ENERGY NORTHWEST

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March 12, 2015
GO2-15-045

Reference: 10 CFR 50.54(f)

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
11555 Rockville Pike
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Subject: **COLUMBIA GENERATING STATION, DOCKET NO. 50-397 SEISMIC HAZARD AND SCREENING REPORT, RESPONSE TO NRC REQUEST FOR INFORMATION PURSUANT TO 10 CFR 50.54(F) REGARDING RECOMMENDATION 2.1 OF THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT**

References:
1) NRC Letter, Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, dated March 12, 2012, ADAMS Accession Nos. ML12056A046 (Pkg.), ML12053A340 (Ltr.)
2) EPRI Report 1025287, Seismic Evaluation Guidance, Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic, ADAMS Accession No. ML12333A170
3) NRC Letter, Endorsement of EPRI Final Draft Report 1025287, "Seismic Evaluation Guidance," dated February 15, 2013, ADAMS Accession No. ML12319A074

Dear Sir or Madam:

On March 12, 2012, the Nuclear Regulatory Commission (NRC) issued Reference 1 to all power reactor licensees and holders of construction permits in active or deferred status. Enclosure 1 of Reference 1 requested that each addressee located in the Western United States (WUS) submit a Seismic Hazard Evaluation and Screening Report within 3 years from the date of Reference 1.

Reference 2 contains industry guidance and detailed information to be included in the Seismic Hazard Evaluation and Screening Report submittals. NRC endorsed this industry guidance in Reference 3.

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Enclosed is the Seismic Hazard and Screening Report for the Columbia Generating Station. This report provides the information requested in Reference 1, Enclosure 1 and its Attachment 1. The Hanford Sitewide Probabilistic Seismic Hazard Analysis referenced in the report, is available on the Department of Energy's Hanford external website. The direct link is: http://www.hanford.gov/page.cfm/OfficialDocuments/HSPSHA.

No new commitments are identified in this letter.

If you have any questions or require additional information, please contact Ms. L. L. Williams at (509) 377-8148.

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

Executed on the 12th day of March, 2015

Respectfully,

D. A. Swank
Assistant Vice President, Engineering

Enclosure: As stated

cc: NRC Region IV Administrator
NRC NRR Project Manager
NRC Senior Resident Inspector/988C
MA Jones – BPA/1399 (email)

Enclosure

COLUMBIA GENERATING STATION, DOCKET NO. 50-397

RESPONSE TO NRC REQUEST FOR INFORMATION PURSUANT TO TITLE 10 OF THE CODE OF FEDERAL REGULATIONS 50.54(F) REGARDING RECOMMENDATION 2.1 OF THE NEAR-TERM TASK FORCE RECOMMENDATION 2.1: SEISMIC FOR SEISMIC HAZARD REEVALUATION AND SCREENING FOR RISK EVALUATION

This report provides information in response to NRC's March 12, 2012, 10 CFR 50.54(f) letter requesting nuclear power plant licensees to perform seismic hazard reevaluation and screening for risk evaluation pursuant to the recommendations in NRC's Near-Term Task Force review of the accident at the Fukushima Dai-ichi nuclear facility.

1.0 Introduction

Following the accident at the Fukushima Daiichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the NRC Commission established a Near Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations and to determine if the agency should make additional improvements to its regulatory system. The NTTF developed a set of recommendations intended to clarify and strengthen the regulatory framework for protection against natural phenomena. Subsequently, the NRC issued a 50.54(f) letter that requests information to assure that these recommendations are addressed by all U.S. nuclear power plants. The 50.54(f) letter requests that licensees and holders of construction permits under 10 CFR Part 50 reevaluate the seismic hazards at their sites against present-day NRC requirements. Depending on the comparison between the reevaluated seismic hazard and the current design basis, the result is either no further risk evaluation or the performance of a seismic risk assessment. Risk assessment approaches acceptable to the staff include a seismic probabilistic risk assessment (SPRA), or a seismic margin assessment (SMA). Based upon the risk assessment results, the NRC staff will determine whether additional regulatory actions are necessary.

This report provides the information requested in items (1) through (7) of the "Requested Information" section and Attachment 1 of the 50.54(f) letter pertaining to NTTF Recommendation 2.1 for the Energy Northwest Columbia Generating Station (CGS), located in Benton County in the State of Washington. In earlier licensing documentation, the CGS plant was referred to as Washington Public Power Supply System Nuclear Project Number 2 (WNP-2). In providing this information, Energy Northwest (EN) followed the guidance provided in the Seismic Evaluation Guidance: Screening, Prioritization, and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic (EPRI, 2013a). The Augmented Approach, Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic (EPRI, 2013b), has been developed as the process for evaluating critical plant equipment as an interim action to demonstrate additional plant safety margin, prior to performing the complete plant seismic risk evaluations.

The original geologic and seismic siting investigations for CGS were performed in accordance with Appendix A to 10 CFR Part 100 and meet General Design Criterion 2 in Appendix A to 10 CFR Part 50. The Safe Shutdown Earthquake (SSE) ground motion was developed in accordance with Appendix A to 10 CFR Part 100 and used for the design of Seismic Category I systems, structures and components.

In response to the 50.54(f) letter and following the guidance provided in the SPID (EPRI, 2013a) with due consideration to the extensive site soil profile data available for the plant site, a seismic hazard reevaluation was performed. For screening purposes, a Ground Motion Response Spectrum (GMRS) was developed.

Based on the results of the screening evaluation, CGS screens in for a risk evaluation, a Spent Fuel Pool evaluation, and a High Frequency evaluation as part of the risk evaluation.

2.0 Seismic Hazard Reevaluation

CGS is located on the eastern side of the Hanford Site. As discussed in PNNL (2014), the Hanford Site is located east of the region tectonically dominated by the Cascadia subduction zone (CSZ), where the Juan de Fuca (JDF) plate under-thrusts northern California and western Oregon and Washington along the Cascadia subduction zone. Magmatism related to the subduction zone is represented by the Cascade volcanoes, which lie to the west of the Hanford Site. Following establishment of the Cascadia subduction zone and related volcanic chain, the later geologic history of eastern Washington was dominated by eruption and deposition of the Columbia River Basalts (CRBs). The CRB flows in eastern Washington are deformed in a series of generally east-west-trending anticlines underlain by reverse faults that are known collectively as the Yakima Fold Belt (YFB). The reverse faults of the YFB dominate the post-CRB tectonics and topography in eastern Washington. The Yakima folds are anticlines that have accommodated approximately north-south shortening. Seismicity and geodetic indicators of contemporary tectonics confirm that north-south stresses continue to be the dominant stress mechanism. However, the rates of shortening, uplift, and fault slip, as recorded by the deformation of various units of the CRB, show that rates of deformation are low relative to the slip rates of faults within active tectonic regions.

The Hanford Site is characterized by a relatively thin layer of supra-basalt sediments (mainly the Hanford and Ringold formations), which have thicknesses ranging from 200 to 660 ft (60 to 200 m) at five sites across the Hanford Site investigated by PNNL (2014). These sediments are underlain by the basalt flows of the Saddle Mountain Basalts (SMB) sequence and interbedded Ellensburg formation sediments; the basalt-interbed stacks have a thickness of about 820 ft (250 m) at the PNNL sites. Below the SMB are the Wanapum Basalts and Grande Ronde Basalts, collectively forming the CRB, with a total thickness of 1.2 to 1.9 mi (2 to 3 km) at the PNNL sites. The CRB is underlain by a thick layer of pre-Miocene sediments, with the crystalline basement encountered at depths ranging from 4.7 to 5.6 mi (7.5 to 9 km) at the five PNNL sites.

Regional seismicity in the YFB region is dominated by small-magnitude earthquakes that occur within the CRB units in the upper 1.9 mi (3 km), and more diffuse seismicity that extends to depths of about 12.4 mi (20 km). Rates of moderate-to-large earthquakes are low relative to plate boundary regions. Within the YFB region, the largest observed earthquakes are the 1936 Milton-Freewater earthquake (M 6) and the 1872 Lake Chelan earthquake (M 6.5–7). To the west of the site region, earthquakes are mainly associated with the Cascadia subduction zone and Holocene crustal faults in the Puget Lowland.

The following section discusses the regional and local geology (Section 2.1), the probabilistic seismic hazard analysis (Section 2.2), the development of site profiles and site response analyses (Section 2.3), and the control point response spectrum (Section 2.4).

2.1 Regional and Local Geology

The CGS site lies in the Pasco Basin which encompasses about 1,600 square miles in south central Washington State. It is one of several physiographic depressions occupying the Columbia Plateau, a major physiographic and geologic province that is surrounded by the Blue Mountains, High Lava Plains and Snake River Plains provinces on the south, the Northern Rocky Mountains and Idaho Batholith provinces on the east, the Okanogan Highlands province to the north, and the Cascade Mountains, Puget-Willamette Trough, and Washington-Oregon Coast Ranges on the west.

Bedrock in the Columbia Plateau consists of a thick sequence of Miocene Basalt flows with minor amounts of interflow sediments, known as interbeds. These rocks, generally mantled by younger sediments of Pliocene and Holocene age, are termed the Columbia River Basalts (CRBs). The CRBs cover about 77,000 square miles in Washington, Oregon and western Idaho. The CRBs consist of the Yakima Basalt Sub-Group (which includes the Saddle Mountains Basalt, Wanapum Basalt and Grande Ronde Basalt) and the Imnaha Basalt. Estimated extrusion period of the CRB is between 6 million and 17 million years ago. The CRBs, particularly in the western part of the Columbia Plateau, have been folded into a series of east-west anticlines.

The Pasco Basin is a gently undulating, semiarid plain, interrupted by low-lying hills and dunes that are dissected by intermittent streams. The basin is transected by the Columbia River. The CGS reactor is located just over 3 miles west of the Columbia River on the eastern edge of the Hanford Site. The CGS site, which covers about 1,100 acres, is essentially flat – average surface elevation prior to construction was 440 ft, with a variation of about 4 ft across the site. Plant grade is El. 441 ft. Depth to the groundwater table is about 62 ft.

The CGS site is immediately underlain by about 45 ft thickness of Pasco Gravel, a Quaternary deposit made up of glaciofluvial sediments. It is noted that at and around the control point the Pasco gravel was removed and replaced with compacted structural backfill. The Pasco Gravel and structural fill are underlain by the Pliocene-age Ringold Formation, consisting of the Middle Member down to 250 ft depth and the Lower Member down to 525 ft depth. The Ringold is predominantly a sandy gravel with interbedded sandy and silty layers (Middle Member) and some interbedded soft sandstone and some conglomerate present at the base of the layer (Lower Member). Several hundred ft of the Ringold Formation materials at the site were removed during Pleistocene floods. The overlying Pasco Gravel was deposited over the eroded surface of the Ringold Formation materials. The Pasco Gravel at the site has not been subjected to significant past loading.

At the CGS site, the top of the CRB occurs immediately below the Ringold Formation, at 525 ft depth. The Saddle Mountains Basalt forms the upper approximately 765 ft of the CRB at the site, ranging from about 10.5 million years old at the top (Elephant Mountain Member) to 13.5 million years old (Umatilla Member) at the base. There are four basalt members within the Saddle Mountains Basalt that range from about 110 ft to 215 ft in thickness, each underlain by a sedimentary interbed consisting mainly of sandstone and claystone, and ranging in thickness from about 15 ft to 70 ft. The interbeds have significantly lower strength and density than the basalt. The Saddle Mountains Basalt comprises less than 1% of the volume of the CRB, but perhaps because of their relatively long period of extrusion at a time of waning volcanism, members of the Saddle Mountains Basalt display the greatest petrographic, chemical and paleomagnetic variability of any formation of the CRB. All stratigraphic units beneath the site appear to be nearly horizontal.

The Wanapum Basalt beneath the Saddle Mountains Basalt is approximately 1,000 ft thick and is between about 13.5 and 14 million years old. It consists of the Priest Rapids Member, the Roza Member, the Frenchman Springs Member, and the Eckler Mountain Member. The Priest Rapids Member contains the Lolo Flow (about 155 ft thick) underlain by the Rosalia Flow (60 ft thick). The Grande Ronde Basalt below the Wanapum Basalt is approximately 7,200 ft thick.

2.2 Probabilistic Seismic Hazard Analysis

Section 2.2 summarizes the results of a probabilistic seismic hazard analysis (PSHA) of the CGS located within the boundaries of the Hanford Site in south central Washington State

The PSHA was performed by the Pacific Northwest National Laboratory (PNNL) in accordance with the provisions of the Nuclear Regulatory Commission (NRC, 2014a) 50.54(f) letter and in fulfillment of the requirement from the U.S. Nuclear Regulatory Commission that Energy Northwest conduct a PSHA using Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 procedures (see Appendix 2.2A).

The PNNL report (2014) provides a detailed characterization of the vibratory hard-rock motion hazard at the CGS location from potential future earthquakes conducted using the Level 3 procedures advanced by SSHAC in detailed guidance published by the U.S. Nuclear Regulatory Commission (see Appendix 2.2A for a description of the SSHAC Level 3 process as used for this PSHA). In accordance with this guidance, a participatory peer review panel (PPRP) oversaw all details of the performance of the PSHA and confirmed that the work was done in conformance with SSHAC guidance. This confirmation is provided in a PPRP closure letter (see Appendix 2.2B).

2.2.1 Probabilistic Seismic Hazard Analysis Results

PNNL (2014) report is the source of the information presented in the following section.

The summary presented here is of the base case rock hazard at the CGS using the seismic source characterization (SSC) and ground motion characterization (GMC) models of the PNNL (2014) report, Chapters 8.0 and 9.0, respectively. A cumulative absolute velocity filter was not applied in this analysis and no site amplification factors are used. Results are consistent with hard-rock conditions (for this site rock with a shear-wave velocity, V_S, very close to 9,800 ft/s or 3,000 m/s). The methodology for seismic hazard analysis is well established in the technical literatures (e.g., McGuire, 2004).

Three sets of seismic sources are included in the SSC model and are identified below:

- Subduction source zones (discussed in Section 8.2 of the PNNL report)
- Crustal area source zones (discussed in Section 8.3 of the PNNL report)
- Crustal fault sources (discussed in Section 8.4 of the PNNL report)

The list of all seismic sources and acronyms used in this analysis are provided in Table 2.2.2-3.

This list of sources represents a hazard-informed compilation of all sources that would be expected to contribute significantly to the site hazard, based on the hazard sensitivity analyses. The identification and characterization of seismic sources for the SSC model gave highest priority to aspects of the model that had the highest potential hazard significance, and the level of complexity of the SSC model was consistent with current knowledge and importance to hazard.

Sensitivity analyses conducted early in the Hanford PSHA project showed that the plate interface seismic source of the CSZ could contribute to long-period ground motions at mean annual frequencies of exceedance (MAFE) of interest to the Hanford Site. For completeness, both the plate interface zone (CSZ) and the intraslab source (JDF) are included in the SSC model.

The seismic area source zones defined for the SSC model are shown in Figure 8.1 of the PNNL (2014) report, together with the earthquake epicenters from the project catalog. All seismic area source zones are assessed to be seismogenic with a probability of unity. Two types of seismic area source zones are identified: 1) the YFTB source zone is a "background" zone to the fault sources of the Yakima Fold and Thrust Belt and 2) Zones B, C, and D are crustal area source zones that do not include identified fault sources. The exceptions are the Arlington (AF), Luna Butte (LB), Laurel (LF), and Maupin (MF) faults that exist within the YFTB background source zone and extend into adjacent Zone D. However, additional faults within Zone D have not been identified separately as fault sources. The reason for the two types of source zones is the relative contribution that nearby sources make to the hazard at the site. Because of their distance from the site, individual faults within Zones B, C, and D are not specifically identified and characterized. Rather, the faults that exist within these source zones are modeled by "virtual faults" whose locations are random within each zone and whose characteristics are assessed in the SSC model.

The twenty faults whose closest approach lies within about 12.4 mi (20 km) of the site and that were assessed to have a seismogenic probability greater than zero are included in the SSC model (Figure 8.2 of the PNNL (2014) report). In addition, the Seattle fault zone (SFZ) is included in the model for completeness. Sensitivity analyses show that it does not contribute significantly to the hazard at the site because of its distance from the site, but it is included in the model as being representative of faults that exist within the Puget Sound region. With the exception of four faults within the YFTB background source all faults were assessed, like the seismic areas sources, to have a seismogenic probability of unity.

Fault trees capturing variation of a number of parameters selected to capture the epistemic uncertainty in the characterization of the three sets of seismic sources are outlined as Figures 8.3 through 8.7 of the PNNL (2014) report.

All elements of the SSC model are included in the hazard input document (HID) provided in Appendix D of the PNNL (2014) report.

The ground motion characterization (GMC) model consists essentially of two logic trees, one for ground motions from crustal earthquakes (both area and fault) and the other for motions caused by subduction earthquakes (both intraslab and interface), taking into account magnitude and distance ranges appropriate for each group and, for the shallow crustal fault sources, appropriate fault rupture characteristics.

In both the shallow crustal and subduction source cases, GMC models represent spectral acceleration at 5% of critical damping and apply to the base rock elevation at the top of the Wanapum Basalts, which have a shear-wave velocity (V_S) very close to 9,840 ft/s (3,000 m/s).

For both the crustal and subduction logic trees, there are branches for the median motions and also for the associated aleatory variability (sigma). The GMC model is defined by suites of equations with coefficients at twenty spectral frequencies ranging from 0.1 Hz to 100 Hz, which were selected in agreement with the project sponsors and which include the seven spectral frequencies (100 Hz, 25 Hz, 10 Hz, 5 Hz, 2.5 Hz, 1 Hz, and 0.5 Hz) specified in the NRC's 50.54(f) letter (NRC, 2012a). All of the information in the GMC logic tree is presented in the HID, which is included as Appendix D of the PPNL (2014) report.

2.2.2 Base Rock Seismic Hazard Curves

Mean seismic hazard curves at CGS are calculated for base rock site conditions (Site C: PNNL, 2014).

The procedure to develop probabilistic seismic hazard curves for base rock follows standard techniques documented in the technical literatures (e.g., McGuire, 2004). Separate seismic hazard calculations are conducted for twenty spectral frequencies (or periods) ranging from 0.1 Hz (10 seconds) to PGA or 100 Hz (0.01 seconds), as available in supplemental digital material of Appendix J of PNNL (2014). Presented in this report are the results for seven spectral frequencies: PGA (100 Hz), 25 Hz, 10 Hz, 5 Hz, 2.5 Hz, 1 Hz, and 0.5 Hz. The SSC and GMC models discussed in Section 2.2.1 are used for the calculation of the mean base rock hazard. All spectral accelerations presented herein correspond to 5% of critical damping (PNNL, 2014). Figure 2.2.2-1 shows the mean base rock hazard curves for the seven spectral frequencies. Table 2.2.2-1 lists the mean rock uniform hazard response spectra (UHRS) for MAFEs of 10^{-4}, 10^{-5}, and 10^{-6} for twenty spectral periods. The digital values for the mean and fractile hazard curves are provided in Tables 2.2.2-2a through 2.2.2-2g.

Deaggregations of the total mean seismic hazard for 10 Hz (0.1 s) and 1 Hz (1.0 s) spectral accelerations at MAFEs of 10^{-4} and 10^{-5} hazard levels are shown in Figure 2.2.2-2. Each figure contains histograms representing the percent contribution to the total mean seismic hazard from different magnitude-distance bins. For 10 Hz spectral acceleration the mean hazard at the two MAFEs is dominated by source zones (small magnitudes at distances of less than 62 mi (100 km)), which, as will be seen, is especially attributable to the YFTB background source. For 1 Hz spectral acceleration the mean hazard at the two MAFEs is clearly being impacted by the distant, very large magnitude Cascadia subduction zone, though the relative contribution is higher at an MAFE of 10^{-4} than at 10^{-5} hazard levels. At the lower hazard level of 10^{-5}, the 1 Hz mean hazard, while the small-to-moderate magnitude sources at near distances are still dominant (YFTB background source), the Cascadia subduction zone and moderate-to-large earthquakes at distances between 6.2 to 31 mi (10 to 50 km), attributable to crustal fault sources, appear near equal contributors to about half of the hazard.

Deaggregation is also presented as a function of the contribution of the individual seismic sources. Figures 2.2.2-3 and 2.2.2-4 are plots, 10 Hz and 1 Hz, respectively, of the comparison between the mean hazard curves at CGS (Site C in PNNL, 2014) obtained for each individual source relative to the total mean hazard. Acronyms used in these figures are listed in Table 2.2.2-3. By inspection of these figures, Table 2.2.2-3 also indicates those sources contributing more than 5% toward the total 10 Hz and/or 1 Hz mean hazard of the site for MAFEs between 10^{-4} and 10^{-5} hazard levels, the MAFEs of specific interest in the estimation of the ground motion response spectrum (GMRS), presented later in this report.

Columbia Generating Station is located within the YFTB background zone that clearly dominates the high frequency seismic hazard at the MAFEs of interest (Figure 2.2.2-3), while both the YFTB background zone and the Cascadia subduction (interface) zone (CSZ) generally dominate the low frequency hazard (Figure 2.2.2-4). The Juan de Fuca (JDF) intraslab subduction source contributes little to the total mean hazard.

