.12
20.418	0.4225	0.4460	5.56
20.893	0.4293	0.4520	5.28
21.380	0.4363	0.4552	4.33
21.878	0.4434	0.4682	5.60
22.387	0.4506	0.4690	4.09
22.909	0.4579	0.4812	5.10
23.442	0.4653	0.4890	5.09
23.989	0.4729	0.4963	4.95
24.547	0.4805	0.5064	5.38
25.119	0.4865	0.5099	4.80
25.704	0.4857	0.5031	3.60
26.303	0.4848	0.5249	8.27
26.916	0.4839	0.5084	5.06
27.542	0.4831	0.4976	3.01
28.184	0.4822	0.5097	5.70
28.841	0.4814	0.5086	5.66
29.512	0.4805	0.5052	5.15
30.200	0.4796	0.4999	4.22
30.903	0.4810	0.5027	4.50
31.623	0.4833	0.4897	1.32
32.360	0.4856	0.5170	6.45
33.113	0.4879	0.5138	5.30
33.885	0.4902	0.5144	4.93
34.674	0.4925	0.5074	3.02
35.482	0.4949	0.5159	4.25
36.308	0.4972	0.5223	5.04
37.154	0.4996	0.5193	3.94

Frequency (Hz)	Vertical FIRS Acceleration (g)	Vertical Response Spectra Acceleration (g)	Difference (%)
38.019	0.5019	0.5228	4.15
38.905	0.5020	0.5234	4.26
39.811	0.4983	0.5214	4.63
40.738	0.4947	0.5185	4.81
41.687	0.4911	0.5129	4.43
42.658	0.4875	0.5103	4.67
43.652	0.4840	0.5069	4.74
44.669	0.4804	0.5022	4.53
45.709	0.4769	0.4975	4.32
46.774	0.4735	0.4942	4.38
47.863	0.4700	0.4900	4.26
48.978	0.4664	0.4863	4.27
50.119	0.4565	0.4769	4.46
51.287	0.4469	0.4653	4.10
52.481	0.4375	0.4583	4.74
53.704	0.4283	0.4483	4.66
54.954	0.4193	0.4341	3.54
56.235	0.4105	0.4297	4.68
57.544	0.4018	0.4211	4.79
58.885	0.3934	0.4110	4.48
60.256	0.3851	0.4028	4.60
61.660	0.3770	0.3924	4.10
63.096	0.3648	0.3825	4.86
64.566	0.3511	0.3648	3.90
66.070	0.3379	0.3525	4.32
67.609	0.3252	0.3401	4.55
69.184	0.3130	0.3253	3.91
70.795	0.3013	0.3167	5.11
72.444	0.2900	0.3098	6.84
74.132	0.2791	0.2959	6.02
75.858	0.2687	0.2762	2.78
77.625	0.2586	0.2648	2.38
79.433	0.2498	0.2603	4.21
81.284	0.2431	0.2485	2.25
83.177	0.2365	0.2460	4.01
85.114	0.2301	0.2420	5.19
87.097	0.2238	0.2392	6.85
89.126	0.2178	0.2313	6.22
91.202	0.2119	0.2194	3.58
93.326	0.2061	0.2140	3.83
95.500	0.2005	0.2103	4.90
97.724	0.1951	0.2057	5.45
100.000	0.1898	0.1994	5.05

TABLE 1-10

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE HORIZONTAL DIRECTION FOR 3UBP & 4UBP

FREQUENCY (HZ)	HORIZONTAL FIRS ACCELERATION (G)	FIRST HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)	SECOND HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0058	0.0061	4.83	0.0061	5.69
0.102	0.0060	0.0062	2.65	0.0064	6.30
0.105	0.0063	0.0063	0.32	0.0068	7.81
0.107	0.0065	0.0065	-0.15	0.0071	9.04
0.110	0.0068	0.0069	1.47	0.0075	10.03
0.112	0.0071	0.0073	3.55	0.0078	10.78
0.115	0.0073	0.0078	5.73	0.0081	10.50
0.118	0.0076	0.0082	8.01	0.0084	10.63
0.120	0.0079	0.0087	9.85	0.0087	10.23
0.123	0.0082	0.0091	10.80	0.0090	9.22
0.126	0.0086	0.0095	10.62	0.0093	7.93
0.129	0.0089	0.0098	10.56	0.0095	6.74
0.132	0.0092	0.0100	8.23	0.0098	6.61
0.135	0.0096	0.0100	4.07	0.0102	6.37
0.138	0.0099	0.0103	3.22	0.0106	6.24
0.141	0.0103	0.0107	3.98	0.0109	6.01
0.145	0.0107	0.0114	6.64	0.0113	5.71
0.148	0.0111	0.0122	10.28	0.0117	5.14
0.151	0.0115	0.0130	12.86	0.0122	6.34
0.155	0.0119	0.0138	15.33	0.0130	9.21
0.159	0.0124	0.0145	17.03	0.0139	12.19
0.162	0.0129	0.0151	17.57	0.0149	15.94
0.166	0.0134	0.0156	16.85	0.0160	20.07
0.170	0.0139	0.0159	14.80	0.0170	23.03
0.174	0.0144	0.0161	11.61	0.0181	25.43
0.178	0.0149	0.0163	9.10	0.0188	25.77
0.182	0.0155	0.0164	5.67	0.0190	22.23
0.186	0.0161	0.0173	7.20	0.0189	17.38
0.191	0.0167	0.0181	7.95	0.0198	18.54
0.195	0.0174	0.0186	7.14	0.0198	14.16
0.200	0.0180	0.0189	4.83	0.0197	9.10
0.204	0.0187	0.0193	2.78	0.0202	7.69
0.209	0.0193	0.0219	13.24	0.0210	8.43
0.214	0.0200	0.0239	19.52	0.0214	7.26
0.219	0.0206	0.0253	22.67	0.0219	6.10

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.224	0.0213	0.0262	23.02	0.0228	6.66
0.229	0.0220	0.0266	20.88	0.0235	6.76
0.234	0.0228	0.0265	16.66	0.0242	6.15
0.240	0.0235	0.0260	10.68	0.0248	5.32
0.246	0.0243	0.0250	2.76	0.0255	4.90
0.251	0.0251	0.0247	-1.67	0.0264	5.22
0.257	0.0259	0.0263	1.66	0.0275	6.06
0.263	0.0267	0.0282	5.50	0.0285	6.70
0.269	0.0275	0.0300	8.90	0.0294	6.72
0.275	0.0283	0.0314	10.87	0.0299	5.54
0.282	0.0292	0.0324	11.07	0.0300	2.64
0.288	0.0301	0.0340	12.97	0.0294	-2.33
0.295	0.0310	0.0368	18.79	0.0309	-0.10
0.302	0.0319	0.0387	21.19	0.0336	5.33
0.309	0.0329	0.0397	20.82	0.0365	11.05
0.316	0.0338	0.0404	19.42	0.0399	18.00
0.324	0.0349	0.0404	15.87	0.0420	20.60
0.331	0.0359	0.0394	9.89	0.0413	15.19
0.339	0.0370	0.0388	4.81	0.0388	4.92
0.347	0.0381	0.0399	4.70	0.0416	9.16
0.355	0.0392	0.0408	3.93	0.0433	10.38
0.363	0.0404	0.0429	6.29	0.0435	7.62
0.372	0.0416	0.0444	6.66	0.0420	1.06
0.380	0.0429	0.0453	5.74	0.0432	0.86
0.389	0.0441	0.0462	4.67	0.0466	5.64
0.398	0.0455	0.0475	4.53	0.0463	1.91
0.407	0.0468	0.0496	5.81	0.0496	5.96
0.417	0.0482	0.0522	8.29	0.0518	7.32
0.427	0.0496	0.0552	11.30	0.0551	11.12
0.437	0.0509	0.0576	13.18	0.0563	10.61
0.447	0.0523	0.0590	12.93	0.0571	9.12
0.457	0.0537	0.0594	10.69	0.0576	7.34
0.468	0.0552	0.0593	7.58	0.0578	4.84
0.479	0.0567	0.0594	4.91	0.0589	4.01
0.490	0.0582	0.0603	3.68	0.0620	6.48
0.501	0.0597	0.0619	3.67	0.0633	6.03
0.513	0.0605	0.0629	4.04	0.0639	5.59
0.525	0.0613	0.0643	5.00	0.0646	5.52
0.537	0.0621	0.0674	8.52	0.0650	4.70
0.550	0.0629	0.0673	7.03	0.0678	7.81
0.562	0.0637	0.0652	2.26	0.0707	10.92

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.575	0.0646	0.0666	3.18	0.0761	17.85
0.589	0.0654	0.0664	1.45	0.0781	19.43
0.603	0.0663	0.0653	-1.40	0.0782	17.96
0.617	0.0671	0.0685	2.01	0.0785	16.95
0.631	0.0680	0.0706	3.78	0.0800	17.60
0.646	0.0689	0.0719	4.31	0.0813	18.01
0.661	0.0698	0.0735	5.31	0.0814	16.64
0.676	0.0707	0.0759	7.28	0.0793	12.17
0.692	0.0715	0.0780	8.96	0.0752	5.14
0.708	0.0724	0.0788	8.88	0.0715	-1.15
0.724	0.0732	0.0773	5.61	0.0753	2.79
0.741	0.0741	0.0760	2.63	0.0780	5.33
0.759	0.0749	0.0826	10.21	0.0785	4.79
0.776	0.0758	0.0818	7.86	0.0794	4.67
0.794	0.0767	0.0814	6.09	0.0808	5.31
0.813	0.0776	0.0828	6.66	0.0819	5.53
0.832	0.0785	0.0822	4.66	0.0836	6.52
0.851	0.0794	0.0832	4.72	0.0844	6.33
0.871	0.0802	0.0857	6.78	0.0852	6.21
0.891	0.0810	0.0887	9.46	0.0851	4.99
0.912	0.0818	0.0926	13.21	0.0888	8.58
0.933	0.0826	0.0942	13.96	0.0941	13.92
0.955	0.0834	0.0906	8.55	0.0953	14.23
0.977	0.0843	0.0866	2.78	0.0969	14.98
1.000	0.0851	0.0891	4.71	0.0955	12.22
1.023	0.0882	0.0968	9.72	0.0915	3.76
1.047	0.0914	0.1037	13.47	0.0934	2.16
1.072	0.0947	0.1073	13.32	0.0993	4.88
1.097	0.0982	0.1067	8.67	0.1027	4.57
1.122	0.1017	0.1066	4.82	0.1056	3.80
1.148	0.1054	0.1123	6.48	0.1142	8.26
1.175	0.1093	0.1214	11.06	0.1165	6.57
1.202	0.1133	0.1275	12.57	0.1219	7.66
1.230	0.1174	0.1287	9.61	0.1246	6.17
1.259	0.1216	0.1276	4.93	0.1242	2.10
1.288	0.1261	0.1299	3.03	0.1284	1.85
1.318	0.1306	0.1357	3.87	0.1364	4.42
1.349	0.1354	0.1414	4.45	0.1450	7.08
1.380	0.1408	0.1476	4.81	0.1508	7.06
1.413	0.1487	0.1595	7.21	0.1562	4.99
1.445	0.1571	0.1698	8.12	0.1654	5.28

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
1.479	0.1659	0.1742	4.96	0.1780	7.27
1.514	0.1753	0.1783	1.76	0.1906	8.77
1.549	0.1851	0.2108	13.87	0.1944	5.05
1.585	0.1955	0.2256	15.41	0.2026	3.62
1.622	0.2065	0.2398	16.13	0.2224	7.75
1.660	0.2181	0.2563	17.55	0.2335	7.06
1.698	0.2303	0.2754	19.59	0.2407	4.54
1.738	0.2432	0.2841	16.79	0.2502	2.85
1.778	0.2551	0.2831	10.99	0.2705	6.05
1.820	0.2667	0.2850	6.89	0.2733	2.49
1.862	0.2788	0.2926	4.96	0.2705	-2.98
1.906	0.2914	0.3132	7.47	0.3057	4.91
1.950	0.3047	0.3403	11.70	0.3436	12.77
1.995	0.3185	0.3553	11.54	0.3641	14.33
2.042	0.3330	0.3482	4.57	0.3596	8.01
2.089	0.3481	0.3431	-1.44	0.4039	16.04
2.138	0.3639	0.3786	4.03	0.4353	19.63
2.188	0.3804	0.4084	7.35	0.4463	17.30
2.239	0.3923	0.4345	10.75	0.4482	14.24
2.291	0.3996	0.4471	11.91	0.4188	4.82
2.344	0.4069	0.4404	8.24	0.4509	10.81
2.399	0.4144	0.4349	4.94	0.4661	12.48
2.455	0.4220	0.4326	2.50	0.4434	5.06
2.512	0.4268	0.4385	2.75	0.4352	1.98
2.570	0.4198	0.4497	7.11	0.4455	6.12
2.630	0.4130	0.4515	9.32	0.4584	10.98
2.692	0.4063	0.4316	6.22	0.4583	12.79
2.754	0.3997	0.4194	4.92	0.4403	10.16
2.818	0.3932	0.4058	3.20	0.4142	5.35
2.884	0.3868	0.3728	-3.63	0.4062	4.99
2.951	0.3806	0.3744	-1.61	0.4209	10.60
3.020	0.3744	0.4029	7.62	0.4395	17.39
3.090	0.3683	0.4149	12.65	0.4206	14.21
3.162	0.3623	0.4016	10.85	0.3802	4.93
3.236	0.3564	0.3905	9.57	0.3799	6.58
3.311	0.3506	0.3820	8.93	0.3680	4.94
3.389	0.3449	0.3623	5.03	0.3544	2.76
3.467	0.3393	0.3572	5.26	0.3553	4.70
3.548	0.3338	0.3456	3.53	0.3464	3.75
3.631	0.3307	0.3311	0.12	0.3404	2.93
3.715	0.3281	0.3368	2.64	0.3327	1.39

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
3.802	0.3255	0.3497	7.42	0.3648	12.06
3.891	0.3230	0.3398	5.20	0.3691	14.29
3.981	0.3205	0.3285	2.51	0.3453	7.74
4.074	0.3179	0.3554	11.80	0.3339	5.03
4.169	0.3154	0.3513	11.36	0.3285	4.13
4.266	0.3130	0.3244	3.64	0.3285	4.96
4.365	0.3105	0.3153	1.56	0.3096	-0.29
4.467	0.3081	0.3250	5.51	0.3119	1.24
4.571	0.3122	0.3388	8.54	0.3354	7.43
4.677	0.3236	0.3489	7.82	0.3455	6.79
4.786	0.3354	0.3477	3.69	0.3445	2.72
4.898	0.3476	0.3598	3.52	0.3635	4.59
5.012	0.3599	0.3787	5.22	0.3602	0.08
5.129	0.3697	0.3921	6.07	0.3810	3.06
5.248	0.3797	0.3999	5.31	0.3959	4.25
5.370	0.3900	0.4123	5.70	0.4115	5.49
5.495	0.4006	0.4261	6.36	0.4189	4.55
5.623	0.4115	0.4298	4.44	0.4337	5.40
5.754	0.4227	0.4266	0.92	0.4508	6.65
5.889	0.4342	0.4553	4.87	0.4567	5.18
6.026	0.4460	0.4751	6.53	0.4661	4.51
6.166	0.4581	0.4830	5.44	0.4799	4.76
6.310	0.4705	0.4917	4.50	0.4939	4.96
6.457	0.4833	0.5069	4.87	0.5071	4.92
6.607	0.4965	0.5073	2.18	0.5136	3.46
6.761	0.5099	0.5286	3.66	0.5197	1.91
6.918	0.5238	0.5645	7.76	0.5547	5.91
7.080	0.5380	0.5699	5.92	0.5594	3.98
7.244	0.5526	0.5473	-0.98	0.5720	3.49
7.413	0.5677	0.5947	4.77	0.5873	3.45
7.586	0.5760	0.6070	5.37	0.5740	-0.35
7.763	0.5773	0.5987	3.71	0.6174	6.94
7.943	0.5786	0.6039	4.38	0.6160	6.46
8.128	0.5798	0.6152	6.10	0.5882	1.45
8.318	0.5811	0.6123	5.37	0.6073	4.51
8.511	0.5824	0.6224	6.86	0.6210	6.63
8.710	0.5837	0.6119	4.84	0.6203	6.28
8.913	0.5849	0.6170	5.48	0.6019	2.90
9.120	0.5862	0.6149	4.89	0.6182	5.46
9.333	0.5875	0.6003	2.17	0.6211	5.71
9.550	0.5888	0.6113	3.82	0.6209	5.45

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
9.772	0.5901	0.6453	9.35	0.6123	3.75
10.000	0.5914	0.6209	4.98	0.6206	4.94
10.233	0.5968	0.5823	-2.42	0.6245	4.65
10.471	0.6022	0.6313	4.83	0.6222	3.32
10.715	0.6077	0.6509	7.11	0.6335	4.25
10.965	0.6132	0.6443	5.07	0.6390	4.21
11.220	0.6188	0.6336	2.40	0.6416	3.68
11.482	0.6244	0.6565	5.14	0.6504	4.17
11.749	0.6294	0.6699	6.45	0.6479	2.95
12.023	0.6280	0.6594	5.01	0.6534	4.05
12.303	0.6266	0.6730	7.41	0.6492	3.61
12.589	0.6252	0.6469	3.47	0.6524	4.35
12.883	0.6238	0.6300	1.01	0.6520	4.53
13.183	0.6224	0.6619	6.35	0.6477	4.07
13.490	0.6210	0.6516	4.94	0.6473	4.24
13.804	0.6196	0.6282	1.40	0.6357	2.59
14.125	0.6182	0.6454	4.40	0.6475	4.74
14.455	0.6168	0.6472	4.92	0.6436	4.34
14.791	0.6154	0.6457	4.93	0.6349	3.16
15.136	0.6143	0.6438	4.80	0.6500	5.81
15.488	0.6133	0.6437	4.95	0.6455	5.24
15.849	0.6123	0.6466	5.60	0.6202	1.28
16.218	0.6113	0.6399	4.68	0.6555	7.23
16.596	0.6103	0.6430	5.37	0.6343	3.94
16.983	0.6093	0.6389	4.86	0.6394	4.95
17.378	0.6083	0.6403	5.26	0.6399	5.19
17.783	0.6073	0.6340	4.40	0.6250	2.92
18.197	0.6063	0.6402	5.59	0.6407	5.68
18.621	0.6053	0.6368	5.21	0.6387	5.51
19.055	0.6021	0.6304	4.71	0.6315	4.88
19.499	0.5958	0.6249	4.88	0.6260	5.07
19.953	0.5896	0.6200	5.15	0.6220	5.48
20.418	0.5835	0.6150	5.39	0.6103	4.59
20.893	0.5775	0.6036	4.53	0.6055	4.86
21.380	0.5715	0.5990	4.82	0.5985	4.74
21.878	0.5655	0.5971	5.59	0.5956	5.33
22.387	0.5596	0.5866	4.82	0.5853	4.59
22.909	0.5538	0.5818	5.06	0.5783	4.42
23.442	0.5481	0.5726	4.48	0.5740	4.74
23.989	0.5424	0.5692	4.95	0.5698	5.06
24.547	0.5367	0.5669	5.61	0.5639	5.06

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
25.119	0.5303	0.5526	4.20	0.5614	5.86
25.704	0.5208	0.5461	4.86	0.5518	5.96
26.303	0.5115	0.5366	4.91	0.5448	6.51
26.916	0.5023	0.5246	4.45	0.5296	5.44
27.542	0.4933	0.5205	5.52	0.4954	0.43
28.184	0.4844	0.5115	5.59	0.5080	4.87
28.841	0.4757	0.5019	5.51	0.4980	4.69
29.512	0.4672	0.4877	4.40	0.4944	5.82
30.200	0.4588	0.4852	5.76	0.4792	4.45
30.903	0.4524	0.4792	5.94	0.4694	3.76
31.623	0.4467	0.4735	5.99	0.4757	6.48
32.360	0.4412	0.4617	4.67	0.4523	2.53
33.113	0.4357	0.4578	5.09	0.4577	5.05
33.885	0.4302	0.4513	4.91	0.4494	4.45
34.674	0.4248	0.4440	4.50	0.4348	2.34
35.482	0.4195	0.4406	5.02	0.4328	3.17
36.308	0.4143	0.4355	5.10	0.4315	4.15
37.154	0.4091	0.4294	4.95	0.4234	3.49
38.019	0.4040	0.4229	4.67	0.4191	3.72
38.905	0.3981	0.4157	4.43	0.4116	3.38
39.811	0.3908	0.4094	4.76	0.4041	3.40
40.738	0.3836	0.4042	5.38	0.3957	3.16
41.687	0.3766	0.3983	5.76	0.3889	3.26
42.658	0.3697	0.3891	5.26	0.3781	2.28
43.652	0.3629	0.3805	4.85	0.3705	2.10
44.669	0.3562	0.3753	5.37	0.3630	1.90
45.709	0.3497	0.3675	5.08	0.3552	1.56
46.774	0.3433	0.3625	5.61	0.3482	1.44
47.863	0.3370	0.3501	3.89	0.3437	2.00
48.978	0.3308	0.3472	4.95	0.3367	1.78
50.119	0.3247	0.3419	5.30	0.3296	1.52
51.287	0.3186	0.3415	7.19	0.3260	2.31
52.481	0.3127	0.3215	2.81	0.3203	2.43
53.704	0.3069	0.3225	5.09	0.3186	3.79
54.954	0.3012	0.3160	4.90	0.3167	5.13
56.235	0.2956	0.3182	7.62	0.3075	4.03
57.544	0.2901	0.3072	5.89	0.3021	4.12
58.885	0.2848	0.3031	6.42	0.2995	5.18
60.256	0.2795	0.2975	6.44	0.3006	7.56
61.660	0.2743	0.2887	5.26	0.2887	5.27
63.096	0.2701	0.2830	4.81	0.2827	4.68

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
64.566	0.2663	0.2856	7.24	0.2799	5.13
66.070	0.2625	0.2808	6.97	0.2760	5.12
67.609	0.2588	0.2768	6.95	0.2727	5.34
69.184	0.2552	0.2741	7.39	0.2694	5.56
70.795	0.2516	0.2726	8.31	0.2668	6.04
72.444	0.2481	0.2670	7.63	0.2641	6.45
74.132	0.2446	0.2578	5.37	0.2598	6.20
75.858	0.2412	0.2537	5.20	0.2482	2.92
77.625	0.2378	0.2536	6.64	0.2374	-0.16
79.433	0.2348	0.2589	10.29	0.2375	1.17
81.284	0.2323	0.2627	13.07	0.2376	2.28
83.177	0.2299	0.2578	12.15	0.2328	1.27
85.114	0.2275	0.2524	10.94	0.2326	2.23
87.097	0.2251	0.2479	10.12	0.2354	4.56
89.126	0.2228	0.2515	12.90	0.2384	7.00
91.202	0.2205	0.2514	14.02	0.2487	12.83
93.326	0.2182	0.2492	14.21	0.2665	22.16
95.500	0.2159	0.2424	12.27	0.2641	22.35
97.724	0.2136	0.2331	9.13	0.2471	15.69
100.000	0.2114	0.2266	7.20	0.2380	12.56

TABLE 1-11

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE VERTICAL DIRECTION FOR 3UBP & 4UBP

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0037	0.0039	4.32
0.102	0.0038	0.0040	4.69
0.105	0.0040	0.0042	4.76
0.107	0.0042	0.0043	4.58
0.110	0.0043	0.0045	4.18
0.112	0.0045	0.0046	3.57
0.115	0.0047	0.0048	3.23
0.118	0.0048	0.0050	2.90
0.120	0.0050	0.0051	2.39
0.123	0.0052	0.0053	1.92
0.126	0.0054	0.0055	2.03
0.129	0.0056	0.0058	2.85
0.132	0.0058	0.0061	3.77
0.135	0.0061	0.0064	4.96
0.138	0.0063	0.0067	6.22
0.141	0.0065	0.0070	7.68
0.145	0.0067	0.0074	9.05
0.148	0.0070	0.0077	10.29
0.151	0.0073	0.0081	11.57
0.155	0.0075	0.0085	12.22
0.159	0.0078	0.0088	12.69
0.162	0.0081	0.0091	12.22
0.166	0.0084	0.0093	11.06
0.170	0.0087	0.0095	9.16
0.174	0.0091	0.0097	6.50
0.178	0.0094	0.0097	3.18
0.182	0.0098	0.0098	0.00
0.186	0.0102	0.0104	2.26
0.191	0.0106	0.0109	3.22
0.195	0.0110	0.0113	3.01
0.200	0.0114	0.0116	1.67
0.204	0.0118	0.0118	-0.51
0.209	0.0122	0.0119	-2.21
0.214	0.0126	0.0125	-0.71
0.219	0.0130	0.0131	0.77
0.224	0.0135	0.0137	2.08
0.229	0.0139	0.0144	3.31

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.234	0.0143	0.0150	4.25
0.240	0.0148	0.0155	4.45
0.246	0.0153	0.0163	6.47
0.251	0.0158	0.0172	8.48
0.257	0.0163	0.0179	9.50
0.263	0.0168	0.0185	9.69
0.269	0.0173	0.0189	8.94
0.275	0.0179	0.0191	7.23
0.282	0.0184	0.0194	5.33
0.288	0.0189	0.0196	3.70
0.295	0.0195	0.0201	2.92
0.302	0.0201	0.0207	2.99
0.309	0.0207	0.0215	3.92
0.316	0.0213	0.0223	4.65
0.324	0.0219	0.0229	4.33
0.331	0.0226	0.0234	3.68
0.339	0.0233	0.0249	7.05
0.347	0.0240	0.0258	7.80
0.355	0.0247	0.0272	10.25
0.363	0.0254	0.0277	9.04
0.372	0.0262	0.0279	6.45
0.380	0.0270	0.0282	4.63
0.389	0.0278	0.0290	4.46
0.398	0.0286	0.0300	4.89
0.407	0.0295	0.0304	2.85
0.417	0.0304	0.0312	2.60
0.427	0.0312	0.0323	3.56
0.437	0.0321	0.0339	5.71
0.447	0.0329	0.0346	5.04
0.457	0.0338	0.0350	3.40
0.468	0.0347	0.0366	5.47
0.479	0.0357	0.0395	10.88
0.490	0.0366	0.0434	18.57
0.501	0.0376	0.0453	20.72
0.513	0.0381	0.0436	14.53
0.525	0.0386	0.0405	5.16
0.537	0.0391	0.0394	0.82
0.550	0.0396	0.0407	2.83
0.562	0.0401	0.0419	4.49
0.575	0.0406	0.0401	-1.33
0.589	0.0412	0.0430	4.37
0.603	0.0417	0.0460	10.26
0.617	0.0423	0.0489	15.68

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.631	0.0428	0.0508	18.56
0.646	0.0434	0.0516	18.99
0.661	0.0440	0.0522	18.74
0.676	0.0445	0.0526	18.07
0.692	0.0451	0.0522	15.76
0.708	0.0456	0.0507	11.30
0.724	0.0461	0.0497	7.70
0.741	0.0467	0.0496	6.30
0.759	0.0472	0.0491	3.92
0.776	0.0478	0.0519	8.75
0.794	0.0483	0.0574	18.85
0.813	0.0489	0.0604	23.50
0.832	0.0495	0.0607	22.70
0.851	0.0500	0.0596	19.08
0.871	0.0506	0.0580	14.82
0.891	0.0510	0.0537	5.11
0.912	0.0515	0.0525	1.84
0.933	0.0521	0.0546	4.96
0.955	0.0526	0.0545	3.60
0.977	0.0531	0.0558	5.09
1.000	0.0536	0.0581	8.38
1.023	0.0556	0.0632	13.68
1.047	0.0577	0.0664	15.09
1.072	0.0599	0.0660	10.17
1.097	0.0622	0.0623	0.27
1.122	0.0645	0.0677	4.96
1.148	0.0670	0.0784	17.03
1.175	0.0695	0.0855	23.07
1.202	0.0721	0.0884	22.63
1.230	0.0748	0.0891	19.00
1.259	0.0777	0.0871	12.18
1.288	0.0806	0.0848	5.20
1.318	0.0836	0.0879	5.06
1.349	0.0868	0.0946	9.00
1.380	0.0904	0.0969	7.19
1.413	0.0956	0.1003	4.94
1.445	0.1011	0.1100	8.71
1.479	0.1070	0.1135	6.07
1.514	0.1132	0.1177	4.05
1.549	0.1197	0.1223	2.18
1.585	0.1266	0.1235	-2.44
1.622	0.1339	0.1324	-1.11
1.660	0.1416	0.1486	4.99

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
1.698	0.1497	0.1630	8.86
1.738	0.1584	0.1704	7.56
1.778	0.1663	0.1765	6.11
1.820	0.1742	0.1762	1.14
1.862	0.1824	0.1756	-3.70
1.906	0.1909	0.2007	5.14
1.950	0.1999	0.2320	16.08
1.995	0.2093	0.2451	17.08
2.042	0.2191	0.2342	6.86
2.089	0.2294	0.2410	5.02
2.138	0.2402	0.2544	5.92
2.188	0.2515	0.2562	1.84
2.239	0.2598	0.2727	4.96
2.291	0.2650	0.3069	15.79
2.344	0.2704	0.3196	18.20
2.399	0.2758	0.3257	18.07
2.455	0.2814	0.3293	17.03
2.512	0.2850	0.3182	11.63
2.570	0.2809	0.2947	4.92
2.630	0.2768	0.2642	-4.53
2.692	0.2728	0.2863	4.97
2.754	0.2688	0.2885	7.33
2.818	0.2649	0.2961	11.80
2.884	0.2610	0.3020	15.73
2.951	0.2572	0.2836	10.25
3.020	0.2534	0.2627	3.67
3.090	0.2497	0.2777	11.20
3.162	0.2461	0.2820	14.57
3.236	0.2425	0.2686	10.74
3.311	0.2390	0.2554	6.88
3.389	0.2355	0.2472	4.99
3.467	0.2321	0.2406	3.68
3.548	0.2287	0.2516	10.05
3.631	0.2273	0.2508	10.38
3.715	0.2262	0.2422	7.05
3.802	0.2252	0.2414	7.17
3.891	0.2242	0.2501	11.54
3.981	0.2232	0.2384	6.81
4.074	0.2222	0.2266	1.99
4.169	0.2212	0.2269	2.58
4.266	0.2202	0.2307	4.76
4.365	0.2192	0.2282	4.09
4.467	0.2182	0.2292	5.02

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
4.571	0.2221	0.2392	7.72
4.677	0.2313	0.2484	7.38
4.786	0.2410	0.2532	5.09
4.898	0.2510	0.2621	4.41
5.012	0.2612	0.2729	4.44
5.129	0.2695	0.2937	8.99
5.248	0.2780	0.2969	6.80
5.370	0.2868	0.3031	5.67
5.495	0.2959	0.3101	4.79
5.623	0.3053	0.3223	5.56
5.754	0.3150	0.3437	9.14
5.889	0.3249	0.3446	6.05
6.026	0.3352	0.3413	1.82
6.166	0.3458	0.3579	3.50
6.310	0.3568	0.3645	2.18
6.457	0.3681	0.3809	3.49
6.607	0.3797	0.4043	6.48
6.761	0.3917	0.4129	5.40
6.918	0.4041	0.4179	3.41
7.080	0.4169	0.4368	4.76
7.244	0.4301	0.4595	6.82
7.413	0.4437	0.4642	4.61
7.586	0.4519	0.4603	1.86
7.763	0.4541	0.4833	6.42
7.943	0.4563	0.4804	5.27
8.128	0.4586	0.4814	4.97
8.318	0.4608	0.4851	5.28
8.511	0.4631	0.4897	5.75
8.710	0.4654	0.4868	4.61
8.913	0.4676	0.4921	5.22
9.120	0.4699	0.4896	4.18
9.333	0.4722	0.5004	5.97
9.550	0.4745	0.4972	4.77
9.772	0.4769	0.4941	3.61
10.000	0.4792	0.5048	5.34
10.233	0.4865	0.5095	4.75
10.471	0.4938	0.5223	5.76
10.715	0.5013	0.5208	3.90
10.965	0.5089	0.5352	5.17
11.220	0.5166	0.5463	5.76
11.482	0.5244	0.5510	5.07
11.749	0.5316	0.5562	4.62
12.023	0.5329	0.5574	4.60

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
12.303	0.5341	0.5569	4.27
12.589	0.5353	0.5552	3.70
12.883	0.5366	0.5384	0.34
13.183	0.5378	0.5803	7.90
13.490	0.5391	0.5680	5.36
13.804	0.5403	0.5529	2.32
14.125	0.5416	0.5763	6.41
14.455	0.5428	0.5730	5.55
14.791	0.5441	0.5425	-0.29
15.136	0.5449	0.5888	8.05
15.488	0.5457	0.5772	5.78
15.849	0.5464	0.5746	5.16
16.218	0.5471	0.5764	5.35
16.596	0.5478	0.5844	6.68
16.983	0.5485	0.5781	5.39
17.378	0.5492	0.5894	7.31
17.783	0.5499	0.5732	4.23
18.197	0.5507	0.5738	4.19
18.621	0.5514	0.5902	7.05
19.055	0.5512	0.5818	5.55
19.499	0.5497	0.5714	3.96
19.953	0.5481	0.5810	5.99
20.418	0.5466	0.5773	5.60
20.893	0.5451	0.5527	1.39
21.380	0.5436	0.5574	2.53
21.878	0.5421	0.5687	4.90
22.387	0.5406	0.5639	4.31
22.909	0.5391	0.5638	4.57
23.442	0.5376	0.5619	4.51
23.989	0.5362	0.5625	4.91
24.547	0.5347	0.5672	6.09
25.119	0.5324	0.5583	4.86
25.704	0.5272	0.5544	5.16
26.303	0.5220	0.5451	4.42
26.916	0.5169	0.5410	4.66
27.542	0.5118	0.5390	5.30
28.184	0.5068	0.5323	5.02
28.841	0.5018	0.5264	4.90
29.512	0.4969	0.5109	2.81
30.200	0.4920	0.5177	5.21
30.903	0.4891	0.5121	4.70
31.623	0.4869	0.5144	5.65
32.360	0.4846	0.5041	4.02

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
33.113	0.4824	0.5012	3.89
33.885	0.4803	0.5012	4.37
34.674	0.4781	0.5044	5.50
35.482	0.4759	0.4871	2.35
36.308	0.4737	0.4731	-0.12
37.154	0.4716	0.4722	0.14
38.019	0.4694	0.4721	0.58
38.905	0.4661	0.4698	0.79
39.811	0.4610	0.4675	1.41
40.738	0.4559	0.4638	1.75
41.687	0.4508	0.4623	2.54
42.658	0.4458	0.4565	2.40
43.652	0.4409	0.4535	2.85
44.669	0.4360	0.4490	2.97
45.709	0.4312	0.4439	2.95
46.774	0.4264	0.4375	2.59
47.863	0.4217	0.4316	2.35
48.978	0.4169	0.4259	2.14
50.119	0.4090	0.4177	2.13
51.287	0.4012	0.4069	1.43
52.481	0.3935	0.4013	1.96
53.704	0.3860	0.3906	1.18
54.954	0.3787	0.3818	0.83
56.235	0.3715	0.3742	0.74
57.544	0.3644	0.3664	0.56
58.885	0.3574	0.3563	-0.32
60.256	0.3506	0.3574	1.93
61.660	0.3440	0.3475	1.03
63.096	0.3372	0.3443	2.10
64.566	0.3306	0.3484	5.38
66.070	0.3241	0.3338	2.98
67.609	0.3177	0.3280	3.25
69.184	0.3114	0.3225	3.56
70.795	0.3053	0.3184	4.27
72.444	0.2993	0.3089	3.22
74.132	0.2934	0.3125	6.50
75.858	0.2876	0.3113	8.25
77.625	0.2820	0.2977	5.60
79.433	0.2762	0.2887	4.52
81.284	0.2703	0.2706	0.11
83.177	0.2645	0.2669	0.89
85.114	0.2589	0.2718	5.00
87.097	0.2533	0.2754	8.72

FREQUENCY (HZ)	VERTICAL FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
89.126	0.2479	0.2703	9.02
91.202	0.2426	0.2726	12.35
93.326	0.2374	0.2747	15.69
95.500	0.2323	0.2700	16.19
97.724	0.2274	0.2568	12.93
100.000	0.2225	0.2553	14.73

TABLE 1-12

CORRELATION COEFFICIENTS AMONG THREE TIME HISTORIES FOR EACH STRUCTURE

STRUCTURE	CORRELATION COEFFICIENT [-]		
	HOR1-HOR2	HOR1-VER	HOR2-VER
3URB	0.052	0.009	0.082
4URB	0.084	-0.007	0.066
12URB	0.002	-0.002	0.116
12UBP	0.012	0.015	0.101
34UBP	0.053	-0.031	0.034

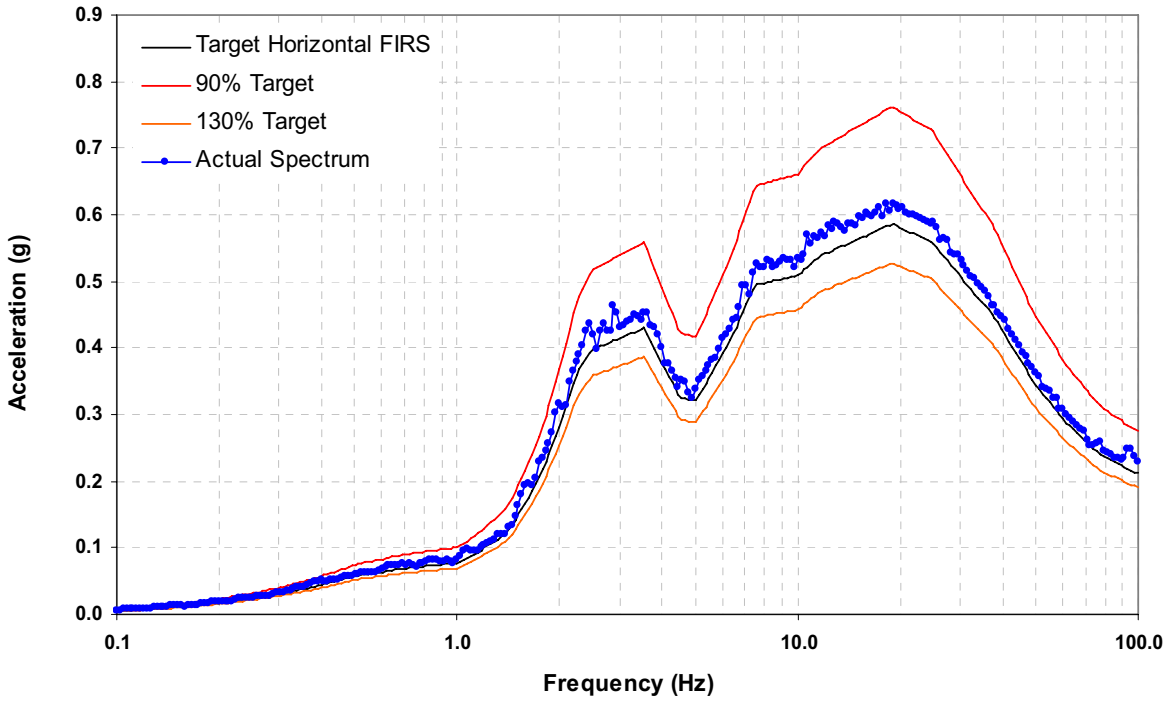


FIGURE 1-8

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(1) T.H. AND FIRS FOR 3URB

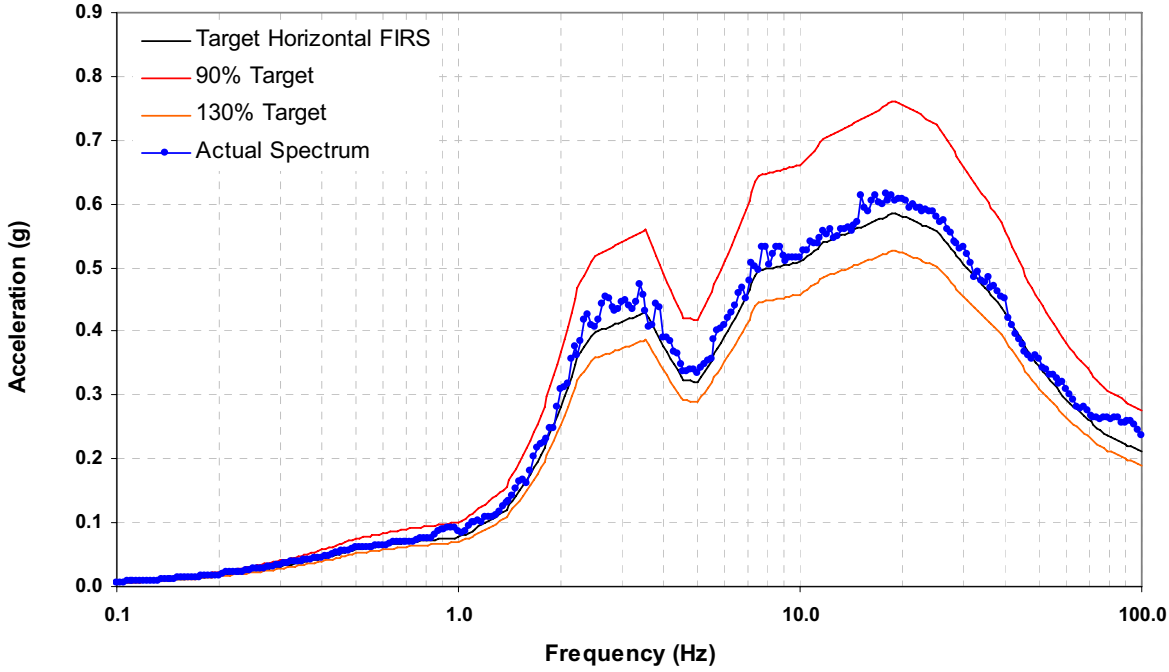


FIGURE 1-9

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(2) T.H. AND FIRS FOR 3URB

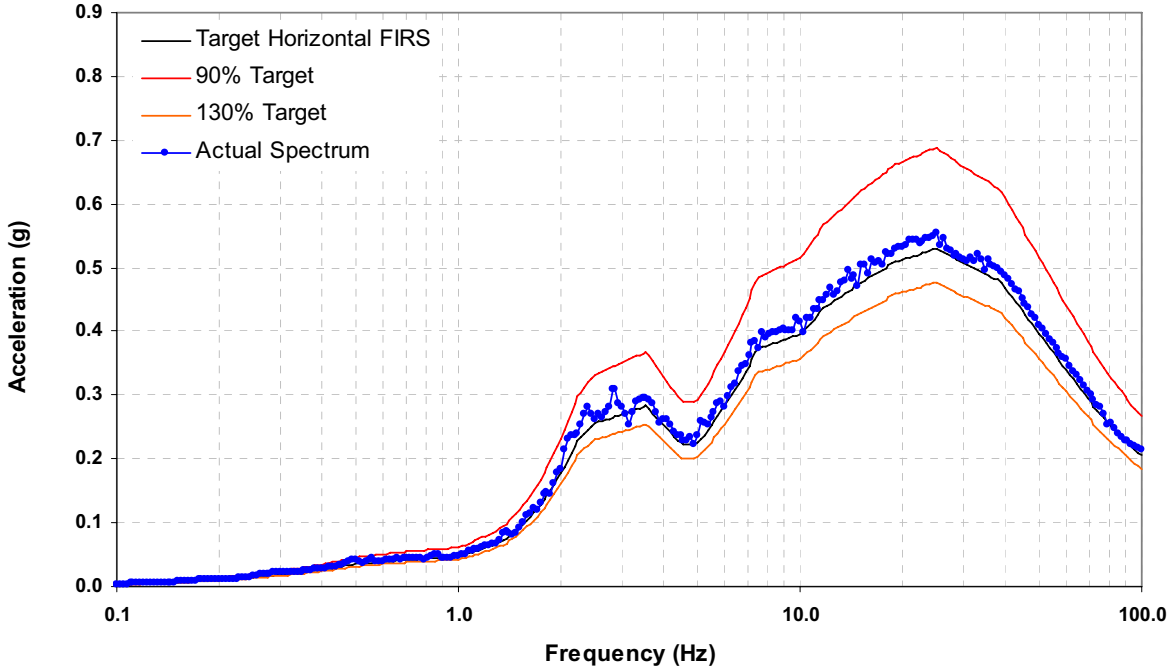


FIGURE 1-10

COMPARISON BETWEEN THE R.S. OF THE INPUT VERTICAL T.H. AND FIRS FOR 3URB

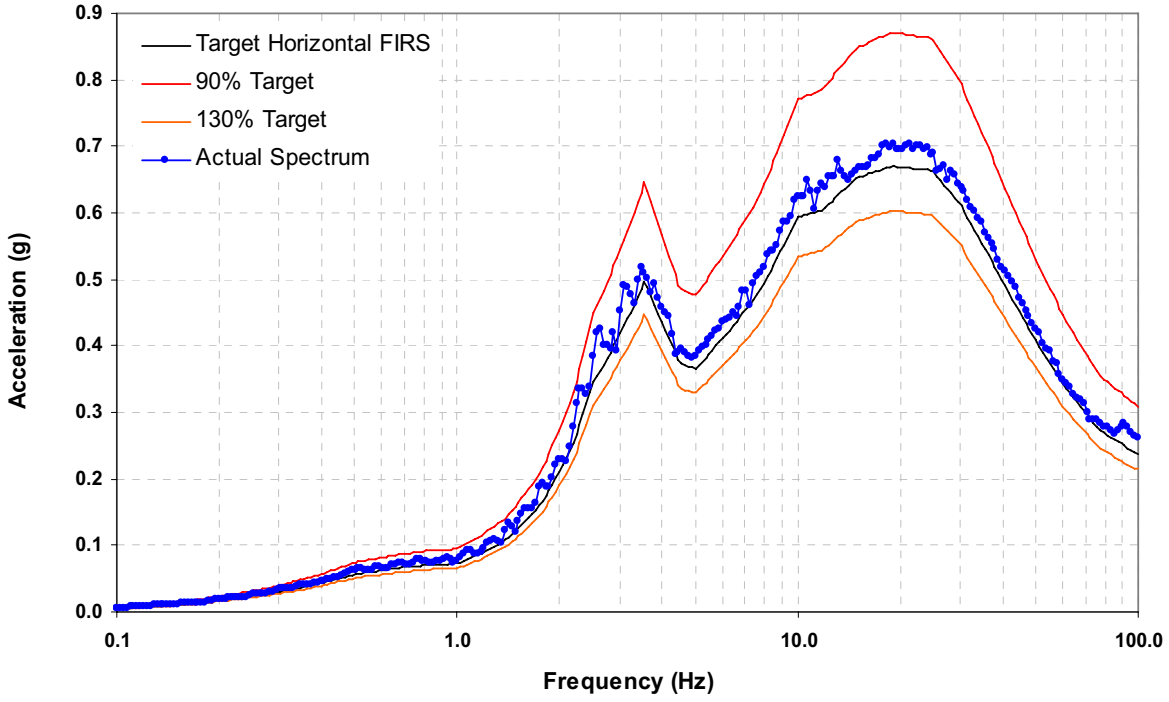


FIGURE 1-11

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(1) T.H. AND FIRS FOR 4URB

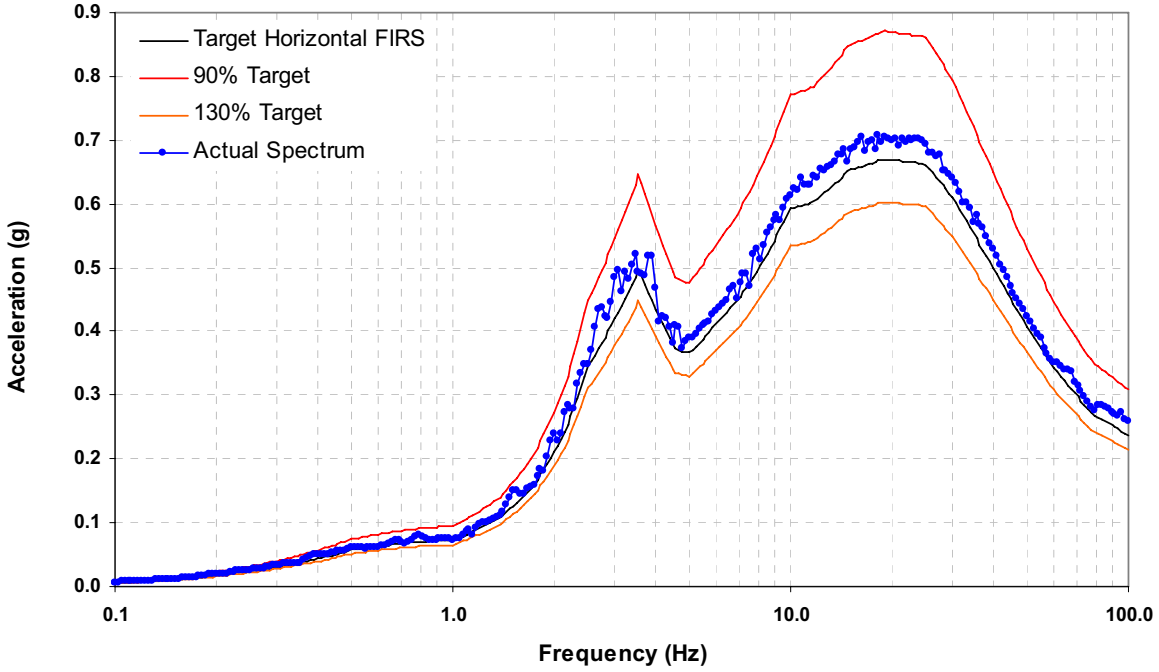


FIGURE 1-12

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(2) T.H. AND FIRS FOR 4URB

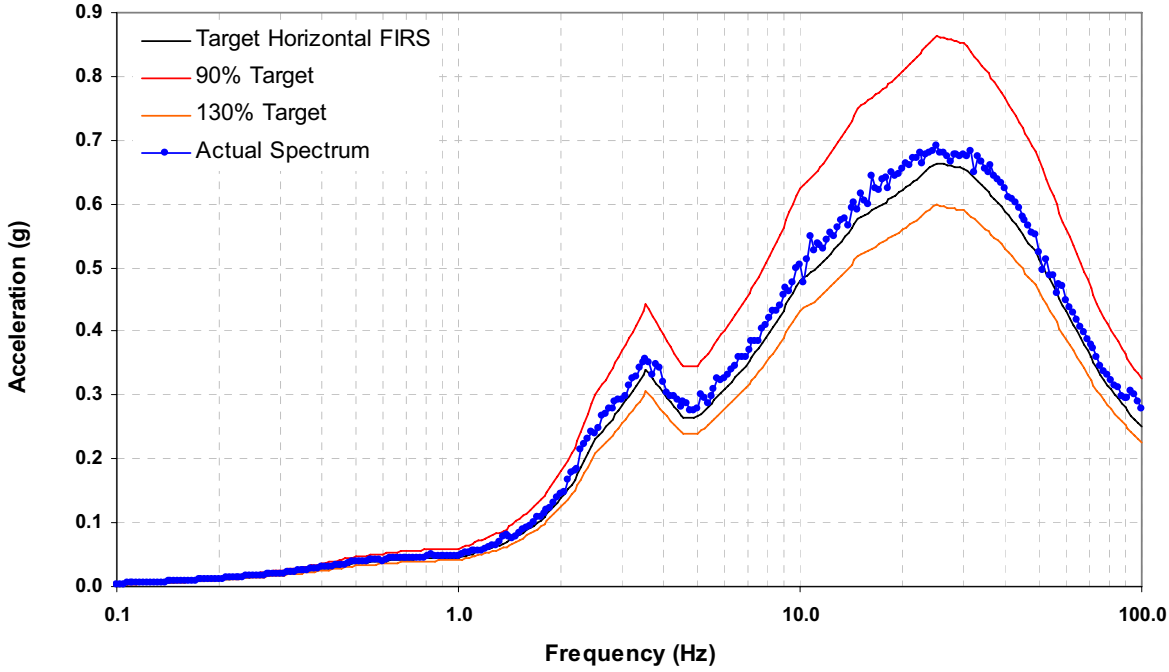


FIGURE 1-13

COMPARISON BETWEEN THE R.S. OF THE INPUT VERTICAL T.H. AND FIRS FOR 4URB

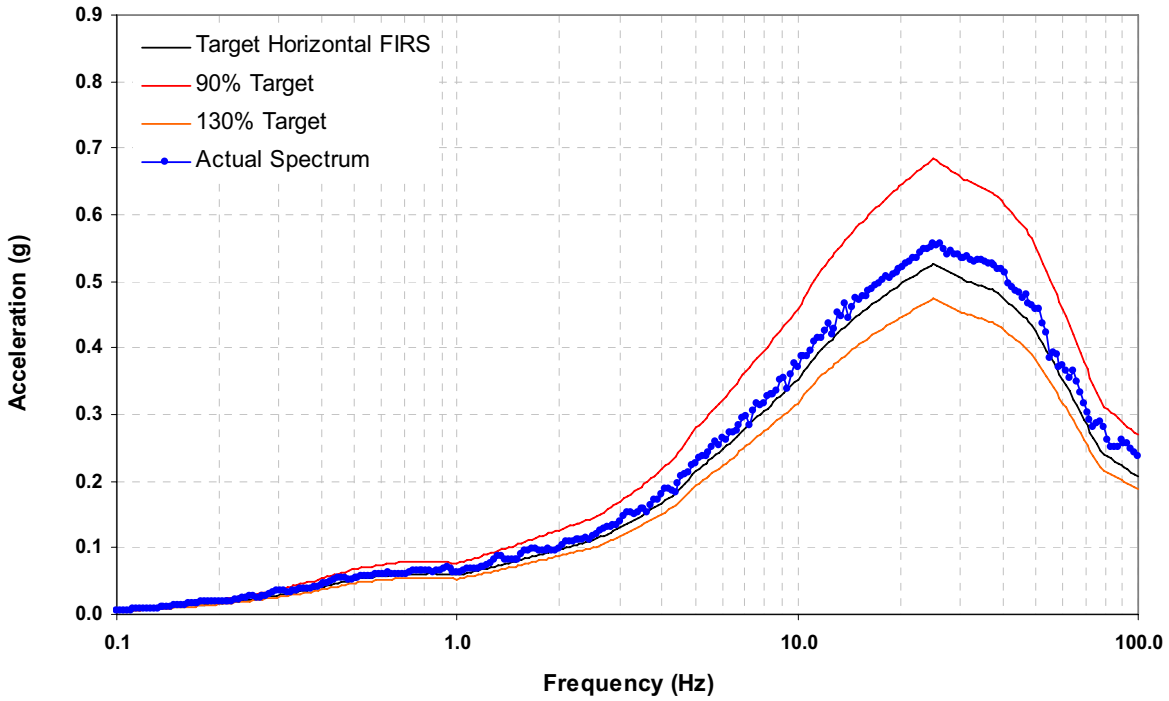


FIGURE 1-14

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(1) T.H. AND FIRS FOR 1URB & 2URB

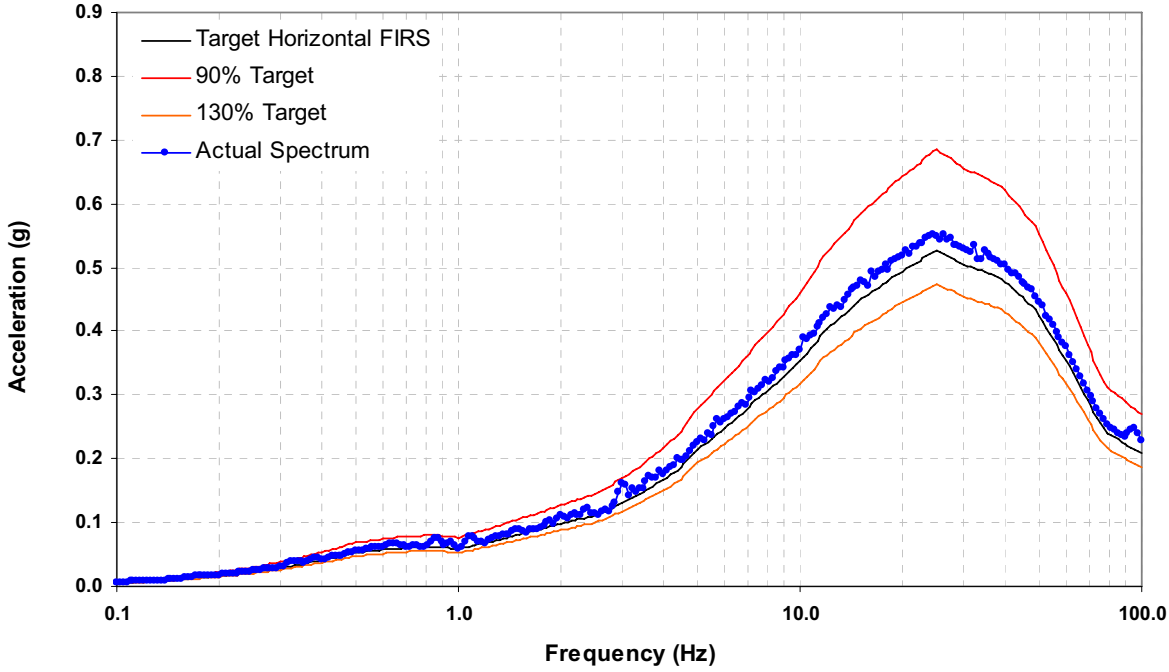


FIGURE 1-15

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(2) T.H. AND FIRS FOR 1URB & 2URB

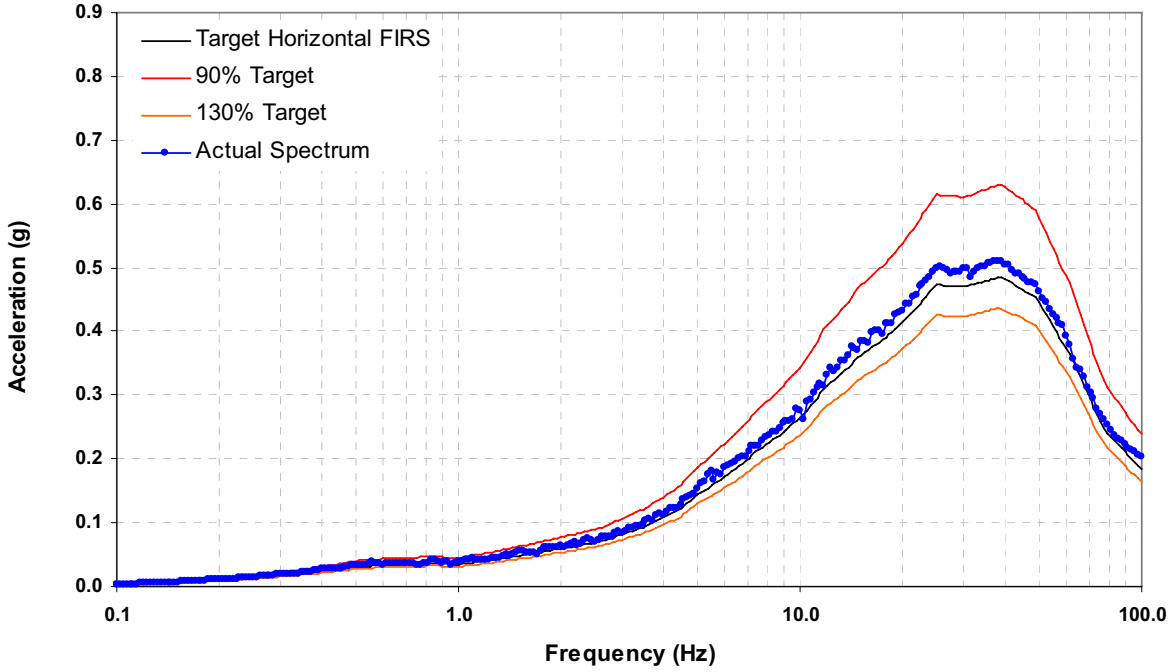


FIGURE 1-16

COMPARISON BETWEEN THE R.S. OF THE INPUT VERTICAL T.H. AND FIRS FOR 1URB & 2URB

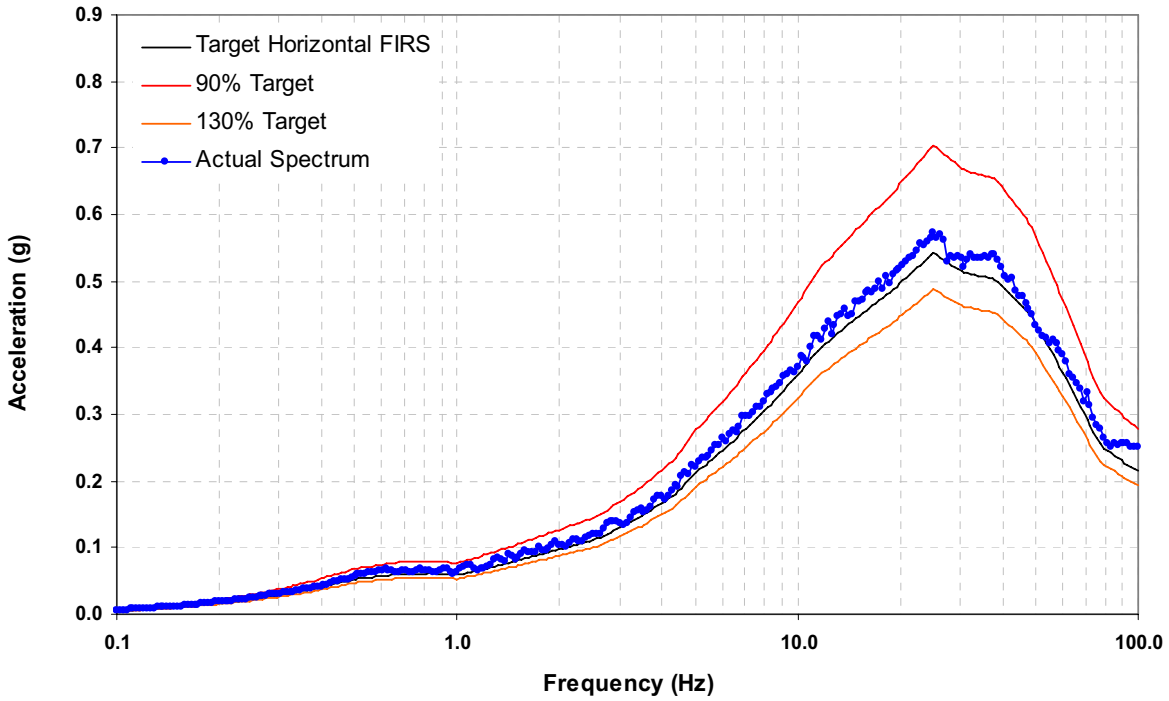


FIGURE 1-17

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(1) T.H. AND FIRS FOR 1UBP & 2UBP