Table 2.2.2-1: Mean Rock UHRS at 5% Damping for MAFEs of 10^{-4}, 10^{-5}, and 10^{-6}

Period [s]	10^{-4} UHRS [g]	10^{-5} UHRS [g]	10^{-6} UHRS [g]
0.01	6.366E-01	1.866E+00	4.132E+00
0.02	7.817E-01	2.138E+00	4.494E+00
0.03	8.189E-01	2.169E+00	4.469E+00
0.04	8.272E-01	2.145E+00	4.369E+00
0.05	8.206E-01	2.100E+00	4.246E+00
0.075	7.976E-01	2.001E+00	3.997E+00
0.1	7.536E-01	1.854E+00	3.689E+00
0.15	6.528E-01	1.590E+00	3.150E+00
0.2	5.878E-01	1.422E+00	2.808E+00
0.3	4.828E-01	1.157E+00	2.292E+00
0.4	3.873E-01	9.415E-01	1.870E+00
0.5	3.218E-01	7.797E-01	1.531E+00
0.75	2.142E-01	5.154E-01	1.030E+00
1	1.541E-01	3.643E-01	7.277E-01
1.5	1.032E-01	2.301E-01	4.430E-01
2	7.755E-02	1.699E-01	3.231E-01
3	5.289E-02	1.110E-01	2.052E-01
5	3.403E-02	7.136E-02	1.282E-01
7.5	2.237E-02	4.648E-02	8.448E-02
10	1.651E-02	3.454E-02	6.261E-02

Table 2.2.2-2a: Annual Frequency of Exceedance Mean and Fractile Base Rock Seismic Hazard Curves for PGA at Columbia Generating Station (PNNL, 2014)

PGA[g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.0001	9.358E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.514E-01
0.0005	8.240E-02	5.370E-02	6.166E-02	7.762E-02	1.000E-01	1.259E-01
0.001	7.063E-02	4.169E-02	5.012E-02	6.761E-02	8.913E-02	1.096E-01
0.003	4.548E-02	1.995E-02	2.570E-02	3.981E-02	6.607E-02	8.511E-02
0.01	2.017E-02	5.623E-03	7.762E-03	1.413E-02	3.548E-02	5.370E-02
0.03	7.029E-03	1.202E-03	1.862E-03	3.890E-03	1.259E-02	2.455E-02
0.05	3.939E-03	5.248E-04	8.511E-04	1.905E-03	7.079E-03	1.479E-02
0.075	2.406E-03	2.455E-04	4.266E-04	1.047E-03	4.365E-03	9.550E-03
0.1	1.667E-03	1.288E-04	2.399E-04	6.607E-04	3.020E-03	6.918E-03
0.2	6.459E-04	1.778E-05	4.266E-05	1.738E-04	1.202E-03	3.020E-03
0.3	3.532E-04	4.074E-06	1.175E-05	6.457E-05	6.607E-04	1.778E-03
0.5	1.544E-04	4.266E-07	1.660E-06	1.413E-05	2.630E-04	8.511E-04
0.75	7.447E-05	5.012E-08	2.512E-07	3.236E-06	1.072E-04	4.365E-04
1	4.219E-05	8.710E-09	5.495E-08	9.772E-07	5.012E-05	2.570E-04
2	8.523E-06	5.495E-11	6.761E-10	3.090E-08	5.370E-06	4.786E-05
3	2.786E-06	1.445E-12	3.020E-11	2.754E-09	1.023E-06	1.380E-05
5	5.433E-07	7.586E-15	3.467E-13	8.128E-11	8.511E-08	2.042E-06
7.5	1.212E-07	3.631E-17	7.079E-15	3.631E-12	8.511E-09	3.388E-07
10	3.712E-08	0.000E+00	2.344E-16	3.548E-13	1.349E-09	7.943E-08
20	1.412E-09	0.000E+00	0.000E+00	1.318E-15	9.120E-12	1.318E-09

Table 2.2.2-2b: Annual Frequency of Exceedance Mean and Fractile Base Rock Seismic Hazard Curves for 5% Damped 25 Hz SA at Columbia Generating Station (PNNL, 2014)

SA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.0001	9.356E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.514E-01
0.0005	8.408E-02	5.370E-02	6.310E-02	7.943E-02	1.023E-01	1.288E-01
0.001	7.406E-02	4.365E-02	5.248E-02	7.079E-02	9.333E-02	1.148E-01
0.003	5.114E-02	2.138E-02	2.884E-02	4.786E-02	7.244E-02	8.913E-02
0.01	2.483E-02	6.457E-03	9.772E-03	1.995E-02	4.266E-02	5.495E-02
0.03	9.315E-03	1.549E-03	2.512E-03	6.310E-03	1.778E-02	2.455E-02
0.05	5.410E-03	7.079E-04	1.230E-03	3.388E-03	1.047E-02	1.514E-02
0.075	3.414E-03	3.467E-04	6.607E-04	2.042E-03	6.761E-03	1.000E-02
0.1	2.426E-03	1.950E-04	4.074E-04	1.380E-03	4.898E-03	7.413E-03
0.2	1.002E-03	3.311E-05	9.333E-05	4.786E-04	2.138E-03	3.388E-03
0.3	5.670E-04	8.913E-06	3.090E-05	2.188E-04	1.230E-03	2.042E-03
0.5	2.545E-04	1.202E-06	5.623E-06	6.457E-05	5.754E-04	1.023E-03
0.75	1.222E-04	1.778E-07	1.122E-06	2.042E-05	2.754E-04	5.248E-04
1	6.780E-05	3.802E-08	3.020E-07	7.762E-06	1.514E-04	3.090E-04
2	1.232E-05	4.571E-10	6.918E-09	4.786E-07	2.399E-05	6.310E-05
3	3.682E-06	2.042E-11	4.898E-10	6.607E-08	6.166E-06	1.950E-05
5	6.265E-07	2.692E-13	1.122E-11	3.802E-09	8.128E-07	3.311E-06
7.5	1.245E-07	6.166E-15	4.467E-13	2.818E-10	1.202E-07	6.166E-07
10	3.526E-08	1.000E-16	4.266E-14	3.890E-11	2.630E-08	1.660E-07
20	1.157E-09	0.000E+00	1.122E-16	3.236E-13	3.715E-10	4.074E-09

Table 2.2.2-2c: Annual Frequency of Exceedance Mean and Fractile Base Rock Seismic Hazard Curves for 5% Damped 10 Hz SA at Columbia Generating Station (PNNL, 2014)

SA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.0001	9.372E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.514E-01
0.0005	8.421E-02	5.623E-02	6.457E-02	7.943E-02	1.000E-01	1.259E-01
0.001	7.411E-02	4.786E-02	5.623E-02	7.079E-02	9.120E-02	1.072E-01
0.005	3.855E-02	1.905E-02	2.512E-02	3.715E-02	5.248E-02	6.310E-02
0.01	2.391E-02	1.000E-02	1.413E-02	2.291E-02	3.388E-02	4.169E-02
0.02	1.318E-02	4.786E-03	6.918E-03	1.202E-02	1.950E-02	2.512E-02
0.05	5.174E-03	1.479E-03	2.344E-03	4.571E-03	7.943E-03	1.096E-02
0.1	2.346E-03	5.370E-04	9.120E-04	1.995E-03	3.802E-03	5.370E-03
0.2	9.721E-04	1.445E-04	2.951E-04	7.762E-04	1.660E-03	2.455E-03
0.3	5.397E-04	5.370E-05	1.288E-04	4.074E-04	9.550E-04	1.445E-03
0.5	2.276E-04	1.148E-05	3.548E-05	1.514E-04	4.266E-04	6.918E-04
0.75	1.011E-04	2.692E-06	1.000E-05	5.754E-05	1.950E-04	3.388E-04
1	5.253E-05	8.128E-07	3.631E-06	2.570E-05	1.023E-04	1.905E-04
1.5	1.848E-05	1.202E-07	6.918E-07	6.918E-06	3.548E-05	7.413E-05
2	8.032E-06	2.570E-08	1.820E-07	2.399E-06	1.514E-05	3.467E-05
3	2.158E-06	2.239E-09	2.239E-08	4.467E-07	3.715E-06	9.772E-06
5	3.225E-07	6.026E-11	9.772E-10	3.631E-08	4.786E-07	1.549E-06
7.5	5.844E-08	2.239E-12	5.754E-11	3.631E-09	7.079E-08	2.754E-07
10	1.566E-08	1.778E-13	6.457E-12	5.888E-10	1.585E-08	7.244E-08
20	4.656E-10	2.818E-16	2.344E-14	4.677E-12	2.630E-10	1.778E-09

Table 2.2.2-2d: Annual Frequency of Exceedance Mean and Fractile Base Rock Seismic Hazard Curves for 5% Damped 5 Hz SA at Columbia Generating Station (PNNL, 2014)

SA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.0001	9.441E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.514E-01
0.0005	8.809E-02	5.888E-02	6.761E-02	8.318E-02	1.047E-01	1.349E-01
0.001	7.878E-02	5.370E-02	6.166E-02	7.586E-02	9.550E-02	1.148E-01
0.005	4.042E-02	2.399E-02	2.951E-02	3.890E-02	5.129E-02	6.166E-02
0.01	2.427E-02	1.318E-02	1.660E-02	2.344E-02	3.236E-02	3.890E-02
0.02	1.290E-02	6.166E-03	8.128E-03	1.230E-02	1.738E-02	2.188E-02
0.05	4.750E-03	1.950E-03	2.692E-03	4.365E-03	6.761E-03	8.913E-03
0.1	1.986E-03	7.079E-04	1.047E-03	1.778E-03	2.951E-03	3.981E-03
0.2	7.420E-04	2.138E-04	3.311E-04	6.310E-04	1.148E-03	1.622E-03
0.3	3.828E-04	8.511E-05	1.479E-04	3.162E-04	6.026E-04	9.120E-04
0.5	1.441E-04	2.138E-05	4.266E-05	1.096E-04	2.399E-04	3.890E-04
0.75	5.762E-05	5.495E-06	1.259E-05	3.890E-05	1.000E-04	1.738E-04
1	2.759E-05	1.820E-06	4.677E-06	1.698E-05	4.898E-05	8.913E-05
1.5	8.565E-06	3.090E-07	9.550E-07	4.365E-06	1.514E-05	3.090E-05
2	3.383E-06	7.244E-08	2.630E-07	1.445E-06	5.888E-06	1.288E-05
3	7.889E-07	7.244E-09	3.388E-08	2.570E-07	1.318E-06	3.311E-06
5	9.839E-08	2.291E-10	1.660E-09	1.995E-08	1.445E-07	4.365E-07
7.5	1.554E-08	8.913E-12	1.000E-10	1.905E-09	1.950E-08	6.918E-08
10	3.796E-09	6.607E-13	1.072E-11	3.020E-10	4.074E-09	1.660E-08
20	9.133E-11	5.129E-16	2.344E-14	1.950E-12	5.754E-11	3.467E-10

Table 2.2.2-2e: Annual Frequency of Exceedance Mean and Fractile Base Rock Seismic Hazard Curves for 5% Damped 2.5 Hz SA at Columbia Generating Station (PNNL, 2014)

SA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.0001	9.452E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.0005	8.962E-02	5.888E-02	6.761E-02	8.318E-02	1.072E-01	1.380E-01
0.001	8.011E-02	5.370E-02	6.166E-02	7.586E-02	9.550E-02	1.175E-01
0.005	3.739E-02	2.239E-02	2.754E-02	3.631E-02	4.786E-02	5.623E-02
0.01	2.075E-02	1.175E-02	1.445E-02	1.995E-02	2.692E-02	3.311E-02
0.02	1.015E-02	5.129E-03	6.607E-03	9.550E-03	1.349E-02	1.698E-02
0.05	3.348E-03	1.380E-03	1.905E-03	3.090E-03	4.786E-03	6.310E-03
0.1	1.247E-03	4.571E-04	6.457E-04	1.096E-03	1.820E-03	2.512E-03
0.2	3.915E-04	1.175E-04	1.820E-04	3.311E-04	6.026E-04	8.511E-04
0.3	1.778E-04	4.365E-05	7.244E-05	1.445E-04	2.818E-04	4.169E-04
0.5	5.624E-05	9.333E-06	1.738E-05	4.169E-05	9.333E-05	1.514E-04
0.75	1.946E-05	2.089E-06	4.571E-06	1.288E-05	3.311E-05	5.888E-05
1	8.381E-06	6.310E-07	1.514E-06	5.012E-06	1.445E-05	2.754E-05
1.5	2.225E-06	8.913E-08	2.570E-07	1.096E-06	3.802E-06	8.128E-06
2	7.827E-07	1.820E-08	6.310E-08	3.236E-07	1.318E-06	3.020E-06
3	1.545E-07	1.445E-09	6.607E-09	4.677E-08	2.455E-07	6.457E-07
5	1.561E-08	3.236E-11	2.344E-10	2.818E-09	2.188E-08	6.918E-08
7.5	2.091E-09	9.120E-13	1.072E-11	2.188E-10	2.455E-09	9.333E-09
10	4.538E-10	5.248E-14	9.333E-13	2.951E-11	4.467E-10	1.950E-09
20	8.102E-12	1.862E-17	1.023E-15	1.230E-13	4.365E-12	3.020E-11

Table 2.2.2-2f: Annual Frequency of Exceedance Mean and Fractile Base Rock Seismic Hazard Curves for 5% Damped 1 Hz SA at Columbia Generating Station (PNNL, 2014)

SA [g]	Mean AFE	5^{th} Fractile AFE	16^{th} Fractile AFE	50^{th} Fractile AFE	84^{th} Fractile AFE	95^{th} Fractile AFE
0.00001	9.457E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.00005	9.445E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.0001	9.366E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.514E-01
0.0005	7.614E-02	5.012E-02	5.754E-02	7.244E-02	9.333E-02	1.148E-01
0.001	5.808E-02	3.715E-02	4.365E-02	5.623E-02	7.244E-02	8.710E-02
0.003	2.844E-02	1.698E-02	2.042E-02	2.754E-02	3.631E-02	4.365E-02
0.005	1.809E-02	1.047E-02	1.288E-02	1.738E-02	2.344E-02	2.884E-02
0.01	8.721E-03	4.571E-03	5.754E-03	8.318E-03	1.148E-02	1.445E-02
0.02	3.754E-03	1.585E-03	2.138E-03	3.467E-03	5.370E-03	6.918E-03
0.03	2.159E-03	7.943E-04	1.096E-03	1.905E-03	3.236E-03	4.467E-03
0.05	9.827E-04	3.236E-04	4.571E-04	8.128E-04	1.514E-03	2.188E-03
0.1	2.712E-04	7.586E-05	1.175E-04	2.188E-04	4.169E-04	6.310E-04
0.2	5.472E-05	1.072E-05	1.905E-05	4.266E-05	8.913E-05	1.413E-04
0.3	1.823E-05	2.512E-06	5.012E-06	1.288E-05	3.090E-05	5.129E-05
0.5	3.758E-06	2.754E-07	6.761E-07	2.239E-06	6.457E-06	1.230E-05
0.75	8.990E-07	3.388E-08	1.023E-07	4.365E-07	1.549E-06	3.311E-06
1	2.938E-07	6.310E-09	2.239E-08	1.175E-07	4.898E-07	1.148E-06
2	1.377E-08	4.786E-11	2.884E-10	2.884E-09	1.995E-08	6.026E-08
5	1.672E-10	2.951E-14	4.467E-13	1.202E-11	1.660E-10	7.244E-10
10	7.121E-12	9.120E-17	3.090E-15	2.042E-13	4.898E-12	2.754E-11

Table 2.2.2-2g: Annual Frequency of Exceedance Mean and Fractile Base Rock Seismic Hazard Curves for 5% Damped 0.55 Hz SA at Columbia Generating Station (PNNL, 2014)

SA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.00001	9.456E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.00005	9.228E-02	6.026E-02	6.918E-02	8.511E-02	1.096E-01	1.479E-01
0.0001	8.577E-02	5.623E-02	6.457E-02	8.128E-02	1.023E-01	1.318E-01
0.0005	4.813E-02	2.951E-02	3.548E-02	4.571E-02	6.026E-02	7.413E-02
0.001	3.171E-02	1.905E-02	2.291E-02	3.020E-02	3.981E-02	4.898E-02
0.003	1.376E-02	8.128E-03	9.772E-03	1.318E-02	1.778E-02	2.138E-02
0.005	8.460E-03	4.677E-03	5.888E-03	8.128E-03	1.096E-02	1.349E-02
0.01	3.935E-03	1.698E-03	2.291E-03	3.631E-03	5.623E-03	7.079E-03
0.02	1.569E-03	4.898E-04	6.918E-04	1.288E-03	2.512E-03	3.631E-03
0.03	8.156E-04	2.188E-04	3.162E-04	6.026E-04	1.318E-03	2.089E-03
0.05	2.997E-04	6.607E-05	1.023E-04	2.089E-04	4.786E-04	8.511E-04
0.1	5.295E-05	8.128E-06	1.479E-05	3.548E-05	8.318E-05	1.549E-04
0.2	5.984E-06	4.677E-07	1.122E-06	3.548E-06	1.023E-05	1.950E-05
0.3	1.357E-06	5.888E-08	1.698E-07	6.918E-07	2.344E-06	4.898E-06
0.5	1.661E-07	2.692E-09	1.047E-08	6.026E-08	2.818E-07	6.761E-07
0.75	2.590E-08	1.479E-10	7.762E-10	6.607E-09	3.981E-08	1.122E-07
1	6.247E-09	1.445E-11	1.000E-10	1.148E-09	8.710E-09	2.818E-08
2	1.422E-10	1.995E-14	3.162E-13	9.120E-12	1.349E-10	6.166E-10
5	5.984E-13	5.623E-19	4.898E-17	6.166E-15	2.692E-13	1.995E-12
10	1.125E-14	0.000E+00	0.000E+00	2.188E-17	2.512E-15	2.754E-14

Table 2.2.2-3: Acronyms for Seismic Sources and Indication of Those Sources Contributing more than 5% of the Total 1 and/or 10 Hz Seismic Hazard for Mean Annual Frequencies of Exceedance Between 10^{-4} and 10^{-5}

Acronym	Seismic Source Name	>5% Contribution*
Subduction Sources		
CSZ	Cascadia Subduction Zone (interface)	2
JDF	Juan de Fuca Intraslab source	
Crustal Area Sources		
YFTB	Yakima Fold and Thrust Belt Background	1
Zone B	Mid-C Study Zone B	
Zone C	Mid-C Study Zone C	
Zone D	Zone D	
Crustal Fault Sources		
AF	Arlington	
ARH	Ahtanum – Rattlesnake Hills	10
CH	Columbia Hills	
CM	Cleman Mountain	
FH	Frenchman Hills	
HHH	Horse Heaven Hills	7
HR	Horn Rapids Fault	6
LB	Luna Butte	
LF	Laurel	
MF	Maupin	
MR	Manastash Ridge	
RAW	Rattles of the Rattlesnake-Wallula Alignment	8
RM	Rattlesnake Mountain	3
SB	Selah Butte	
SFZ	Seattle Fault	
SM	Saddle Mountain	9
TR	Toppenish Ridge	
UR	Umtanum Ridge	4
WF	Wallula Fault	
YR	Yakima Ridge	5

Note: Modified after Table 10.13 in PNNL (2014)

* Number represents approximate order of contribution to the total hazard; lack of a number indicates that the source contributed <5% to the total hazard