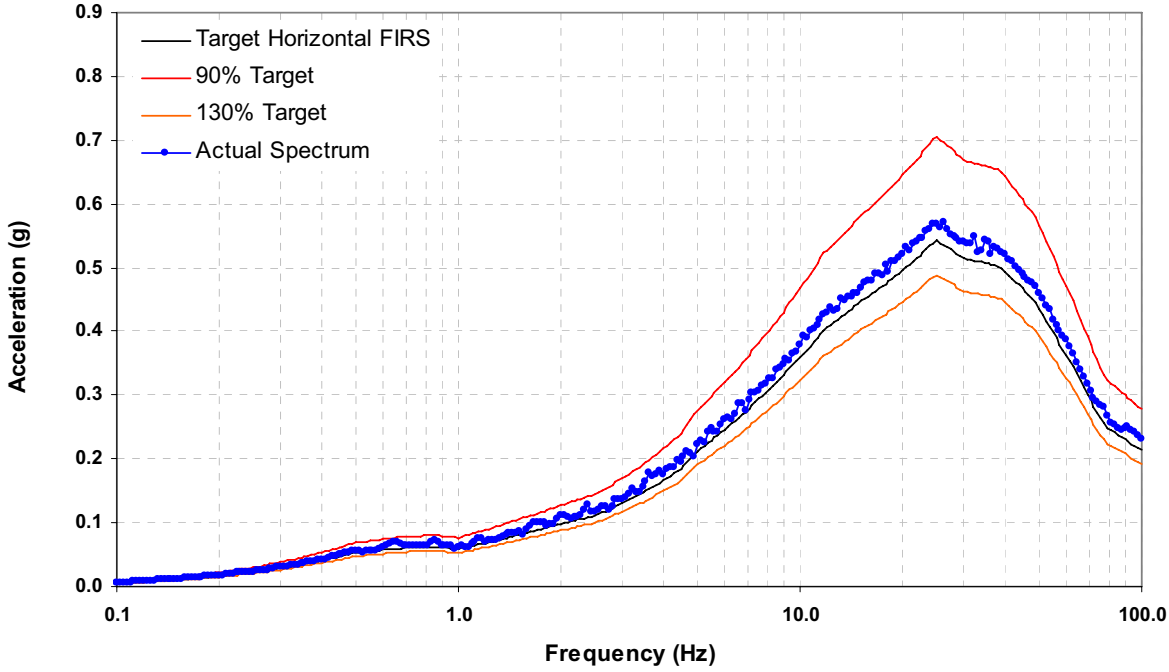


FIGURE 1-18

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(2) T.H. AND FIRS FOR 1UBP & 2UBP

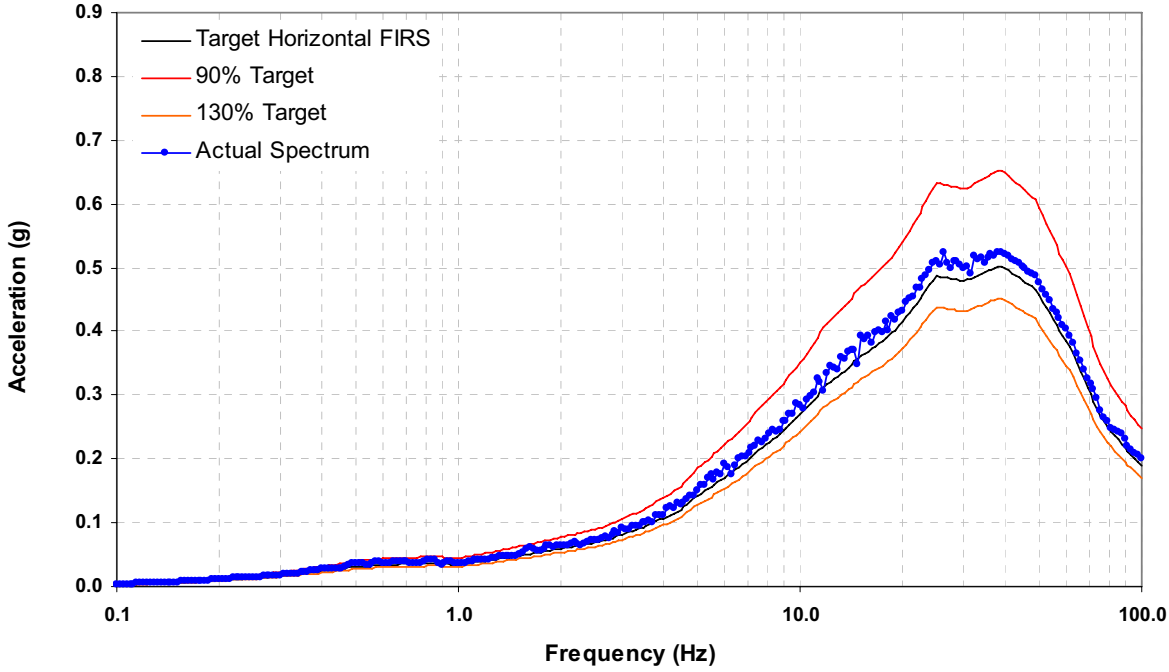


FIGURE 1-19

COMPARISON BETWEEN THE R.S. OF THE INPUT VERTICAL T.H. AND FIRS FOR 1UBP & 2UBP

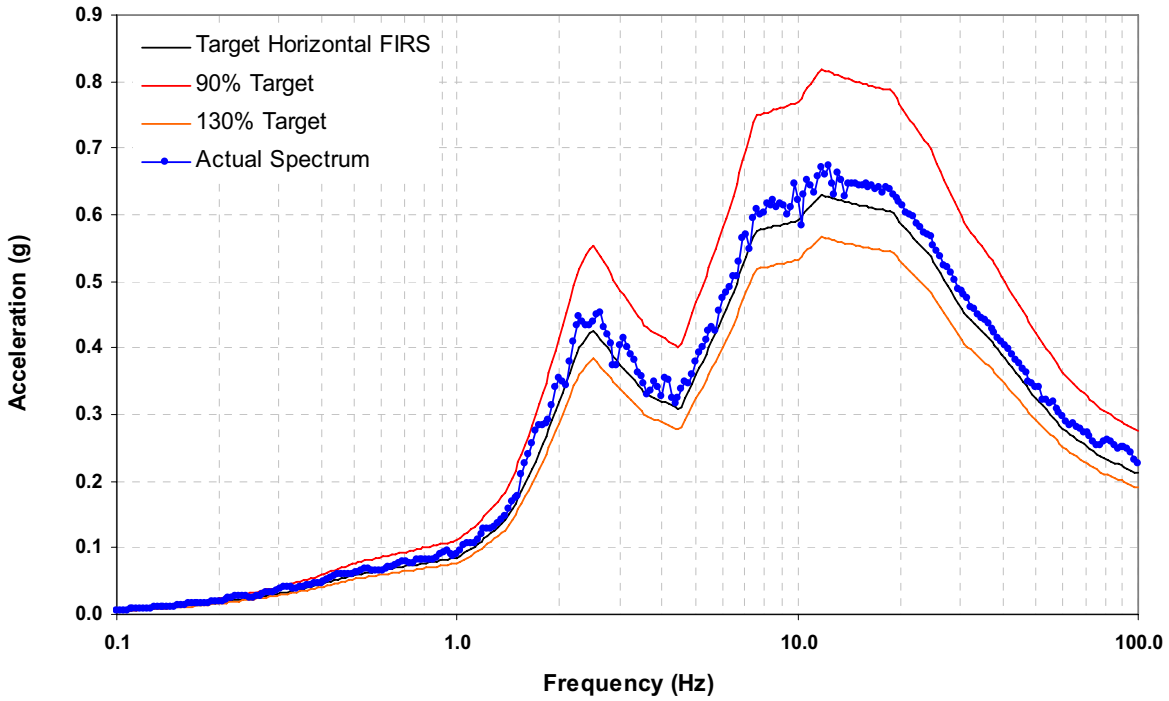


FIGURE 1-20

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(1) T.H. AND FIRS FOR 3UBP & 4UBP

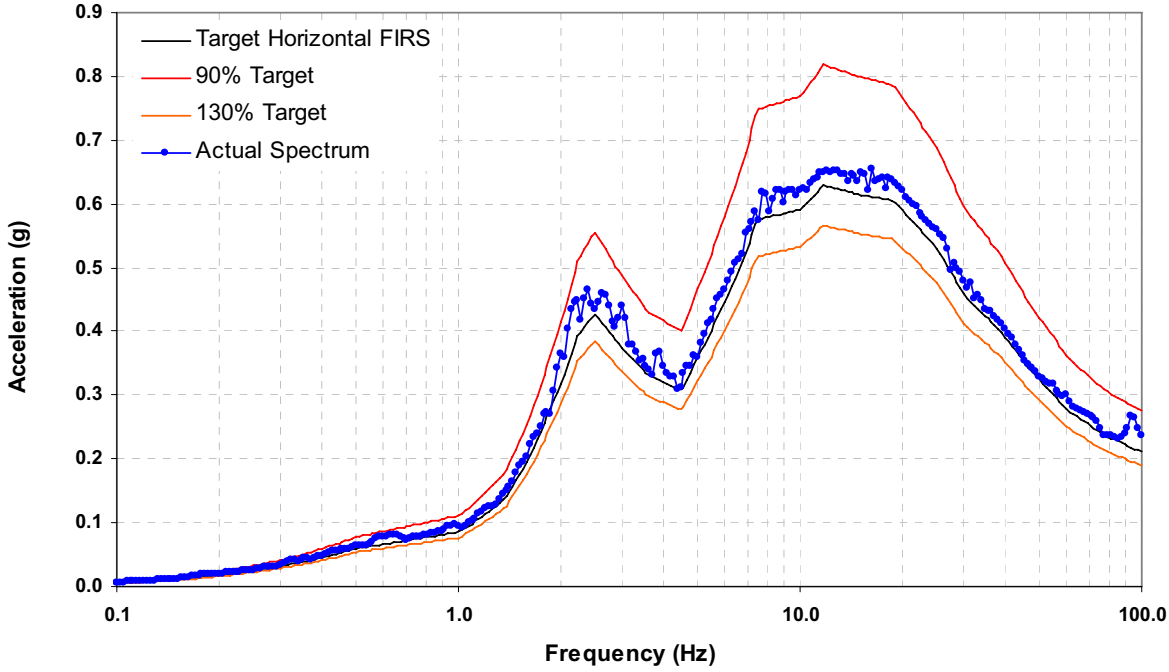


FIGURE 1-21

COMPARISON BETWEEN THE R.S. OF THE INPUT HORIZONTAL(2) T.H. AND FIRS FOR 3UBP & 4UBP

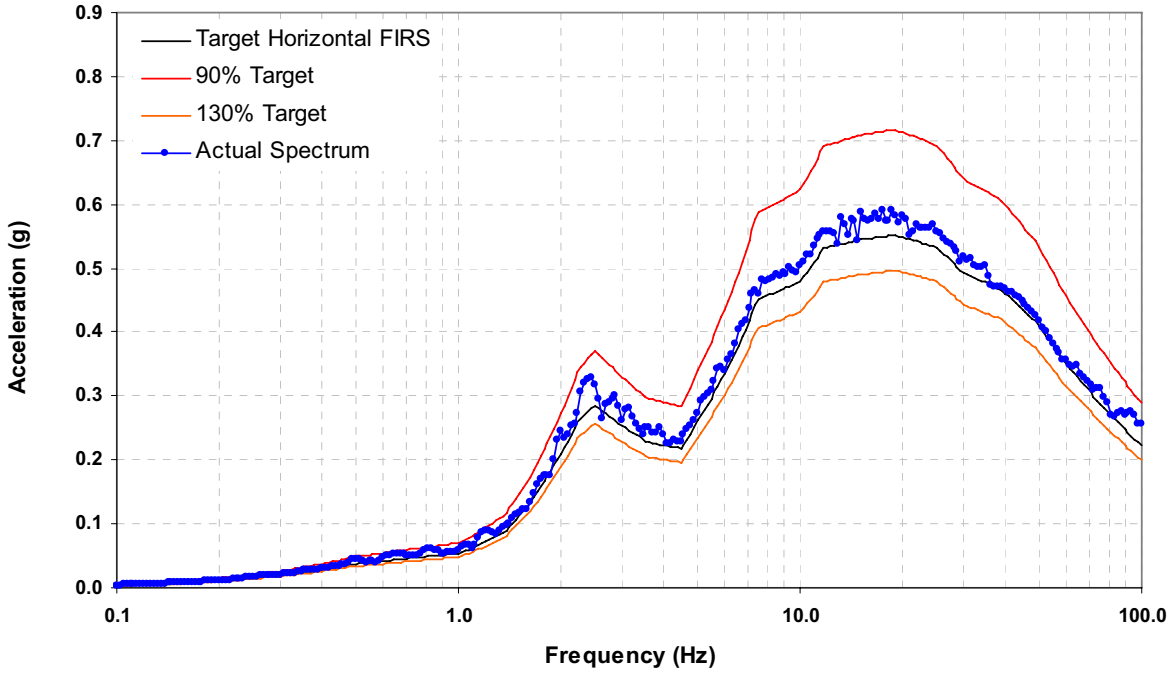


FIGURE 1-22

COMPARISON BETWEEN THE R.S. OF THE INPUT VERTICAL T.H. AND FIRS FOR 3UBP & 4UBP

4) Describe the SSI analyses performed, including a description of the computer codes, seismic models, how embedment effects were considered, modeling assumptions, and how the backfill was incorporated into the analyses. Address in your response how the SSI analysis meets SRP Acceptance Criteria 4 of SRP Section 3.7.2.

Response
A response to this question will be provided by 11/18/2009.

5) In the site-specific SSI analyses performed for the EPGB and ESWB, provide a definition of the BE, upper bound (UB) and LB profiles that were selected for the analysis of these structures including a description of concrete fill or soil backfill that was used in the analyses.

Response
A response to this question will be provided by 11/18/2009.

6) Provide information to clarify and support the statement that the EPGB is a "conservatively surface founded" structure.

Response
A response to this question will be provided by 11/18/2009.

COLA Impact

There are no changes to the COLA based on this RAI response.

03.07.01-5

In FSAR Section 3.7.1.1.1 (Design Ground Motion Response Spectra) on page 3-36 the results of the site-specific analysis for the NI Common Basemat Structures are discussed. It states that the BBNPP zero period accelerations (ZPAs) are within the corresponding U.S. EPR FSAR ZPAs except at one location of the Containment Building. At this location, which is not identified, it states that the horizontal (y-direction) ZPA of the BBNPP exceeds the ZPA of the U.S. EPR by less than 10 percent. However in FSAR Section 3.8.1.3, covering the concrete containment and in FSAR Section 3.8.3.3, covering the Reactor Containment Building Internal Structures, it states that the BBNPP site specific ZPA values are enveloped by the standard U.S. EPR design certification values. The statement that the exceedance is less than 10 percent of the U.S. EPR ZPA is not a basis for accepting the result without suitable technical justification, which needs to be included in the FSAR. In order for the staff to complete its review of whether seismic Category I standard plant structures can meet the requirements of GDC 2, provide the following information.

1) In FSAR Section 3.7.1.1.1, identify the location where the exceedance takes place.

Response
A response to this question will be provided by 2/17/2010.

2) Describe the technical justification for accepting the exceedance and include the numerical results that support this position.

Response
A response to this question will be provided by 2/17/2010.

03.07.01-6

In FSAR Section 3.7.1.1.1 (Design Ground Motion Response Spectra) on page 3-36 the ZPA results of the site-specific analysis for the EPGB and ESWB structures are discussed. In Table 3.7-4, there are a number of locations where the zero period acceleration (ZPA) results from the site specific analysis exceed the ZPA of the U.S. EPR certified design. On page 3-181 of FSAR Section 3.8.4.3 it states that additional confirmatory evaluation for the site specific response spectra and soil profiles were performed and confirmed that the other Seismic Category I structures are acceptable for the BBNPP site. No details are provided as to what was done to perform this confirmatory evaluation, nor does it provide any numerical results. The statement that an exceedance is less than 10 percent of the U.S. EPR ZPA is not a basis for accepting the result without suitable technical justification. The applicant is requested to describe the reconciliation process and technical justification for each of the exceedances shown in Table 3.7-4. Include in the response the numerical results that support the basis for the acceptability of the exceedances identified.

Response

A response to this question will be provided by 2/17/2010.

03.07.01-7

In FSAR Section 3.7.1.3 (Supporting Media for Seismic Category I structures) on page 3-38 it states that the supporting media for the EPGB and ESWB are also bounded by generic soil profiles 5u and 5a when concrete fill is used, but are a departure from the U.S. EPR FSAR when structural fill is used. Identify which type of fill is used under these structures for the SSI site-specific analysis. In addition, provide the properties and the basis for the properties used in the SSI analyses. Address in your response how SRP Acceptance Criteria 3 of SRP 3.7.1 and SRP Acceptance Criteria 4 of SRP 3.7.2 are met, or justify why they are not met.

Response

A response to this question will be provided by 2/17/2010.

03.07.01-8

In FSAR Section 3.7.1.2 (Percentage of Critical Damping Values) on page 3-38, no exception is taken to the U.S. EPR damping values used in the NI Common Basemat Structures. These values are shown in Table 3.7.1.1 of the U.S.EPR FSAR.

1) The site specific peak ground accelerations (PGA) are 0.21g horizontal and 0.18g vertical, which are both less than the 0.30g PGA of the CSDRS used for design certification. As the site-specific ground accelerations should, in general, result in lower stress levels in the structure, justify in the FSAR why the damping values used in the design certification seismic analysis remain valid for the site specific seismic analysis of the NI structures.

Response
A response to this question will be provided by 11/18/2009.

2) Regulatory Guide 1.61 states that for the generation of In-Structure Response Spectra (ISRS), structural damping values associated with an operating basis earthquake (OBE) should be used unless a plant-specific technical basis is provided which supports the use of higher than OBE damping values. State the structural damping values used for the generation of ISRS for the NI common basemat structures, EPGB, and ESWB, and if different from the OBE values stated in RG 1.61, provide a technical justification for the values used.

Response
A response to this question will be provided by 11/18/2009.

3) In Section 3.7.1.2 (Percentage of Critical Damping Values) on page 3-38 it indicates that 5 percent of critical damping is used for the analysis of the essential service water emergency make-up system (ESWEMS) Pumphouse. RG 1.61 recommends special consideration for development of In-Structure Response Spectra (ISRS). Specifically, the applicant may use OBE damping values (4 percent for reinforced concrete) or submit a plant-specific technical basis for use of damping values higher than the OBE damping values, but not greater than the SSE damping values (7 percent). In addition the applicant has assumed that the concrete is un-cracked, implying low damping values in the structure. What is the technical basis that supports the use of 5 percent damping for this structure?

Response
The time history Soil Structure Interaction (SSI) analysis of the Essential Service Water Emergency Make-up System (ESWEMS) pumphouse was repeated with 4 percent damping. FSAR Figures 3.7-140 through 3.7-148 will be updated with the results from the calculation performed with a cut-off frequency of 100 Hz and damping of 4 percent.

<u>COLA Impact</u>

FSAR Section 3.7 Figures 3.7-140 through 3.7-148 will be updated as shown in the following mark-ups:

Figure 3.7-140 {In-Structure Floor Response Spectra in E-W Direction at First Floor Level of the ESWEMS Pumphouse}

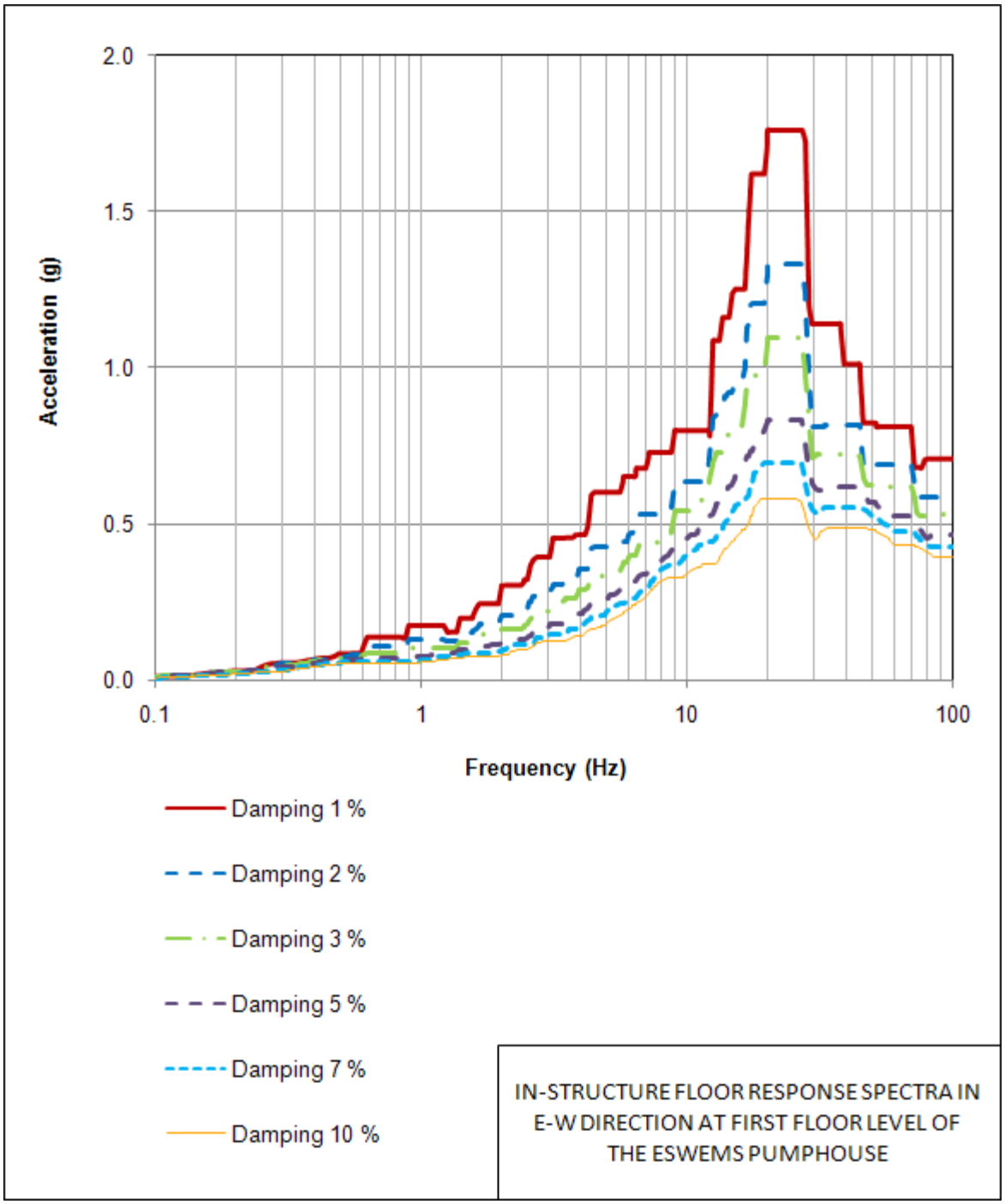


Figure 3.7-141 {In-Structure Floor Response Spectra in N-S Direction at First Floor Level of the ESWEMS Pumphouse}

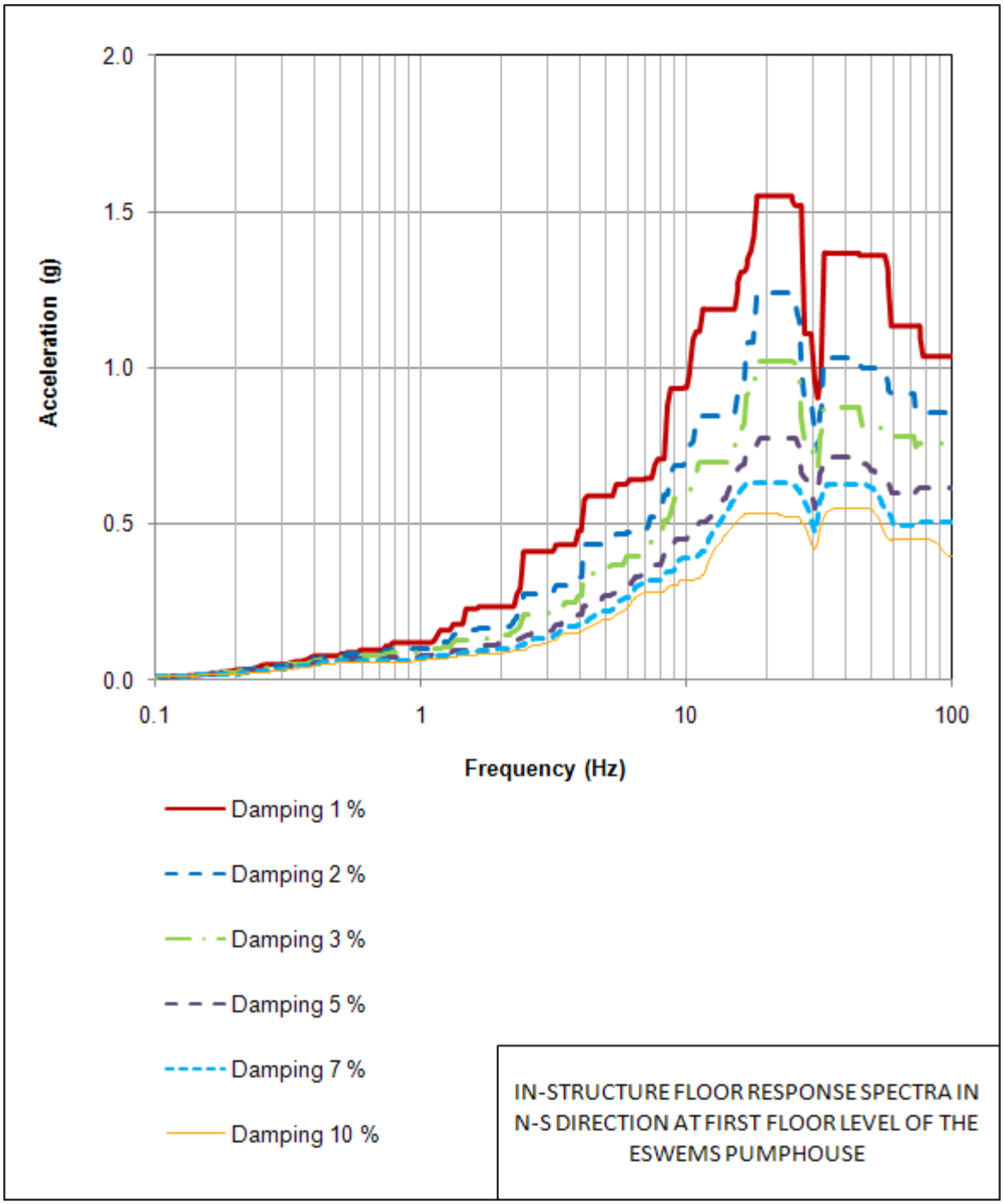


Figure 3.7-142 {In-Structure Floor Response Spectra in Vertical Direction at First Floor Level of the ESWEMS Pumphouse}

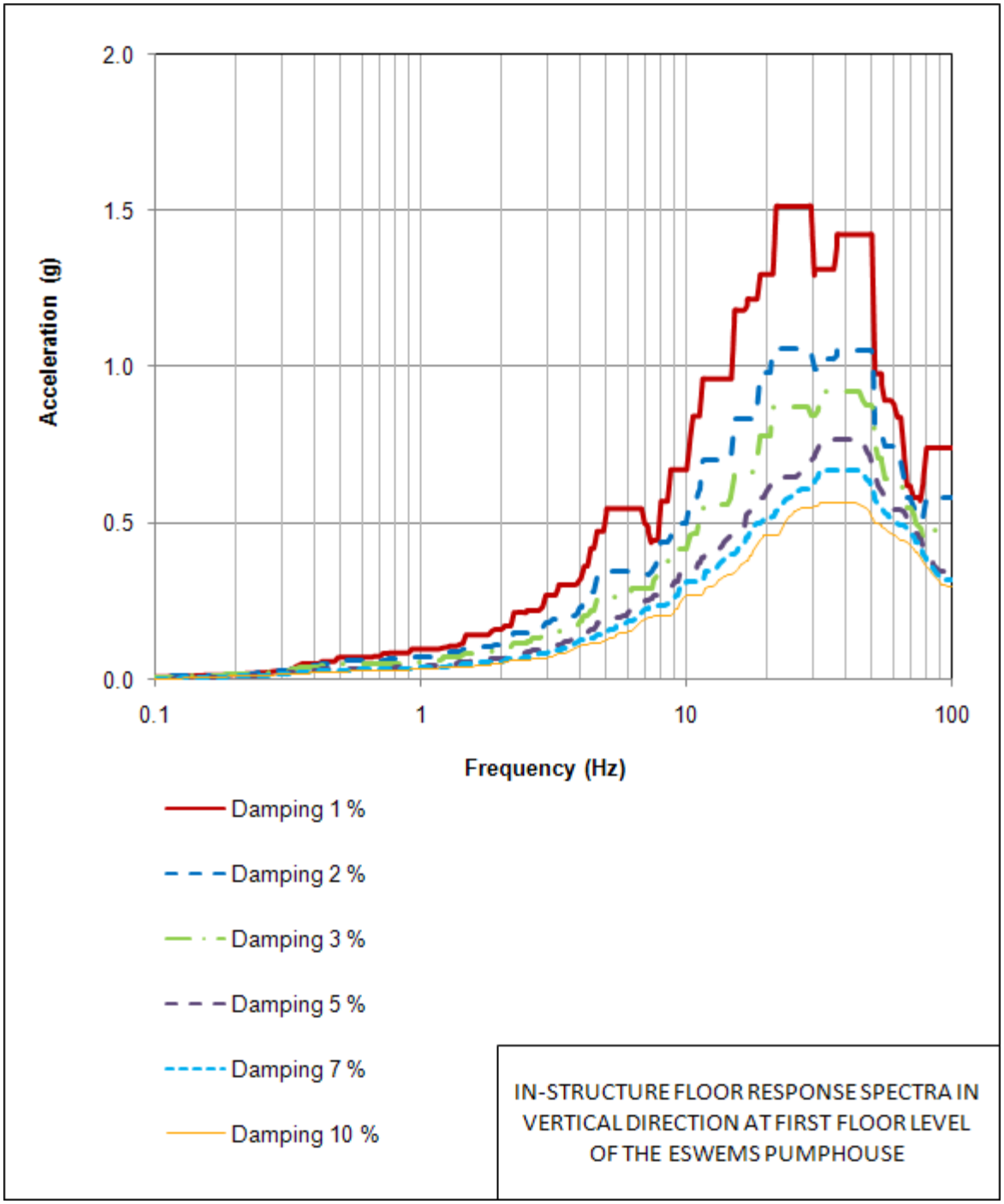


Figure 3.7-143 {In-Structure Floor Response Spectra in E-W Direction at Mezzanine Level of the ESWEMS Pumphouse}

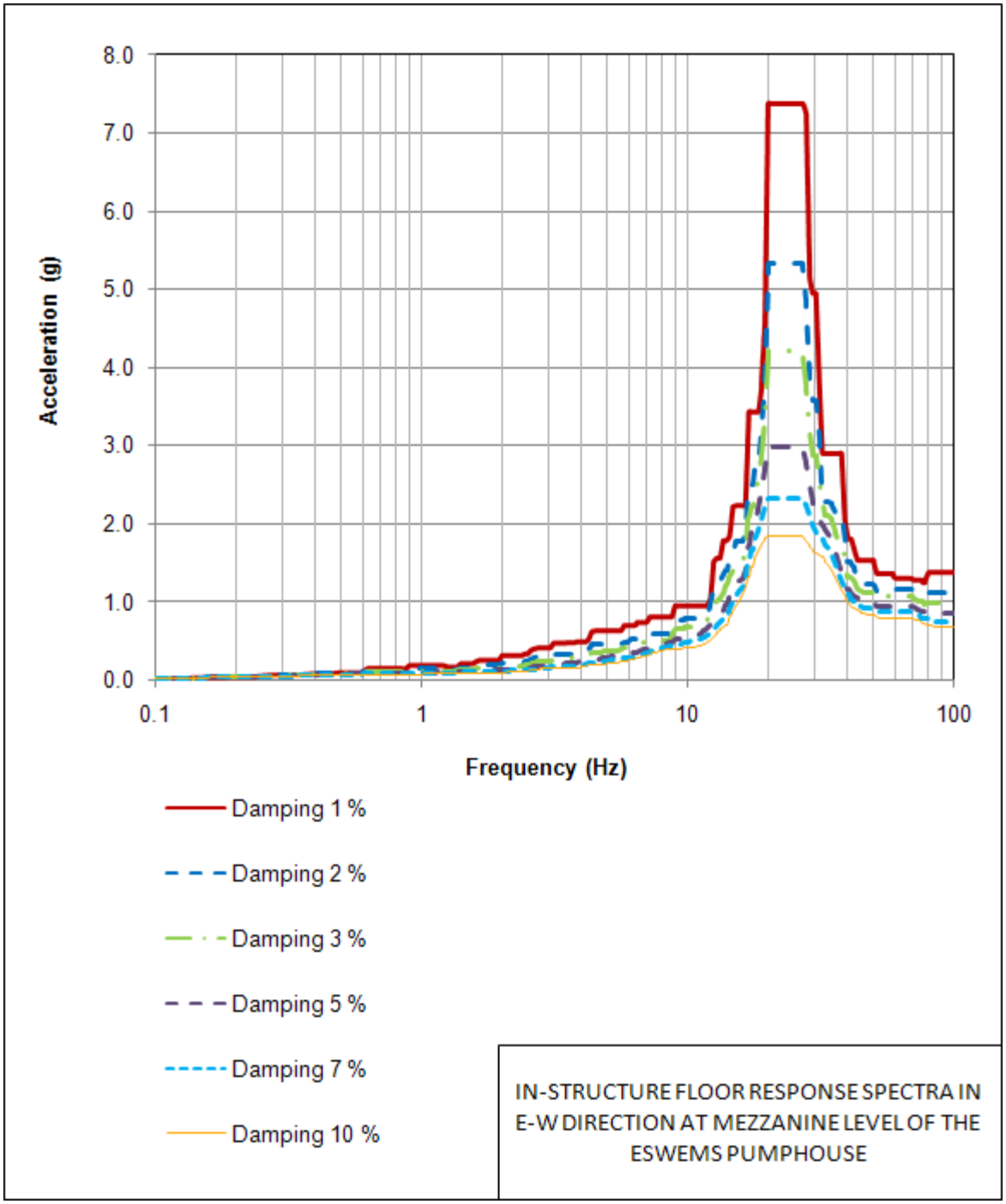


Figure 3.7-144 {In-Structure Floor Response Spectra in N-S Direction at Mezzanine Level of the ESWEMS Pumphouse}

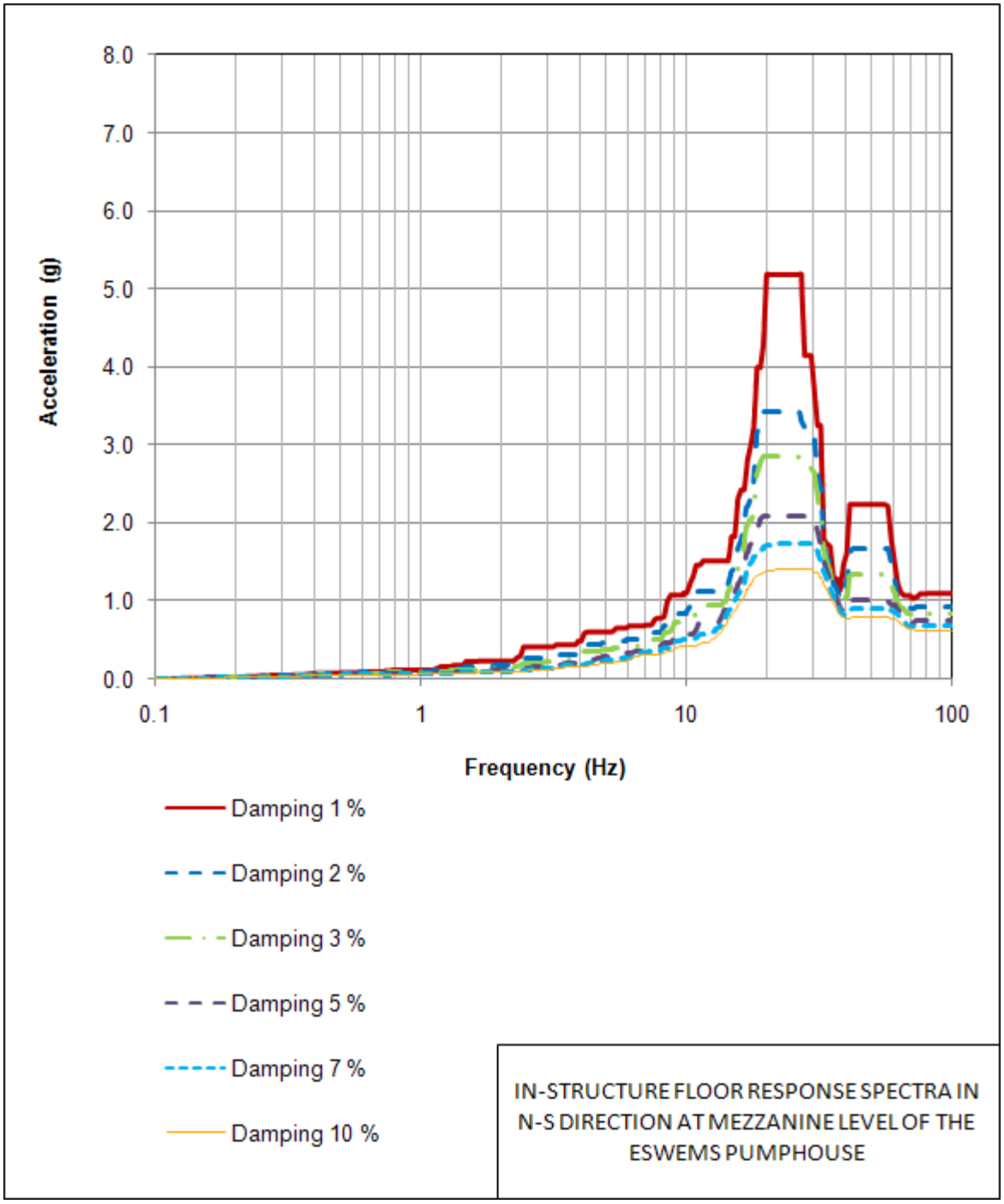


Figure 3.7-145 {In-Structure Floor Response Spectra in Vertical Direction at Mezzanine Level of the ESWEMS Pumphouse}

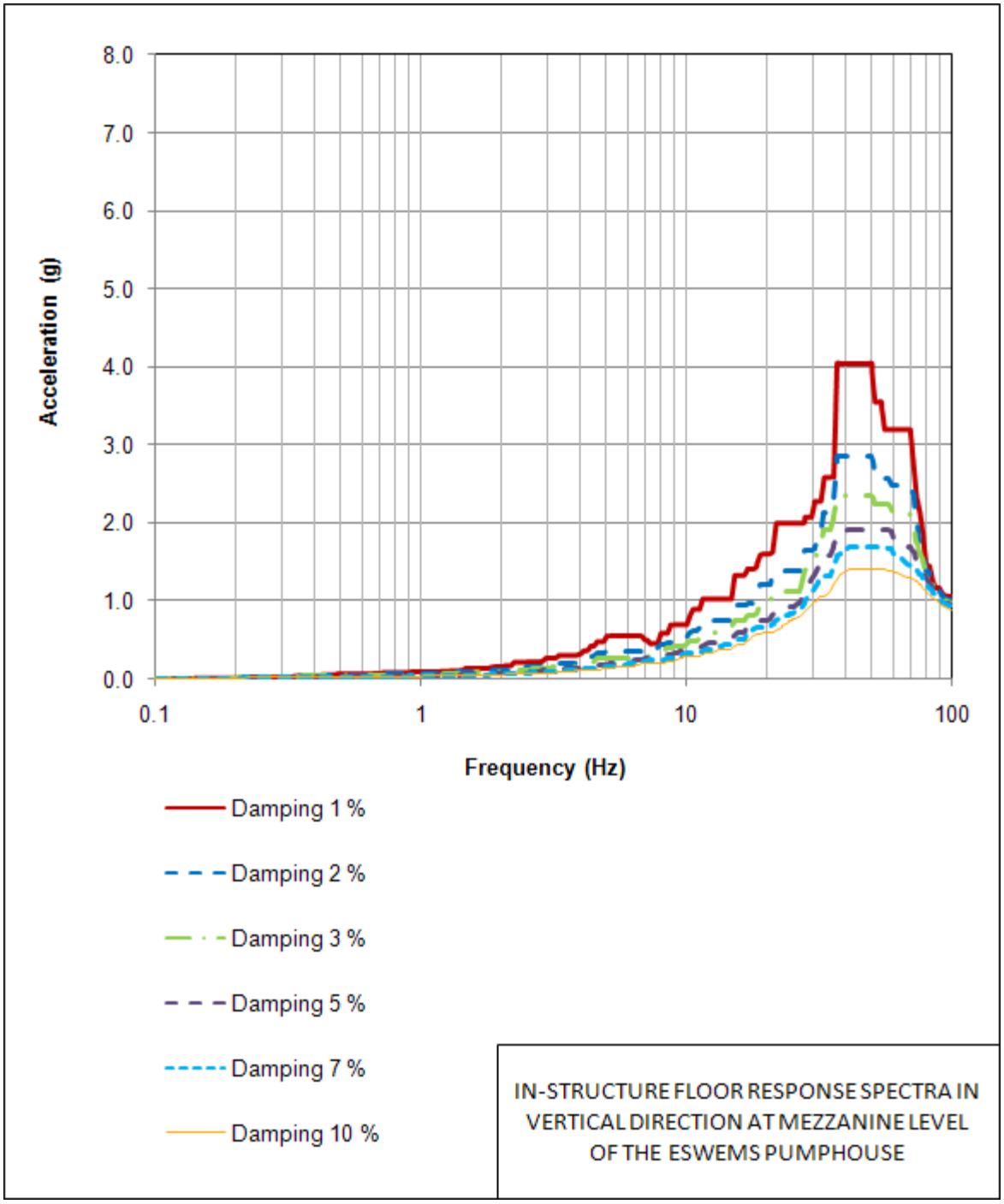


Figure 3.7-146 {In-Structure Floor Response Spectra in E-W Direction at Roof Level of the ESWEMS Pumphouse}

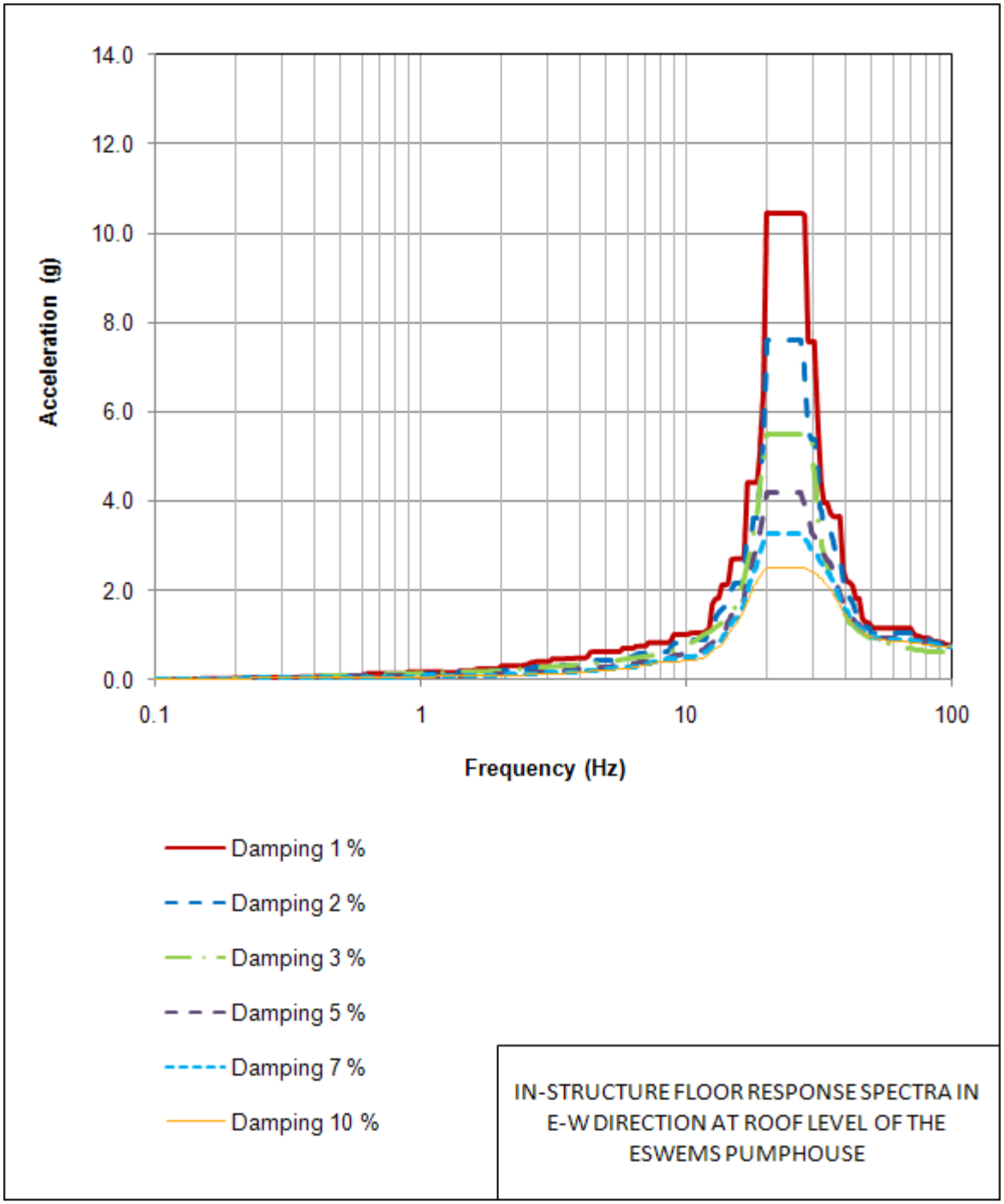


Figure 3.7-147 {In-Structure Floor Response Spectra in N-S Direction at Roof Level of the ESWEMS Pumphouse}

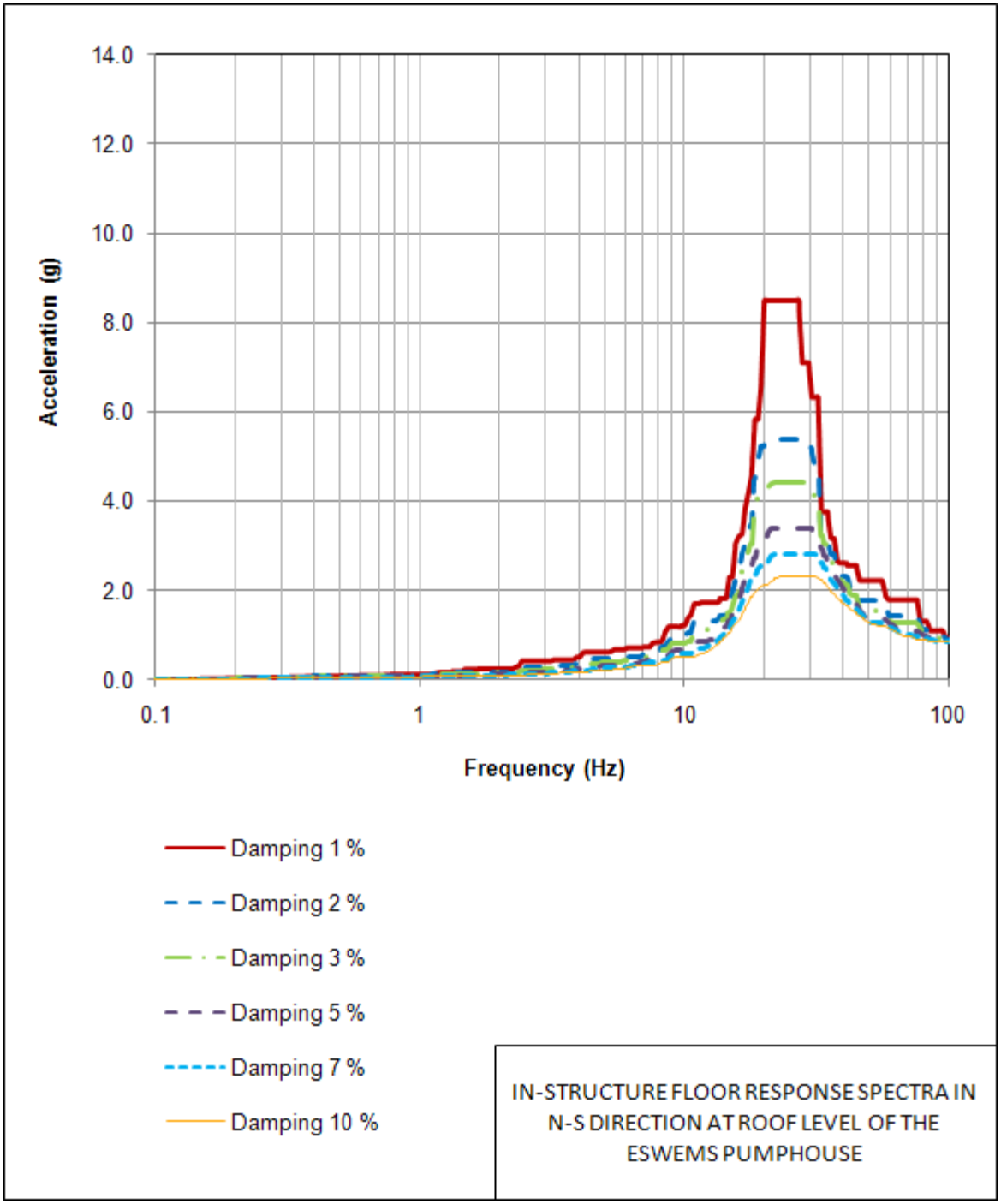
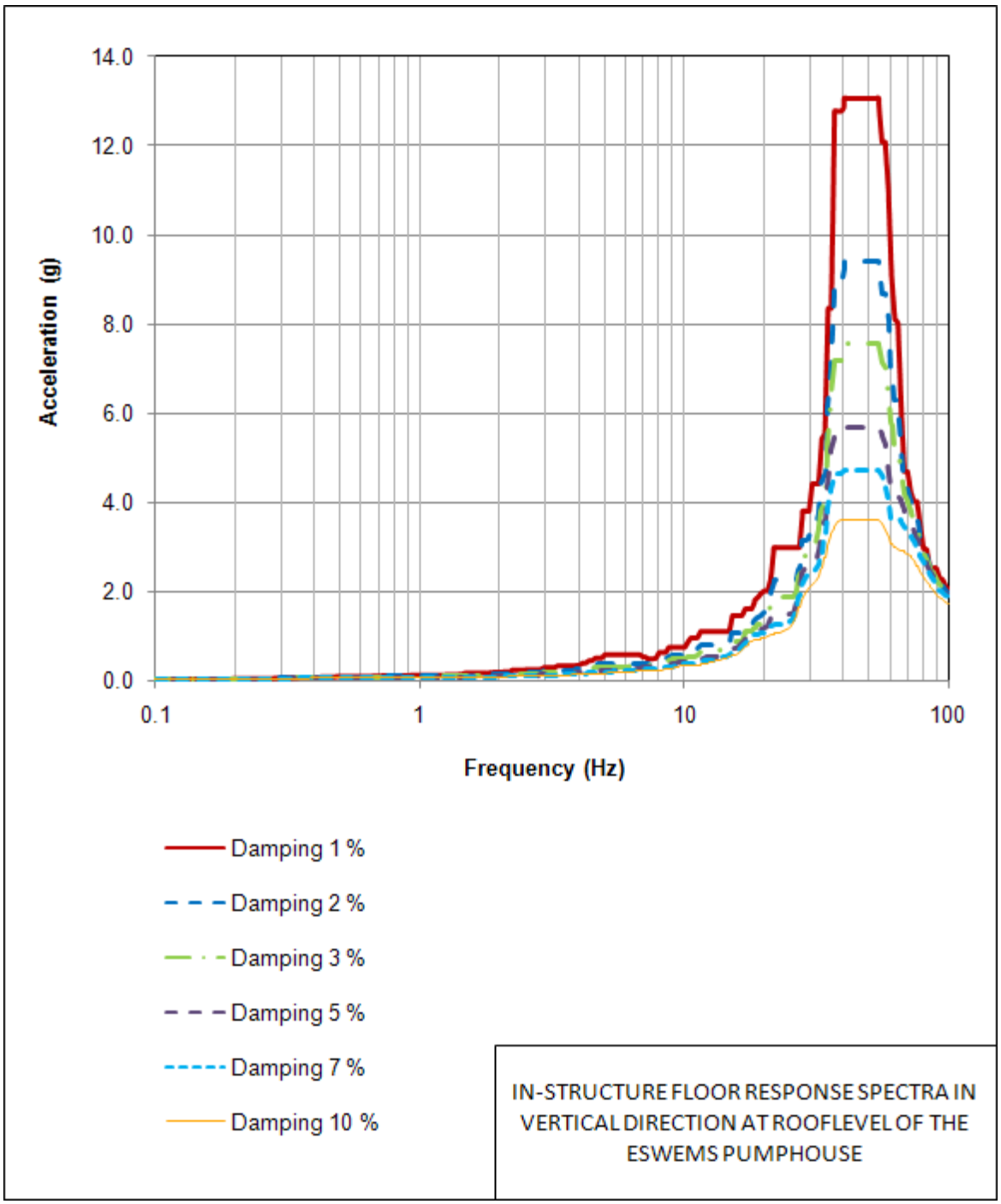


Figure 3.7-148 {In-Structure Floor Response Spectra in Vertical Direction at Roof Level of the ESWEMS Pumphouse}



03.07.01-9

In FSAR Section 3.7.1.1.1 on page 3-36 it states that a comparison of the Bell Bend ISRS with the corresponding peak broadened U.S. EPR FSAR ISRS show that the certified design ISRS are exceeded by the Bell Bend ISRS by more than 10 percent at some of the key building locations including the NI Common Basemat structures, EPGB and ESWB. It also states that the exceedance of certified design ISRS is a departure from the U.S.EPR FSAR and is justified consistent with the seismic reconciliation guidelines contained in the U.S. EPR FSAR Section 2.5.2.6 as described in BBNPP FSAR Section 2.5.2.6. In the BBNPP FSAR Section 2.5.2.6, Step 9, it states: "These evaluations, summarized below, confirm that the safety-related structures, systems and components of the U.S. EPR are not affected." The staff, however, could not identify any such evaluations. The applicant is requested to provide an evaluation of each exceedance (not just those that are in excess of 10 percent) and to justify the use of the U.S. EPR certified design ISRS at the BBNPP site for all Seismic Category I Structures including the NI, EPGB, and ESWB. State whether the seismic models used for the BBNPP site are different from those used for the U.S. EPR certified design, and, if so, justify why a comparison of results from the two sets of models is valid.

Response

A response to this question will be provided by 2/17/2010.

03.07.01-10

In FSAR Section 3.7.1.1.1 on page 3-37 it states that the free field surface FIRS at elevation 669.0 ft. were obtained for the ESWEMS Pumphouse mat which envelope the GMRS at all frequencies.

1) In Figure 3.7-131, it is not clear that the FIRS shown envelope the GMRS at all frequencies. Accordingly, provide a comparison of the GMRS with the FIRS for both the horizontal and vertical directions. In addition, provide the specific steps that are used, including the computer codes, to develop the FIRS for this structure.

Response

Figures 1-1 and 1-2 provide the comparison between GMRS and FIRS. Although both curves are very similar, the GMRS does not envelope the FIRS. The statement that the "GMRS envelopes the FIRS" has been removed from the FSAR and that change was reflected in Revision 1 of the COLA. FSAR Figures 2.5-138 and 2.5-139 provide the soil profile used for the development of the ESWEMS Pumphouse FIRS. Response to Question 03.07.01-4 provides a description of the theoretical basis for the development of the FIRS. For the particular case of the ESWEMS pumphouse, the FIRS were developed at zero depth without considering embedment and with a surface outcropping motion. Section 2.5.2.6 of the FSAR describes the process for development of vertical spectra by scaling the horizontal spectra by a frequency-dependent vertical-to-horizontal (V/H) factor.

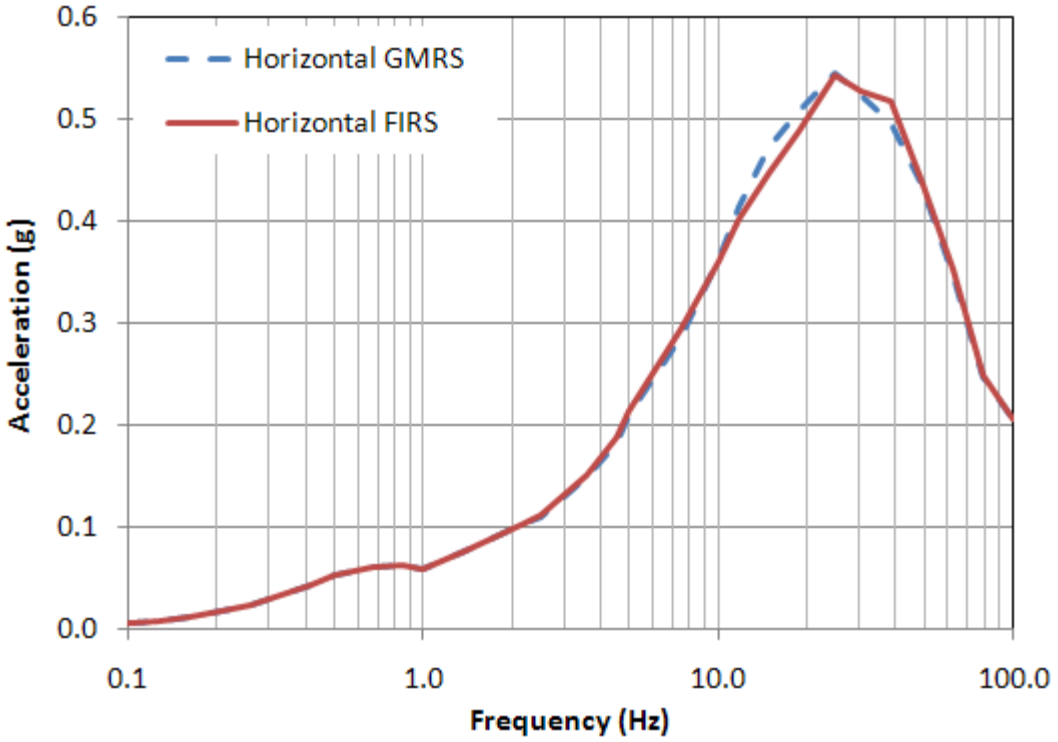


FIGURE 1-1
HORIZONTAL GMRS AND FIRS COMPARISON

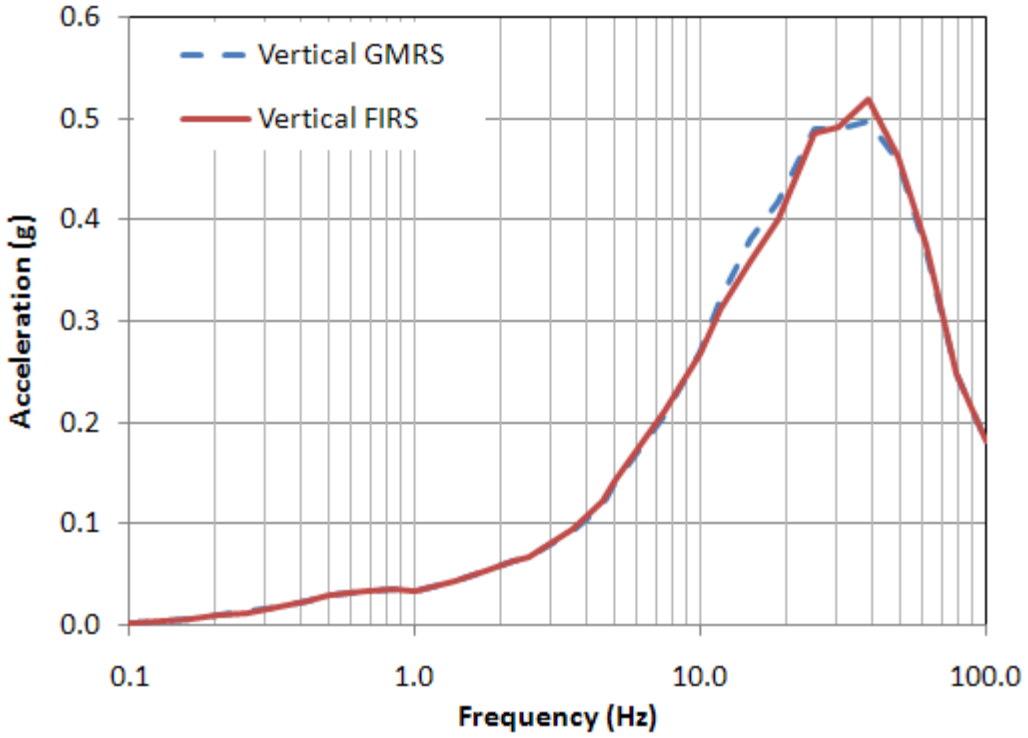


FIGURE 1-2
VERTICAL GMRS AND FIRS COMPARISON

2) Describe how the ground motion input time histories for the ESWEMS meet each of SRP Acceptance Criteria 1.B of SRP Section 3.7.1. If all the acceptance criteria are not met, provide suitable justification for not doing so.

Response
The ground motion input time histories meet the requirement prescribed in Approach 2 of the Acceptance Criteria 1.B of SRP Section 3.7.1. The time increment is 0.005 seconds and a Nyquist frequency of 100 Hz (1/(2*0.005)) equal to the maximum frequency of interest. The total duration is greater than the minimum of 20 seconds. The 5 percent damped response spectrum of the time history calculated at 100 points per frequency decade, uniformly spaced over the log frequency scale from 0.1 Hz to 100 Hz, do not fall more than 10 percent below the target response spectrum and do not exceed the target response spectrum by more than 30 percent and no more than nine adjacent frequency points fall below the target response spectrum.

3) Provide a comparison of the response spectra developed from the input time histories with the FIRS for this structure and demonstrate how the time histories meet Approach 1 or Approach 2 in SRP Acceptance Criteria 1.B of SRP 3.7.1.

Response
FSAR Figures 3.7-135 through 3.7-137 shows the comparison of the 5 percent damped response spectrum of the input time histories, and the 90 percent, 100 percent, and 130 percent target response spectra. This comparison demonstrates that the 5 percent damped response spectra of the time histories does not drop more than 10 percent below the target response spectra, and does not exceed the target response spectra by more than 30 percent.
Table 1-1 and Table 1-2 show the comparison of the response spectra of the input time history and the target response spectra for the horizontal and vertical direction. No more than nine adjacent frequency points fall below the target response spectra.
The two horizontal time histories and the vertical input time history have a time increment of 0.005 seconds and a Nyquist frequency of 100 Hz (1/(2*0.005)) equal to the maximum frequency of interest, and its total duration is greater than 20 seconds.

Finally, the correlation coefficients among the three time histories are less than 0.16 prescribed by the SRP.