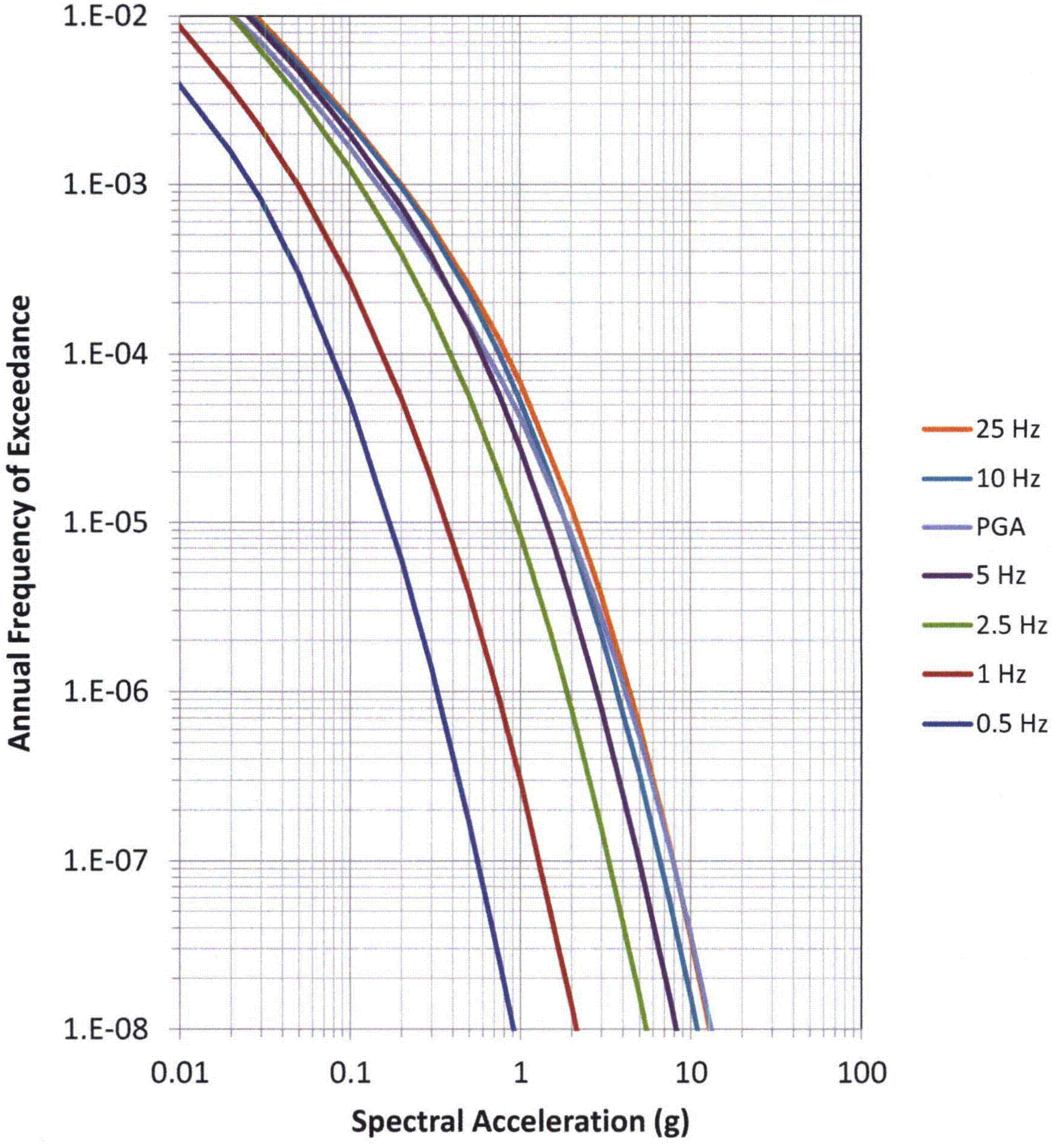
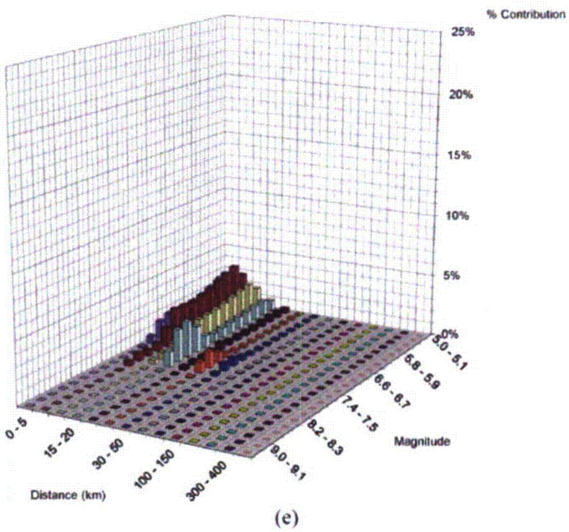
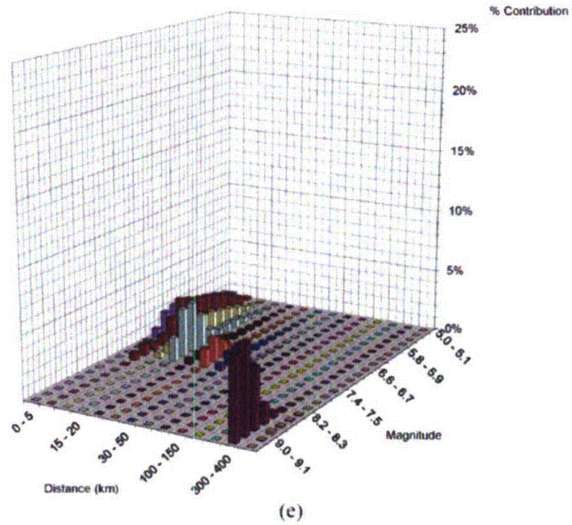


Figure 2.2.2-1: Mean Base Rock Hazard Curves for Oscillator Frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 Hz at Columbia Generating Station (PNNL, 2014) at 5% Spectral Damping

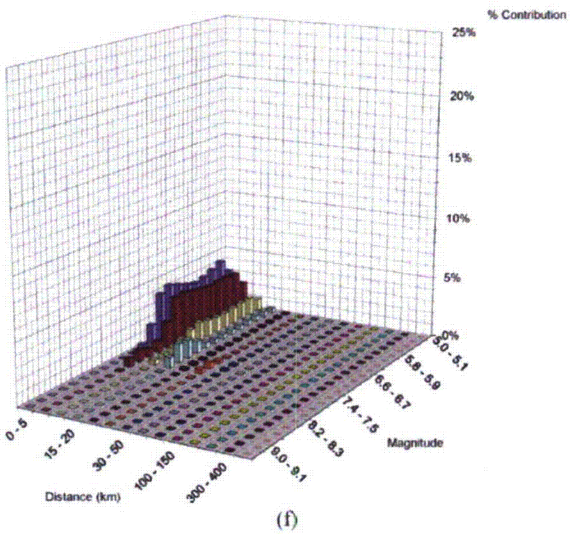
Site C (CGS): 10^{-4} MAFE: T=0.1 sec SA



Site C (CGS): 10^{-4} MAFE: T=1.0 sec SA



Site C (CGS): 10^{-5} MAFE: T=0.1 sec SA



Site C (CGS): 10^{-5} MAFE: T=1.0 sec SA

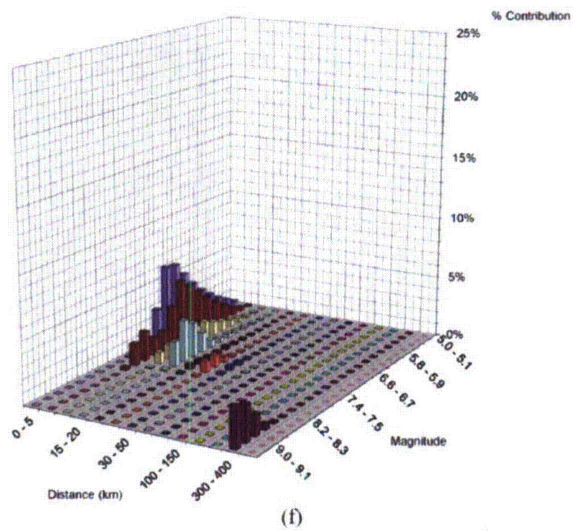


Figure 2.2.2-2: Deaggregation Histogram Showing Magnitude-Distance Contributions to the Total Mean Hazard at Site C for 5% Damped 10 Hz (0.1 s) (left column) and 1 Hz (1.0 s) (right column) Spectral Accelerations at MAFEs of 10^{-4} (top row) and 10^{-5} (bottom row) (Source: Figures 10.41 and 10.42 in PNNL, 2014)

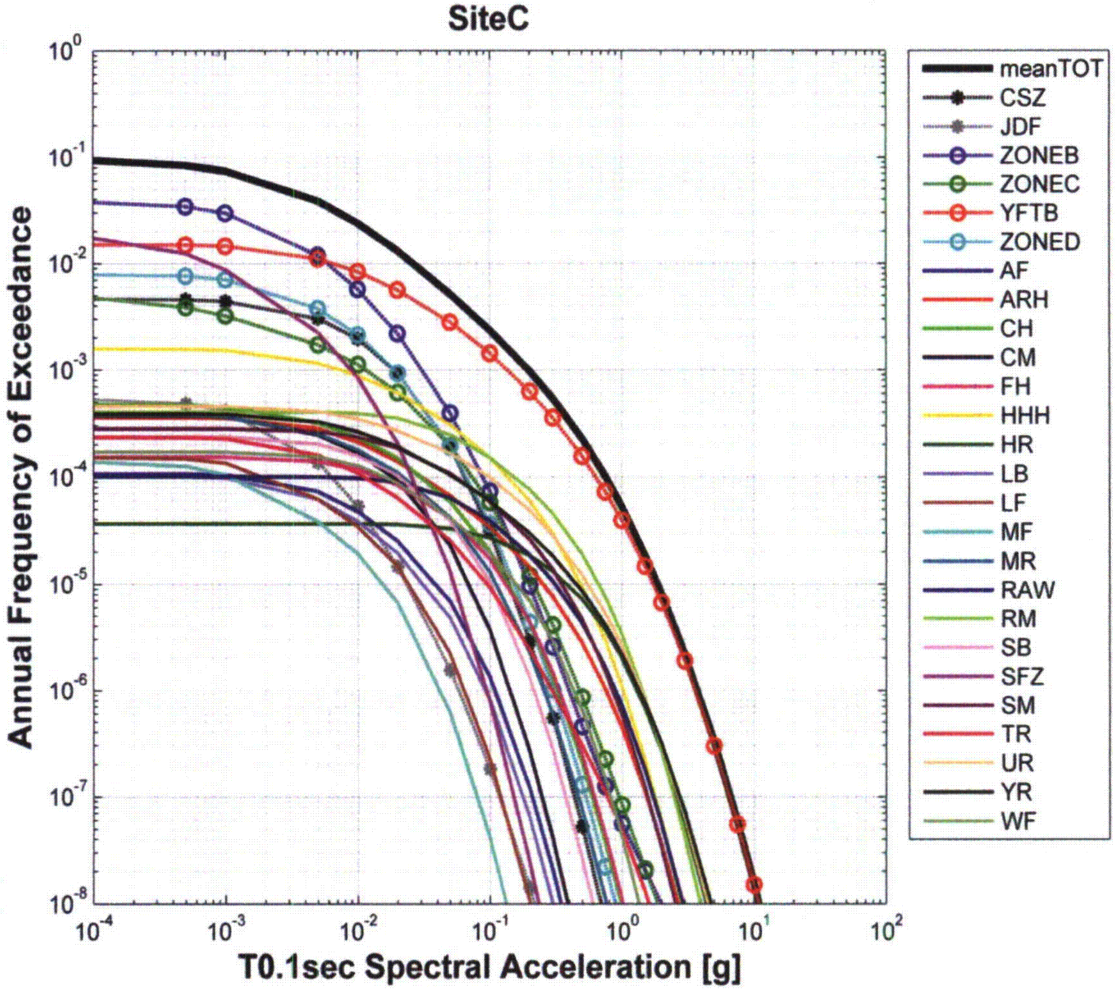


Figure 2.2.2-3. Comparison Between the Mean Hazard Curves at Columbia Generating Station (Site C) Obtained for Each Individual Source: subduction sources are shown by dotted star curves; crustal sources by dotted circle curves; and fault sources by solid curves for 5% damped 10 Hz (0.1 s) SA. Acronyms used in figures are listed in Table 2.2.2-3 (Source: Figure 10.44 in PNNL, 2014)

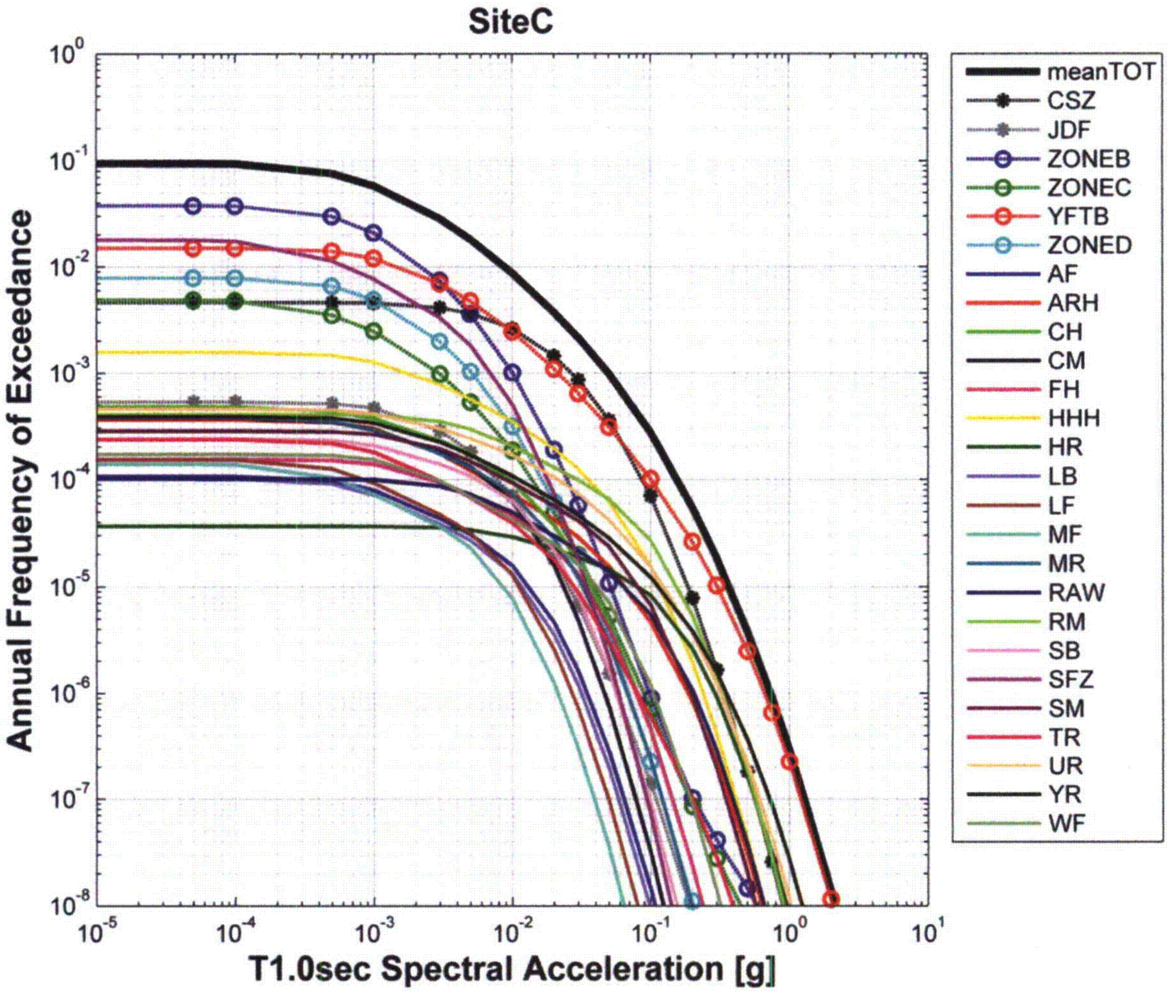


Figure 2.2.2-4. Comparison Between the Mean Hazard Curves at Columbia Generating Station (Site C) Obtained for Each Individual Source: subduction sources are shown by dotted star curves; crustal sources by dotted circle curves; and fault sources by solid curves for 5% damped 1 Hz (1.0 s) PSA. Acronyms used in figures are listed in Table 2.2.2-3 (Source: Figure 10.44 in PNNL, 2014)

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the NRC (2012a) 50.54(f) Request for Information and in the SPID (EPRI, 2013a) for nuclear power plant sites that are not located on hard rock (defined as $V_s \geq$ 9,200 ft/s or 2,830 m/s), a site response analysis was performed for CGS.

2.3.1 Description of Subsurface Material

Soils beneath the CGS site extend down to approximately 525 ft depth. The top soil layer consists of about 45 ft thickness of Pasco Gravel, a Quaternary deposit made up of glaciofluvial sediments consisting of loose to medium dense sand with scattered gravel. These soils are underlain by the Pliocene-age Ringold Formation. The Ringold comprises (1) the Middle Member, a very dense sandy gravel with interbedded sandy and silty layers, down to 250 ft depth, and (2) the Lower Member, from 250 ft to 525 ft depth, consisting of very dense interbedded layers of sandy gravel, silt and soft sandstone with some conglomerate present at the base of the layer. Several hundred feet of the Ringold Formation materials at the site were removed during Pleistocene floods. The overlying Pasco Gravel was deposited over the eroded surface of the Ringold Formation materials and has not been subjected to significant past loading. The groundwater table is in the Middle Ringold Member at a depth of about 62 ft.

The rock below 525 ft consists of the Saddle Mountains Basalt (SMB) down to about 1300 ft depth, underlain by the Wanapum Basalt, Grande Ronde Basalt, and the Imnaha Basalt. The Wanapum Basalt is counted as the start of basement rock, with a shear wave velocity (V_S) of over 9,200 ft/s. There are four basalt members within the SMB that range from about 110 ft to 215 ft in thickness, each underlain by a sedimentary interbed consisting mainly of sandstone and claystone, and ranging in thickness from about 15 ft to 70 ft. The collective interbeds are called the Ellensburg Formation. The deepest boring at the CGS plant extended to about 850 ft depth, to just below the bottom of the second sedimentary interbed (Selah Interbed) of the SMB. The stratigraphy below the Selah Interbed was inferred from four borings not drilled for CGS but within 2.6 to 3.4 miles of the site. The SMB stratigraphy at CGS (from the 850-ft deep boring at the site and the four borings beyond the site) is compared in Table 2.3.1-1 with the stratigraphy at the Waste Treatment Plant (WTP) about 10 miles northwest of CGS.

Table 2.3.1-1: Comparison of Estimated SMB Layer Thicknesses at CGS and WTP

Stratum	Thickness (ft)	
	CGS	WTP
Elephant Mountain Basalt	130(1)	110
Rattlesnake Ridge Interbed	25(1)	45
Pomona Basalt	160(1)	200
Selah Interbed	15(1)	20
Esquatzel Basalt	110(2)	90
Cold Creek Interbed	44(2)	95
Umatilla Basalt	214(2)	150
Mabton Interbed	67(2)	100

(1) From the 850-ft deep CGS site boring
(2) From the four borings located 2.6 miles to 3.4 miles from the CGS site

Table 2.3.1-1 shows that all of the basalt members and sedimentary interbeds of the SMB present at WTP are also present at the CGS site. The total thicknesses of the SMB at each site are comparable (765 ft at CGS and 810 ft at WTP) although the elevations of the top of the SMB are different (El. -85 ft at CGS and El. 290 ft at WTP). The thicknesses of each basalt member are comparable, with generally more variation in the interbed thicknesses. It is noted that at WTP, the Umatilla Member consists of the upper Sillusi flow and the underlying Umatilla flow. At CGS, the Umatilla Member is assumed to consist only of the Umatilla flow (PNNL, 2014).

The 850-ft deep boring at CGS did not include measurements of V_S or other geotechnical parameters. Actual V_S measurements at CGS were taken to 105 ft depth. V_S measurements were taken down to close to the bottom of the Ringold Formation at the nearby WNP-1 (1 mile southeast of the CGS site) and WNP-4 (3/4 mile northeast of the CGS site) sites, and can be used for the CGS site. (The WNP-1 and WNP-4 nuclear plants were started but not completed.) However, no measurements of V_S or other geotechnical parameters were made in the SMB at CGS, WNP-1 or WNP-4. Extensive V_S and unit weight (γ) measurements were performed down to about 1,450-ft depth at WTP, i.e., into the Wanapum Basalt basement rock. Given the level of agreement between the SMB stratigraphy at the CGS and WTP, it is reasonable to apply the WTP SMB V_S and γ values to the CGS site.

Table 2.3.1-2 provides a brief description of the subsurface materials in terms of the geologic units and layer thicknesses. This table includes best estimate values of V_S, compressive wave velocity (V_P), γ and Poisson's ratio. As discussed in Section 2.3.2, both down-hole and P-S suspension logging measurements were used to measure V_S at WTP. The V_S values in the SMB in Table 2.3.1-2 are the mean values from the down-hole measurements since they are considered to be more representative. The P-S suspension logging V_S measurements are presented and discussed in Section 2.3.2.

Table 2.3.1-2: Geologic Profile and Estimated Layer Thicknesses for CGS

Depth Range (ft)	Soil/Rock Description	Density (pcf)	V_S (ft/s)	V_P (ft/s)	Poisson's Ratio
0	SSE control point	---	---	---	---
0-6	Pasco Gravel	105	520	1,080	0.35
6-13	Pasco Gravel	105	700	1,460	0.35
13-21	Pasco Gravel	105	840	1,750	0.35
21-45	Pasco Gravel	105	900	1,875	0.35
45-56	Middle Ringold	141	1,320	2,620	0.33
56-85	Middle Ringold	145	2,040	4,805	0.39
85-250	Middle Ringold	145	4,740	10,135	0.36
250-300	Lower Ringold	145	2,300	4,920	0.36
300-325	Lower Ringold	145	3,260	6,970	0.36
325-525	Lower Ringold	145	2,200	4,705	0.36
525-655	Elephant Mountain Basalt (SMB)	175	7,575	15,950	0.35
655-680	Rattlesnake Ridge Interbed	118	2,750	7,520	0.42
680-840	Pomona Basalt (SMB)	175	8,300	16,120	0.32
840-855	Selah Interbed	133	2,945	7,400	0.41
855-965	Esquatzel Basalt (SMB)	171	8,285	17,175	0.35
965-1009	Cold Creek Interbed	121	2,700	6,560	0.40
1009-1223	Umatilla Basalt (SMB)	166	8,360	17,270	0.35
1223-1290	Mabton Interbed	127	2,720	7,445	0.42
1290+	Basement Rock	176	9,840	20,870	0.36

There are transition zones called flow tops between the interbeds and the SMB basalt members, ranging in thickness from approximately 20 ft above the Elephant Mountain Basalt to 31 ft above the Pomona Basalt. These flow tops consist of breccia, vesicular basalt, or a mixture of sedimentary clay and basalt breccia. V_S increases through these flow tops from the interbed V_S to the basalt V_S. The thickness of the flow tops is included in the depth range for each of the basalt members listed in Table 2.3.1-2. There is also a thin flow top at the top of the underlying Wanapum Basalt. The flow top V_S values (and corresponding flow top densities) are not included in Table 2.3.1-2, but are modeled in the seismic response analysis.