TABLE 1-1

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE HORIZONTAL DIRECTION

FREQUENCY (HZ)	HORIZONTAL FIRS ACCELERATION (G)	FIRST HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)	SECOND HORIZONTAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0056	0.0057	2.32	0.0058	3.04
0.102	0.0058	0.0057	-1.89	0.0059	1.20
0.105	0.0061	0.0057	-5.79	0.0060	-1.49
0.107	0.0063	0.0061	-3.81	0.0065	2.38
0.110	0.0065	0.0064	-1.68	0.0068	4.59
0.112	0.0068	0.0069	1.76	0.0072	5.87
0.115	0.0071	0.0074	4.66	0.0076	7.91
0.118	0.0074	0.0080	8.56	0.0080	8.56
0.120	0.0077	0.0085	11.24	0.0082	7.71
0.123	0.0080	0.0090	12.81	0.0084	5.40
0.126	0.0083	0.0094	13.65	0.0086	3.74
0.129	0.0086	0.0098	13.74	0.0089	3.49
0.132	0.0089	0.0101	13.37	0.0092	3.26
0.135	0.0092	0.0104	12.23	0.0095	2.81
0.138	0.0096	0.0106	10.87	0.0098	2.51
0.141	0.0099	0.0108	9.05	0.0102	2.21
0.145	0.0103	0.0111	7.58	0.0105	2.24
0.148	0.0107	0.0113	5.90	0.0110	2.62
0.151	0.0111	0.0116	4.78	0.0115	3.43
0.155	0.0115	0.0121	5.31	0.0120	4.70
0.159	0.0119	0.0126	6.05	0.0127	6.39
0.162	0.0123	0.0132	7.13	0.0134	8.43
0.166	0.0128	0.0139	8.53	0.0142	10.95
0.170	0.0132	0.0145	9.67	0.0150	13.45
0.174	0.0137	0.0152	10.58	0.0159	15.90
0.178	0.0142	0.0158	11.28	0.0167	17.97
0.182	0.0147	0.0164	11.69	0.0176	19.31
0.186	0.0152	0.0169	11.03	0.0182	19.70
0.191	0.0158	0.0172	9.07	0.0188	18.90
0.195	0.0163	0.0174	6.30	0.0191	17.14

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.200	0.0169	0.0184	8.57	0.0195	15.43
0.204	0.0175	0.0192	9.70	0.0197	12.21
0.209	0.0181	0.0198	9.63	0.0195	8.08
0.214	0.0187	0.0199	6.76	0.0193	3.32
0.219	0.0193	0.0197	2.13	0.0201	4.62
0.224	0.0199	0.0198	-0.15	0.0214	7.50
0.229	0.0205	0.0211	2.88	0.0222	8.10
0.234	0.0211	0.0216	2.37	0.0228	7.95
0.240	0.0218	0.0217	-0.60	0.0234	7.29
0.246	0.0225	0.0227	1.07	0.0238	5.82
0.251	0.0232	0.0240	3.27	0.0241	3.92
0.257	0.0240	0.0251	4.68	0.0245	2.21
0.263	0.0247	0.0261	5.72	0.0250	1.18
0.269	0.0254	0.0272	6.93	0.0256	0.91
0.275	0.0261	0.0284	8.45	0.0265	1.30
0.282	0.0269	0.0298	10.55	0.0274	1.90
0.288	0.0277	0.0313	12.81	0.0283	2.20
0.295	0.0285	0.0327	14.48	0.0291	2.14
0.302	0.0294	0.0333	13.49	0.0307	4.56
0.309	0.0302	0.0331	9.60	0.0326	7.81
0.316	0.0311	0.0326	4.63	0.0338	8.55
0.324	0.0320	0.0327	2.19	0.0342	6.90
0.331	0.0329	0.0323	-2.06	0.0343	4.04
0.339	0.0339	0.0340	0.44	0.0365	7.68
0.347	0.0348	0.0359	3.13	0.0376	8.11
0.355	0.0357	0.0374	4.67	0.0375	5.07
0.363	0.0367	0.0388	5.77	0.0369	0.44
0.372	0.0377	0.0409	8.49	0.0370	-1.83
0.380	0.0387	0.0424	9.32	0.0385	-0.59
0.389	0.0398	0.0430	8.12	0.0401	0.63
0.398	0.0409	0.0442	8.12	0.0421	3.03
0.407	0.0420	0.0450	7.14	0.0437	3.95
0.417	0.0432	0.0460	6.46	0.0448	3.68
0.427	0.0443	0.0466	5.15	0.0463	4.49
0.437	0.0455	0.0476	4.62	0.0478	5.26

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
0.447	0.0466	0.0486	4.27	0.0492	5.40
0.457	0.0479	0.0505	5.45	0.0501	4.74
0.468	0.0491	0.0520	6.01	0.0511	4.01
0.479	0.0504	0.0531	5.42	0.0524	4.07
0.490	0.0517	0.0556	7.60	0.0541	4.68
0.501	0.0530	0.0577	8.95	0.0553	4.51
0.513	0.0535	0.0588	10.06	0.0559	4.53
0.525	0.0540	0.0592	9.63	0.0561	3.85
0.537	0.0545	0.0598	9.82	0.0563	3.34
0.550	0.0550	0.0605	9.96	0.0570	3.62
0.562	0.0555	0.0610	9.85	0.0582	4.86
0.575	0.0561	0.0627	11.90	0.0596	6.35
0.589	0.0566	0.0644	13.67	0.0607	7.28
0.603	0.0572	0.0664	16.11	0.0619	8.22
0.617	0.0577	0.0675	17.04	0.0628	8.77
0.631	0.0583	0.0668	14.69	0.0635	8.91
0.646	0.0588	0.0649	10.27	0.0633	7.57
0.661	0.0594	0.0624	5.07	0.0626	5.39
0.676	0.0599	0.0581	-3.01	0.0620	3.53
0.692	0.0600	0.0601	0.13	0.0628	4.63
0.708	0.0602	0.0635	5.46	0.0653	8.37
0.724	0.0604	0.0632	4.65	0.0669	10.76
0.741	0.0606	0.0604	-0.31	0.0675	11.41
0.759	0.0608	0.0603	-0.79	0.0651	7.16
0.776	0.0609	0.0596	-2.25	0.0650	6.61
0.794	0.0611	0.0607	-0.74	0.0643	5.23
0.813	0.0613	0.0624	1.83	0.0644	5.02
0.832	0.0615	0.0642	4.31	0.0658	6.93
0.851	0.0617	0.0657	6.57	0.0649	5.14
0.871	0.0613	0.0667	8.84	0.0647	5.46
0.891	0.0609	0.0696	14.25	0.0625	2.56
0.912	0.0605	0.0716	18.33	0.0588	-2.91
0.933	0.0601	0.0705	17.34	0.0613	2.06
0.955	0.0597	0.0662	10.90	0.0632	5.80
0.977	0.0593	0.0618	4.15	0.0628	5.97

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
1.000	0.0589	0.0606	2.80	0.0604	2.51
1.023	0.0600	0.0615	2.47	0.0631	5.12
1.047	0.0611	0.0627	2.55	0.0697	14.06
1.072	0.0622	0.0648	4.16	0.0727	16.74
1.097	0.0634	0.0664	4.67	0.0695	9.67
1.122	0.0646	0.0683	5.71	0.0634	-1.86
1.148	0.0658	0.0715	8.76	0.0695	5.66
1.175	0.0670	0.0744	11.06	0.0736	9.81
1.202	0.0682	0.0745	9.25	0.0724	6.11
1.230	0.0695	0.0735	5.73	0.0698	0.50
1.259	0.0708	0.0750	5.96	0.0736	4.03
1.288	0.0721	0.0801	11.11	0.0756	4.79
1.318	0.0734	0.0839	14.23	0.0795	8.29
1.349	0.0748	0.0834	11.51	0.0843	12.70
1.380	0.0762	0.0801	5.21	0.0858	12.61
1.413	0.0774	0.0812	4.90	0.0827	6.88
1.445	0.0786	0.0798	1.48	0.0827	5.20
1.479	0.0799	0.0763	-4.55	0.0839	5.03
1.514	0.0812	0.0830	2.20	0.0824	1.44
1.549	0.0825	0.0908	9.96	0.0824	-0.13
1.585	0.0839	0.0945	12.61	0.0876	4.40
1.622	0.0852	0.0922	8.20	0.0920	7.90
1.660	0.0866	0.0951	9.76	0.0900	3.86
1.698	0.0880	0.0930	5.61	0.0932	5.82
1.738	0.0895	0.0917	2.46	0.0951	6.33
1.778	0.0908	0.0963	6.03	0.0941	3.64
1.820	0.0921	0.0982	6.56	0.0914	-0.84
1.862	0.0935	0.0979	4.73	0.0983	5.13
1.906	0.0948	0.0967	1.99	0.0958	1.02
1.950	0.0962	0.1065	10.67	0.1001	4.09
1.995	0.0976	0.1094	12.10	0.1029	5.43
2.042	0.0990	0.1029	3.91	0.0999	0.88
2.089	0.1005	0.1088	8.30	0.1044	3.92
2.138	0.1019	0.1106	8.55	0.1073	5.26
2.188	0.1034	0.1099	6.25	0.1072	3.67

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
2.239	0.1048	0.1053	0.47	0.1025	-2.14
2.291	0.1060	0.1113	4.92	0.1067	0.64
2.344	0.1073	0.1161	8.16	0.1132	5.44
2.399	0.1086	0.1140	4.91	0.1175	8.17
2.455	0.1099	0.1118	1.66	0.1156	5.15
2.512	0.1115	0.1182	6.06	0.1229	10.29
2.570	0.1137	0.1206	6.08	0.1256	10.48
2.630	0.1160	0.1201	3.54	0.1263	8.92
2.692	0.1183	0.1215	2.71	0.1272	7.52
2.754	0.1207	0.1298	7.61	0.1270	5.21
2.818	0.1231	0.1324	7.59	0.1207	-1.96
2.884	0.1256	0.1422	13.28	0.1258	0.20
2.951	0.1281	0.1431	11.74	0.1307	2.08
3.020	0.1306	0.1383	5.89	0.1366	4.59
3.090	0.1333	0.1530	14.80	0.1411	5.85
3.162	0.1359	0.1510	11.07	0.1536	13.02
3.236	0.1386	0.1471	6.12	0.1578	13.80
3.311	0.1414	0.1513	6.96	0.1497	5.83
3.389	0.1443	0.1509	4.57	0.1448	0.38
3.467	0.1472	0.1545	5.00	0.1498	1.83
3.548	0.1501	0.1551	3.36	0.1674	11.53
3.631	0.1533	0.1495	-2.44	0.1806	17.85
3.715	0.1565	0.1594	1.83	0.1730	10.53
3.802	0.1599	0.1723	7.77	0.1756	9.83
3.891	0.1633	0.1729	5.85	0.1773	8.58
3.981	0.1668	0.1720	3.11	0.1757	5.32
4.074	0.1704	0.1884	10.61	0.1864	9.42
4.169	0.1740	0.1939	11.44	0.1872	7.58
4.266	0.1777	0.1872	5.34	0.1871	5.27
4.365	0.1815	0.1892	4.26	0.1934	6.57
4.467	0.1854	0.1935	4.37	0.1974	6.46
4.571	0.1901	0.2062	8.48	0.2049	7.76
4.677	0.1958	0.2061	5.25	0.2120	8.27
4.786	0.2017	0.2202	9.16	0.2150	6.58
4.898	0.2078	0.2370	14.05	0.2187	5.23

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
5.012	0.2138	0.2211	3.41	0.2254	5.43
5.129	0.2177	0.2225	2.20	0.2399	10.19
5.248	0.2217	0.2319	4.62	0.2275	2.62
5.370	0.2257	0.2393	6.03	0.2379	5.40
5.495	0.2298	0.2447	6.48	0.2416	5.12
5.623	0.2340	0.2498	6.76	0.2457	4.99
5.754	0.2383	0.2632	10.45	0.2477	3.97
5.889	0.2426	0.2577	6.20	0.2550	5.12
6.026	0.2470	0.2331	-5.65	0.2639	6.84
6.166	0.2515	0.2595	3.16	0.2662	5.82
6.310	0.2561	0.2739	6.94	0.2663	3.97
6.457	0.2608	0.2769	6.19	0.2715	4.11
6.607	0.2655	0.2746	3.40	0.2827	6.47
6.761	0.2704	0.2808	3.84	0.2864	5.94
6.918	0.2753	0.2977	8.13	0.2767	0.50
7.080	0.2803	0.2980	6.32	0.2925	4.34
7.244	0.2854	0.2879	0.88	0.3062	7.28
7.413	0.2906	0.3070	5.63	0.3048	4.87
7.586	0.2957	0.3171	7.24	0.2996	1.31
7.763	0.3007	0.3141	4.46	0.3196	6.29
7.943	0.3057	0.3193	4.44	0.3252	6.37
8.128	0.3108	0.3320	6.82	0.3255	4.72
8.318	0.3160	0.3368	6.57	0.3286	3.97
8.511	0.3213	0.3308	2.95	0.3400	5.81
8.710	0.3267	0.3406	4.26	0.3447	5.52
8.913	0.3322	0.3532	6.35	0.3496	5.25
9.120	0.3377	0.3582	6.06	0.3603	6.68
9.333	0.3434	0.3532	2.86	0.3570	3.96
9.550	0.3491	0.3614	3.51	0.3661	4.85
9.772	0.3550	0.3889	9.57	0.3688	3.89
10.000	0.3609	0.3792	5.07	0.3782	4.78
10.233	0.3667	0.3793	3.43	0.3894	6.19
10.471	0.3726	0.3881	4.17	0.3872	3.92
10.715	0.3786	0.4098	8.26	0.4055	7.11
10.965	0.3846	0.4044	5.13	0.4042	5.09

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
11.220	0.3908	0.4134	5.76	0.4033	3.19
11.482	0.3971	0.4171	5.03	0.4150	4.52
11.749	0.4032	0.4242	5.21	0.4228	4.85
12.023	0.4074	0.4274	4.91	0.4272	4.88
12.303	0.4115	0.4418	7.34	0.4379	6.40
12.589	0.4158	0.4192	0.83	0.4291	3.21
12.883	0.4200	0.4316	2.76	0.4340	3.34
13.183	0.4243	0.4520	6.53	0.4496	5.96
13.490	0.4287	0.4480	4.51	0.4479	4.49
13.804	0.4331	0.4373	0.98	0.4548	5.02
14.125	0.4375	0.4643	6.14	0.4536	3.69
14.455	0.4420	0.4635	4.86	0.4617	4.47
14.791	0.4465	0.4603	3.09	0.4755	6.49
15.136	0.4505	0.4739	5.20	0.4809	6.77
15.488	0.4543	0.4747	4.51	0.4750	4.57
15.849	0.4581	0.4785	4.45	0.4746	3.62
16.218	0.4619	0.4806	4.04	0.4749	2.81
16.596	0.4658	0.4844	3.97	0.4928	5.79
16.983	0.4698	0.4902	4.35	0.4910	4.53
17.378	0.4737	0.4934	4.15	0.4880	3.00
17.783	0.4777	0.4999	4.65	0.5037	5.44
18.197	0.4817	0.5042	4.66	0.4916	2.05
18.621	0.4858	0.5051	3.98	0.5086	4.69
19.055	0.4900	0.5083	3.73	0.5082	3.73
19.499	0.4943	0.5140	3.99	0.5140	4.00
19.953	0.4986	0.5155	3.39	0.5186	4.02
20.418	0.5030	0.5272	4.80	0.5291	5.20
20.893	0.5074	0.5319	4.82	0.5234	3.16
21.380	0.5119	0.5343	4.38	0.5348	4.49
21.878	0.5164	0.5402	4.61	0.5353	3.67
22.387	0.5209	0.5440	4.43	0.5430	4.25
22.909	0.5255	0.5480	4.28	0.5435	3.43
23.442	0.5301	0.5513	4.00	0.5536	4.43
23.989	0.5348	0.5577	4.30	0.5584	4.42
24.547	0.5394	0.5634	4.43	0.5644	4.63

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
25.119	0.5428	0.5694	4.89	0.5625	3.62
25.704	0.5410	0.5620	3.87	0.5566	2.87
26.303	0.5392	0.5685	5.43	0.5677	5.28
26.916	0.5374	0.5639	4.94	0.5592	4.06
27.542	0.5356	0.5661	5.70	0.5674	5.95
28.184	0.5338	0.5627	5.42	0.5527	3.54
28.841	0.5320	0.5582	4.93	0.5551	4.35
29.512	0.5302	0.5556	4.80	0.5536	4.42
30.200	0.5284	0.5567	5.36	0.5543	4.90
30.903	0.5272	0.5530	4.90	0.5544	5.16
31.623	0.5263	0.5548	5.42	0.5484	4.20
32.360	0.5253	0.5457	3.89	0.5465	4.03
33.113	0.5244	0.5505	4.99	0.5566	6.14
33.885	0.5234	0.5494	4.98	0.5493	4.94
34.674	0.5225	0.5490	5.08	0.5522	5.70
35.482	0.5215	0.5409	3.71	0.5531	6.05
36.308	0.5206	0.5479	5.26	0.5529	6.21
37.154	0.5196	0.5460	5.07	0.5472	5.30
38.019	0.5187	0.5443	4.94	0.5478	5.60
38.905	0.5151	0.5375	4.35	0.5448	5.77
39.811	0.5072	0.5341	5.30	0.5351	5.49
40.738	0.4995	0.5196	4.03	0.5274	5.59
41.687	0.4918	0.5163	4.97	0.5186	5.45
42.658	0.4843	0.5107	5.46	0.5104	5.38
43.652	0.4769	0.4980	4.43	0.5026	5.39
44.669	0.4696	0.4914	4.63	0.4926	4.89
45.709	0.4624	0.4848	4.84	0.4872	5.35
46.774	0.4554	0.4754	4.39	0.4790	5.19
47.863	0.4484	0.4649	3.68	0.4715	5.14
48.978	0.4415	0.4608	4.39	0.4637	5.03
50.119	0.4319	0.4557	5.50	0.4530	4.88
51.287	0.4226	0.4369	3.38	0.4436	4.97
52.481	0.4135	0.4295	3.87	0.4341	4.99
53.704	0.4046	0.4227	4.49	0.4257	5.23
54.954	0.3958	0.4109	3.81	0.4092	3.38

Frequency (Hz)	Horizontal FIRS Acceleration (g)	First Horizontal Response Spectra Acceleration (g)	Difference (%)	Second Horizontal Response Spectra Acceleration (g)	Difference (%)
56.235	0.3873	0.4050	4.58	0.4071	5.11
57.544	0.3789	0.3981	5.05	0.3997	5.48
58.885	0.3707	0.3889	4.89	0.3734	0.71
60.256	0.3627	0.3741	3.14	0.3796	4.66
61.660	0.3549	0.3691	4.00	0.3696	4.15
63.096	0.3444	0.3606	4.72	0.3607	4.75
64.566	0.3329	0.3404	2.25	0.3471	4.26
66.070	0.3218	0.3401	5.70	0.3361	4.43
67.609	0.3111	0.3289	5.72	0.3249	4.44
69.184	0.3007	0.3206	6.62	0.3144	4.56
70.795	0.2907	0.3164	8.83	0.3031	4.26
72.444	0.2810	0.3114	10.81	0.2921	3.92
74.132	0.2717	0.2968	9.25	0.2828	4.09
75.858	0.2626	0.2802	6.69	0.2726	3.80
77.625	0.2539	0.2698	6.27	0.2628	3.50
79.433	0.2467	0.2637	6.87	0.2570	4.15
81.284	0.2423	0.2698	11.36	0.2565	5.85
83.177	0.2379	0.2629	10.50	0.2512	5.58
85.114	0.2336	0.2506	7.28	0.2430	4.04
87.097	0.2294	0.2355	2.65	0.2343	2.15
89.126	0.2252	0.2333	3.56	0.2364	4.97
91.202	0.2212	0.2309	4.41	0.2334	5.55
93.326	0.2172	0.2320	6.82	0.2444	12.56
95.500	0.2132	0.2355	10.42	0.2475	16.08
97.724	0.2094	0.2410	15.10	0.2430	16.05
100.000	0.2056	0.2384	15.95	0.2359	14.71

TABLE 1-2

COMPARISON OF THE RESPONSE SPECTRA OF THE INPUT TIME HISTORY AND THE TARGET RESPONSE SPECTRA ALONG THE VERTICAL DIRECTION

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
0.100	0.0032	0.0034	5.31
0.102	0.0033	0.0035	6.31
0.105	0.0035	0.0037	7.20
0.107	0.0036	0.0039	7.18
0.110	0.0038	0.0040	6.90
0.112	0.0039	0.0042	6.36
0.115	0.0041	0.0043	5.62
0.118	0.0043	0.0045	5.62
0.120	0.0044	0.0048	7.21
0.123	0.0046	0.0050	7.13
0.126	0.0048	0.0051	6.22
0.129	0.0050	0.0053	5.39
0.132	0.0052	0.0054	4.62
0.135	0.0054	0.0056	3.35
0.138	0.0056	0.0057	1.25
0.141	0.0058	0.0059	1.73
0.145	0.0060	0.0063	4.33
0.148	0.0062	0.0067	7.40
0.151	0.0065	0.0071	9.61
0.155	0.0067	0.0074	10.93
0.159	0.0069	0.0077	11.26
0.162	0.0072	0.0080	11.00
0.166	0.0074	0.0082	9.95
0.170	0.0077	0.0084	8.44
0.174	0.0080	0.0086	7.77
0.178	0.0083	0.0089	7.26
0.182	0.0086	0.0092	6.88
0.186	0.0089	0.0094	6.43
0.191	0.0092	0.0097	5.55
0.195	0.0095	0.0099	4.41
0.200	0.0099	0.0102	3.55

Frequency (Hz)	FIRS Acceleration (g)	Vertical Response Spectra Acceleration (g)	Difference (%)
0.204	0.0102	0.0105	3.23
0.209	0.0105	0.0109	3.23
0.214	0.0109	0.0112	3.13
0.219	0.0112	0.0116	3.21
0.224	0.0116	0.0120	3.54
0.229	0.0119	0.0124	4.10
0.234	0.0123	0.0129	4.79
0.240	0.0127	0.0134	5.35
0.246	0.0131	0.0139	6.18
0.251	0.0135	0.0144	6.65
0.257	0.0140	0.0149	6.88
0.263	0.0144	0.0153	6.61
0.269	0.0148	0.0157	5.74
0.275	0.0152	0.0159	4.66
0.282	0.0157	0.0162	3.19
0.288	0.0161	0.0164	1.49
0.295	0.0166	0.0167	0.72
0.302	0.0171	0.0173	1.05
0.309	0.0176	0.0178	1.20
0.316	0.0181	0.0185	2.05
0.324	0.0186	0.0194	4.03
0.331	0.0191	0.0202	5.33
0.339	0.0197	0.0207	5.44
0.347	0.0202	0.0211	4.21
0.355	0.0208	0.0212	2.26
0.363	0.0213	0.0217	1.83
0.372	0.0219	0.0225	2.51
0.380	0.0225	0.0241	6.84
0.389	0.0232	0.0260	12.14
0.398	0.0238	0.0278	16.90
0.407	0.0245	0.0290	18.40
0.417	0.0251	0.0299	18.83
0.427	0.0258	0.0307	19.24
0.437	0.0265	0.0305	15.46
0.447	0.0272	0.0301	10.79
0.457	0.0279	0.0293	5.17

Frequency (Hz)	FIRS Acceleration (g)	Vertical Response Spectra Acceleration (g)	Difference (%)
0.468	0.0286	0.0295	3.29
0.479	0.0293	0.0311	5.86
0.490	0.0301	0.0332	10.13
0.501	0.0308	0.0349	13.23
0.513	0.0311	0.0352	12.98
0.525	0.0314	0.0340	8.18
0.537	0.0317	0.0333	4.82
0.550	0.0320	0.0337	5.09
0.562	0.0323	0.0339	4.89
0.575	0.0326	0.0343	5.12
0.589	0.0330	0.0359	8.98
0.603	0.0333	0.0339	1.86
0.617	0.0336	0.0326	-2.95
0.631	0.0339	0.0344	1.50
0.646	0.0342	0.0360	5.08
0.661	0.0346	0.0367	6.11
0.676	0.0348	0.0373	7.15
0.692	0.0349	0.0379	8.45
0.708	0.0350	0.0377	7.71
0.724	0.0351	0.0369	4.89
0.741	0.0353	0.0365	3.40
0.759	0.0354	0.0364	2.97
0.776	0.0355	0.0365	2.99
0.794	0.0356	0.0372	4.55
0.813	0.0357	0.0384	7.57
0.832	0.0358	0.0385	7.46
0.851	0.0359	0.0374	4.32
0.871	0.0357	0.0374	4.68
0.891	0.0355	0.0379	7.00
0.912	0.0352	0.0383	8.60
0.933	0.0350	0.0389	11.23
0.955	0.0348	0.0392	12.74
0.977	0.0345	0.0387	12.16
1.000	0.0343	0.0384	12.07
1.023	0.0350	0.0393	12.44
1.047	0.0357	0.0393	10.17

Frequency (Hz)	FIRS Acceleration (g)	Vertical Response Spectra Acceleration (g)	Difference (%)
1.072	0.0364	0.0396	8.93
1.097	0.0371	0.0404	8.95
1.122	0.0379	0.0409	8.01
1.148	0.0386	0.0415	7.49
1.175	0.0394	0.0420	6.58
1.202	0.0402	0.0435	8.34
1.230	0.0410	0.0444	8.50
1.259	0.0418	0.0450	7.81
1.288	0.0426	0.0463	8.59
1.318	0.0434	0.0456	5.00
1.349	0.0443	0.0444	0.27
1.380	0.0452	0.0447	-0.95
1.413	0.0460	0.0484	5.35
1.445	0.0468	0.0510	8.94
1.479	0.0476	0.0518	8.76
1.514	0.0484	0.0513	5.92
1.549	0.0493	0.0508	3.12
1.585	0.0502	0.0500	-0.32
1.622	0.0511	0.0537	5.09
1.660	0.0520	0.0564	8.56
1.698	0.0529	0.0591	11.78
1.738	0.0538	0.0594	10.44
1.778	0.0547	0.0576	5.27
1.820	0.0556	0.0632	13.66
1.862	0.0565	0.0661	17.12
1.906	0.0574	0.0665	15.91
1.950	0.0583	0.0638	9.35
1.995	0.0592	0.0622	5.07
2.042	0.0602	0.0628	4.37
2.089	0.0611	0.0641	4.86
2.138	0.0621	0.0653	5.14
2.188	0.0631	0.0704	11.50
2.239	0.0641	0.0708	10.58
2.291	0.0650	0.0674	3.80
2.344	0.0659	0.0693	5.13
2.399	0.0668	0.0714	6.92

Frequency (Hz)	FIRS Acceleration (g)	Vertical Response Spectra Acceleration (g)	Difference (%)
2.455	0.0677	0.0712	5.05
2.512	0.0688	0.0752	9.30
2.570	0.0703	0.0792	12.60
2.630	0.0718	0.0826	14.98
2.692	0.0734	0.0770	4.93
2.754	0.0750	0.0783	4.40
2.818	0.0766	0.0827	7.93
2.884	0.0783	0.0877	12.02
2.951	0.0800	0.0889	11.14
3.020	0.0818	0.0851	4.04
3.090	0.0835	0.0949	13.55
3.162	0.0854	0.0973	14.05
3.236	0.0872	0.0916	5.02
3.311	0.0891	0.0991	11.18
3.389	0.0911	0.1054	15.72
3.467	0.0930	0.1037	11.50
3.548	0.0951	0.1028	8.14
3.631	0.0974	0.1125	15.50
3.715	0.0998	0.1104	10.66
3.802	0.1023	0.1113	8.86
3.891	0.1048	0.1107	5.67
3.981	0.1074	0.1125	4.72
4.074	0.1100	0.1170	6.35
4.169	0.1128	0.1241	10.05
4.266	0.1156	0.1222	5.75
4.365	0.1184	0.1289	8.82
4.467	0.1214	0.1281	5.50
4.571	0.1250	0.1372	9.74
4.677	0.1294	0.1395	7.79
4.786	0.1339	0.1421	6.10
4.898	0.1386	0.1440	3.89
5.012	0.1433	0.1517	5.83
5.129	0.1466	0.1611	9.88
5.248	0.1499	0.1619	8.02
5.370	0.1533	0.1736	13.24
5.495	0.1568	0.1799	14.76

Frequency (Hz)	FIRS Acceleration (g)	Vertical Response Spectra Acceleration (g)	Difference (%)
5.623	0.1604	0.1670	4.15
5.754	0.1640	0.1713	4.44
5.889	0.1677	0.1773	5.73
6.026	0.1715	0.1847	7.69
6.166	0.1754	0.1864	6.25
6.310	0.1794	0.1876	4.58
6.457	0.1835	0.1939	5.69
6.607	0.1876	0.1998	6.51
6.761	0.1919	0.2037	6.14
6.918	0.1962	0.2036	3.77
7.080	0.2007	0.2105	4.87
7.244	0.2053	0.2203	7.33
7.413	0.2099	0.2198	4.72
7.586	0.2143	0.2252	5.06
7.763	0.2185	0.2294	4.97
7.943	0.2228	0.2342	5.15
8.128	0.2271	0.2404	5.85
8.318	0.2315	0.2459	6.21
8.511	0.2361	0.2469	4.61
8.710	0.2407	0.2522	4.78
8.913	0.2453	0.2602	6.07
9.120	0.2501	0.2669	6.72
9.333	0.2550	0.2629	3.09
9.550	0.2600	0.2683	3.20
9.772	0.2650	0.2816	6.24
10.000	0.2702	0.2836	4.94
10.233	0.2760	0.2650	-3.97
10.471	0.2818	0.2948	4.61
10.715	0.2878	0.2998	4.17
10.965	0.2939	0.3060	4.10
11.220	0.3002	0.3203	6.70
11.482	0.3066	0.3214	4.85
11.749	0.3129	0.3247	3.78
12.023	0.3172	0.3333	5.08
12.303	0.3217	0.3409	5.98
12.589	0.3262	0.3420	4.84

Frequency (Hz)	FIRS Acceleration (g)	Vertical Response Spectra Acceleration (g)	Difference (%)
12.883	0.3308	0.3429	3.67
13.183	0.3354	0.3517	4.85
13.490	0.3401	0.3545	4.24
13.804	0.3449	0.3673	6.51
14.125	0.3497	0.3744	7.07
14.455	0.3546	0.3708	4.57
14.791	0.3596	0.3695	2.76
15.136	0.3637	0.3827	5.23
15.488	0.3675	0.3835	4.36
15.849	0.3714	0.3845	3.53
16.218	0.3753	0.3907	4.11
16.596	0.3792	0.3977	4.86
16.983	0.3832	0.3993	4.20
17.378	0.3873	0.4005	3.42
17.783	0.3914	0.4199	7.30
18.197	0.3955	0.4173	5.51
18.621	0.3996	0.4052	1.38
19.055	0.4047	0.4198	3.72
19.499	0.4111	0.4284	4.21
19.953	0.4176	0.4346	4.06
20.418	0.4242	0.4401	3.75
20.893	0.4309	0.4470	3.73
21.380	0.4377	0.4549	3.92
21.878	0.4446	0.4613	3.76
22.387	0.4517	0.4721	4.53
22.909	0.4588	0.4808	4.80
23.442	0.4660	0.4872	4.55
23.989	0.4734	0.4936	4.27
24.547	0.4809	0.5036	4.73
25.119	0.4870	0.5041	3.50
25.704	0.4877	0.5041	3.38
26.303	0.4883	0.5069	3.80
26.916	0.4890	0.5118	4.67
27.542	0.4896	0.5107	4.31
28.184	0.4903	0.5110	4.23
28.841	0.4909	0.5150	4.91

Frequency (Hz)	FIRS Acceleration (g)	Vertical Response Spectra Acceleration (g)	Difference (%)
29.512	0.4916	0.5135	4.46
30.200	0.4922	0.5177	5.18
30.903	0.4942	0.5186	4.92
31.623	0.4968	0.5243	5.53
32.360	0.4994	0.5246	5.05
33.113	0.5020	0.5263	4.85
33.885	0.5046	0.5257	4.20
34.674	0.5072	0.5233	3.17
35.482	0.5098	0.5280	3.57
36.308	0.5124	0.5325	3.92
37.154	0.5151	0.5359	4.03
38.019	0.5177	0.5381	3.94
38.905	0.5172	0.5400	4.42
39.811	0.5113	0.5395	5.51
40.738	0.5055	0.5282	4.48
41.687	0.4998	0.5277	5.58
42.658	0.4942	0.5048	2.15
43.652	0.4886	0.5140	5.20
44.669	0.4831	0.5016	3.83
45.709	0.4776	0.4930	3.22
46.774	0.4722	0.4888	3.51
47.863	0.4669	0.4825	3.34
48.978	0.4615	0.4756	3.05
50.119	0.4523	0.4754	5.12
51.287	0.4433	0.4672	5.40
52.481	0.4344	0.4630	6.58
53.704	0.4257	0.4483	5.31
54.954	0.4172	0.4405	5.58
56.235	0.4089	0.4270	4.43
57.544	0.4008	0.4109	2.53
58.885	0.3928	0.4024	2.45
60.256	0.3849	0.3927	2.02
61.660	0.3773	0.3856	2.20
63.096	0.3649	0.3713	1.74
64.566	0.3509	0.3542	0.93
66.070	0.3375	0.3466	2.72

FREQUENCY (HZ)	FIRS ACCELERATION (G)	VERTICAL RESPONSE SPECTRA ACCELERATION (G)	DIFFERENCE (%)
67.609	0.3245	0.3333	2.70
69.184	0.3120	0.3187	2.13
70.795	0.3001	0.3074	2.44
72.444	0.2886	0.2940	1.88
74.132	0.2775	0.2819	1.60
75.858	0.2668	0.2756	3.28
77.625	0.2566	0.2696	5.08
79.433	0.2475	0.2584	4.40
81.284	0.2400	0.2460	2.50
83.177	0.2327	0.2367	1.68
85.114	0.2257	0.2315	2.55
87.097	0.2189	0.2267	3.59
89.126	0.2123	0.2220	4.59
91.202	0.2059	0.2176	5.68
93.326	0.1997	0.2116	5.97
95.500	0.1936	0.2071	6.98
97.724	0.1878	0.2014	7.26
100.000	0.1821	0.1957	7.45

4) FSAR Section 3.7.1 (page 3-30) indicates that soil liquefaction is not an issue for the ESWEMS Pumphouse since the structure is located on a concrete backfill overlying the Mahantango formation. Please provide information on the extent of the concrete fill under the structure and whether there will be any soil backfill or in-situ material to the sides of the structure that is susceptible to liquefaction. If liquefaction can occur, describe the impact on the assessment of sliding stability and structural wall loads. Perform a similar assessment for the other seismic Category I structures at the BBNPP site.

Response

FSAR Figure 3.7-138 indicates the presence of concrete fill from the surface grade elevation down to a depth of 34 feet or down to contact with bedrock. The site investigation located pockets of loose sands that could be susceptible to liquefaction. Therefore, engineered fill will be placed around the building after excavation of the in-situ soils. Liquefaction of the engineered fills will be prevented by fill construction controls and compaction adherence to a unit weight above 95 percent of the Modified Proctor optimum value.

COLA Impact

No changes to the COLA are required by this RAI response.

03.07.02-1

Bell Bend Nuclear Power Plant (BBNPP) combined license (COL) Final Safety Analysis Report (FSAR) Section 3.7.2, page 3-39, states that a COL applicant that references the U.S. EPR design certification will confirm that the site-specific seismic response is within the parameters of Section 3.7 of the U.S. EPR standard design. The FSAR addresses the COL item by stating, on page 3-40, that the site-specific Nuclear Island (NI) basemat response spectra, response spectra at the Emergency Power Generating Buildings' (EPGB) and Emergency Service Water Buildings' (ESWB) footprints, In-Structure Response Spectra (ISRS) and maximum accelerations represent a departure from the U.S. EPR FSAR, as described in Section 3.7.1.1.1 and augment the response spectra and maximum accelerations in the U.S. EPR FSAR. Please explain how NI basemat response spectra, response spectra at the EPGB and ESWB footprints, ISRS and maximum accelerations are used to augment the analysis that was done for the U.S. EPR Certified Design by providing specific examples of their application to the design of U.S. EPR structures, systems, and components (SSCs) at the BBNPP site.

Response

A response to this question will be provided by 2/17/2010.

03.07.02-2

FSAR Section 3.7.2 (Seismic System Analysis) on page 3-39, provides a description of a dynamic finite element model (ANSYS) of the NI Common Basemat Structures, which is based on the detailed static finite element model. A compatibility check showing a comparison of results between the dynamic and static finite element model is provided in Figures 3.7-99 through 3.7-116.

(1) Describe the input that was used to provide the comparison of results, and provide the response spectra of the input motion used in the dynamic analysis.
(2) Describe why a separate dynamic model was necessary, and reconcile the exceedances of the static model results with the dynamic model results.
(3) Explain the legends at the bottom of each figure and explain why in many cases multiple results for both static and dynamic models are provided in Figures 3.7-99 through 3.7-116.
(4) Is the static model referred to in the BBNPP FSAR the same as the one used for the certified design of the U.S. EPR standard plant? If not, identify the differences and describe the impact these differences have on the U.S. EPR certified design.
(5) The static loads representing dead and live loads from the static finite element model are converted to masses for the dynamic finite element model.
   (a) What percentage of these loads is used to represent additional mass in the dynamic model?
   (b) Does the application of these additional masses meet SRP Acceptance Criteria 3.D of SRP Section 3.7.2? If not, provide justification.

Response

A response to this question will be provided by 12/17/2009.

03.07.02-3

FSAR Section 3.7.2 on page 3-39 describes a number of site-specific changes that have been made to the seismic models described in the U.S. EPR FSAR. To assist the staff in its review of FSAR Section 3.7.2, provide in a table format:

(1) The structure being modeled;
(2) The type of model (stick or FEM):
(3) The computer code used;
(4) The purpose of the analysis;
(5) Whether the model proposed for use at BBNPP is identical to the model used for the U.S. EPR certified design; and
(6) If site-specific changes have been made to the U.S. EPR design certification model for the BBNPP, identify the changes and provide supporting reasons for the changes.

Response

A response to this question will be provided by 12/17/2009.

03.07.02-4

FSAR Section 3.7.2 states on page 3-39 that section properties of the stick models for both the reactor building internal structure (RBIS) and reactor containment building (RCB) were modified to capture the response due to the high frequency content of the ground motion response spectra (GMRS).

(1) (a) As this site-specific modification represents a departure from the U.S. EPR design basis, describe how the RBIS and RCB models were modified; and
(b) Describe how these changes allow capture of the high frequency input contained in the GMRS.

(2) Provide comparisons of the new site-specific models to the EPR certified design models which illustrate the site-specific changes that were made.

(3) (a) If used in the U.S. EPR seismic analysis, would the revised RBIS and RCB stick models change the seismic results presented in the U.S. EPR FSAR?; and
(b) if so, describe the nature of the change and explain why the seismic results of the U.S. EPR certified design are still valid.

(4) The NRC Interim Staff Guidance (COL/DC-ISG-1, Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications, May 2008) indicates that structural models should have the capability to capture responses to at least 50 Hz. As the GMRS has a zero period acceleration (ZPA) greater than 50 Hz, explain how the change to a dynamic finite element model (FEM) for the NI common basemat structures captures frequencies of up to at least 50 Hz and identify the cutoff frequency used in the seismic analysis of this structure.

Response

A response to this question will be provided by 12/17/2009.

03.07.02-5

FSAR Section 3.7.2 states on page 3-40 that an input motion called G1.1 was used as a study motion to compare the ISRS at key locations of the RBIS and RCB between the concrete-only stick models, the static finite element models and, in the case of the RCB, the dynamic finite element model. The FSAR also states the G1.1 has frequency content similar to that of the BBNPP GMRS.

(1) Provide a comparison of the response spectrum of the G1.1 input motion with the GRMS base-lined to the same ZPA.
(2) Describe the development of the G1.1 input motion and how it meets SRP Acceptance Criteria 1.B of SRP Section 3.7.1.
(3) Explain why G1.1 was used for this study rather than the BBNPP GMRS.

Response

A response to this question will be provided by 2/17/2010.

03.07.02-6

FSAR Section 3.7.2 states on page 3-40 that the ESWB model has the same number of modes and elements as the original model, except for node re-sequencing and the reshaping of the elements.

(1) Please explain the reasons for renumbering the nodes and reshaping the elements, and explain what impact these changes have on the natural frequencies of the original model.

(2) Why is it valid to compare the ESWB seismic analysis results from the U.S. EPR certified design with those from the BBNPP site, when in each case different models were used for this structure?

Response

A response to this question will be provided by 2/17/2010.

03.07.02-7

FSAR Section 3.7.2 states on page 3-40 that for the EPGB, the soil structure interaction (SSI) model is a refined FEM and represents a departure from the U.S. EPR FSAR.

(1) Describe the site-specific changes to the model and why they were made.
(2) Will physical changes be made to the building (EPGB) described in the U.S. EPR FSAR? If so, explain the reasons for these changes and why they are necessary.
(3) Explain why a comparison of ISRS values and ZPA values in the BBNPP FSAR and the U.S. EPR FSAR remain valid, since in each case a different structure and seismic model was used.
(4)(a) Are the original design loads and critical sections presented in the U.S. EPR FSAR still valid for the BBNPP site?
(b) If not, describe the differences between the U.S. EPR EPGB and the BBNPP EPGB, and provide reasons why the BBNPP EPGB should not be considered as a site-specific structure.
(5) Provide the basis for the design loads and ISRS for the BBNPP EPGB.

Response

A response to this question will be provided by 12/17/2009.

03.07.02-8

FSAR Section 3.7.2 states on page 3-40 that the 26 Hz cutoff frequency is deemed sufficient for the BBNPP ESWB, as it is governed by low frequency input motion and there is no high frequency sensitive equipment currently identified for this structure. Since the GMRS has a ZPA that exceeds 50 Hz, provide the following information regarding this structure.

(1) How was this cutoff frequency determined?
(2) How was the NRC Interim Staff Guidance (COL/DC-ISG-1, May 2008) considered in determining the cutoff frequency?
(3) List and describe the equipment, including breakers and control modules, which will be located in the BBNPP ESWB, and identify the frequency range for which the equipment will need to be seismically qualified.
(4) For the BBNPP ESWB, provide a comparison of the difference(s) in the BBNPP ESWB response and ISRS between a 26 Hz cutoff frequency and 50 Hz cutoff frequency.
(5) Table 3.7.2-7 of the U.S. EPR FSAR identifies slabs with cutoff frequencies above 26 Hz.
   (a) What is the impact of higher frequencies on the design loads for these slabs?
   (b) Were these higher frequencies considered?
   (c) If not, provide justification for omitting this analysis.?
(6) Since the BBNPP EPGB used a cutoff frequency of 50 Hz, please explain why the same cutoff frequency wasn't used for the BBNPP ESWB.

Response

A response to this question will be provided by 2/17/2010.

03.07.02-9

FSAR Section 3.7.2.1.2, page 3-41, provides a description of the seismic design evaluation of the BBNPP Essential Service Water Emergency Makeup System (ESWEMS) Pumphouse.

1) For clarification, provide a figure of the dynamic analysis model in the FSAR including the boundary conditions and the point of application of the input motion.

Response

Figure 1-1 below provides the dynamic Soil Structure Interaction (SSI) Model.

Figure 1-2 shows the boundary conditions for the GT-STRUDL model used in the Response Spectrum analysis.

These figures will be included in a future revision of the FSAR.

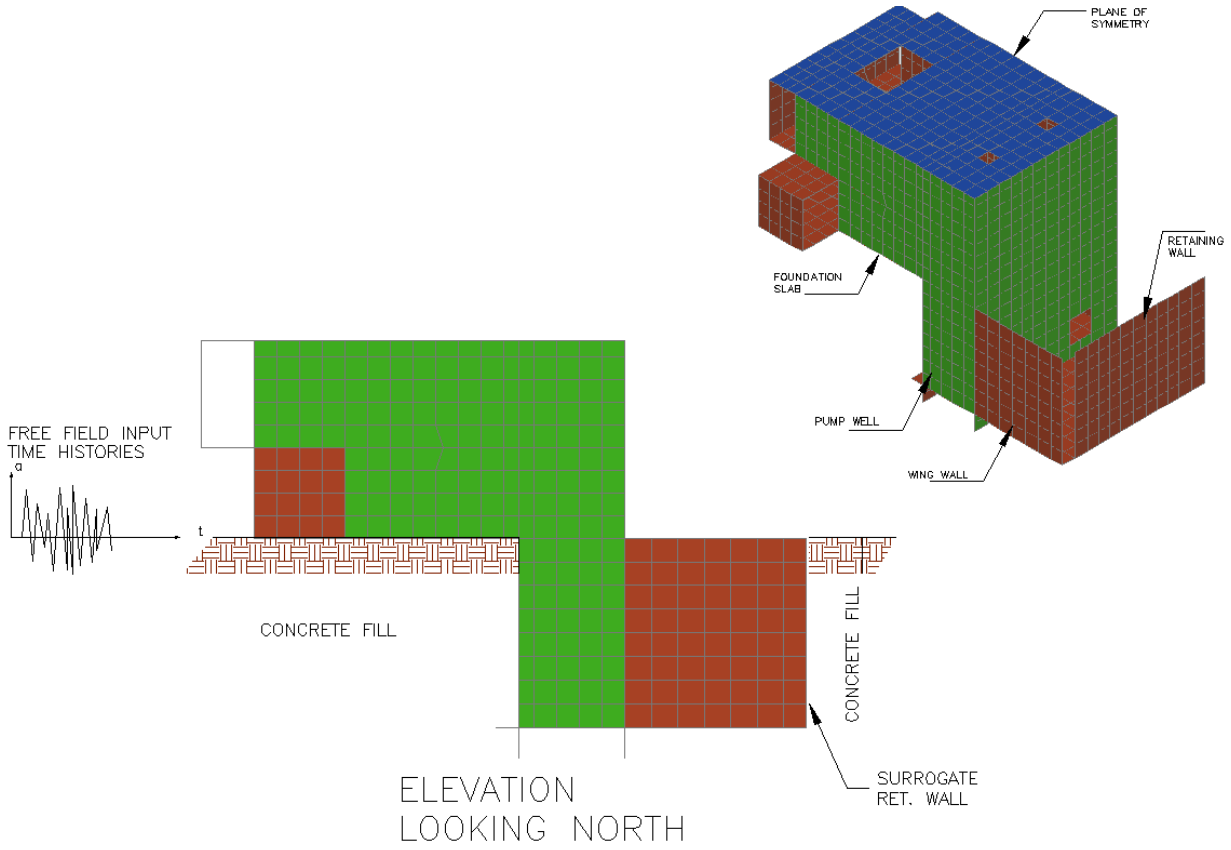


FIGURE 1-1

DYNAMIC SOIL STRUCTURE INTERACTION MODEL

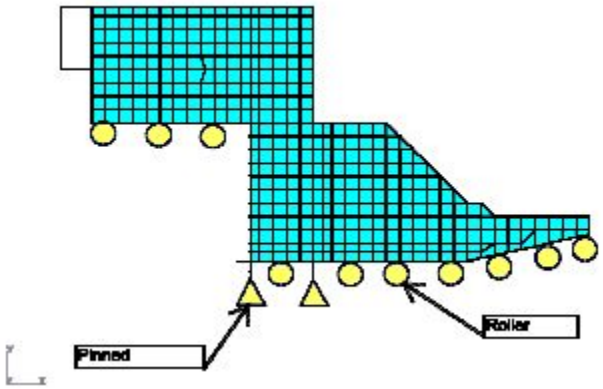


FIGURE 1-2

BOUNDARY CONDITIONS OF THE GT-STRUDL MODEL

2) Provide a description and basis for the soil springs used to support the model.

Response
As shown in Figure 1-2, pinned and roller supports were used to idealize the pumphouse founded on concrete backfill and/or on top of Mahantango formation. The soil springs were not used given the rigidity concrete backfill and/or Mahantango formation. Hence, rigid supports are considered appropriate.

3) FSAR Section 3.7.2.1.2 (Response Spectrum Method) states on page 3-41 that Figure 3.7-1 presents the response spectrum at 5 percent damping used in the analysis of the ESWEMS. The referenced figure is actually the GMRS. Is this the correct reference? If not, provide the correct reference in the FSAR.

Response
FSAR Section 3.7.2.1.2 inadvertently lists Figure 3.7-1 as presenting the response spectrum at 5 percent damping used in the Response Spectrum analysis of the ESWEMS. The referenced figure should have been Figure 3.7-131 (Concrete Back Fill) as the input FIRS. It is noted that actual analysis has used engineered back fill rather than concrete back fill (Figure 3.7-131) as the input FIRS. The comparison of the input FIRS (FIRS Back Fill) with FSAR Figure 3.7-131 (FIRS Concrete Fill) is included in Figures 3.7-131 It can be seen that the input FIRS (Back Fill) for the design of the ESWEMS Pumphouse enveloped the required FIRS (Concrete Fill) by a wide margin for frequencies beyond 1.0 Hz.. Therefore, the design is conservative. As a result, subject FSAR Section and Figure 3.7-131 will be revised.

4) In FSAR Section 3.7.2.1.1 (Time History Analysis Method) on page 3-41, there is a reference missing in the second sentence. Correct the FSAR to include the reference.

Response

The correction for the missing FSAR section is provided in the COLA Impact section of this response.

COLA Impact

3.7.2.1.1 Time History Analysis Method

The seismic analysis of the ESWEMS Pumphouse including soil structure interaction is performed in the frequency domain at selected analysis frequencies utilizing the program SASSI. The model was built with the same geometry, except that a symmetrical plane was introduced and the apron slab was cut to reduce the computation time. Figure 1-1 shows the mathematical representation of the model. This analysis uses the three ground motion time histories

described in ~~above~~ Section 3.7.1.1.2 to represent the design basis seismic ground motion in the three orthogonal directions. The time histories represent the control motions at the free field soil surface of the soil-structure system.

The seismic evaluation of the ESWEMS Retention Pond is based on slope stability analyses of various sections of the sides of the ESWEMS Retention Pond. The slope stability analyses include the effects of horizontal seismic acceleration on potential failure blocks. The slope stability analysis and the factors of safety are reported in Section 2.5.5.

3.7.2.1.2 Response Spectrum Method

The seismic design evaluation for the ESWEMS Pumphouse is based on response spectrum analysis. The analysis uses the calculated FIRS at 669 ft msl (203.9 m). Figure 3.7-131 presents this response spectrum at 5% damping.

.FSAR Figure 3.7-131 will be replaced with the following:

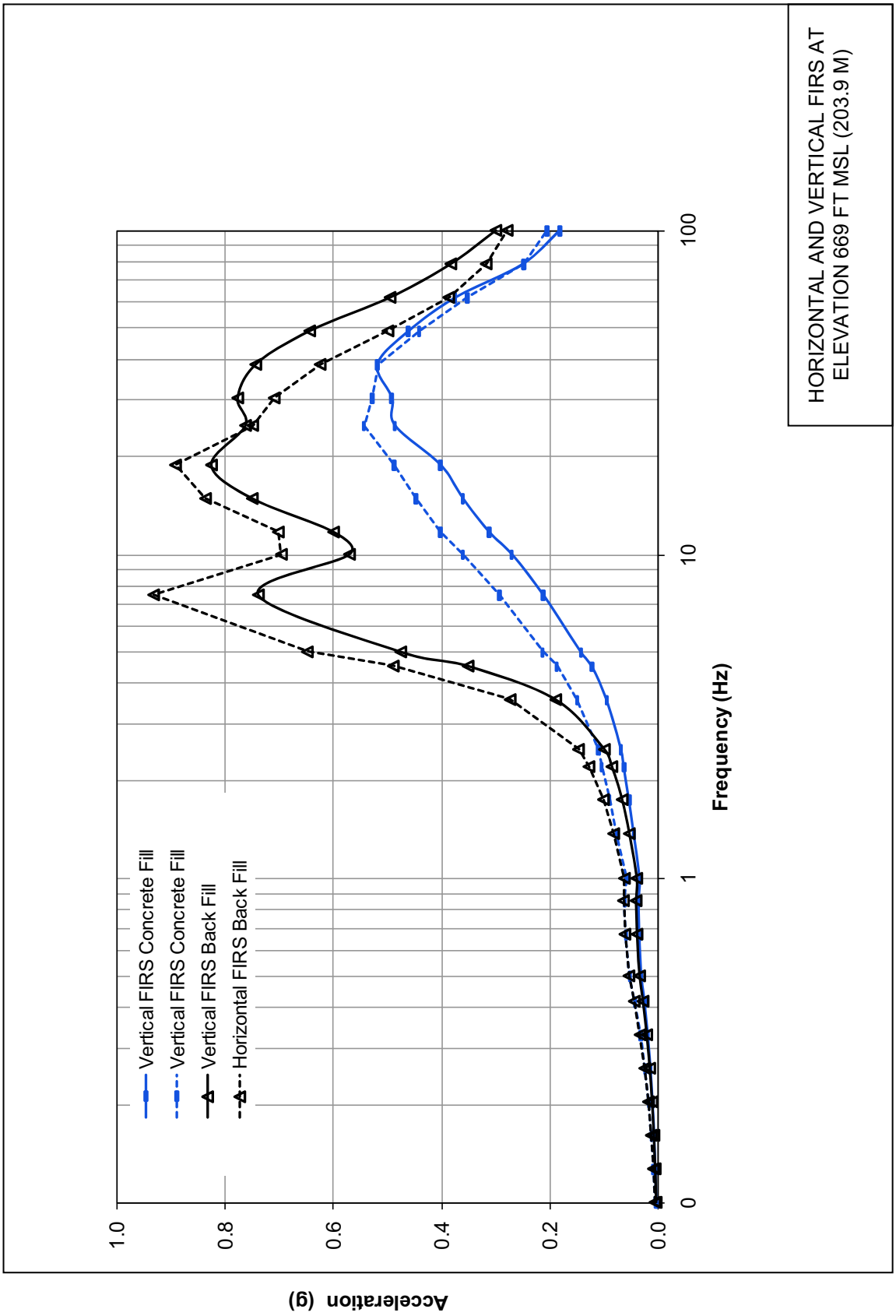


Figure 3.7-131 {Horizontal and Vertical Firs at Elevation 669 ft msl (203.9 m)}

FSAR 3.7.2.4, third paragraph after bullet list:

Details of the analysis method are described in Section 3.7.2.4. Figure 1-1 shows the numerical model used in the SSI analysis. The input time history is placed at foundation grade at the base of the upper level.

This Figure will be added to the FSAR:

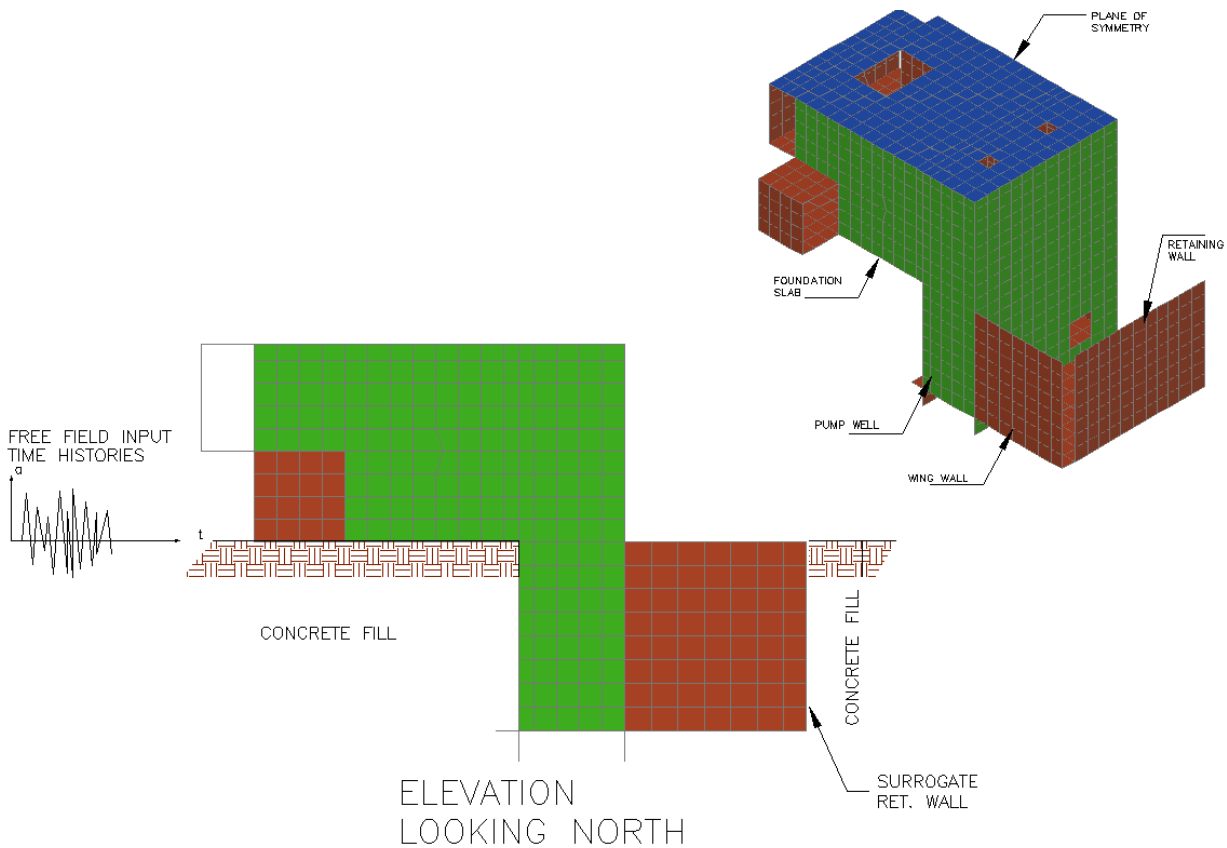


FIGURE 1-1

DYNAMIC SOIL STRUCTURE INTERACTION MODEL

FSAR Section 3.7.2.1.2, second paragraph:

The response spectrum analysis uses GT-Strudl 3-D FEM model for the modal frequency and Response Spectrum (RS) stress analysis. The 3D structural model is outlined in Figure 3.4-2. Figure 1-2 shows a conceptual representation of the boundary conditions. The base-mat founded on concrete backfill is modeled as roller supports. The building shear keys, which are embedded in the Mahantango formation, are modeled as hinged supports.

This Figure will be added to the FSAR:

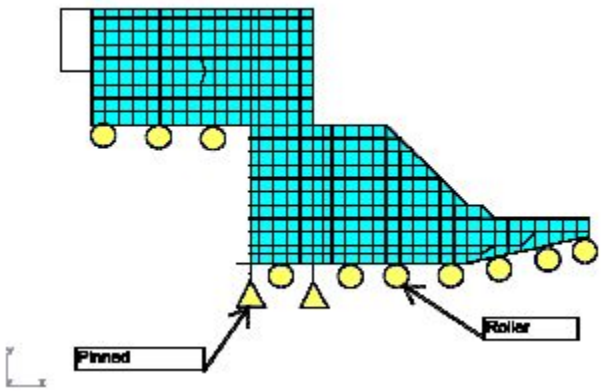


FIGURE 1-2

BOUNDARY CONDITIONS OF THE GT-STRUDL MODEL

03.07.02-10

FSAR Section 3.7.2.1.4 (Equivalent Static Load Method of Analysis) states on page 3-41 that the steel platforms, hangers and/or monorail of the ESWEMS Pumphouse will be analyzed using the equivalent static method during detailed design. It also states that the accelerations for this analysis are determined directly from the soil-structure interaction time history analysis of the structure.

1) As upper bound (UB), best estimate (BE) and lower bound (LB) soil profiles were used in the SSI analysis, provide the basis for the selection of the accelerations to be applied to the components listed.

Response

In the Equivalent Static Method of analysis, seismic accelerations are determined directly from applicable In-Structure Response Spectra (ISRS) for ESWEMS Pumphouse – Refer to FSAR Figures 3.7-140 through 3.7-148. These Foundation Input Response Spectra (FIRS) are developed using the envelope of the ISRS obtained with UB, BE and LB soil properties.

2) State whether the application of the three components of earthquake motion meets the guidance of Regulatory Guide 1.92, Combining Modal Responses and Spatial Components in Seismic Response Analysis, Rev. 2 (July 2006) (RG 1.92), and include a description of how out-of-plane motion is accounted for in the analysis of these components.

Response

The Equivalent Static Analysis applies the inertia loads in all three directions of earthquake motions. Each direction is calculated separately and independently. Subsequently, the method combines similar forces and moments using the Square Root of the Sum of the Squares (SRSS) procedure, which conforms to RG 1.92, Rev. 2. Alternatively, the 100-40-40 percent rule in lieu of the SRSS procedure may be also employed, as permitted in RG 1.92, Rev. 2, pages 7 & 17. Therefore, the out-of-plane motion is accounted for in the combination of spatial components of the earthquake motions.

3) Justify the direct use of the accelerations from the seismic analysis of the building; and

Justify why the peak acceleration from the ISRS at these points multiplied by a factor of 1.5 should not be used for these componentsmultiplied by a factor of 1.5 should not be used for these components.

Response

Seismic accelerations are determined directly from applicable ISRS. If peak seismic responses are used, calculation of fundamental system frequency of the steel platforms, hangers, and/or monorail is not required. Peak seismic acceleration is increased by a factor of 1.5 to account for multi-frequency input motion and multi-mode responses. If the calculated frequency is beyond the cutoff frequency, such as 33 Hz, then Zero

Period Acceleration (ZPA) of the ISRS can be used. The ZPA range does not require the 1.5 multi-mode factor.

COLA Impact

FSAR Section 3.7.2.1.4 will be revised as follows:

The ESWEMS Pumphouse structural components, such as steel platforms, hangers, and/or monorail, will be analyzed using the equivalent static method during detailed design. In the equivalent static analysis, seismic response ~~used~~ accelerations are determined directly from applicable ISRS, resulting from soil-structure interaction time history analysis. If peak seismic responses are used, calculation of fundamental system frequency of the structural components is not required. Peak seismic acceleration is increased by a factor of 1.5 to account for multi-frequency input motion and multi-mode responses. If the calculated frequency is beyond the cutoff frequency, such as 33 Hz, then ZPA of the ISRS can be used. The ZPA range does not require the 1.5 multi-mode factor.

03.07.02-11
FSAR Section 3.7.2.2 ({Natural Frequencies} and Response Loads) states on page 3-42 that seismic loads in the equivalent static analysis are calculated by applying accelerations determined from the SSI time history analysis to the applicable masses in the finite element model. The FSAR then states that a comparison of the nodal accelerations indicates that the response accelerations from the SASSI analysis are enveloped by the effective accelerations used in the response spectrum method.

1) Describe how the loads are determined from the response spectrum analysis method.

Response
The Response Spectrum Method applies the inertia loads in all three directions of earthquake motions. Each direction is calculated separately and independently. Subsequently, the method combines similar forces and moments using the Square Root of the Sum of the Squares (SRSS) procedure, which conforms to RG 1.92, Rev. 2. Alternatively, the 100-40-40 percent rule in lieu of the SRSS procedure may be also employed, as permitted in RG 1.92, Rev. 2, pages 7 & 17.

2) Describe how the loads are used to determine the bending moments, axial forces, and shear forces used in the design of the structure.

Response
The axial and shear forces and moments for the design of the structural components, such as walls, floors, and shear keys of the ESWEMS Pumphouse, are derived from element reactions resulted from Finite Element Model (FEM) analysis. They are tabulated in FSAR Section 3E, Tables 3.4-3 through 3.4-6. The orientation of forces and moments is shown in FSAR, Section 3E, Figure 3.4-3. The reactions are used for design of main reinforcement of concrete structural components.

(3) (a) Describe in the FSAR how modal responses are combined.

Response
The modal responses are combined using the 100-40-40 percent rule, which is an acceptable alternative to SRSS procedure by RG 1.92, Rev. 2.

(b) Explain the extent to which the process used meets the guidance of Regulatory Guide 1.92.