As noted earlier in this section, the Wanapum Basalt below the SMB is counted as the start of basement rock, with a shear wave velocity (V_S) of over 9,200 ft/s. The basement rock is modeled with an assigned V_S of 9,840 ft/s (3,000 m/s) in the seismic response analysis and this is the value shown in Table 2.3.1-2.

2.3.2 Development of Base Case Profiles and Nonlinear Material Properties

The approach taken in developing base case profiles and nonlinear material properties for the upper 525 ft of soil materials at CGS is substantially different from that for the underlying basalt members and interbeds.

<u>Soil Materials to 525 Ft Depth</u>

Available Data

There are four sources of data available to create the base-case soil V_S profile:

1. The cross-hole V_S profile from CGS (originally called WNP-2) to a depth of 105 ft.
2. Cross-hole and down-hole V_S results from nearby WNP-1 and WNP-4.
3. Seismic refraction survey interpretation in the upper materials at CGS.
4. Indirect means of determining shear wave variation using SPT N-value data for the shallower deposits.

Figure 2.3.2-1 shows V_S plotted versus depth for data sources 1 and 2. These plotted results do not show the actual measured values, but rather averaged results over specified depth intervals. There is generally good agreement between the results in the figure. The V_S measurements in the Middle Member of the Ringold Formation between about 100 ft to 250 ft depth range from around 4,500 ft/s to 5,000 ft/s. These values are considerably higher than would be expected in what is generally regarded as a soil formation. However, there is strong supporting evidence for these higher values:

- The results at CGS increased to around 4,200 ft/s towards the bottom of the boring.
- Similar measurements were obtained at WNP-1 and WNP-4 using both cross-hole and down-hole methods, which are quite different techniques that use entirely different instruments.
- The Vs measurements below 250-ft depth in the Lower Member of the Ringold Formation at WTP-1 and WTP-4 drop back into the expected Vs range of about 2,000 to 2,500 ft/s, again suggesting that the equipment was providing accurate measurements.

Three shallow seismic refraction survey lines (data source 3) were run at CGS. V_S values were obtained from the V_P measurements using the Poisson's ratio values given in Table 2.3.1-2. The measured cross-hole and derived seismic refraction V_S values down to 105 ft depth were in good agreement, including a jump to between 4,350 to 4,490 ft/s from seismic refraction, compared to 4,200 ft/s noted above for the same depth interval from the cross-hole.

There are numerous relationships developed in the literature to determine V_S using standard penetration test (SPT) N-values. For the CGS site, boring logs were available from 29 borings with SPT N-values taken at 2.5-ft to 10-ft intervals (data source 4). Refusal (N = 100 blows/ft) was reached typically at about 45 ft depth, i.e., at the bottom of the Pasco Gravel. Analysis of the standard deviation of these data using the natural log of V_S (i.e., σ_{lnVs}) showed that for the Pasco Gravel, the average σ_{lnVs} was about 0.25.

V_S measurements at WNP-1 extend to about 435 ft depth and at WNP-4 to about 400 ft depth. The bottom of the Ringold Formation is at about 437 ft depth at WNP-1 and at about 406 ft depth at WNP-4. Thus it can be concluded that the V_S measurements at these two sites extend to within a few feet of the bottom of the Ringold. It is reasonable to conclude that the best fitting V_S value of just over 2,000 ft/s in the lower portions of WNP-1 and WNP-4 (Figure 2.3.2-1) extends also to the bottom of the Ringold at CGS at 525 ft depth.

Base Case Profiles

EPRI (2013a) (SPID), Appendix B-3.2 indicates that for sites with very limited V_S data, the estimate for epistemic uncertainty is to be taken as $\sigma_{lnVs} = 0.35$. In this situation, there will be three base case V_S profiles, the best estimate or base case (V_{BC}), the lower range (V_{LR}) and the upper range (V_{UR}). Each of these V_S profiles is randomized and a weight given to each. EPRI (2013a) recommends that V_{LR} is the 10th percentile and V_{UR} is the 90th percentile, with V_{BC} being the 50th percentile. According to EPRI (2013a), the 10th and 90th percentiles correspond to a profile scale factor of 1.28 σ_{lnVs}. This results in $V_{LR} = 0.639\ V_{BC}$ and $V_{UR} = 1.565\ V_{BC}$. This is a much greater variation in V_S than obtained from the measured V_S values shown in Figure 2.3.2-1.

A more realistic approach is to accept that there is not a great deal of epistemic uncertainty at CGS, given the good agreement between the CGS, WNP-1 and WNP-4 V_S results, and the good agreement using cross-hole, down-hole and seismic refraction techniques., there is no distinct epistemic uncertainty on the shear-wave velocity data. Epistemic uncertainty represents the lack of knowledge about the V_S profile of the CGS site. Given the V_S profile shown in Figure 2.3.2-1, it is probable that an additional measured V_S profile would fall close to the V_{BC} profile derived from the Figure 2.3.2-1 results. Thus, the V_{BC} profile derived from Figure 2.3.2-1 will be used, and the aleatory variability (i.e., the inherent variability found at any site) will be accommodated by assigning standard deviation values to the V_{BC} profile to be used in the randomization process. The randomization process (Section 2.3.3) typically considers up to 2 standard deviations from the base case. As noted before, since seismic properties are typically considered to be log-normally distributed, σ_{lnVs} will be used, i.e., the log normal standard deviation. To summarize, a single base case profile (V_{BC}) will be used, and the variability in the randomization process will be accounted for by using simulated profiles. Table 2.3.2-1 shows the V_{BC} values computed from the Figure 2.3.2-1 results down to 525 ft depth. Values of σ_{lnVs} that are used to obtain V_{UB} and V_{LB} are discussed next.

For aleatory variability, EPRI (2013a) Appendix B-4.1 recommends using σ_{lnVs} = 0.25 down to 15 m (49 ft (15 m) depth and σ_{lnVs} = 0.15 below that. As noted above, the average σ_{lnVs} based on correlation with N-value for the top approximately 45 ft is about 0.25, in agreement with the EPRI (2013a) recommendation. The σ_{lnVs} = 0.25 is extended down to 56 ft depth, the nearest interval bottom to 49 ft.

Between 300 ft and 325 ft depth, (El. 140 ft to El. 115 ft) the WNP-1 V_S is about 2,300 ft/s while the WNP-4 V_S is about 4,300 ft/s, and V_{BC} is 3,260 ft/s. To account for this larger variation, σ_{lnVs} will be assigned a value of 0.3 in this range. Below 325 ft depth (El. 115 ft), although there are down-hole data for WNP-1 and WNP-4, these do not extend down to El. -85 ft (bottom of Ringold at CGS). Thus, there is a somewhat higher level of uncertainty in this range, and so σ_{lnVs} is increased to 0.2.

Table 2.3.2-1 shows the recommended V_S with the corresponding σ_{lnVs} values. The V_{BC}, V_{LB} and V_{UB} profiles, which respectively represent the 10th and 90th percentiles, are plotted in Figure 2.3.2-2. Note that the values from Figure 2.3.2-1 for CGS (WNP-2), WNP-1 and WNP-4 (cross-hole CH and down-hole DH) are also included in Figure 2.3.2-2.

Rock Below 525 Ft Depth

The rock beneath the bottom of the Ringold Formation is described in Section 2.3.1. It consists of the Saddle Mountains Basalt (SMB) down to about 1300 ft depth, underlain by the Wanapum Basalt which is counted as the start of basement rock, with V_S of over 9,200 ft/s. The stratigraphy of the rock at CGS is taken from a deep boring at the site down to about 850 ft depth and from four borings outside but relatively close to the site down to 1,300 ft depth. However, no V_S measurements were made in the rock in any of these five borings. As described in Section 2.3.1, the V_S values for the rock at CGS were obtained from extensive measurements made in the rock at WTP.

Both down-hole and P-S suspension logging V_S measurements were made down to about 1,400 ft depth at WTP, terminating in the Rosalia Flow of the Wanapum Basalt. The down-hole measurements (Profile C1) were judged to be more representative since it was determined that the P-S suspension logging measurements (Profile C2) would probably have required higher frequency signals to accurately measure the hard basalt (PNNL, 2014). It was concluded that the down-hole measurements could be considered to be twice as reliable as the P-S suspension logging measurements in this environment, leading to the assignment of relative weights of 2:1, i.e., a weight of 2 to V_S Profile C1 and a weight of 1 to V_S Profile C2 (PNNL, 2014).

The V_{BC} values versus depth and elevation for Profile C1 and Profile C2 are given in Table 2.3.2-2. *For variation of each* V_{BC} *profile,* σ_{lnVs} *of 0.1 is used for each basalt member, and* σ_{lnVs} *of 0.2* is used for each interbed (PNNL, 2014). The V_{BC}, V_{LB} and V_{UB} profiles are plotted on Figure 2.3.2-3 for both the rock and the soil with V_{LB} and V_{UB} representing the 10th and 90th percentiles.

As noted in Section 2.3.1, there are transition zones called flow tops between the interbeds and the SMB basalt members, ranging in thickness from approximately 20 ft above the Elephant Mountain Basalt to 31 ft above the Pomona Basalt. There is also a thin flow top at the top of the underlying Wanapum Basalt. The flow top V_S values (and corresponding flow top densities) are not included in Table 2.3.2-2 or Figure 2.3.2-3, but are modeled in the seismic response analysis. The flow top V_S values and corresponding flow top densities are shown in Figure 2.3.2-4 (from PNNL, 2014).

Table 2.3.2-1: Base Case Shear-Wave Velocity (V_{BC}) for the Soil Profile

Material	Depth (ft)	Top El. (ft)	V_s (ft/s)	σ_{lnVs}
Sand	0-6	440	520	0.25
Sand	6-13	434	700	0.25
Sand	13-21	427	840	0.25
Sand	21-45	419	900	0.25
Middle Ringold	45-56	395	1,320	0.25
Middle Ringold	56-85	384	2,040	0.15
Middle Ringold	85-250	355	4,740	0.15
Lower Ringold	250-300	190	2,300	0.15
Lower Ringold	300-325	140	3,260	0.30
Lower Ringold	325-525	115	2,200	0.20

Table 2.3.2-2: Base Case Shear-Wave Velocity (V_{BC}) Rock Profiles C1 and C2

Material	Depth (ft)	Top El. (ft)	V_{BC} C1 (ft/s)	V_{BC} C2 (ft/s)	$\sigma_{ln Vs}$
Elephant Mtn Basalt (SMB)	525-655	-85	7,575	9,550	0.1
Rattlesnake Ridge Interbed	655-680	-215	2,750	2,730	0.2
Pomona Basalt (SMB)	680-840	-240	8,300	10,235	0.1
Selah Interbed	840-855	-400	2,945	3,190	0.2
Esquatzel Basalt (SMB)	855-965	-415	8,285	9,690	0.1
Cold Creek Interbed	965-1009	-525	2,700	2,490	0.2
Umatilla Basalt (SMB)	1009-1223	-569	8,360	9,420	0.1
Mabton Interbed	1223-1290	-783	2,720	2,565	0.2
Basement Rock	1290+	-850	9,840	9,840	-

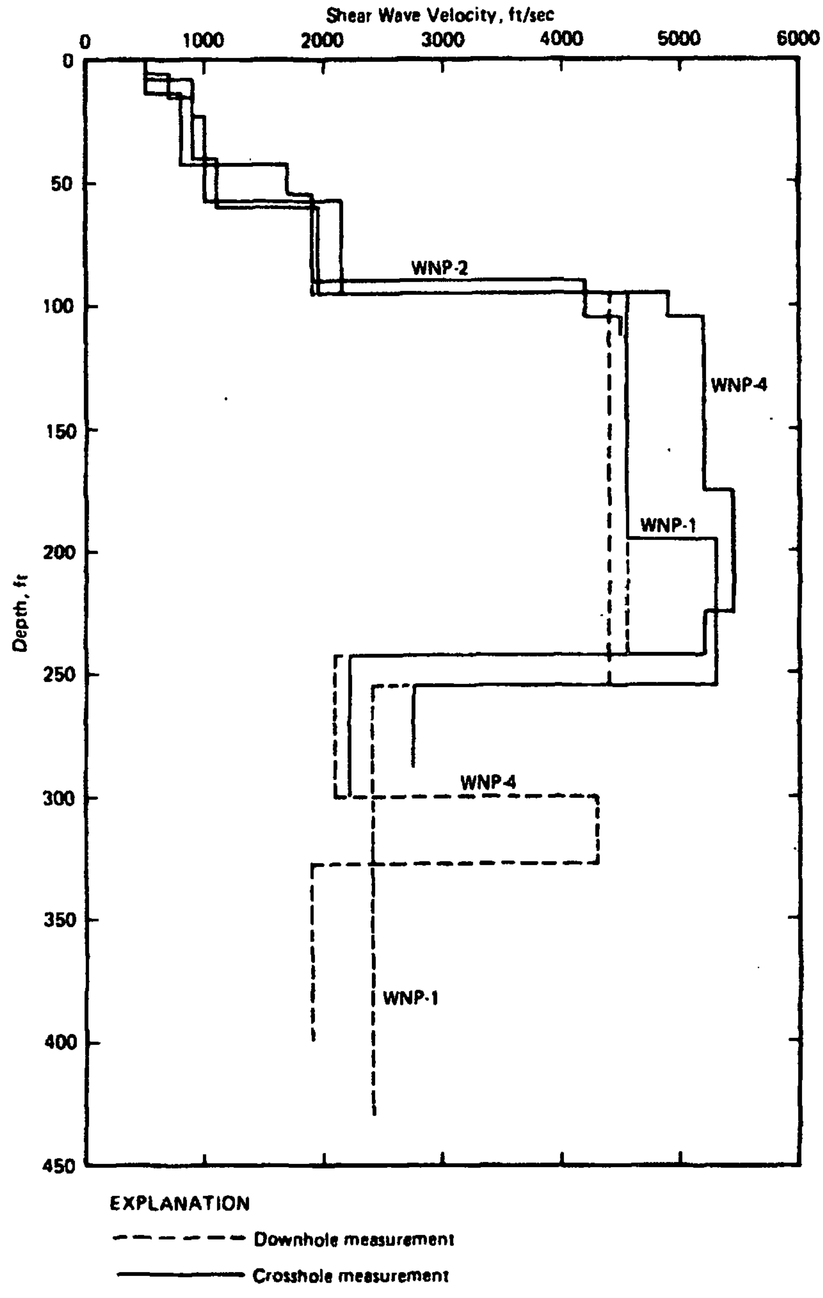


Figure 2.3.2-1: V_S Values in Soil from CGS (WNP-2), WNP-1 and WNP-4
(Source: FSAR Figure 361.017-1; EN, 2013b)

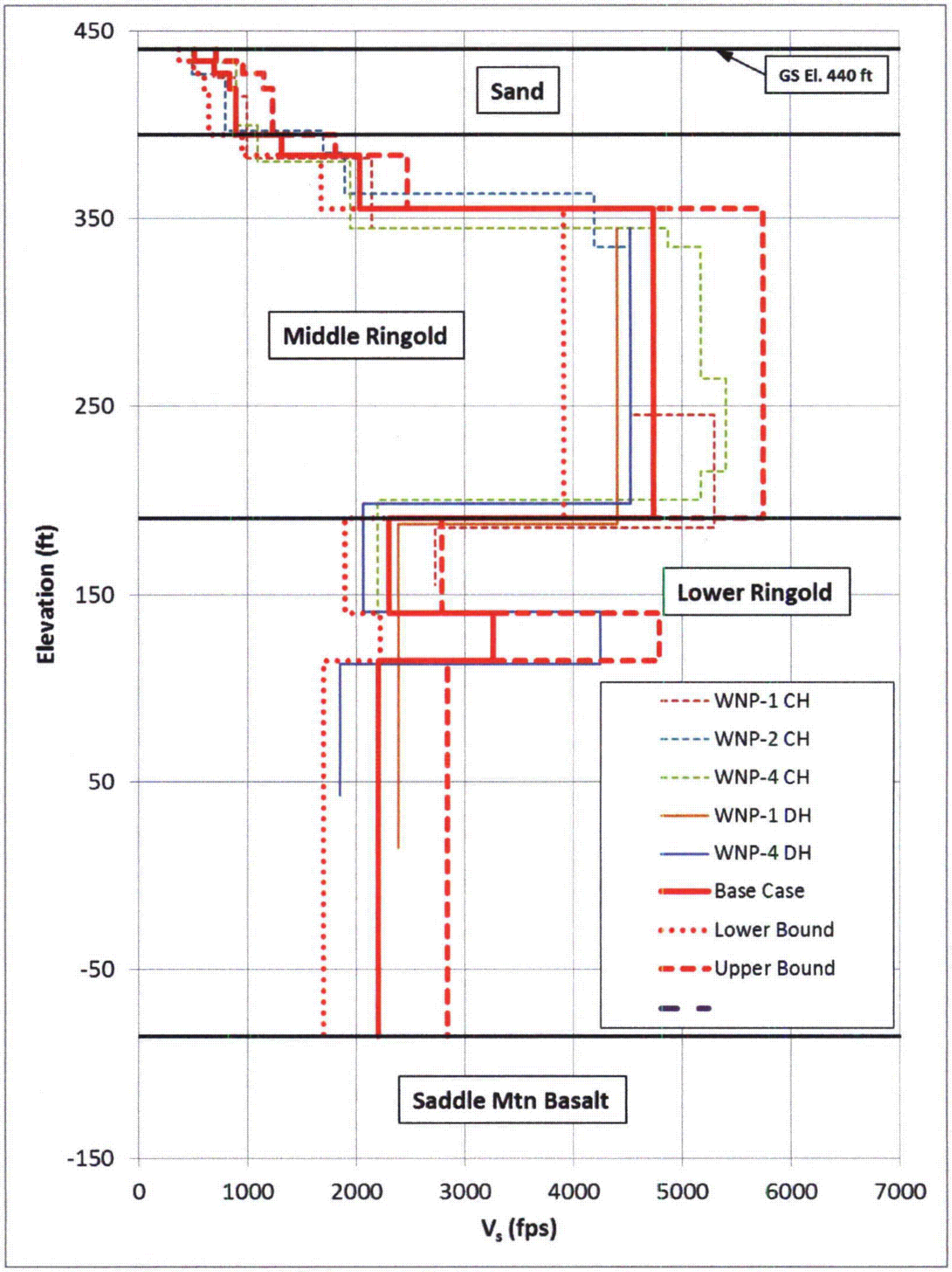


Figure 2.3.2-2: Base Case, Lower Bound and Upper Bound V_S in Top 525 Ft

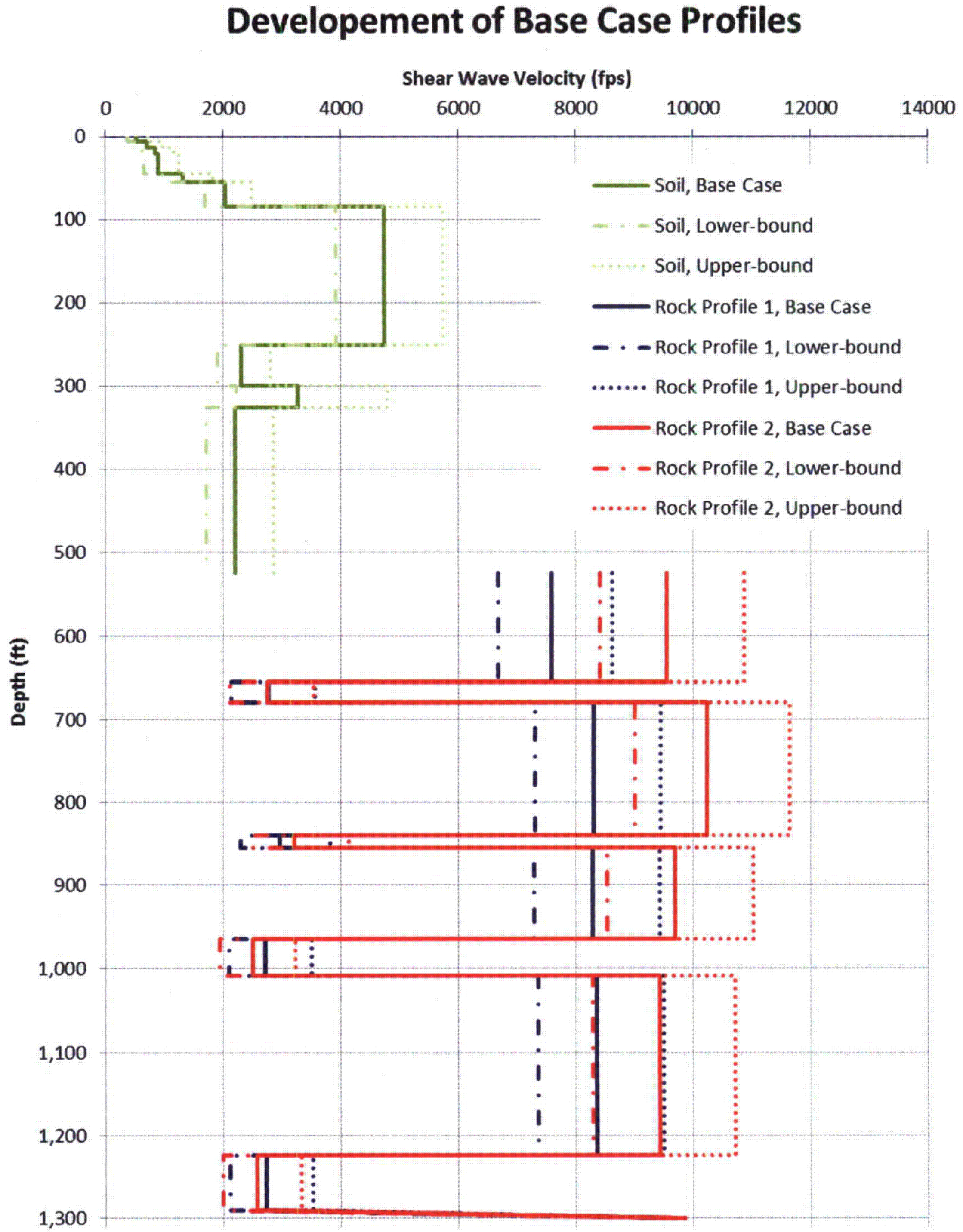


Figure 2.3.2-3: Base Case, Lower Bound and Upper Bound V_S for Rock Profiles C1 & C2

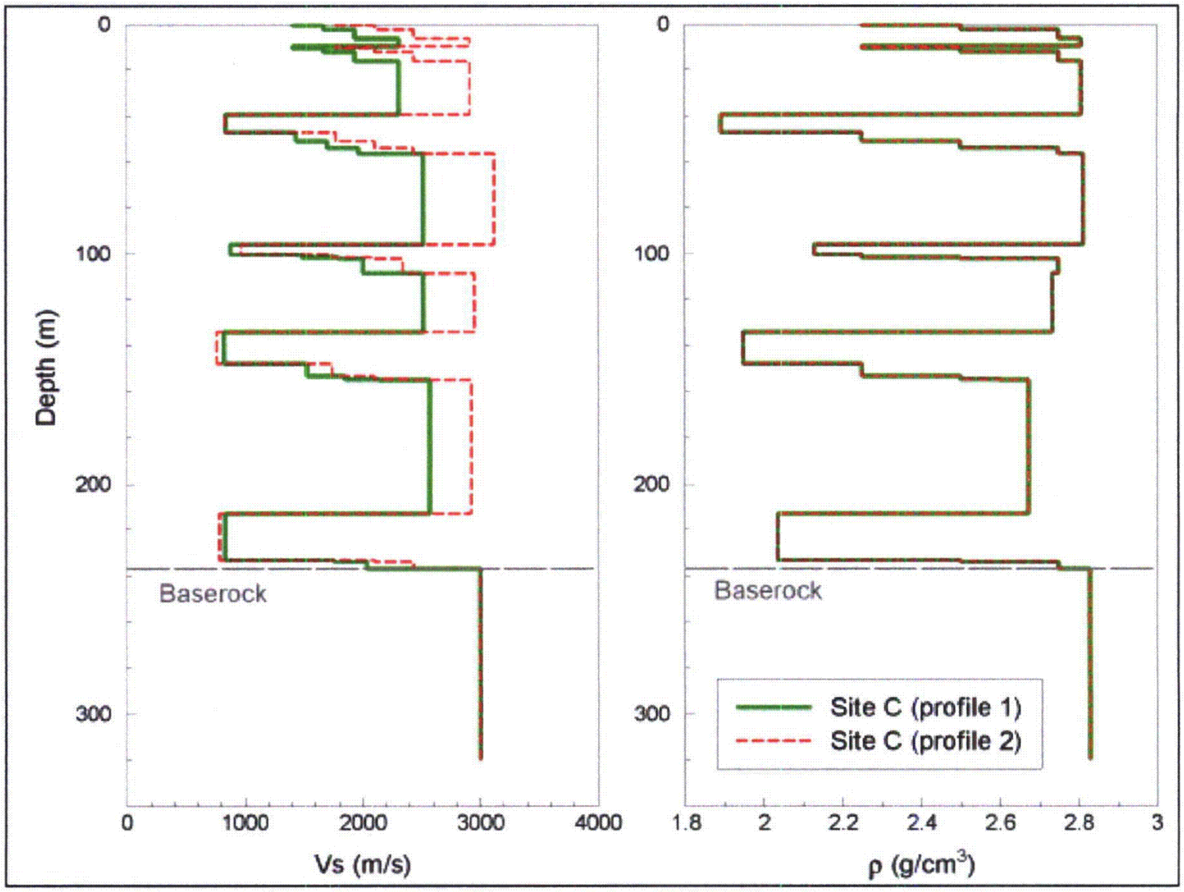


Figure 2.3.2-4: Rock Profiles C1 & C2 Showing Flow Top Shear-Wave Velocities and Densities (PNNL, 2014)

2.3.2.1 Shear Modulus and Damping Ratio Curves

2.3.2.1.1 Shear Modulus and Damping for Soil Materials to 525 Ft Depth

For curves of soil shear modulus reduction (G/G_{MAX}) and damping ratio (D) versus cyclic shear strain, EPRI (2013a) (SPID) recommends using the EPRI and Peninsular curves for cohesionless soils defined by depth, giving an equal weight to each. Since the CGS soils are classified as mainly sand in the upper 45 ft, and the Ringold Formation from 45 ft to 525 ft is mainly sandy gravel, these curves are appropriate. Figure B-8 of EPRI (2013a) shows the EPRI curves, giving curves from 0-20 ft depth all the way down to 500-1,000 ft depth (from EPRI, 1993). This figure is included here as Figure 2.3.2.1-1. The tabulated values scaled from these curves are given in Table 2.3.2.1-1 for G/G_{MAX} and Table 2.3.2.1-2 for D.

The Peninsular curves (from Silva et al, 1997) for G/G_{MAX} and D versus shear strain for depth of 0 to 50 ft and depth of 50 to 500 ft are given in Figure 2.3.2.1-2. The tabulated values of the Peninsular curves are given in Table 2.3.2.1-3 for G/G_{MAX} and D. Comparison of the values in Tables 2.3.2.1-1, 2.3.2.1-2 and 2.3.2.1-3 shows that for G/G_{MAX} and D, the Peninsular curve for depth of 0 to 50 ft is very similar to the EPRI curve for depth of 50 to120 ft, and the Peninsular curve for depth of 50 to 500 ft is very similar to the EPRI curve for depth of 500 to 1,000 ft. This similarity is noted in EPRI (2013a).

As noted in EPRI (2013a), D values are limited to 15% in the soil column analysis.
Table 2.3.2.1-4 shows the applicable curves from Tables 2.3.2.1-1, 2.3.2.1-2 and 2.3.2.1-3 for use in each depth range.

The uncertainty of each G/G_{MAX} and D versus shear strain curve is computed following the methodology outlined in EPRI (2013a) and further explained in PNNL (2014). At a shear strain of 0.03%, the variation of G/G_{MAX} and D is treated as a log normal distribution with the natural log of the standard deviation σ_{ln} = 0.15 for G/G_{MAX} and σ_{ln} = 0.30 for D. For D, σ_{ln} is independent of shear strain. For G/G_{MAX}, σ_{ln} is varied with shear strain to taper the variation at small strains such that the non-linear curves converge to 1 at small strains.

2.3.2.1.2 Shear Modulus and Damping for Rock below 525 Ft Depth

The basalt members of the Saddle Mountains Basalt behave as elastic materials with G/G_{MAX} = 1 over the strain range of interest. Damping of the basalt members is independent of strain, and was estimated as a function of the inverse of V_S (PNNL, 2014). Damping values ranged from a high of 1.03% in Profile 1 for the uppermost flow top of the Elephant Mountain Basalt to 0.46% in Profile 2 for the Pomona Basalt, with a median of about 0.75% (Profile 1) and about 0.65% (Profile 2).

Several non-linear models were considered for establishing G/G_{MAX} and D for the Saddle Mountains Basalt interbeds. The model proposed by Darendeli (2001) was considered viable for the interbeds and was adopted because it offers more flexibility and accounts for confining stress dependence which is important for the depths at which the interbeds are located (PNNL, 2014).

The Darendeli (2001) equations for damping have two separate terms. The first term is independent of strain and controls low-strain damping. As with the basalt members, this low-strain term was estimated for the interbeds as a function of the inverse of V_S (PNNL, 2014). The second term represents hysteretic damping and is strain-dependent. This term has very low values at low strains but is the dominant term at high strains. The damping curves for the interbeds are constructed as the sum of the low-strain damping (function of the inverse of V_S) and the hysteretic damping term (PNNL, 2014). Examination of the PNNL (2014) interbed damping curves indicates that the low-strain damping term is reduced with increasing strain, and only the hysteretic portion is used at shear strains above about 0.05%.

All four interbeds have very large confining stresses, with the deepest interbed (Mabton) having the most and the shallowest interbed (Rattlesnake Ridge) having the least. This results in the Mabton interbed having slightly less G/G_{MAX} reduction with increasing shear strain than the Rattlesnake Ridge interbed. Similarly, the Mabton interbed has slightly less damping with increasing shear strain than the Rattlesnake Ridge interbed. The Cold Creek interbed (shallower than the Mabton and deeper than the Rattlesnake Ridge) has G/G_{MAX} and D curves that are between (but very close to) those of the Mabton and Rattlesnake Ridge interbeds. These Cold Creek curves will be used to illustrate the G/G_{MAX} and D values for the interbeds.

The Cold Creek interbed curves (derived from PNNL, 2014) for G/G_{MAX} and D versus shear strain are shown in Figure 2.3.2.1-3. The tabulated values of these curves are given in Table 2.3.2.1-5 for G/G_{MAX} and D. As noted in EPRI (2013a), D values are limited to 15% in the rock column analysis.

The uncertainty of G/G_{MAX} and D for the interbeds is treated the same way as for the overlying soils, as described in Section 2.3.2.1.1.

Table 2.3.2.1-1: Shear-Modulus Reduction Curves for the EPRI (1993) Model

	G/G_{MAX}					
Shear Strain (%)	0-20 ft	20-50 ft	50-120 ft	120-250 ft	250-500 ft	500-1000 ft
0.0001	1.0	1.0	1.0	1.0	1.0	1.0
0.000316	1.0	1.0	1.0	1.0	1.0	1.0
0.001	0.99	0.995	0.995	0.995	1.0	1.0
0.00316	0.92	0.95	0.97	0.98	0.99	0.995
0.01	0.76	0.83	0.88	0.91	0.94	0.96
0.0316	0.50	0.60	0.70	0.75	0.80	0.86
0.1	0.28	0.36	0.44	0.50	0.57	0.65
0.316	0.125	0.18	0.23	0.28	0.33	0.40
1.0	0.05	0.075	0.10	0.13	0.16	0.20

Table 2.3.2.1-2: Damping Ratio Curves for the EPRI (1993) Model

	Damping Ratio (%)(1)					
Shear Strain (%)	0-20 ft	20-50 ft	50-120 ft	120-250 ft	250-500 ft	500-1000 ft
0.0001	1.5	1.25	1.0	1.0	1.0	0.5
0.000316	1.5	1.25	1.0	1.0	1.0	0.5
0.001	2.0	1.5	1.25	1.0	1.0	0.5
0.00316	2.6	2.0	1.5	1.25	1.1	0.75
0.01	5.0	3.5	2.7	2.2	2.0	1.25
0.0316	9.5	7.5	5.7	4.2	3.6	2.5
0.1	15.1	12.5	10.3	8.75	7.3	5.1
0.316	22.0	19.0	16.5	14.5	12.8	10.2
1.0	27.5	24.7	22.6	20.8	19.0	16.2

(1) Damping is limited to 15% maximum in the soil column analysis.

Table 2.3.2.1-3: The Shear-Modulus Reduction and Damping Ratio Curves for the Peninsular Range (Silva et al., 1997) model

Shear Strain (%)	G/G_{MAX}		Damping Ratio (%)[1]	
	0-50 ft	50-500 ft	0-50 ft	50-500 ft
0.0001	1.0	1.0	1.1	0.5
0.000316	1.0	1.0	1.1	0.5
0.001	1.0	1.0	1.3	0.5
0.00316	0.96	0.99	1.6	0.9
0.01	0.85	0.95	3.0	1.4
0.0316	0.67	0.84	5.5	2.6
0.1	0.43	0.64	10.3	5.5
0.316	0.22	0.40	16.5	10.3
1.0	0.09	0.20	22.8	16.5

(1) Damping is limited to 15% maximum in the soil column analysis.

Table 2.3.2.1-4: Selected G/G_{max} and Damping Ratio Curves for Depths Above 525 ft

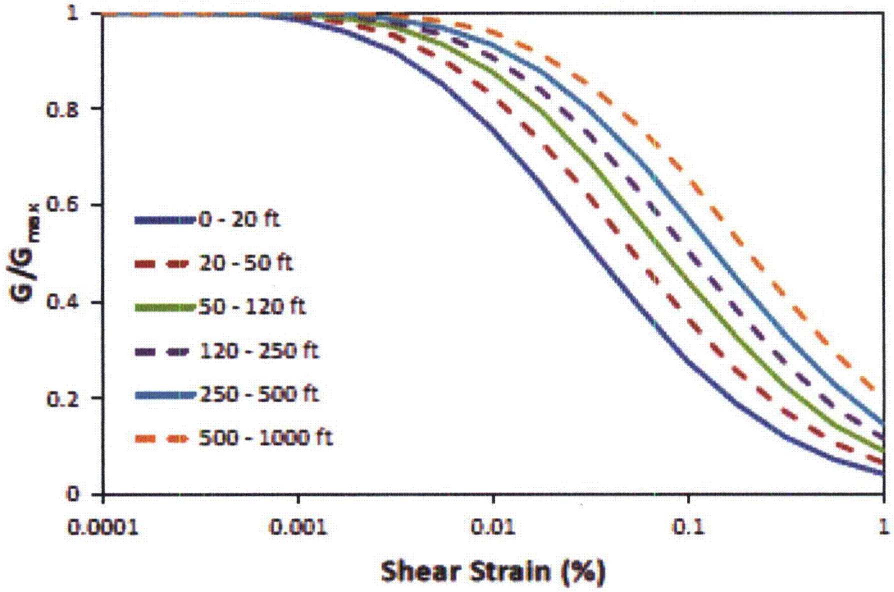
Material	Depth (ft)	Top El. (ft)	G/G_{MAX} & D Curves[1]	
			EPRI	Peninsular
Sand	0-6	440	0-20 ft	0-50 ft
Sand	6-13	434		
Sand	13-21	427		
Sand	21-45	419	20-50 ft	
Middle Ringold	45-56	395		
Middle Ringold	56-85	384	50-120 ft	50-500 ft
Middle Ringold	85-250	355	120-250 ft	
Lower Ringold	250-300	190	250-500 ft	
Lower Ringold	300-325	140		
Lower Ringold	325-525	115		
Saddle Mtn. Basalt	-	-85		

(1) Analyses are performed using both the EPRI and Peninsular curves, with equal weighting for each.

Table 2.3.2.1-5: Cold Creek Interbed G/G_{max} and Damping Ratio Versus Shear Strain

Shear Strain (%)	G/G_{MAX}	Damping Ratio (%)[1]
0.0001	1.0	1.8
0.000316	1.0	1.85
0.001	0.99	1.9
0.00316	0.97	2.0
0.01	0.90	2.8
0.0316	0.77	4.2
0.1	0.53	8.0
0.316	0.28	14.0
1.0	0.12	20.0

(1) Damping is limited to 15% maximum in the rock column analysis.



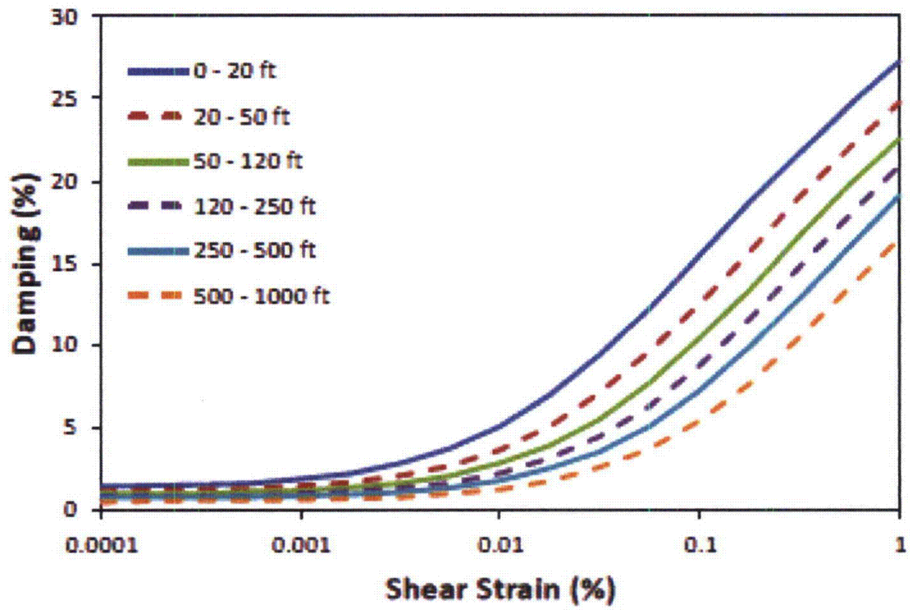


Figure 2.3.2.1-1: EPRI G/Gmax and Damping Ratio Curves (EPRI, 1993)

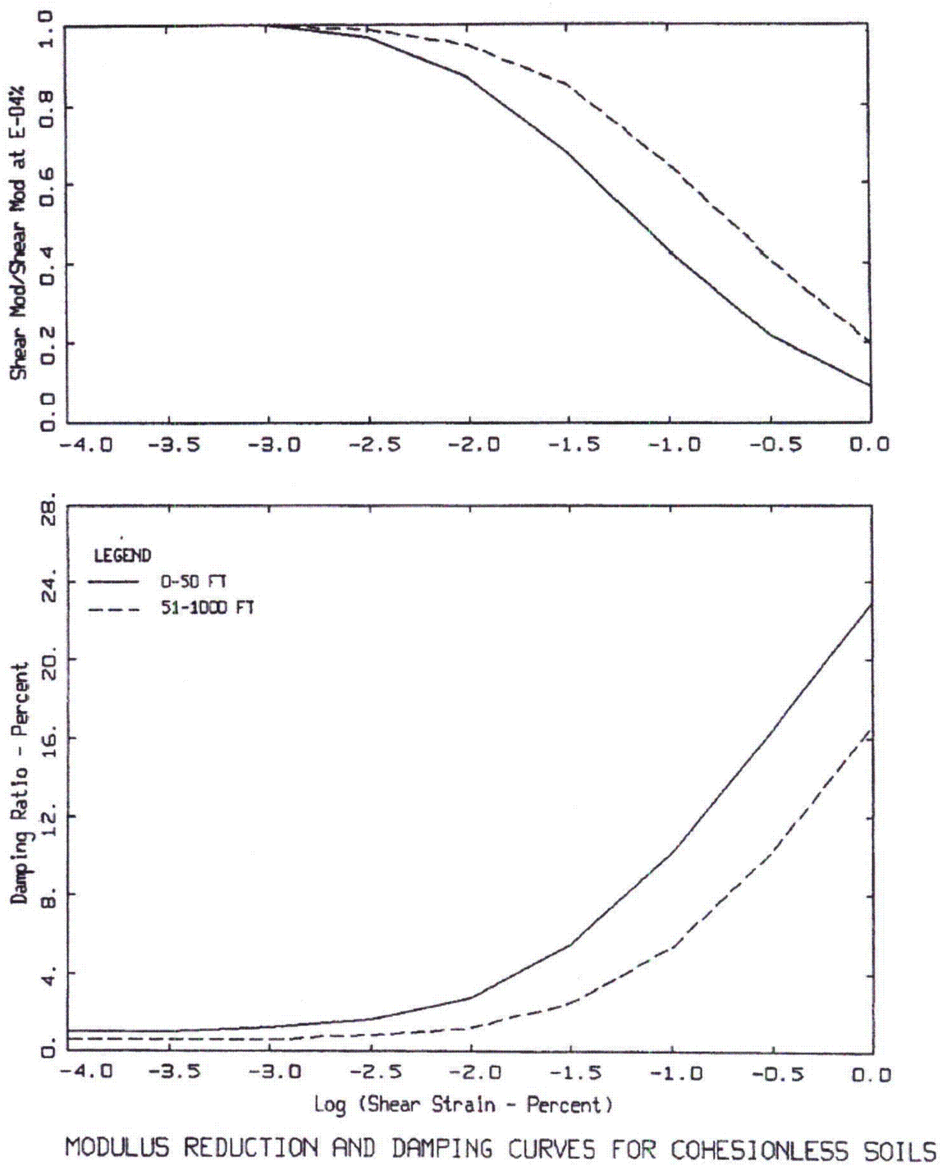


Figure 2.3.2.1-2: Peninsular G/Gmax and Damping Ratio Curves (Silva et al., 1997)