Response
The process for combination of the modal responses meets the guidance of RG 1.92, Rev. 2, pages 7 & 17.

(c) If the methods used for BBNPP do not conform to the RG guidance, provide justification for the method used.

Response
The method used for BBNPP conforms to RG guidance as described above.

(4) The figures referenced are identical and appear to provide nodal identifications for the GT STRUDL FEM. Please identify the reference and/or figure for the FEM model used in the SASSI analysis, and explain why these node points were selected.

Response
The location of the node points in SASSI model are shown on Figure 2-1. The criterion for the selection of these points was to adjust to the closest location of equivalent point nodes in the GT-STRUDL model. FSAR Figure 3.7-150 will be revised to identify the nodal points.

(5) Provide the basis for the design loads of this structure.

Response
The basis for design loads of ESWEMS Pumphouse is described in FSAR Section 3E, Table 3.E-1 Response Spectrum Analysis – Design Load Combinations for ESWEMS Pumphouse Structure.

(6) The foundation input response spectra (FIRS) for this structure has a ZPA of 0.21g horizontal and 0.18g vertical. Please explain why some of the horizontal response accelerations listed in the time history analysis in Table 3.7-7 are less than the ZPA of the FIRS.

Response
The time history Soil-Structure Interaction (SSI) analysis was performed with the computer program SASSI considering a cut off frequency of 50 Hz, while the input time history has frequency contributions in the range of 0.1 to 100 Hz. Table 3.7-7 will be updated in the FSAR. To provide consistency, the analysis was redone with a cut off frequency of 100 Hz to address RAI Question 03.07.01-08 Part 3 and the analysis was re-performed with 4 percent damping. FSAR Figures 3.7-140 through 3.7-148 are being updated with the results from the calculation performed with a cut-off frequency of 100 Hz and damping of 4 percent based on the response to Question 03.07.01-8

(7) (a) Provide a comparison of the natural frequencies and mass participation factors for each of the models.

Response
Although SASSI did not calculate natural frequencies and mass participation factors, the first two natural frequencies can be derived using the transfer functions. Table 1-1 shows the summary of the natural frequencies found for the first two modes, while Figures 1-2 through 1-4 show the transfer function and identified natural frequencies. These results are based on the Best Estimate (BU) set of soil properties.

TABLE 1-1

COMPARISON OF THE RELEVANT NATURAL FREQUENCIES - SASSI ANALYSIS

MODE	FREQUENCY (HZ)		
	E-W	N-S	Vertical
1	24.0	23.8	46.2
2	66.2	51.3	60.0

See Notes for Table 2-1

FIGURE 1-2

TRANSFER FUNCTION AND NATURAL FREQUENCIES IN THE E-W DIRECTION SASSI ANALYSIS

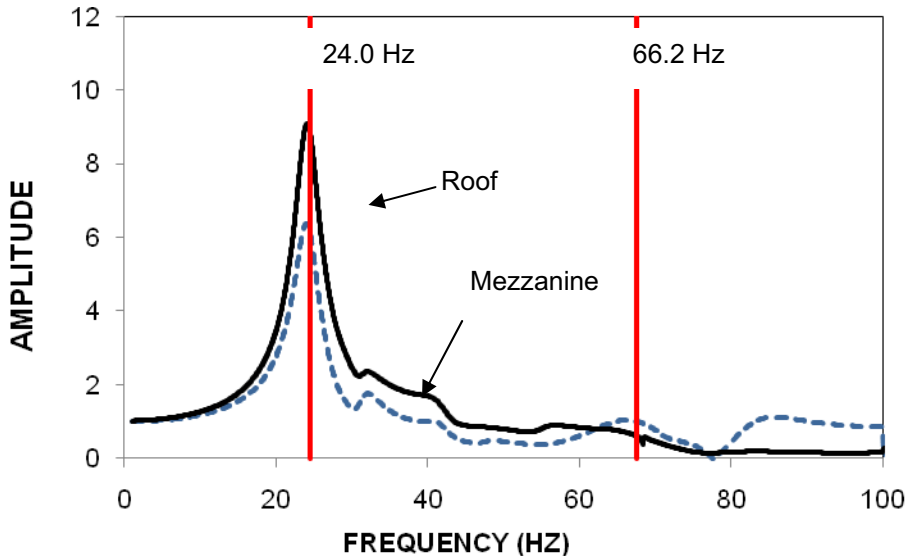


FIGURE 1-3

TRANSFER FUNCTION AND NATURAL FREQUENCIES IN THE N-S DIRECTION SASSI ANALYSIS

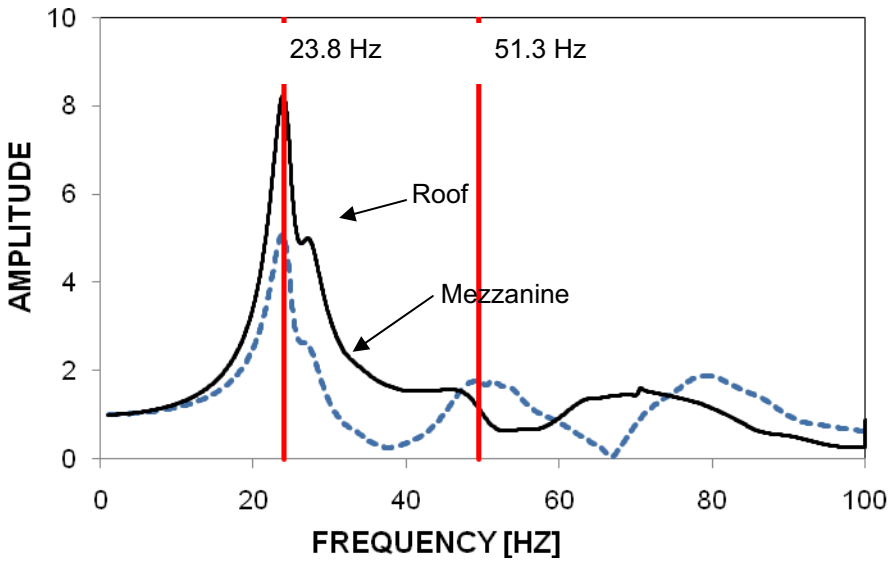


FIGURE 1-4

TRANSFER FUNCTION AND NATURAL FREQUENCIES IN THE VERTICAL DIRECTION
SASSI ANALYSIS

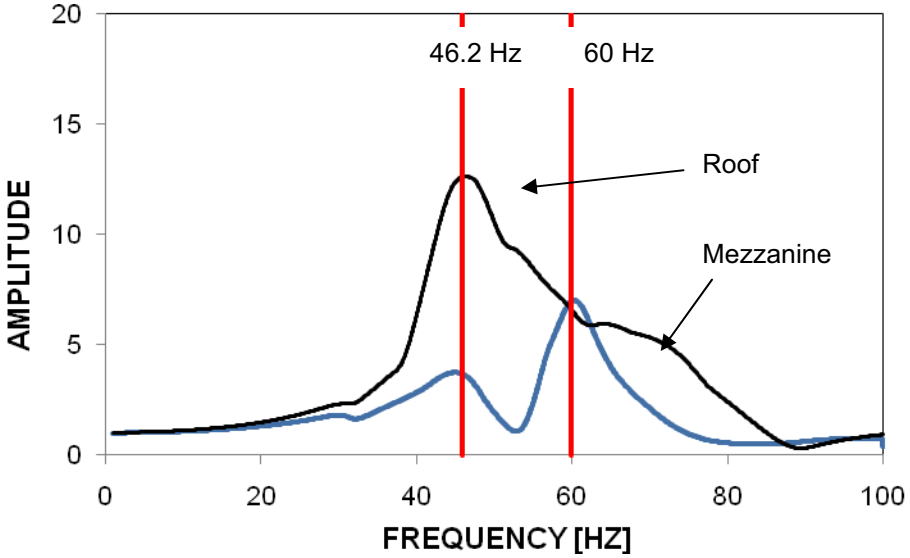


TABLE 2-1

NATURAL FREQUENCIES AND MASS PARTICIPATIONS- RESPONSE SPECTRUM ANALYSIS

Mode	Frequency (Hz)	Mass Participation Percent		
		X (E-W)	Z (N-S)	Y (Vertical)
1	6.76	-	27.42	-
2	8.55	79.18	-	-
3	12.83	-	49.15	-
4	16.70	-	-	-
5	16.75	-	-	-
6	19.73	-	0.92	-
7	27,32	6.27	-	-
8	29.61	1.93	-	1.31
9	30.74	3.63	-	0.95
10	31.30	4.96	-	3.34

Notes for Table 1-1 and Table 2-1:

1) Insignificant mass participations are indicated with "-"
2) The differences in natural frequencies calculated by SASSI and Response Spectrum analyses in horizontal directions because in the later analysis, the boundary conditions of supporting elements representing interface between the foundation mat and the soil beneath are modeled as rollers, which allow lateral translation. In the SASSI model, this condition is not considered.
3) It can be seen in Table 2-1, there is no an important mode in the vertical direction that move the whole building. The two frequencies that are listed in SASSI results per Table 1-1 are related to local vibration mode. The first one is related to movement of the roof, and the second is the movement of the slab in the mezzanine.

(b) Describe any refinement analysis that was performed on the models to meet SRP Acceptance Criteria 3.C.ii of SRP Section 3.7.2.

Response

The Finite Element Model (FEM) model utilizes shell/plate elements comprising 4 nodes (quadrilateral) or 3 nodes (triangular) finite plate elements. These elements have been commonly used for modeling concrete structures. They exhibit out-of-plane bending stiffness together with in-plane membrane stiffness. The element mesh sizes are properly selected so that the aspect ratio is not exceeding three, and the internal angle is not less than 30 degrees. The model of the ESWEMS Pumphouse involves the subdivision of the structure into discrete finite elements, which appropriately represent the structural components, such as walls, slabs, shear keys, etc., and can be assemble into a comprehensive model. The elements are interconnected at nodal points. This analytical idealization has resulted in a three-dimensional FEM computer model, as shown in FSAR Figure 3.7-149 and 3.7-150. In the process of developing the 3D FEM model, geometry plots are used to check element dimensions, their geometry shapes, aspect ratio, skewness or distortion, and warping, etc. The FEM model is a complete three dimensional (3-D) finite element model, which is generally preferred for static and

dynamic analyses of safety-related structures. No refinement analysis has been performed on the models in order to meet SRP Acceptance Criteria 3.C.ii of SRP Section 3.7.2.

(a) If no such refinement analysis was performed, justify the omission of this analysis and explain the accuracy of the results achieved without it.

Response

Although the 3-D FEM model for Response Spectrum Analysis has ignored embedment of pumpwells, the omission does not affect the accuracy of the result analysis. The results have been conservative and no further refinement analysis is required.

COLA Impact:

FSAR Section 3.7 Figures 3.7-140 through 3.7-148 will be revised and are addressed in the Question 03.07.01-8 response.
Other changes will be made to the FSAR as indicated by the following mark-up pages:

3.7.2.2 Natural Frequencies and Response Loads

Table 3.7-7 shows a comparison for selected representative critical locations of the effective nodal accelerations based on the seismic loads implemented in the response spectrum method with the maximum nodal accelerations resulting from the time history analysis method. The nodal locations are shown on Figure 3.7-149 and Figure 3.7-150. Figure 3.7-150 indicates the nodal locations in the SASSI model. The results from the time history analysis method are given for three set of soil properties: lower bound, best estimate and upper bound.

Figure 3.7-105 will be replaced with the following:

Figure 3.7-150 {Isometric View of the ESWEMS Pumphouse – GT-STRUDL Finite Element SASSI Model – Exterior Wall, Roof, and Apron}

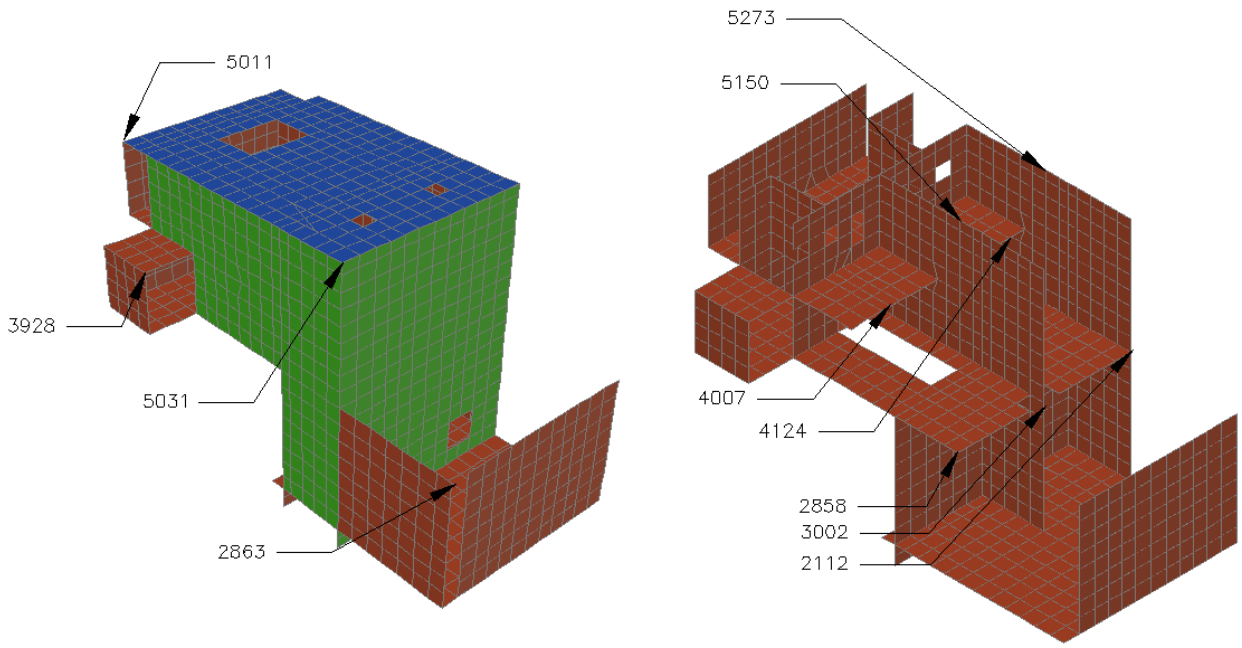


Table 3.7-7 will be replaced with the following:

Table 3.7-7 {Comparison of Nodal Accelerations for Selected Critical Locations in the ESWEMS Pumphouse}

Joint No		Response Spectra Analysis		Time History Analysis Amax (g)		
GT-STRUDL	SASSI	Response direction	Amax (g)	LB	BE	UB
S18	2858	E-W	0.736	0.227	0.241	0.242
2112	2863	E-W	0.691	0.200	0.206	0.216
W318	3002	E-W	0.922	0.246	0.258	0.268
W218	3146	E-W	0.972	0.242	0.255	0.262
zz31	3928	E-W	1.097	0.347	0.363	0.369
M118	4007	E-W	1.063	0.422	0.433	0.453
M109	4124	E-W	1.058	0.397	0.425	0.441
TW200	5011	E-W	1.420	0.698	0.792	0.857
S180	5031	E-W	1.109	0.469	0.514	0.546
W3173	5150	E-W	1.072	0.486	0.537	0.583
W2173	5273	E-W	1.112	0.515	0.575	0.601
S18	2858	N-S	0.848	0.242	0.255	0.268
2112	2863	N-S	2.018	0.202	0.217	0.234
W318	3002	N-S	0.692	0.279	0.287	0.305
W218	3146	N-S	0.544	0.297	0.307	0.317
zz31	3928	N-S	1.096	0.379	0.406	0.439
M118	4007	N-S	1.171	0.439	0.456	0.477
M109	4124	N-S	0.816	0.415	0.434	0.427
TW200	5011	N-S	1.354	0.779	0.864	0.898
S180	5031	N-S	1.118	0.530	0.545	0.569
W3173	5150	N-S	0.906	0.484	0.552	0.634
W2173	5273	N-S	0.754	0.470	0.522	0.606
S18	2858	VERTICAL	0.232	0.197	0.200	0.199
2112	2863	VERTICAL	0.273	0.184	0.184	0.184
W318	3002	VERTICAL	0.315	0.233	0.243	0.246
W218	3146	VERTICAL	0.356	0.239	0.249	0.253
zz31	3928	VERTICAL	0.420	0.210	0.213	0.216
M118	4007	VERTICAL	2.006	0.971	1.032	1.081
M109	4124	VERTICAL	0.692	0.477	0.510	0.540
TW200	5011	VERTICAL	0.780	0.630	0.647	0.640
S180	5031	VERTICAL	0.373	0.246	0.256	0.268
W3173	5150	VERTICAL	0.522	0.381	0.405	0.435
W2173	5273	VERTICAL	0.616	0.400	0.437	0.475

03.07.02-12

FSAR Section 3.7.2.3.2 states on page 3-44 that the hydrodynamic effects on the wing walls are represented as nodal masses, consistent with the constrained mass of water between the wing walls as well as the sloshing component. For seismic motions parallel to the wing walls the mass of the water will behave differently when the ESWEMS pump house is moving away from the pond than when it is moving toward the pond. As both the time history analysis and response spectrum analysis are based on an assumption of linear response, how was the nonlinear response of the water taken into account in each of the analyses of this structure (SASSI and Response Spectrum)?

Response

In the SASSI model, the approach described by Newmark (1971) to consider the hydrodynamic pressure on the wall was used. This method substitutes the water in the pond with virtual masses, fixed to the face of the wall and having the same distribution of the computed hydrodynamic pressure.

Two non-linear effects are identified: potential cavitation associated with negative hydrodynamic pressure, and transient, non-linear distribution of hydrodynamic loads.

When the water is moving away from the wall, the hydrodynamic pressure becomes negative compared to the hydrostatic pressure, decreasing the total absolute pressure (hydrodynamic plus hydrostatic and atmospheric pressure). If the value of the total absolute pressure becomes negative, cavitations could take place at the up-stream face of the wall since water can only exert normal compression against the wall. If cavitation occurs, the analysis approach used in the calculation of the pumphouse would not be conservative. However, it has been documented that cavitation could happen for horizontal accelerations around 0.65g (Chwang, 1979), which is greater than peak ground acceleration of 0.208g used for the SSI analysis. Therefore, cavitation cannot happen according with this criterion, and the approach used in the calculations is valid.

The ESWEMS pumphouse load analysis for the Soil Structure Interaction (SSI) model is based on the condition of steady free surface. In order to account for undulatory motion on the surface, a nonlinear analysis is required (Cheng, 1996). For the particular case of the ESWEMS pumphouse analysis, the non-linearity effect was not accounted for due to the following reasons.

The displacements obtained from the SSI model at the location of the pump well wall facing the pond indicate rigid body motion. This condition is driven by the restriction of the soil behind and beneath the pump well. The estimated displacement at these locations is therefore constant with a ground displacement value of 0.23 ft. The rise of the free surface for this displacement, considering the ESWEMS depth of the steady water of 25 ft. is 0.02 times the height of the wave (Chwang, 1983). Therefore, the required modification of the resultant pressure acting on the wall is negligible (Chwang, 1983). This conclusion is consistent with other studies related to rigid dams for which a negligible effect of the rise of water surface is obtained with a ground displacement equal to 5 percent of the height of the water (Cheng, 1996). Even though this displacement is greater than 2 percent of the height of the water value obtained in the SSI model, the resultant water pressure acting on the structure can be obtained using a hydrodynamic force coefficient equal to 0.525 times the horizontal accelerations (Cheng, 1996). This coefficient is very similar to the reported 0.543 value obtained without considering undulatory surface motion (Newmark, 1971). Therefore, the non-linear

effect of undulatory motion of water surface on the water pressure resultant is negligible and does not need to be incorporated into the SSI model.

COLA Impact

There are no changes to the COLA based on the response to this RAI question.

03.07.02-13

FSAR Section 3.7.2.3.2 states on page 3-43 under 'Analytical Modeling for Response Spectrum Analysis' that if the reaction forces are beyond the capability of the shear key to withstand, then lateral friction forces will be taken into account to reduce the reaction forces.

(1) What is the design capacity of each shear key and what are the reaction loads at the shear key locations?

Response

In accordance with results from Response Spectrum Analysis for ESWEMS Pumphouse, the design capacity of each shear key exceeded the demand forces and moments, which are listed in FSAR Section 3E, Table 3.4-5, "ESWEMS Shear keys Reaction Forces and Moments", by more than 20% and 70% for forces and moments, accordingly.

(2) If the shear key design capacity is exceeded, describe how the lateral friction forces will be taken into account to reduce the reaction forces. In your response, include coefficients of friction and their basis, and assumed dead load; explain whether uplift was considered in determining the available friction reaction force; and address the basis for assuming that the shear key still has some capacity to resist lateral loads.

Response

Load capacity of the shear keys would be exceeded if there is no reduction of reactions from lateral friction force. The frictional force is a product of coefficient of friction and total dead weight of the structures, including equipment, and the weight of water over the apron footprint area. The dead weight of the structure is obtained from GTSTUDL output for dead load. The water weight is calculated based on average depth of 20.5 feet. The coefficient of friction is taken at 0.6 for concrete placed against hardened concrete not intentionally roughed - Reference ACI 349-01, Section 11.7.4.3.

In calculation of the lateral friction, seismic uplift was not considered given following reasons:

- The shear key design is in accordance with shear friction concept in ACI 349-01, Section 11.7. It considered shear transfer across an interface between two concretes cast at different times. It is for static load condition, assuming no sliding would occur.
- The analysis ignored skin frictional resistance to the seismic uplift due to passive soil acting on two side walls of the pump wells. Based on modal responses, the structure is relatively rigid in the vertical direction. There is no major mode, which moves whole building globally. Hence, the seismic uplift force is considered insignificant.

(3) If the shear key reaction forces are exceeded, the response of the structure becomes nonlinear. Please explain how the linear response spectrum analysis method can be used to analyze this nonlinear response.

Response
The shear keys are properly designed in accordance with shear friction concept. The shear keys had enough shear capacity to transfer loads to the bedrock. Interfacing surfaces cannot slide sufficiently to cause non-linear responses of the pumphouse structure.

COLA Impact:

There are no changes to the COLA based on the response to this RAI question.

03.07.02-14

FSAR Section 3.7.2.6 (Three Components of Earthquake Motion) states on page 3-45 that three statistically independent earthquake time histories are used for the SSI analysis of the ESWEMS Pumphouse. For the response spectrum analysis of the ESWEMS Pumphouse, inertia loads are applied in three orthogonal directions and internal forces and moments in the structure from each of these applied earthquakes are combined by the 100-40-40 rule from ASCE Standard 4-98 (ASCE, 1986). The staff has not accepted ASCE 4-98 as providing guidance for the analysis of nuclear power plant structures.

1) Please explain the basis for the formulas used from ASCE Standard 4-98, and why the guidance provided in RG 1.92, Revision 2 was not used.

Response

For Response Spectrum Analysis, both ASCE Standard 4-98 and RG 1.92 accept the application of 100-40-40 rule – Refer to ASCE 4-98, Section 3.2.72, "Combination of Spatial Components for SSI Time History Analysis and RG 1.92, pages 7 and 17. Since the staff has not accepted ASCE 4-98 guidance, its reference will be replaced with a reference to "RG 1.92, Revision 2".

2) Provide the basis for combining the results from the SSI analysis.

Response

The three spatial components were calculated separately and combined according with Square Root of the Sum of the Squares (SRSS) rule. This conforms to RG 1.92.

COLA Impact:

3.7.2.6 Three Components of Earthquake Motion

For the site-specific ESWEMS Pumphouse, three statistically independent time histories are considered in the Soil Structure Interaction (SSI) analysis. Each direction is calculated separately and the maximum values of response are combined according with the Square Root of the Sum of the Squares (SRSS) method. The response spectrum analysis uses the GT-STRUDL finite element model. This analysis applies the inertia loads in all three directions, and subsequently combines similar internal forces and moments using the acceptable ~~ASCE 4-98 (ASCE, 1986)~~ "100-40-40" rule by RG 1.92, Revision 2, to calculate the overall seismic forces and moments for use in the design evaluation of structural components.

03.07.02-15

FSAR Section 3.7.2.3.3 (Seismic Category II Structures) states on page 3-44 that BBNPP utilizes a Seismic Classification of Seismic Category II-SSE (safe-shutdown earthquake) to address Fire Protection structures, systems, and components (SSC) that are relied upon to remain functional during and following a seismic event, in order to support equipment which is relied upon to achieve safe shutdown in accordance with Regulatory Guide 1.189, Fire Protection for Nuclear Power Plants, Rev. 1 (March 2007) (Regulatory Guide 1.189). A similar statement is presented in FSAR Section 3.2.1.2. This new Seismic Category II-SSE classification, however, is not addressed in the SRP, Regulatory Guide 1.189, or other Regulatory Guides. Regulatory Guide 1.189 indicates that fire protection systems are designed to remain functional during and following a safe-shutdown earthquake (SSE) but does not specifically recommend or endorse a new seismic classification.

The NRC Staff requests that the applicant provide the technical basis for introducing and using this new Seismic Category II-SSE classification for the BBNPP design.

Response:

A response to this question will be provided by 12/17/2009.

03.07.02-16

The interaction of non-seismic Category I structures with seismic Category I structures is described in FSAR Section 3.7.2.8. In this section on page 3-46, it states that fire protection SSCs are categorized as either Seismic Category II-SSE, meaning the SSC must remain functional during and after an SSE, or Seismic Category II, meaning the SSC must remain intact after an SSE without deleterious interaction with Seismic Category I or Seismic Category II-SSE SSCs. The U.S. EPR FSAR states on page 3.7-95 that Seismic Category II SSCs are designed using the same criteria as Seismic Category I structures. In SRP Acceptance Criterion 8 of SRP Section 3.7.2, which addresses the interaction of non-Category I structures with Category I SSCs, it states that when non-Category I structures are designed to prevent failure under an SSE event, the margin of safety shall be equivalent to that of the Seismic Category I structure.

(1) (a) Describe how a Seismic Category I margin of safety is achieved for the Seismic Category II-SSE and Seismic Category II portions of the fire protection system. Include in your response the seismic inputs, seismic models, loading combinations, codes and acceptance criteria.
(b) Identify and explain the differences between the methods of analysis, design, and acceptance criteria for Seismic Category II-SSE SSCs and those used for Seismic Category II SSCs.

(2) Describe the basis of the design response spectra used to analyze above ground seismic Category II and seismic Category II-SSE fire protection SSCs, including the fire protection tanks, and provide figures in the FSAR.

(3) (a) Identify and explain the methods of analysis and acceptance criteria for both the buried and above ground portions of the Seismic Category II-SSE fire protection system.
(b) Explain how the applicant will ensure that these portions of the system remain functional following an SSE event.

(4) (a) Identify and explain the modeling and analysis methods used for the fire protection tanks.

(b) To what extent do the fire protection tanks meet SRP Acceptance Criteria 14.A through 14.J of SRP Section 3.7.3?
(c) Where the tank analysis does not meet the SRP Acceptance Criteria 14.A through 14.J of SRP Section 3.7.3, provide the technical justification for not doing so.

Response

A response to this question will be provided by 12/17/2009.

03.07.02-17

FSAR Section 3.7.2.8 states on page 3-47 that the U.S.EPR FSAR Section 3.7.2.8 addresses the interaction of certain Non-Seismic Category I structures with Seismic Category I structures. These structures are the Vent Stack, Nuclear Auxiliary Building (NAB), Access Building (AB), Turbine Building (TB), Radioactive Waste Processing Building (RWPB), the Firewater Storage Tanks, and the Fire Protection Building.

(1) The Fire Protection Tanks and Fire Protection Building are classified as Seismic Category II-SSE in the BBNPP FSAR. The U.S. EPR FSAR classifies these structures as conventional seismic. Clarify whether you intend to depart from this provision of the U.S. EPR FSAR, and if so, describe the departure.

(2) A seismic analysis was performed for the NAB in the U.S. EPR FSAR.

(a) Since the NAB could potentially interact with Seismic Category I structures, reconcile the U.S. EPR analysis with the site-specific analysis of the BBNPP NAB.

(b) Also, demonstrate that the combined displacement of this structure and that of the NI Common Basemat Structure is enveloped by the results of the U.S. EPR analysis.

Response

A response to this question will be provided by 12/17/2009.

03.07.02-18

FSAR Section 3.7.2.8 states on page 3-44 that the Switchgear Building is adjacent to the Turbine Building and is analyzed using the same methodology as that employed for the Turbine Building.

(1) Identify and explain the potential interactions of the Switchgear Building with other Seismic Category I structures.

Response

A response to this question will be provided by 12/17/2009.

(2) Explain what effect the Switchgear Building structure could have on the Turbine Building, which is capable of interacting with Seismic Category I structures.

Response

A response to this question will be provided by 12/17/2009.

(3) To assist the staff in its review, using the SRP Acceptance Criteria 08 of SRP Section 3.7.2, state how the Switchgear Building is analyzed, its seismic input, the codes and acceptance criteria and its factor of safety against collapse.

Response

A response to this question will be provided by 12/17/2009.

(4) Provide an evaluation of the potential interaction of the conventional seismic ESWEMS Pumphouse with other seismic Category I SSCs.

Response

In accordance the U.S. EPR FSAR Section 3.2.1.4, the conventional seismic (SC) classification is not applicable to the ESWEMS Pumphouse. FSAR Section 3.7.1 specifies that the pumphouse is a site-specific Seismic Category I structure, which must be designed to remain functional following a postulated Safe Shutdown Earthquake (SSE). The evaluation of its potential interaction with other Category I SSCs, as required by SRP Section 3.7.2, Acceptance Criteria 08, is not required.

COLA Impact:

There are no COLA changes as a result of this RAI response.

03.07.02-19

FSAR Section 3.7.2.9 (Effect of Parameter Variation on Floor Response Spectra), on page 3-48, describes the effects of parameter variations on floor response spectra and states that to account for uncertainties or variations in parameters, ISRS for the ESWEMS Pumphouse are broadened +/- 15 percent, in accordance with ASCE 4-98 and Regulatory Guide 1.122, Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components, Rev. 1 (February 1978) (RG 1.122). However, the text in FSAR Section 3.7.2.5 only references RG 1.122 and SRP Section 3.7. ASCE 4-98 has not been accepted for use by the staff to develop ISRS, and, in addition, provides methods to account for uncertainties and parameter variations that are not included in the regulatory guide.

1) Provide the specific methods used to account for uncertainties and parameter variations in the analysis, and state whether or not these methods meet the guidance in RG 1.122.

Response

The specific method used to account for uncertainties and parameter variations in the analysis is the broadening of the peaks associated with each structural frequency by ± 15 percent of the frequency at that point. This method conforms to the guidelines prescribed by Regulatory Guide (RG) 1.122.

2) If they do not, provide the technical justification for the specific methods used.

Response

Not applicable.

3) The reference for ASCE 4-98 in Section 3.7.2.9 is listed as ASCE, 1986. State which code revision is being used and identify the correct revision dates.

Response

The reference for ASCE 4-98 in Section 3.7.2.9 needs to be removed. The calculations conform to guidelines of RG 1.122 and not to ASCE 4-98.

COLA Impact

3.7.2.9 Effects of Parameter Variations on Floor Response Spectra

To account for uncertainties or variation in parameters, ISRS resulting from the time history analyses for the ESWEMS Pumphouse are broadened +/- 15 percent in accordance with ~~ASCE 4-98 (ASCE, 1986) and~~ Regulatory Guide 1.122 (NRC, 1978).

03.07.02-20

FSAR Section 3.7.2.11 (Method Used to Account for Torsional Effects) states on page 3-49 that the conservatism in modeling the supporting boundary conditions, especially at the shear keys, satisfies the accidental torsion to be considered in accordance with ASCE 4-98 (ASCE, 1986). The staff has not accepted ASCE 4-98 as providing general guidance for performing seismic analysis. The staff requests that the applicant describe how the analysis performed meets SRP Acceptance Criteria 11 of SRP Section 3.7.2, "Methods Used to Account for Torsional Effects," or provide justification as to why it does not meet the SRP Acceptance Criteria.