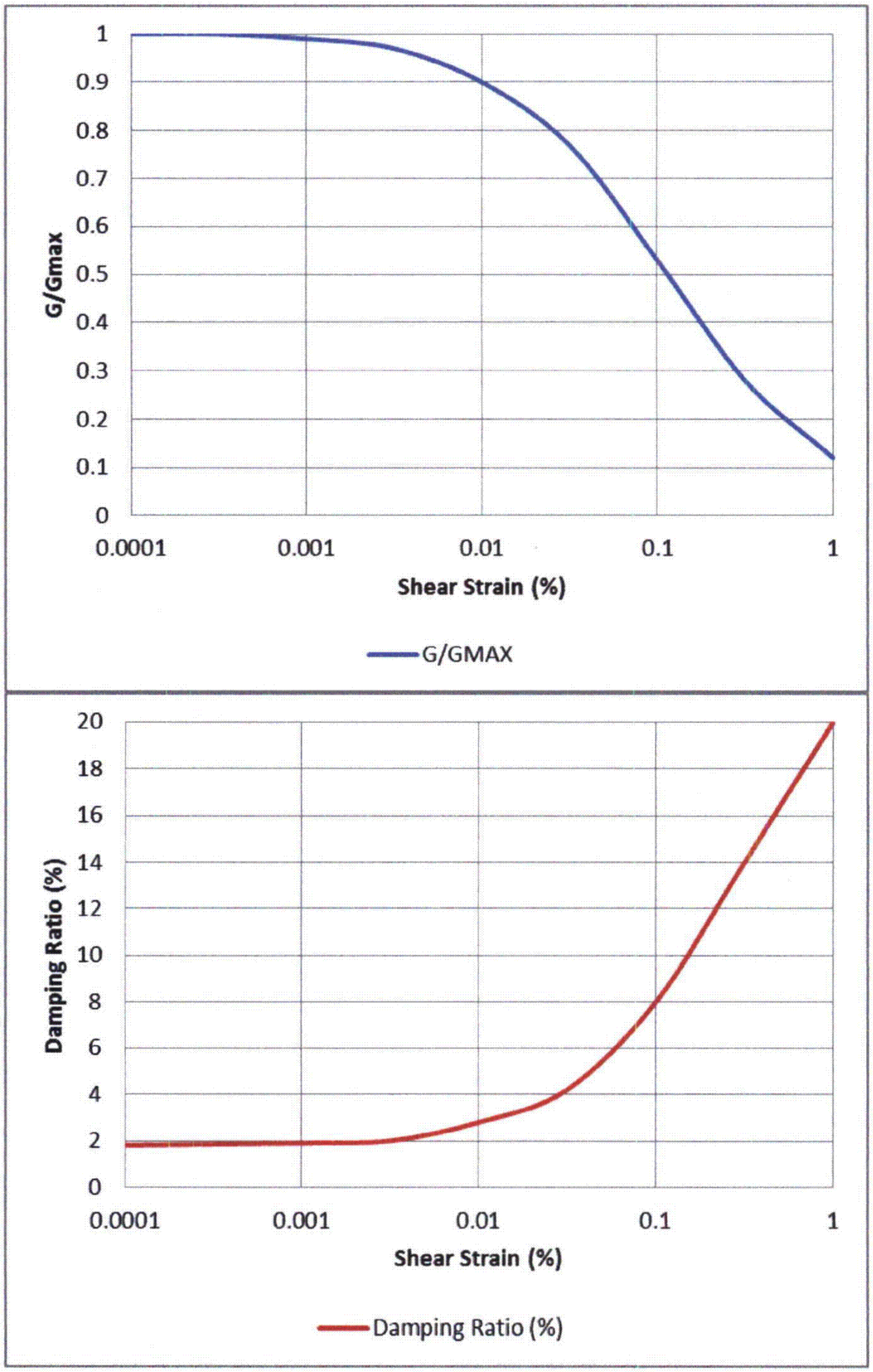


Figure 2.3.2.1-3: Cold Creek Interbed G/G$_{max}$ and Damping Ratio Curves (PNNL, 2014)

2.3.2.2 Kappa

The site attenuation parameter (κ_0) at the CGS is dependent on the supra-basalt sediments, the SMB stack, and the input motion. The PNNL (2014) report documented an extensive study regarding the κ_0 contributions of the SMB stack and the input motion. In the study, the empirical estimates of the κ_0 were computed using two methods and recordings from 59 earthquakes recorded at 6 different sites around the Hanford site. The result of the study was the distributions of κ_0 at the reference condition (i.e., input motion horizon) and at the top of the SMB stack, shown in Figures 2.3.2.2-1 and 2.3.2.2-2, respectively. No explicit consideration of the contribution of the supra-basalt sediment to the total κ_0 was made. Instead, this contribution was based on the low strain damping from the assigned soil strain-dependent nonlinear curves.

The site attenuation parameter (κ_0) at the surface of the site is a combination of the contributions at the reference rock horizon ($\kappa_{0,ref}$) and the wave propagation through the site ($\Delta\kappa_0 = \kappa_0 - \kappa_{0,ref}$). The $\Delta\kappa_0$ value is computed by the linear-elastic transfer function for the site profile using each of the four base soil case profiles with and without damping following the procedure by Boore and Joyner (1997). For each transfer function, the log-linear slope ($\Delta\kappa_0$) is computed. The $\Delta\kappa_0$ value is defined as the difference of these two slopes ($\Delta\kappa_{0,damping} - \Delta\kappa_{0,no\ damping}$). The transfer function without damping is used to isolate the effects of the velocity profile from the effects of the damping on the slope transfer function.

For example, the linear-elastic transfer functions for the C1-EPRI site profile are computed, as well as the logarithmic mean of transfer functions, shown in Figure 2.3.2.2-3. The $\Delta\kappa_{0,damping}$ is then computed to be 0.0085 s using log-linear fit between 60 and 200 Hz to the logarithmic mean transfer function as shown in Figure 2.3.2.2-3. The $\Delta\kappa_{0,no\ damping}$ is computed to be -0.0002 as shown in Figure 2.3.2.2-4. The $\Delta\kappa_{0,no\ damping}$ value is relatively small because of the selected frequency range and the characteristics of the velocity profile at the site. For the C1-EPRI base-case profile, this approach provides a $\Delta\kappa_0$ value of 0.0087 s. The values for all four site profiles are provided in Table 2.3.2.2-1.

PNNL (2014) provides $\kappa_{0,ref}$ values for the C1 and C2 SMB profile, presented in Table 2.3.2.2-2. Using the weights from Figure 7.61 of PNNL (2014), the logarithmic weighted average of $\kappa_{0,ref}$ is computed to be 0.0205 s. These values are significantly larger than the $\Delta\kappa_0$ computed for the site, which indicates that the reference condition is controlling the total site attenuation (κ_0).

The total site attenuation ($\kappa_0 = \Delta\kappa_0 + \kappa_{0,ref}$) for the four profiles is provided in Table 2.3.2.2-3 and that shows a variation between 0.0287 and 0.0357 s.

A log-normal standard deviation of 0.4 is used in randomization to model the uncertainty in the strain-independent damping ratios.

Table 2.3.2.2-1: The Incremental Site Attenuation ($\Delta\kappa 0$) for the Four Base-Case Profiles

	SMB Velocity Model	
Nonlinear Model	C1	C2
EPRI	0.0087 s	0.0086 s
PEN	0.0065 s	0.0064 s

Table 2.3.2.2-2: The Reference (i.e., base rock) Site Attenuation ($\kappa_{0,ref}$) for the C1 and C2 SMB Profiles (Table 7.25 of PNNL, 2014)

	SMB Velocity Model	
	C1	C2
$\kappa_{0,ref}$	0.0222 s	0.0271 s

Table 2.3.2.2-3: The Total Site Attenuation (κ_0) for the Four Base-Case Profiles

	SMB Velocity Model	
Nonlinear Model	C1	C2
EPRI	0.0309 s	0.0357 s
PEN	0.0287 s	0.0335 s

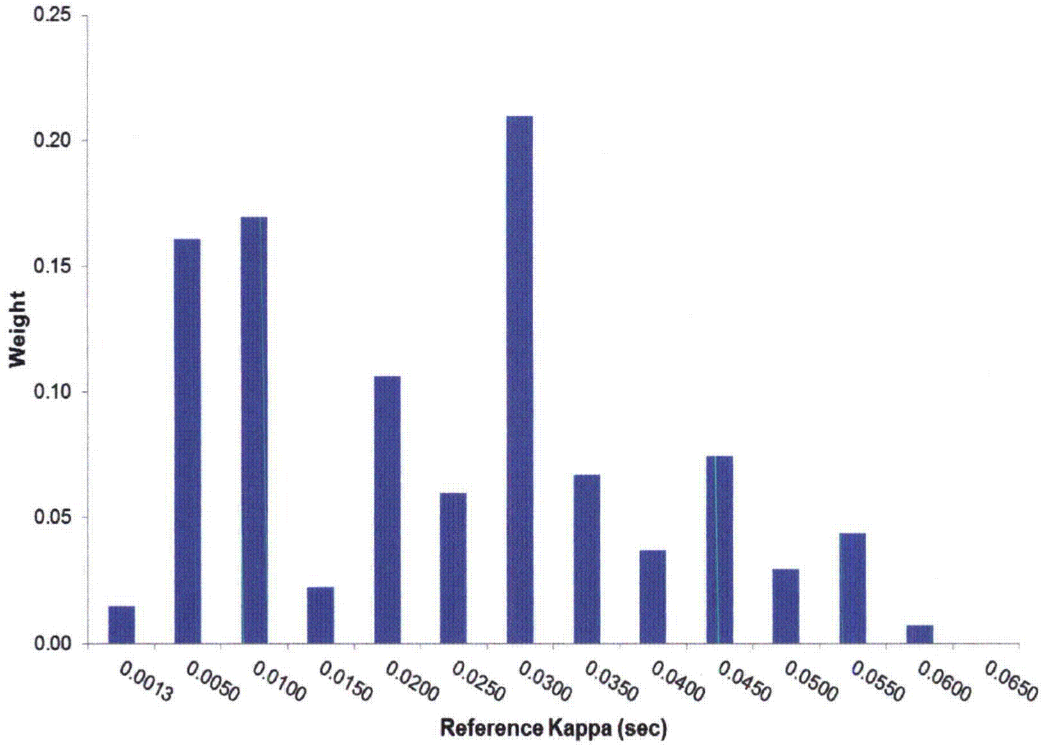


Figure 2.3.2.2-1: Site Attenuation (kappa) at the Reference Condition (Figure 7.66 from PNNL, 2014)

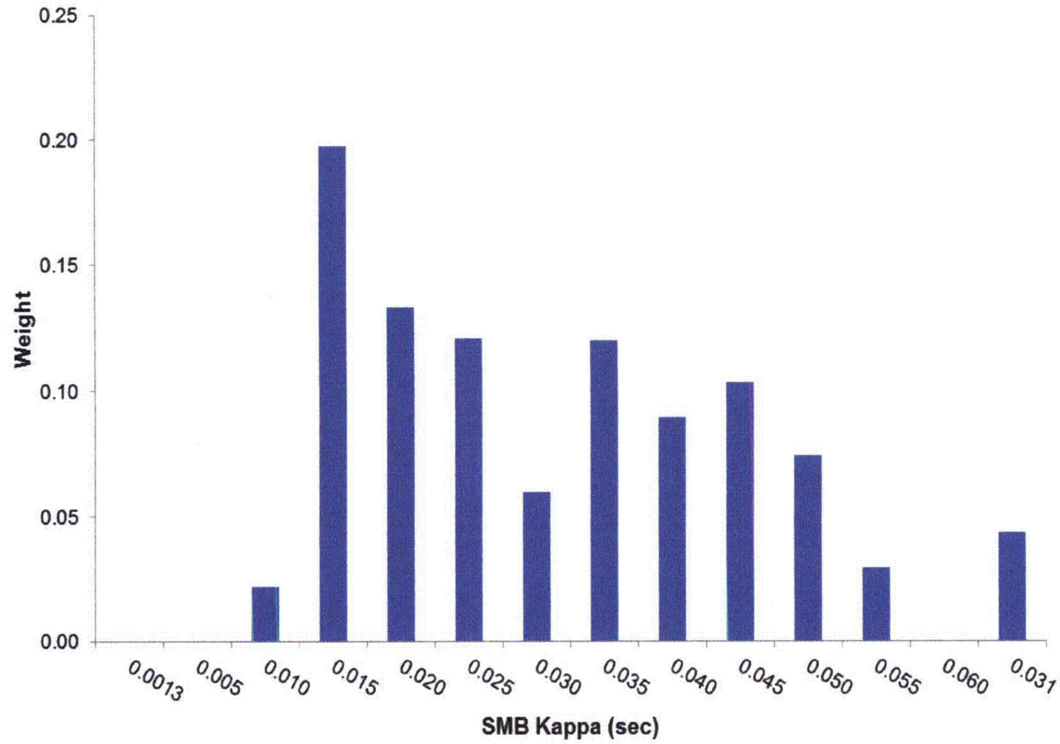


Figure 2.3.2.2-2: Site Attenuation (kappa) at the SMB Stack (Figure 7.63 from PNNL, 2014)

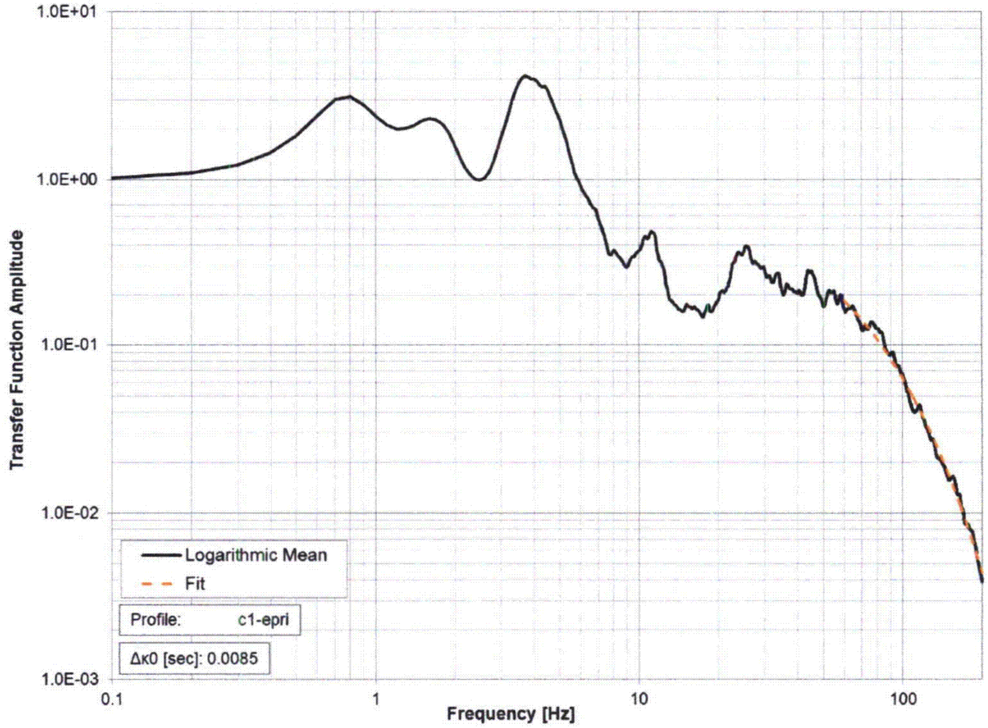


Figure 2.3.2.2-3: Fit Between the Geometric Mean Transfer Function and the Log-Linear Model for the C1-EPRI Base-Case Site Profile with Damping

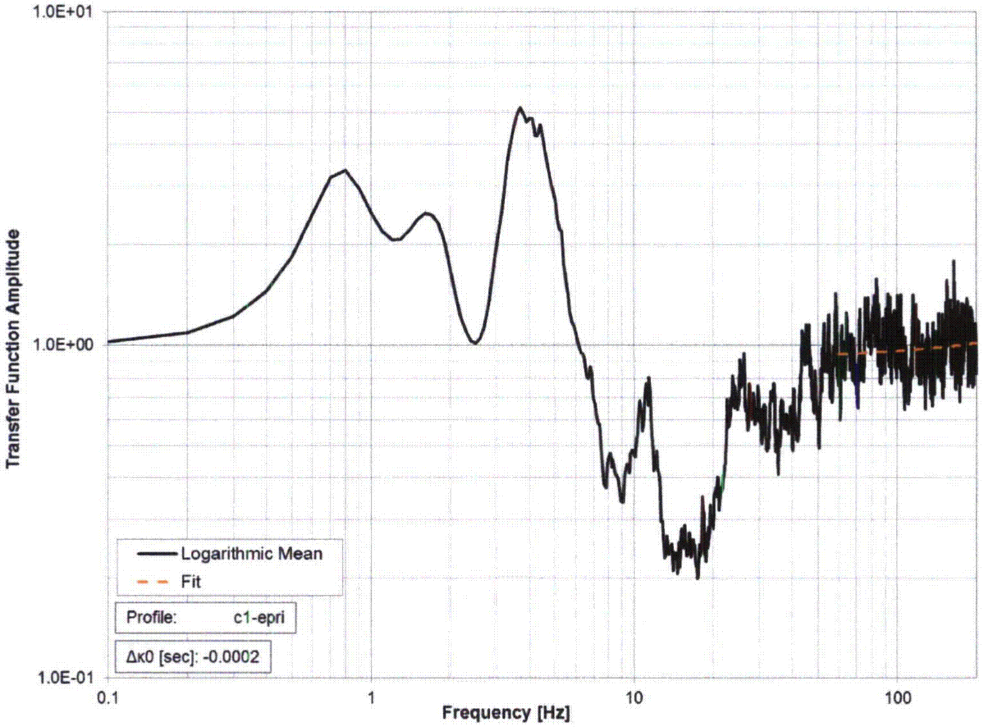


Figure 2.3.2.2-4: Fit Between the Geometric Mean Transfer Function and the Log-Linear Model for the C1-EPRI Base-Case Site Profile without Damping

2.3.3 Randomization of Base Case Profiles

The simulated base case profiles for the CGS site include both aleatory and epistemic uncertainty. The site profile consists of an upper supra-basalt zone and the lower SMB stack. The epistemic uncertainty of the supra-basalt zone is characterized by a single base-case velocity profile and two different models for the nonlinear behavior of the soil. The EPRI (1993) and Peninsular (PEN) Range (Silva et al., 1997) are used and given equal weight. PNNL (2014) provides two sets (C1 and C2) of sixty simulated profiles and associated nonlinear curves for the Saddle Mountain Basalt zone for the CGS site (Site C). The two sets of simulated profiles correspond to profiles developed using different rock velocity measurement methods. As described in Section 7.2.6 of PNNL (2014), C1 profiles are based on down-hole measurements and given a weight of 0.67, while the C2 profiles are based on PS suspension logging measurements and given a weight of 0.33. The weight for each of the considered profiles is summarized in Table 2.3.3-1.

Combining the 2 base profiles representing the supra-basalt and the 2 base profiles representing the lower SMB stack, a total of 4 base profiles are selected for simulation. The simulated profiles for the lower SMB stack (60 profiles for each base case) are provided in PNNL (2014).

For the supra basalt, variability in the shear-wave velocity profiles has been incorporated in the soil profile simulation to account for the aleatory variability in material properties that is expected to occur across a site at the scale of a typical nuclear facility. For the CGS site, simulated shear-wave velocity profiles were developed from the base case profiles, as presented in Section 2.3.2. The simulation procedure generates a set of sixty site-specific simulated (randomized) soil profiles to represent the dynamic properties of the site while considering the uncertainty associated with each of these properties, and correlations between different parameters. Simulated profiles were generated for the supra-basalt zone, and were subsequently augmented with the simulated profiles provided for the Site C SMB stack in Appendix J of PNNL (2014).

As specified in the SPID (EPRI, 2013a), correlation of shear wave velocity between layers was modeled using the USGS B correlation model. In profile simulation, a limit of ± 2 standard deviations about the median value in each layer was assumed for the limits on random velocity fluctuations, as well as on strain-dependent shear modulus reduction and damping ratios. The simulated damping ratios are limited to a maximum of 15%.

The variation in the thickness and S-wave velocity of the supra-basalt layers is presented in Table 2.3.3-2. The variation for the SMB stack is described in Sections 7 and 9 of PNNL (2014).

The hard-rock half-space is defined by an S-wave velocity of 9,840 ft/s, a unit weight of 0.177 kcf, and a damping ratio of 0.1% as defined by Section 9.6.1 of PNNL (2014).

The combined simulated velocity profiles with the C1 Saddle Mountain Basalt profiles are shown in Figures 2.3.3-1 and 2.3.3-2. Similarly, the C2 Saddle Mountain basalt profiles are shown in Figures 2.3.3-3 and 2.3.3-4. The EPRI and PEN simulated shear-wave velocity profiles have the same simulated velocity profiles, and only have different shear modulus reduction and damping ratio curves.

Table 2.3.3-1: The Weight Factors for the Four Base-Case Profiles

	SMB Velocity Model	
Nonlinear Model	C1 (0.67)	C2 (0.33)
EPRI (0.5)	0.335	0.165
PEN (0.5)	0.335	0.165

Table 2.3.3-2: Variation of the Thickness and S-wave Velocity in the Supra-Basalt Zone

Stratum	Unit	Thickness Variation	S-Wave Velocity Uncertainty, σ_{lnVs}
P-1	Pasco Gravel	±22%	0.25
P-2	Pasco Gravel	±22%	0.25
P-3	Pasco Gravel	±22%	0.25
P-4	Pasco Gravel	±22%	0.25
MR-1	Middle Ringold	±10%	0.25
MR-2	Middle Ringold	±10%	0.15
MR-3	Middle Ringold	±10%	0.15
LR-1	Lower Ringold	±15%	0.15
LR-2	Lower Ringold	±15%	0.30
LR-3	Lower Ringold	±15%	0.20

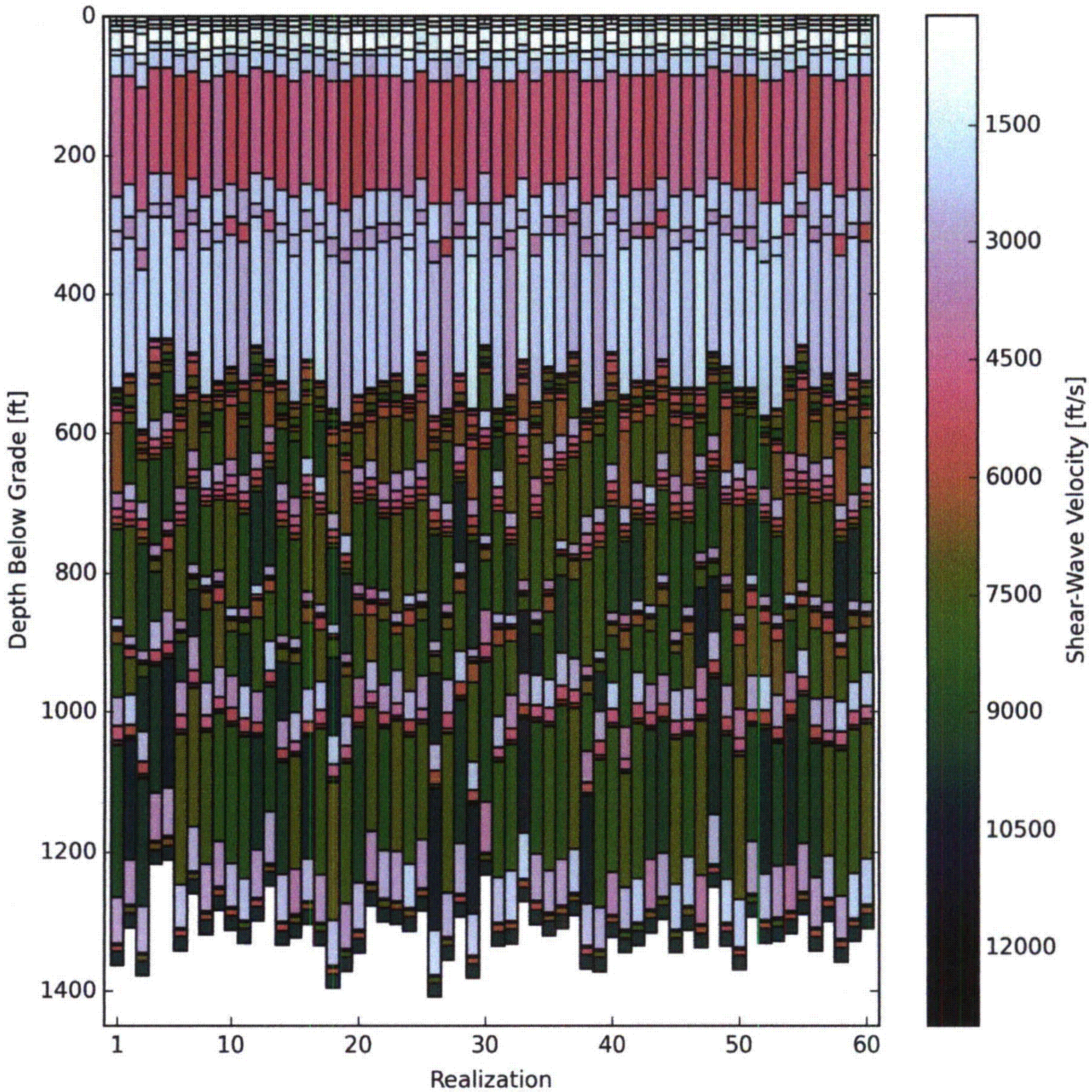


Figure 2.3.3-1: Bar Plots of the Combined Simulated Site Profiles with the C1 SMB Profile

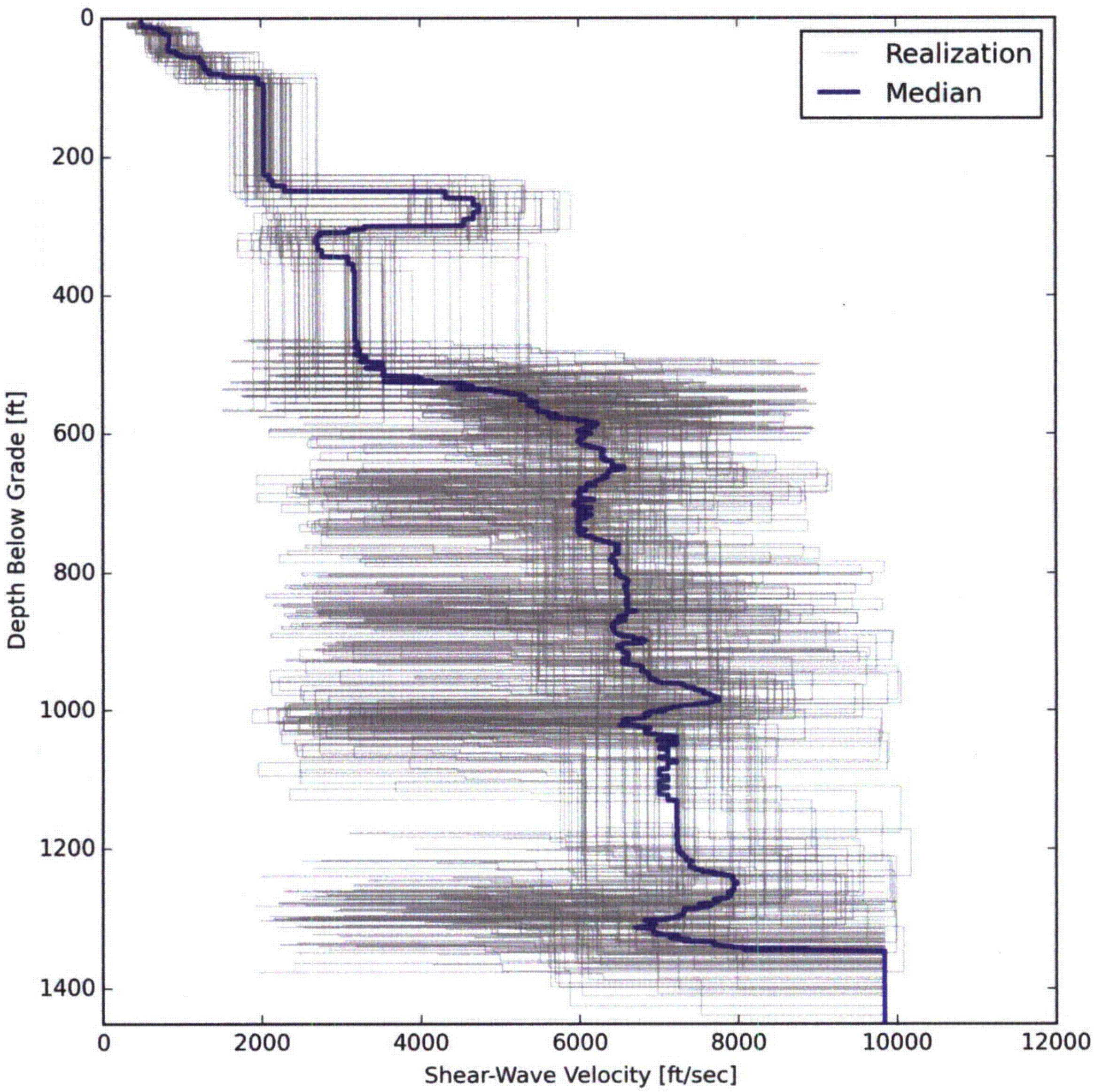


Figure 2.3.3-2: Line Plots of the Combined Simulated Site Profiles with the C1 SMB Profile

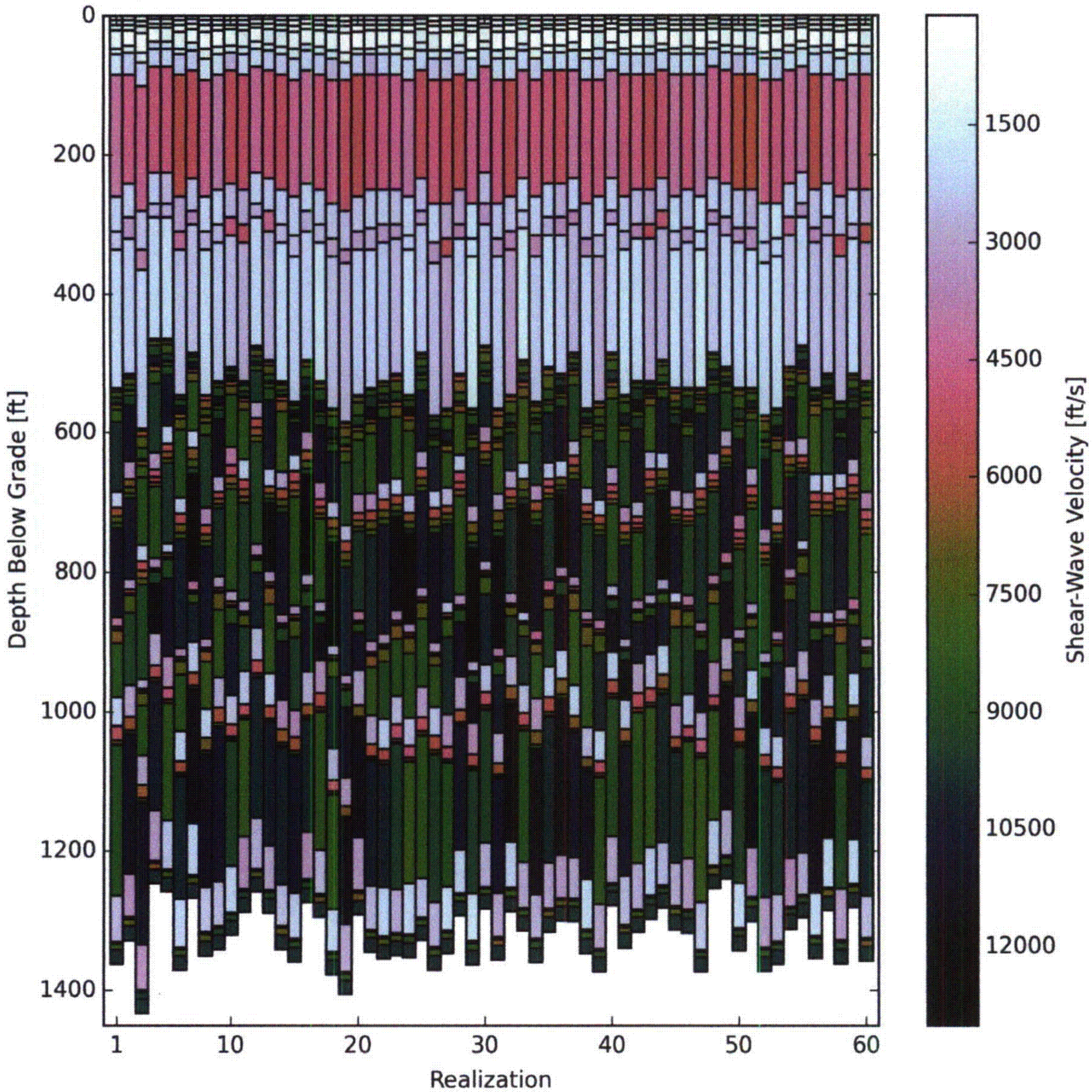


Figure 2.3.3-3: Bar Plots of the Combined Simulated Site Profiles with the C2 SMB Profile

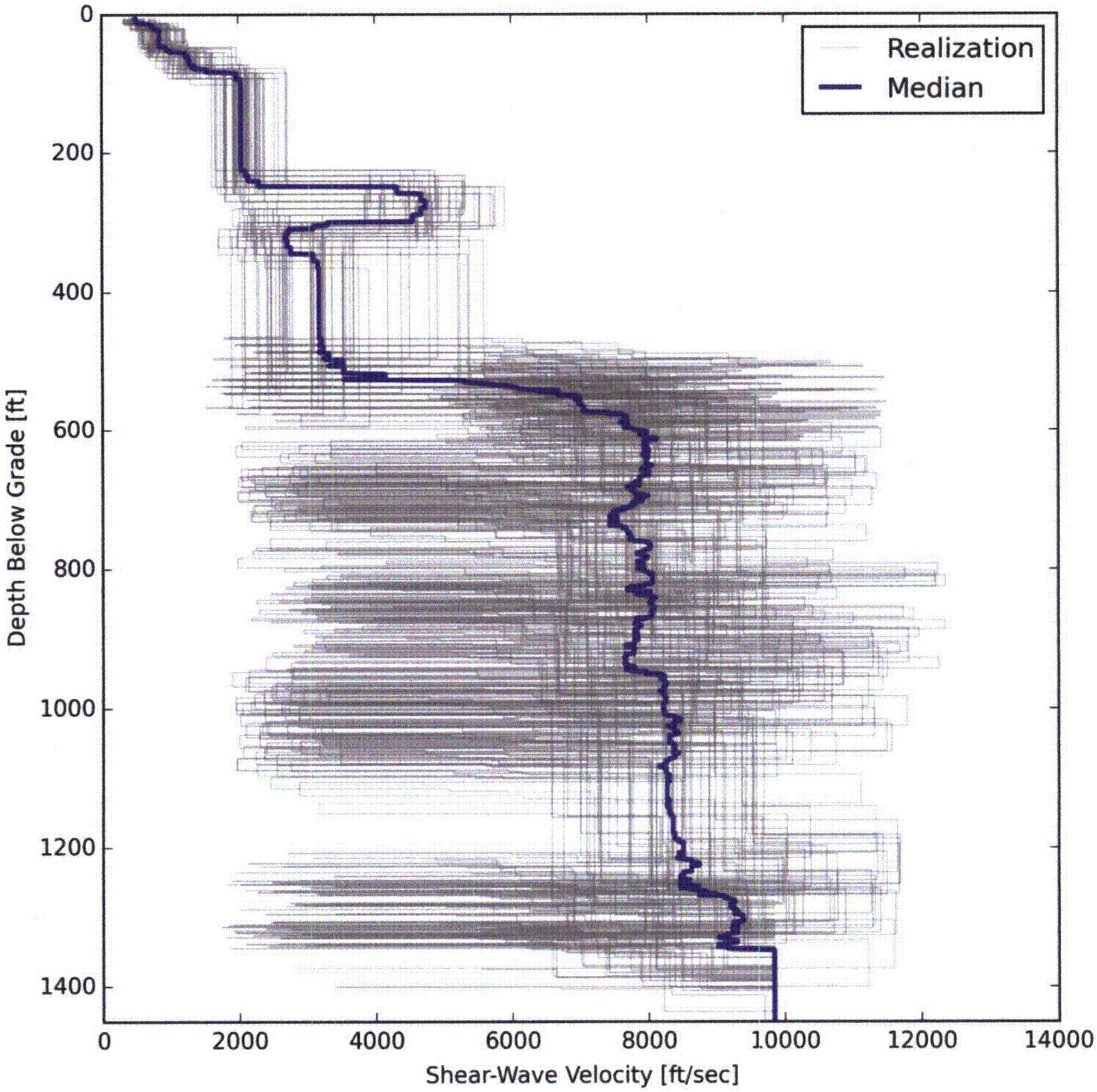


Figure 2.3.3-4: Line Plots of the Combined Simulated Site Profiles with the C2 SMB Profile

2.3.4 Input Spectra

Appendix J of PNNL (2014) provides the hard-rock hazard and site-specific horizontal 5% damped hard-rock acceleration response spectra (ARS) calculated at bedrock with an S-wave velocity of 9,840 ft/s (3,000 m/s). The data for Site C designated for the CGS is used. In the site response analysis simulations, the rock ARS are used as outcrop motions at the bedrock horizon, which is defined by an S-wave velocity of 9,840 ft/s. The rock horizon is identified as top of the Lolo formation in Section 7.2.5 of PNNL (2014).

The input motions are provided as both scaled mean spectra and conditional mean spectra (CMS). The site response analyses presented in this report use the CMS. Baker (2010) proposed the concept of the CMS in which a mean response spectrum is modified to fit a target spectral acceleration at a specific frequency, which is referred to as the conditioning frequency. The spectral accelerations at the other frequencies are computed by the Baker (2010) relationship, which provides for realistic scaling of the ground motions. PNNL (2014) provides CMS spectra at the mean annual frequencies of exceedance (MAFEs) and frequencies presented in Table 2.3.4-1. With a total of 4 event spectra for each of the 20 frequencies and the total of 27 MAFEs, a total of 2,160 spectra were used for each of the simulated profiles for site response analysis. The magnitude and distance of each event is dependent on the deaggregation, and thus vary with MAFE and conditioning frequency. At MAFE of 10^{-4}, the mean magnitude and distances computed for the 20 frequencies of the 4 events are: 0) M_w 5.5 at 5.6 mi (9 km), 1) M_w 6.5 at 7.5 mi (12 km), 2) M_w 7.2 at 13 mi (21 km), and 3) M_w 9.0 at 207 mi (333 km). Examples of the CMS for conditioning frequencies of 1 and 10 Hz and a MAFE of 10^{-4} are shown in Figures 2.3.4-1 and 2.3.4-2, respectively. The scenario magnitude and distance listed in Figures 2.3.4-1 and 2.3.4-2 are specific to the conditioning frequency and MAFE. In some cases, the weight factor of an event may be zero (see M_w=9.1 event in Figure 2.3.4-2). In the CMS motions provided in PNNL (2014), the methodology is limited to only increase the spectral acceleration at the conditioning frequency.

In addition to the acceleration response spectrum, the duration and effective strain ratio need to be defined for each of the input motions. The ground motion duration is estimated using the magnitude and distance of the events listed in CMS text files along with the WUS duration model (Equation H-9) of NUREG/CR-6728 (McGuire, 2001). The durations range from 1.5 to 60.4 seconds and correspond to earthquakes with moment magnitudes from 5.4 to 9.2.
For materials with nonlinear properties, the effective strain ratio, which relates the peak shear strain to the effective shear strain, is computed using the following equation from Idriss and Sun (1992):

$$\frac{\gamma_{\text{eff}}}{\gamma_{\max}} = \frac{M_W - 1}{10} \qquad (2.3.4\text{-}1)$$

Using the magnitudes reported in CMS text files, the effective strain ratio is computed for each of the events. The effective strain ratios range from 0.44 to 0.82.