Response

- In Response Spectrum Analysis for ESWEMS Pumphouse, the mathematical model specified all boundary nodes as either rollers or pins, which allow for rotations. It satisfies SRP 3.7.2, Acceptance Criteria 11 requirement, in which torsional degree of freedom has been incorporated. Moreover, masses of all major equipment and their corresponding locations are modeled. Effect of accidental torsions is reasonably controlled. The dynamic analysis, indeed, is a combined vertical, horizontal, and torsional system dynamic analysis. On the other hand, the SRP acceptable alternative method for accounting the accidental torsion, using static factors with 5% extra eccentricity for the loading, would account for only torsional accelerations.

- In the absence of torsional restraints, which could have modeled for deep embedment of the pumpwell structure, reactions at the shear keys are maximized. However, their design capacity still exceeds the demand forces and moments, which are listed in FSAR Table 3.4-5, by a minimum 20 percent. Moreover, the analysis conservatively used input FIRS, which were for engineered back fill rather than concrete back fill. The comparison of the input FIRS (FIRS Back Fill) with FSAR Figure 3.7-131 (FIRS Concrete Fill) is included in Figures A & B below: It can be seen that the input FIRS (Back Fill) for the design of the ESWEMS Pumphouse enveloped the Required FIRS (Concrete Fill) by a wide margin for frequencies beyond 1.0 Hz.

FIGURE A

COMPARISON OF THE FIRS ALONG THE HORIZONTAL DIRECTION

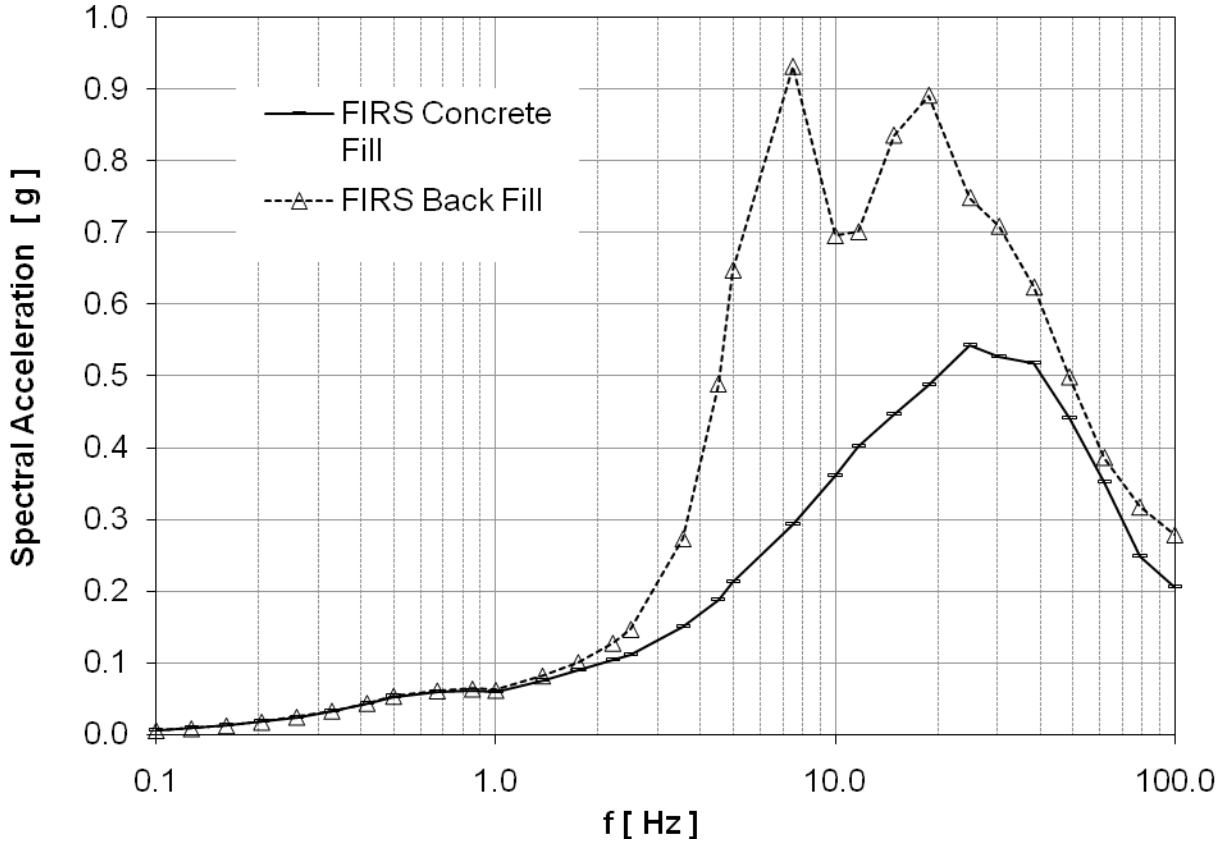
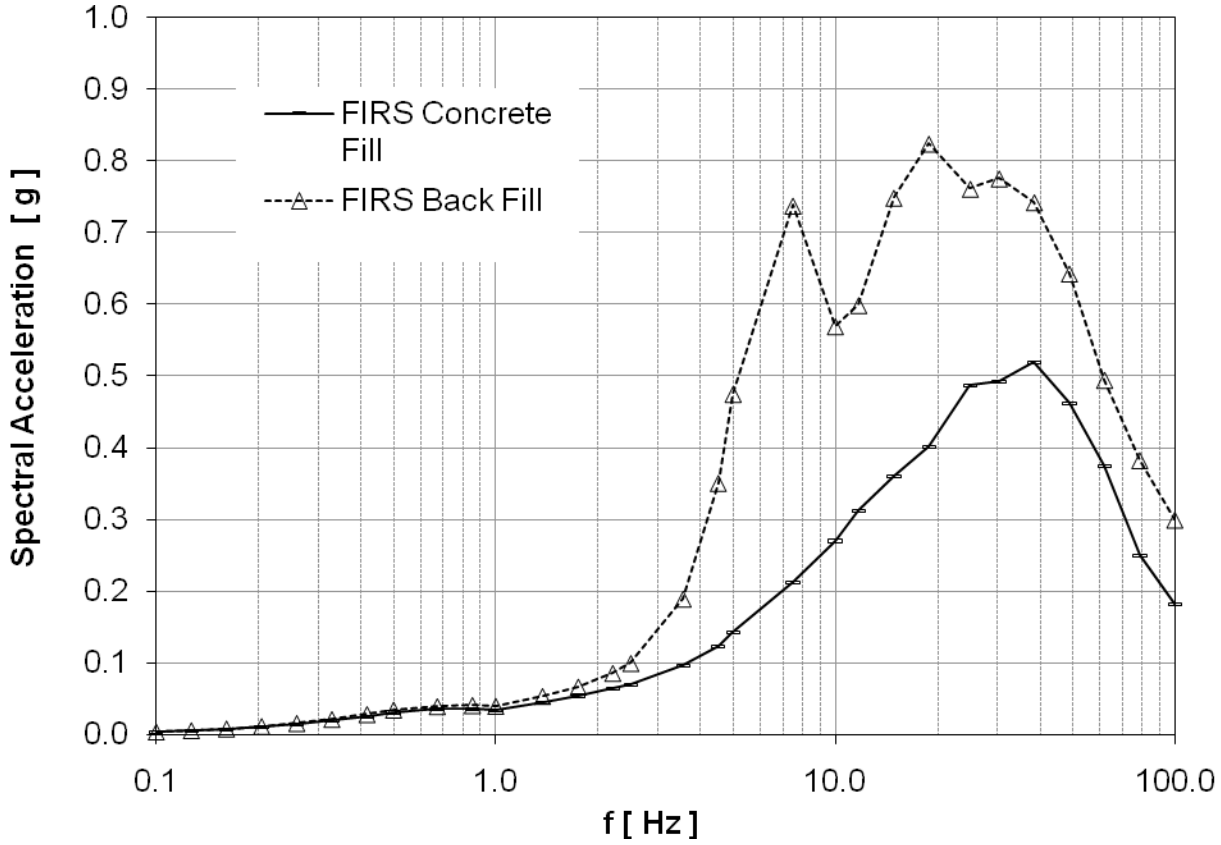


FIGURE B

COMPARISON OF THE FIRS ALONG THE VERTICAL DIRECTION



Given such cited conservatisms in the design, the structural components of the pumphouse, including shear walls, floors, and the shear keys shall have sufficient safety margin for withstanding the accidental torsion.

- Since the staff has not accepted ASCE 4-98 guidance, its reference will be replaced with a reference to “SRP 3.7.2, Acceptance Criteria 11” (See COLA Impact section).

COLA Impact:

FSAR Section 3.7.2.11 will be revised to read:

For the ESWEMS Pumphouse, the conservatism in modeling the supporting boundary conditions, especially at the shear keys, satisfied the accidental torsion per ~~ASCE 4-98 (ASCE, 1986)~~ SRP 3.7.2, Acceptance Criteria 11 requirements.

03.07.02-21

FSAR Section 3.7.2.12 (Comparison of Responses) states on page 3-49 that multiple seismic methods are not employed for the ESWEMS Pumphouse. However, FSAR Section 3.7.2.2 provides a comparison of results using the time history input method with the results obtained using the response spectrum method. The staff requests that the applicant identify each of the seismic methods used and identify the purpose of each as they apply to the ESWEMS Pumphouse.

Response

This FSAR Section inadvertently indicated that there were no multiple seismic analyses methods for the ESWEMS Pumphouse. In fact, the Response Spectrum Analysis and Soil-Structure Interaction (SSI) Time History Analysis methods have been used for evaluation of the ESWEMS Pumphouse.

The Response Spectrum Analysis considered fixed supports for the structure. Its results are used for the design of the structural components, such as shear walls, floors, etc. SSI Time History Analysis employs SASSI, which takes into account soil-structure interaction to obtain ISRS.

As cited in the FSAR Section 3.7.2.2, comparison of the nodal accelerations between Response Spectrum and SASSI analyses are included in FSAR Table 3.7-7. The nodal responses from Response Spectrum Analysis bound the SASSI analysis by a significant margin. It is concluded that the design forces and moments taken from Response Spectrum Analysis are conservative and structurally acceptable.

FSAR Section 3.7.2.12, Comparison of Responses, will be revised.

COLA Impact:

FSAR Section 3.7.2.12 will be revised to read:

~~As~~ A multiple seismic analysis method ~~are not employed for the ESWEMS Pumphouse,~~ using Response Spectrum and SSI Time History Analyses, is used for design and analysis of the ESWEMS Pumphouse. *A* comparison of their nodal responses is ~~not applicable~~ included in Table 3.7-7.

03.07.02-22

SRP Acceptance Criteria 14 of SRP Section 3.7.2 states that the determination of seismic overturning moments and sliding forces should include three components of input motion and conservative consideration of the simultaneous action of the vertical and horizontal seismic forces.

(1) Describe the calculation method for determining the overturning moments and sliding forces for the stability analysis of Seismic Category I, Seismic Category II-SSE, Seismic Category II and conventional seismic structures that could interact with Seismic Category I structures and whether this method meets Acceptance Criteria 14 of SRP Section 3.7.2. If not, provide justification for the method used.

(2) As the GRMS exceeds the CSDRS at higher frequencies, provide the factors of safety against overturning and sliding stability for the U.S. EPR Seismic Category I structures at the BBNPP site.

(3) Provide the factors of safety against overturning and sliding stability for Seismic Category II-SSE, Seismic Category II and conventional seismic structures that could interact with Seismic Category I structures at the BBNPP site.

Response

A response to this question will be provided by 2/17/2010.

03.07.03-1

FSAR Section 3.7.3.12 starting on page 3-50 describes the analysis for buried Seismic Category I piping, conduits and tunnels and indicates that the analyses will be done in accordance with American Society of Civil Engineers (ASCE)4-98 (Note: reference to ASCE 4-86 appears to be incorrect). For the analysis of these buried utilities, provide the following information:

1. Provide the basis for the foundation input response spectra (FIRS) shown in Figures 3.7-151 and 3.7-152.

Response

A total of 10 FIRSs were developed for the seven projected locations of safety-related structures. The envelope of the 10 FIRSs was developed to add conservatism in engineering practice. Based on the envelope FIRS, the recommended FIRS are established by smoothing the envelope. The analysis of buried utilities conservatively uses the recommended FIRS, which are shown in FSAR Figures 3.7-151 and 3.7-152.

The procedure documented in Regulatory Guide (RG) 1.208 (pp 17-18) is followed to develop the Foundation Input Response Spectra (FIRS) at different elevations throughout the site and underneath the safety related buildings. In the procedure, the site-specific Uniform Hazard Response Spectra (UHRS) are the product of the UHRS multiplied by the mean site amplification function. The UHRS and mean site amplification function are generated with the use of a Probabilistic Seismic Hazard Analysis (PSHA) and 60 random site response calculations, respectively. Therefore, the FIRS are developed in a probabilistic manner.

Based on the technical guideline NUREG 6728 (pp 6-20, 6-21), the conventional approach to develop the site-specific FIRS involves convolutional analysis, either equivalent-linear or fully nonlinear. In the convolutional analysis, uncertainty in dynamic material properties is generally accommodated through a Monte Carlo approach using randomly generated properties with statistically used distributions. Uncertainties in soil properties and model deficiencies of the convolutional analysis are accommodated by either smoothly enveloping the deterministic variations or selecting a fractile level, generally the mean. According to the guideline, the approach using randomized material properties is preferred since the conservatism is quantified, provided the parameter distributions reflect a realistic assessment of how well the base case profile and non-linear properties are known and variability over the Site. Since the component of model uncertainty in the convolutional analysis is currently unquantified, it is not possible to add it explicitly; however, it is expected to be very small based on validation exercises of the entire model (Appendix D, NUREG 6728). As a result, the possible double counting of site variability may be largely offset by neglecting the deficiencies in the convolutional formulation. Regarding the development of the control motions used in the convolutional analysis, mean, high, and low percentile magnitudes from de-aggregation for each design earthquake are used to scale spectral shape to the rock UHS; the resulting controlling motions are used to develop weighted mean transfer function for each design earthquake.

The procedure documented in the NUREG 6728 considering uncertainties of material properties, model deficiencies was followed to develop the FIRS. Section 2.5.2.6 of the

FSAR describes the process for development of vertical spectra by scaling the horizontal spectra by a frequency-dependent vertical-to-horizontal (V/H) factor.

The FIRS for each building in the power block area and the ESWEMS Pumphouse (PH) are developed independently to accommodate a specific soil column.

Table 1-1 summarizes the criteria to develop the FIRS for each of the facilities. Moreover, a general plan view and building nomenclature is shown in Figure 1-1.

TABLE 1-1

SUMMARY OF CRITERIA USED FOR DEVELOPMENT OF FIRS

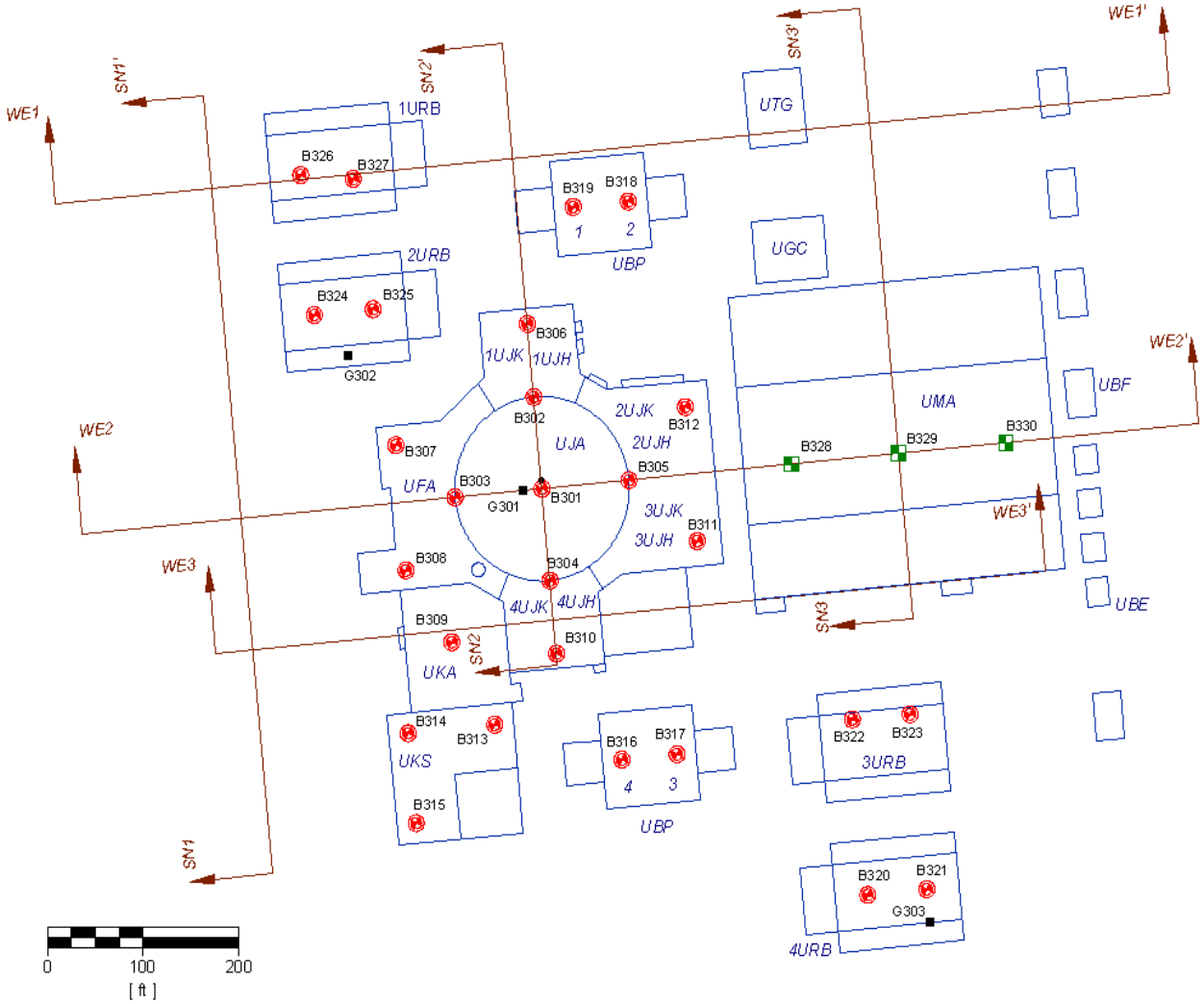
FACILITY	BASE LEVEL (FT)		FOUNDATION MATERIAL	EMBEDMENT CONSIDERED	FIRS CRITERIA
	DEPTH	EL.			
NI	0	638	C-MF	No	Outcropping ground motion at base after excavation
3URB	22	652	Fill	Yes	Equivalent outcropping motion at foundation level
4URB	22	652	Fill	Yes	Equivalent outcropping motion at foundation level
3UBP and 4 UBP (34UBP(S))	5	669	Fill	No	Surface structure, outcropping ground motion at foundation level
1URB and 2URB (12URB(N))	22	652	C-MF	Yes	Equivalent outcropping motion at foundation level
1UBP and 2UBP (12UBP-CONC(N))	5	669	C-MF	No	Surface structure, outcropping ground motion at foundation level
1UBP and 2UBP (12UBP-SOIL(N))	5	669	Fill	No	Surface structure, outcropping ground motion at foundation level

PH El. 669	5	669	C-MF	No	Surface structure, outcropping ground motion at foundation level
PH El. 669 Soil	5	669	Fill	No	Surface structure, outcropping ground motion at foundation level
PH El. 641	33	641	None	Yes	Free surface ground motion on top of the Mahantango Formation

C-MF: Concrete fill over Mahantango Formation

FIGURE 1-1

GENERAL PLAN VIEW AND BUILDING NOMENCLATURE



2. Describe any computer codes used and their application to the analysis and design of buried utilities.

Response
If a rigorous analysis is warranted, one of the following computer codes may be used to determine strain, curvature, displacement, rotation, and forces of the buried utilities (It is possible that other computer codes may be used):

- COADE Engineering Analysis Software: CAESAR II
- Bentley Systems, Inc: AutoPIPE
- A general purpose finite element code, such as ANSYS or ABAQUS
- SSTIPN by Utah State University (A.P. Moser, 3rd Edition)

3. Provide the soil properties used in the analysis and how differences in soil properties are accommodated in the analysis.

Response
Soil properties for the evaluation of buried utilities are either bounding values for all locations or values pertaining to location specific. As noted in "Buried Pipe Design" by A. P. Moser, McGraw-Hill, Third Edition: "It is often necessary to perform sensitivity analyses where key parameters are varied around a best-estimate value to ensure that the design is safe, accounting for uncertainties". Moreover, the recommended soil properties are provided in FSAR Section 2.5.4, Tables 2.5-44 through 2.5-52. The following soil properties are used:

3.1 Wet or dry density of soil is used for calculating soil bearing pressure due to overburden.
3.2 For calculating static soil pressure due to surcharge, Bossinesq's method, Westergaard's method, and/or the Slope Method may be used, in which soil Poisson's ratio is included in Westergaard's equation.
3.3 For evaluating stress or strain induced by seismic wave propagation, maximum ground velocity and apparent wave velocity in accordance with ASCE 4-98, Section 3.5.2, "Buried Pipe and Conduits" are used. The maximum ground velocities are summarized in Table 1-2 below. These values were obtained by integrating the acceleration time histories matching the FIRS at locations shown in the Table 1-1. These time histories match FIRSs according with SRP Acceptance 1.B of SRP Section 3.7.1. Moreover, for determination of the apparent wave velocity, refer to response to Part 8 below.

TABLE 1-2

SUMMARY OF MAXIMUM GROUND VELOCITIES

Facility	First Horizontal Max. Ground Velocity (fps)	Second Horizontal Max. Ground Velocity (fps)	Vertical Max. Ground Velocity (fps)
NI	0.32	0.39	0.23
3URB	0.35	0.37	0.23
4URB	0.41	0.46	0.22
3UBP and 4 UBP (34UBP(S))	0.43	0.45	0.22
1URB and 2URB (12URB(N))	0.29	0.31	0.19
1UBP and 2UBP (12UBP-CONC(N))	0.37	0.30	0.21
PH El. 669	0.28	0.30	0.18

4. Identify the design codes and acceptance criteria for each category of buried utilities.

Response

The buried utilities may include, but not limited to:

- Piping consisting of cast iron pipes, ductile iron pipe, corrugated metal pipe (CMP), concrete pipe, pre-stressed concrete cylinder pipes (PCCP), flexible steel pipe, and PVC conduit.
- Buried duct bank refers to multiple PVC or steel electrical conduits encased in reinforced concrete.

In general, different design codes and acceptance criteria apply to each type of buried utilities. They are described as follows:

4.1 Buried Piping:

- Cast Iron Pipe: The evaluation process and acceptance criteria follow the Guidance of Cast Iron Pipe Institute Publication: “Recommendations for Deep Buried of Cast Iron Soil Pipe”, 1983.
- Ductile Iron Pipe: The methodology for the evaluation is in accordance with ANSI A21.50 -1976 (AWWA C150-76), “American National Standard for the Thickness Design of Ductile-Iron Pipe”, approach, which is also given in Buried Pipe Design by A. P. Moser, McGraw-Hill, Third Edition. The acceptable pipe thickness is determined by considering stresses, due to trench loads, ring deflection, and internal pressure that are determined separately and independently.
- CMP Pipe: The evaluation process refers to “Buried Pipe Design” by A. P. Moser, McGraw-Hill, Third Edition, for assessing ring compression load and buckling stress of pipe wall, in addition to the pipe deflection. Acceptance is based on allowable stresses and deformation as recommended by either the manufacturers or given in the reference.

- Concrete Pipe: The method of evaluation takes Marston's equation for earth load and varies the trench with until the ditch load is equal to the embankment load or the transition width – Refer to "Buried Pipe Design" by A. P. Moser, McGraw-Hill, Third Edition. Strength classification and required Factor of Safety (FS) are derived from "Concrete Pipe Handbook", by American Concrete Pipe Association, 1981.
- PCCP Pipe: The evaluation is based on the pipe a Technical Specification available from manufacturers. For example, the Technical Specification specified that the pipe is designed for an E-80 rail loading plus 50% impact factor, then this load shall bound the actual loading on the pipe.
- Flexible Steel Pipe: For most flexible pipes, a combined loading analysis is not required. The pipes are evaluated based on external loading and internal pressure acting independently – Refer to "Buried Pipe Design" by A. P. Moser, McGraw-Hill, Third Edition. In many instances, the internal pressure governs the design for pressurized pipes. On the other hand, for small non-pressurized pipes or conduits with diameter less than 6 inches, the assessment is to determine the maximum external pressure that the pipe can sustain and to compare it with the external load.
- PVC Conduits: PVC conduits, such as buried sewer and/or drain pipes, are, indeed, flexible pipes. Their evaluation and acceptance criteria are in accordance with "Buried Pipe Design" by A.P. Moser, McGraw-Hill, Third Edition.

4.2 Duct Banks:

The analysis of un-reinforced electrical duct bank assumes the duct acting as a structural beam on an elastic foundation. The soil pressure induces stresses on the duct. If the stresses are greater than the modulus of rupture of concrete, the reinforcing is required to withstand the load. The design of reinforced concrete electrical duct banks is in accordance with IEEE 628-2001, ASCE 4-98, and ACI 349-01.

4.3 For safety-related, seismic category I buried utilities, it is required that seismic loadings, which induce additional strains and stresses on the utilities, are evaluated in accordance with acceptance criteria from ASCE 4-98.

As applicable to a long and straight pipe section:

- Maximum axial strain ignoring friction - Refer to ASCE 4-98, Part 3.5.2.1.1
- Maximum axial strain considering friction – Refer to ASCE 4-98, Part 3.5.2.1.2
- Maximum curvature – Refer to ASCE 4-98, Part 3.5.2.1.3
- Maximum joint displacement and rotation in segmented structures – Refer to ASCE 4-98, Part 3.5.2.1.4.

Additionally, forces on bends, intersections, and anchor points are evaluated in accordance with ASCE 4-98, Part 3.5.2.2. For anchor point movement, the evaluation is in accordance with ASCE 4-98, Part 3.5.2.3.

4.4 Seismic stresses on the buried utilities are additive to their corresponding static stresses. Interaction among axial, shear, and bending tress with respect to their allowable shall be less than the unity.

4.5 As noted in “Buried Pipe Design” by A.P. Moser, McGraw-Hill, Third Edition, the strain limits on the buried pipe have not been standardized despite of proposed strain limits, such as a 1 to 2 percent compressive strain limit (Hall and Newmark 1970) and a 3 to 6 percent tensile strain limit for modern steel pipeline construction.

5. Describe the missile protection provided for safety-related buried utilities.

Response
Safety-Related buried utilities are protected from external generated missiles in accordance with the U.S. EPR FSAR Section 3.5.2. The utilities routed outside of missile-protected structures are buried with a sufficient depth to provide protection from missile impact. The externally generated missiles for which the U.S. EPR is designed are addressed in FSAR Section 3.5.1. The depth of missile penetration though soil may be evaluated, using formulas in the U.S. EPR FSAR Section 3.5.3.1.1. Alternatively, its evaluation may be based on Young’s Method per “Young W.C., Depth Prediction for Earth-Penetrating Projectiles”, by ASCE Journal of Solid Mechanics and Foundations Division, May 1969. The design soil cover to preclude missile impact on buried structures is conservatively determined for exceeding the predicted penetrating soil depth by a minimum of 20 percent. Lastly, buried concrete missile barriers with a minimum wall thickness of 18.2 inches based on concrete strength of 3000 psi is considered adequate, ignoring the soil protection – Refer to the U.S. EPR FSAR Table 3.5-2.

6. Describe how ground water effects are considered in the analysis.

Response
Safety-related buried utilities have adequate soil protection from the design external generated missiles. As a result, deep soil cover can prevent flotation effects. The buoyant force is assumed acting at the centroid of the volume of water displaced by the submerged potion of the utilities. As delineated in “Buried Pipe Design” by A.P. Moser, McGraw-Hill, Third Edition, the buoyant force of the utility cannot exceed the its weight and the effective weight of the soil wedge, or anchorages would be designed to resist the flotation. The minimum required Factor of Safety against flotation is taken at 1.5 for normal loading conditions, 1.3 under severe environmental conditions, and 1.1 under construction.

7. For utility runs that are both above and below ground, describe how above ground inertial effects are combined with below ground seismic wave effects.

Response
As described in ASCE 4-98, Section C3.5.2 of the Commentary, the “long, buried structures are primarily subjected to relative displacement-induced strains rather than inertia effects.” For utility runs both above and below ground, the buried portion is considered anchored by the above portion. The induced strains, due to differential displacement between them, are evaluated using the criteria for anchor point movement per ASCE Part 3.5.2.3.

8. Describe how the wave velocities are determined for calculating the maximum axial strain.

Response
In order to determine maximum axial strain on the buried utilities, Equation 3.5-1 of ASCE 4-98 utilizes a value, c, which is the apparent wave velocity. Part 3.5.2.1.1 (b) states that, "The apparent wave velocity, c, used in Eq. 3.5-1, depends on the wave type that results in the maximum ground velocity. Candidate wave types are compressional waves, shear waves, and Rayleigh waves. The apparent wave velocity, c, depends on the wave type and is associated with the travel path from the location of energy release to the location of the long, linear structure."

In order to determine the wave type that results in maximum ground velocity, an equivalent linear response analysis is performed, as follows:
- Using shear wave velocities and horizontal motions at the top of rock to model a vertically propagating shear wave.
- Using compression wave velocities and vertical motions at the top of rock to model a vertically propagating compression wave.

Additionally, a linear dynamic finite element analysis is performed to assess Rayleigh wave propagation.

Based on the three response analysis results, the low-strain wave velocity for the applicable glacio-fluvial deposits or back fill is determined. The zone to determine the wave velocity will be between the rock surface and the pipeline in question. The modulus degradation will be iterated until strain compatibility is achieved with the pipe strain.

9. Provide the basis for determining the maximum friction force per unit length of pipe.

Response
The maximum friction force per unit length of pipe can be in accordance with "Guidelines for the Seismic Design of Oil and Gas Pipeline Systems", prepared by the Committee on Gas and Liquid Fuel Lifelines of the ASCE Technical Council on Lifeline Earthquake Engineering, 1984. The axial soil frictional resistance along the pipe is a bilinear spring. For example:

<u>In Clays:</u>

$$tu = \pi D \alpha Su$$

where:

tu = ultimate axial soil frictional load per unit pipe length
D = pipe outside diameter
α = adhesion coefficient based on pile shaft load transfer theory.
Su = clay un-drained shear strength

In Sands:

$$tu = ((\pi D)/2)\gamma H(1 + Ko)$$

where:

tu = ultimate axial soil frictional load per unit pipe length
D = pipe outside diameter
H = depth from ground surface to pipeline center
Ko = coefficient of soil pressure at rest
γ = effective soil unit weight

Generally, the basis for determining the maximum friction force per unit length of pipe comes from similar considerations for unit skin friction, or shaft resistance, for piles. For cohesive soils, un-drained loading is assumed, and the alpha method will be used to estimate the friction force based on the un-drained soil shear strength. For granular materials, assuming drained loadings, the maximum friction force will be developed based on overburden stresses, the coefficient of earth pressure at rest, and the interface friction angle between soil and pipe.

10. Describe how displacement time histories were generated for structures from the SASSI analyses.

Response
A response to this question will be provided by 10/21/2009.

11. Describe how the building anchor point displacements are determined and how these are combined with seismic wave effects and soil loads. Include in the description how out-of-phase displacements between the free field and building response are addressed.

Response
A response to this question will be provided by 10/21/2009.

COLA Impact:

There are no changes to the COLA based on the response to this RAI.