Table 2.3.4-1: The MAFE and Conditioning Frequencies of the Conditional Mean Spectra (PNNL, 2014)

MAFE
1.00E-02
7.52E-03
5.00E-03
3.00E-03
2.00E-03
1.00E-03
7.50E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
1.00E-04
7.50E-05
5.00E-05
3.00E-05
2.00E-05
1.00E-05
7.50E-06
5.00E-06
3.00E-06
2.00E-06
1.00E-06
7.50E-07
5.00E-07
3.00E-07
2.00E-07
1.00E-07

Frequency [Hz]
100.000
50.000
33.333
25.000
20.000
13.333
10.000
6.667
5.000
3.333
2.500
2.000
1.333
1.000
0.667
0.500
0.333
0.200
0.133
0.100

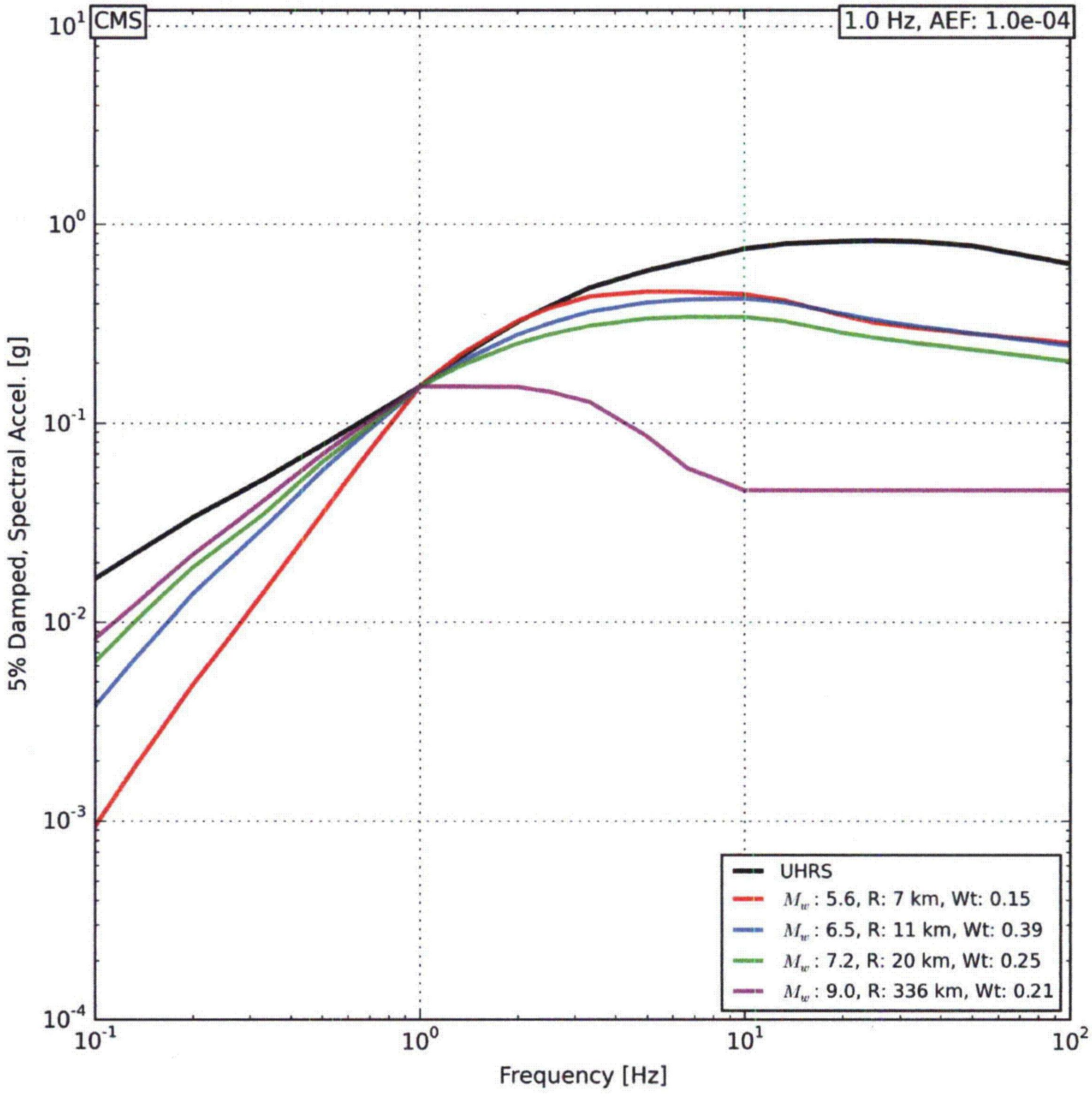


Figure 2.3.4-1: The Four Input Rock Conditional Mean Spectra with a Conditioning Frequency of 1 Hz and a MAFE of 10^{-4}.Compared with the Hard-Rock Uniform Hazard Response Spectrum

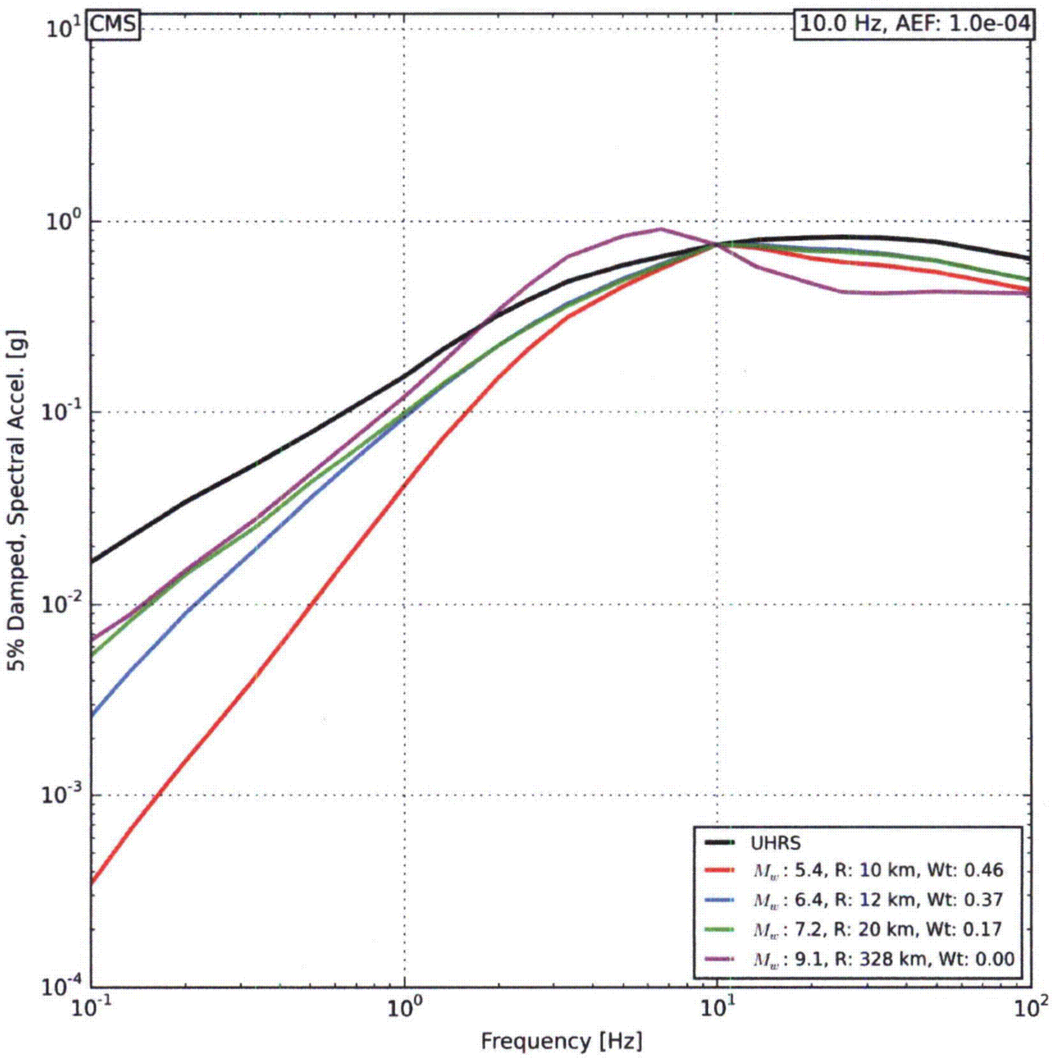


Figure 2.3.4-2: The Four Input Rock Conditional Mean Spectra with a Conditioning Frequency of 10 Hz and a MAFE of 10^{-4}.Compared with the Hard-Rock Uniform Hazard Response Spectrum

2.3.5 Methodology

To perform the site response analyses for the CGS site, a random vibration theory (RVT) approach and the computer program P-SHAKE was used. This process utilizes a simple, efficient approach for computing site-specific amplification functions and is consistent with existing NRC guidance and the SPID (EPRI, 2013a). Each set of sixty simulated profiles based on the 4 base profiles (4 x 60 = 240), presented in Section 2.3.3, are subjected to the 2,160 hard rock spectra, presented in Section 2.3.4, at the top of hard rock, which is characterized by a minimum shear-wave velocity of 9,840 ft/s (3,000 m/s).

The 5% damped acceleration response spectra at the ground surface (SSE control point) are computed, and the amplification functions are calculated as the ratio of the surface response spectra to the hard rock spectra both at 5% spectral damping. For a set of sixty site profile realizations, the logarithmic mean amplification function is computed by:

$$\mu_{\ln} = \frac{1}{N}\sum_{i=1}^{N} \ln m_i \qquad (2.3.5\text{-}1)$$

and associated logarithmic standard deviation ($\sigma_{\ln}$) is then computed as

$$\sigma_{\ln} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(\ln m_i - \mu_{\ln})^2} \qquad (2.3.5\text{-}2)$$

where m_i is is the i-th site amplification. At each MAFE and CMS conditioning frequency, there are four values of $\mu_{\ln}$ and $\sigma_{\ln}$ provided by the four different events. From these four values, the weighted average of the logarithmic mean amplification is computed by:

$$\mu_{\ln,T} = \sum_{i} w_i \mu_{\ln,i} \qquad (2.3.5\text{-}3)$$

where $\mu_{\ln,i}$ is the logarithmic mean site amplification for event i and w_i is the weight assigned to event i. These weight factors are provided for each of the 2,160 events in PNNL (2014). The total logarithmic standard deviation ($\sigma_{\ln,T}$) is computed by:

$$\sigma_{ln,T} = \sqrt{\sum_{i} w_i \left[\left(\mu_{\ln,i} - \mu_{\ln,T}\right)^2 + \sigma_{\ln,i}^2\right]} \qquad (2.3.5\text{-}4)$$

where $\mu_{\ln,i}$ is the logarithmic mean site amplification for event i, $\sigma_{\ln,i}$ is the logarithmic standard deviation for event i, and w_i is the weight assigned to event i. This process is repeated for all MAFE and CMS conditioning frequencies to develop the site amplification for one of the base-case profiles, and then repeated for the remaining three base-case profiles. As a result, for each base profile and each MAFE and each frequency for which CMS is provided, the associated logarithmic mean and total standard deviation of the amplification is obtained.

2.3.6 Amplification Functions

The site amplification functions that are developed rely on 518,400 site response analyses, which were carried out for the: 240 simulated profiles from 4 base case profiles (60 simulated profiles for each base case), 20 conditioning frequencies with 4 CMS, 27 mean MAFEs. All different cases are analyzed and processed the same way, thus only a portion of these analyses are taken as examples and are discussed in detail in this report. The portion of site response analyses to be discussed herein is for the sixty simulated profiles for a C1-EPRI profile, CMS period of 0.1 s, MAFE of 10^{-4}, and earthquake event 1. The resulting 5% damped surface acceleration response spectra (ARS) and logarithmic mean ARS for one case is shown in Figure 2.3.6-1. The site amplification is computed as the ratio of the surface ARS to the hard-rock (i.e., at outcrop input layer) ARS both at 5% spectral damping, shown in Figure 2.3.6-2. The logarithmic mean using Equation 2.3.5-1 and logarithmic standard deviation using Equation 2.3.5-2 are computed from the sixty realizations, shown in Figure 2.3.6-3. The logarithmic standard deviation is shown in Figure 2.3.6-4. An important characteristic of the site response analyses is the large variability (i.e., large standard deviation) in the response between 2 and 6 Hz, which correspond to natural frequencies of the site. This characteristic is observed in the ARS (Figure 2.3.6-1) and site amplification (Figure 2.3.6-2) and is present to a varying degree in all of the considered cases.

For a specific profile and CMS frequency, the arithmetic mean, logarithmic mean, and logarithmic standard deviation from all of the analyses (27 MAFEs and 4 events) are collected together. The weight factors are shown in Figure 2.3.6-5. Using these weight factors, the weighted average of the logarithmic mean site amplification are computed using Equation 2.3.5-3 as shown in Figure 2.3.6-6. The total standard deviation is computed using Equation 2.3.5-4 as shown in Figure 2.3.6-7. The results indicate that as the intensity of the input motion increases (i.e., decreasing MAFE) the 10 Hz site amplification decreases (see Figure 2.3.6-6). This decrease in site amplification is associated with an increase in total standard deviation. This behavior is attributed to the nonlinear response of the site.

The composite site amplification (weighted average logarithmic mean and total standard deviation) is developed for each profile. The weighted average logarithmic mean for the C1-EPRI profile are shown in Figure 2.3.6-8. The associated total standard deviations for the C1-EPRI profile are shown in Figure 2.3.6-9. As intensity increases (decreasing MAFE), the amplification tends to shift to lower frequency, due to strain softening, and the once significant 2^{nd} and 3^{rd} natural frequencies decrease. This decrease in amplification at the 2^{nd} and 3^{rd} natural frequencies (2 to 6 Hz) is attributed to varying natural frequencies, again due to strain softening, and is accompanied by an increase in uncertainty (quantified by the logarithmic standard deviation) over the same frequency range. The site amplification results from the other profiles show similar characteristics to the C1-EPRI profile.

The logarithmic mean with $\pm1 \cdot \sigma_{ln}$ variation of the C1-EPRI site amplification is shown in Figures 2.3.6-10 and 2.3.6-11. The site amplification tends to be a generally smooth curve. The logarithmic mean site amplification for the four profiles are shown in Figures 2.3.6-12 and 2.3.6-13. The profiles show similar behavior with increasing intensity.

The weighted average logarithmic mean and total logarithmic standard deviation of the site amplification are presented in Tables 2.3.6-1 and 2.3.6-2 for the C1-EPRI base-case profile, Tables 2.3.6-3 and 2.3.6-4 for the C1-PEN base-case profile, Tables 2.3.6-5 and 2.3.6-6 for the C2-EPRI base-case profile, and Tables 2.3.6-7 and 2.3.6-8 for the C2-PEN base-case profile.

It should be noted that in computing the amplification factors, the recommended minimum variability in the site amplification factors, which is defined as a function of spectral frequency from PNNL (2014), was not implemented in the calculation of the surface hazard. This minimum variability is intended include the variability in epistemic uncertainty of the site term and particularly important at low frequencies. However, comparison of the computed standard deviation with the suggested minimum variability shows that for frequencies less than 1Hz, this minimum epistemic uncertainty is greater than the standard deviation values computed from the site response analysis. For frequencies greater than 1 Hz, the computed standard deviation values are greater than the recommended minimum values from PNNL (2014).These observed differences in the uncertainty would lead to an increase in the surface hazard for frequencies less than 1 Hz by a small margin (note that the as-computed surface hazard exceeds the SSE over this frequency range without the minimum requirement) and does not cause any change for frequencies greater than 1 Hz in the surface hazard. Since the refinement using the minimum requirement does not affect the assessment presented in this report, the comparison of GMRS to the SSE (see Section 4.0), and the HCLPF as defined in terms of PGA (see Section 5.0), no further refinement of GMRS is considered.

Another point to be noted is the evaluation of the minimum value for soil amplification function. At some frequencies, the calculated site amplification for high base rock amplitudes is less than the minimum value of 0.5 recommended by the SPID (EPRI, 2013a). The 0.5 limit is not imposed here in the calculation of the surface hazard because the intended purpose of this report is to obtain the best estimate of the mean and fractile levels of the seismic response for plant risk assessment with no added conservatism.

Table 2.3.6-1: *Weighted Average Logarithmic Mean of the 5% Damped Site Amplification for Base-Case Profile C1-EPRI*

	Period [s]	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.15	0.20	0.30	0.40	0.50	0.75	1.00	1.50	2.00	3.00	5.00	7.50	10.00
	Frequency [Hz]	100.00	50.00	33.33	25.00	20.00	13.33	10.00	6.67	5.00	3.33	2.50	2.00	1.33	1.00	0.67	0.50	0.33	0.20	0.13	0.10
Annual Exceedance Frequency	1.00E-02	1.047	0.900	0.951	1.019	0.968	1.069	1.238	1.796	3.074	3.223	1.671	1.969	2.214	2.453	2.700	1.953	1.444	1.233	1.173	1.147
	7.52E-03	0.968	0.847	0.904	0.973	0.923	1.032	1.201	1.756	3.006	3.204	1.684	1.971	2.215	2.447	2.706	1.952	1.432	1.224	1.155	1.130
	5.00E-03	0.899	0.791	0.850	0.914	0.865	0.963	1.130	1.687	2.887	3.158	1.700	1.974	2.217	2.437	2.707	1.946	1.424	1.205	1.136	1.117
	3.00E-03	0.817	0.733	0.790	0.849	0.802	0.896	1.058	1.607	2.725	3.087	1.715	1.969	2.219	2.419	2.713	1.950	1.421	1.194	1.125	1.113
	2.00E-03	0.741	0.686	0.743	0.797	0.753	0.841	0.997	1.537	2.584	3.022	1.731	1.967	2.217	2.402	2.716	1.961	1.419	1.189	1.124	1.114
	1.00E-03	0.653	0.595	0.650	0.694	0.655	0.739	0.885	1.399	2.315	2.849	1.753	1.965	2.212	2.359	2.729	1.987	1.419	1.182	1.118	1.116
	7.50E-04	0.610	0.559	0.611	0.655	0.619	0.700	0.840	1.329	2.193	2.768	1.758	1.969	2.212	2.344	2.736	2.001	1.420	1.180	1.116	1.117
	5.00E-04	0.553	0.508	0.555	0.595	0.561	0.642	0.774	1.232	2.032	2.616	1.753	1.976	2.211	2.325	2.746	2.022	1.426	1.177	1.114	1.115
	4.00E-04	0.523	0.483	0.527	0.565	0.533	0.613	0.742	1.182	1.945	2.548	1.747	1.981	2.217	2.313	2.755	2.035	1.429	1.176	1.113	1.115
	3.00E-04	0.481	0.449	0.486	0.522	0.494	0.574	0.700	1.120	1.843	2.459	1.738	1.979	2.232	2.306	2.763	2.056	1.433	1.179	1.112	1.115
	2.00E-04	0.418	0.399	0.428	0.468	0.446	0.524	0.645	1.033	1.705	2.350	1.715	1.959	2.255	2.293	2.784	2.084	1.441	1.177	1.110	1.114
	1.00E-04	0.339	0.325	0.354	0.389	0.375	0.450	0.566	0.897	1.471	2.167	1.648	1.910	2.306	2.295	2.822	2.139	1.458	1.175	1.107	1.114
	7.50E-05	0.309	0.301	0.327	0.361	0.350	0.424	0.538	0.846	1.390	2.088	1.613	1.876	2.316	2.304	2.827	2.166	1.466	1.174	1.106	1.113
	5.00E-05	0.276	0.267	0.298	0.329	0.321	0.387	0.495	0.783	1.269	1.963	1.555	1.828	2.310	2.307	2.833	2.208	1.480	1.174	1.105	1.109
	3.00E-05	0.242	0.228	0.261	0.289	0.287	0.348	0.451	0.707	1.136	1.803	1.475	1.759	2.283	2.282	2.846	2.257	1.499	1.174	1.103	1.102
	2.00E-05	0.218	0.204	0.235	0.262	0.262	0.319	0.418	0.652	1.043	1.685	1.399	1.679	2.254	2.254	2.853	2.308	1.516	1.176	1.102	1.091
	1.00E-05	0.179	0.169	0.198	0.222	0.223	0.277	0.368	0.565	0.900	1.499	1.278	1.490	2.153	2.112	2.764	2.416	1.556	1.181	1.100	1.070
	7.50E-06	0.166	0.158	0.186	0.209	0.211	0.261	0.349	0.534	0.846	1.422	1.227	1.425	2.104	2.085	2.715	2.456	1.576	1.183	1.100	1.062
	5.00E-06	0.152	0.143	0.169	0.191	0.194	0.241	0.325	0.492	0.782	1.315	1.158	1.330	1.985	2.066	2.620	2.492	1.600	1.188	1.100	1.070
	3.00E-06	0.134	0.127	0.151	0.172	0.175	0.217	0.296	0.445	0.706	1.187	1.068	1.226	1.906	1.937	2.456	2.515	1.636	1.197	1.099	1.058
	2.00E-06	0.123	0.117	0.139	0.158	0.162	0.202	0.275	0.413	0.649	1.096	0.996	1.122	1.868	1.840	2.344	2.482	1.674	1.205	1.099	1.050
	1.00E-06	0.106	0.100	0.121	0.138	0.141	0.177	0.243	0.361	0.556	0.955	0.880	1.000	1.592	1.644	2.217	2.367	1.764	1.226	1.099	1.040
	7.50E-07	0.099	0.093	0.114	0.130	0.134	0.168	0.232	0.342	0.519	0.897	0.841	0.944	1.544	1.580	2.117	2.332	1.750	1.232	1.099	1.037
	5.00E-07	0.091	0.086	0.105	0.120	0.124	0.156	0.216	0.316	0.477	0.815	0.795	0.881	1.476	1.420	1.964	2.297	1.776	1.243	1.099	1.036
	3.00E-07	0.080	0.078	0.095	0.109	0.113	0.142	0.198	0.286	0.428	0.725	0.730	0.802	1.359	1.308	1.765	2.124	1.795	1.249	1.102	1.036
	2.00E-07	0.066	0.071	0.089	0.102	0.105	0.133	0.185	0.265	0.393	0.664	0.681	0.752	1.264	1.258	1.590	1.937	1.787	1.260	1.106	1.036
	1.00E-07	0.051	0.062	0.078	0.090	0.094	0.118	0.166	0.233	0.338	0.565	0.627	0.648	1.095	1.163	1.332	1.678	1.820	1.288	1.118	1.039

Table 2.3.6-2: Total Logarithmic Standard Deviation of the 5% Damped Site Amplification for Base-Case Profile C1-EPRI

	Period [s]	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.15	0.20	0.30	0.40	0.50	0.75	1.00	1.50	2.00	3.00	5.00	7.50	10.00
	Frequency [Hz]	100.00	50.00	33.33	25.00	20.00	13.33	10.00	6.67	5.00	3.33	2.50	2.00	1.33	1.00	0.67	0.50	0.33	0.20	0.13	0.10
Annual Exceedance Frequency	1.00E-02	0.299	0.294	0.273	0.316	0.309	0.309	0.287	0.291	0.360	0.475	0.356	0.315	0.130	0.121	0.152	0.133	0.076	0.048	0.045	0.035
	7.52E-03	0.284	0.274	0.260	0.309	0.299	0.297	0.279	0.297	0.366	0.467	0.361	0.318	0.131	0.121	0.152	0.134	0.072	0.048	0.033	0.024
	5.00E-03	0.264	0.249	0.245	0.301	0.285	0.285	0.272	0.312	0.380	0.454	0.371	0.321	0.133	0.123	0.152	0.135	0.072	0.038	0.033	0.038
	3.00E-03	0.240	0.229	0.234	0.294	0.273	0.277	0.269	0.330	0.396	0.437	0.390	0.331	0.135	0.125	0.151	0.137	0.072	0.039	0.030	0.035
	2.00E-03	0.228	0.222	0.231	0.291	0.269	0.273	0.269	0.346	0.408	0.425	0.400	0.340	0.139	0.128	0.149	0.140	0.072	0.037	0.029	0.037
	1.00E-03	0.222	0.217	0.230	0.290	0.266	0.275	0.276	0.367	0.430	0.403	0.418	0.363	0.153	0.134	0.144	0.147	0.073	0.033	0.032	0.036
	7.50E-04	0.221	0.218	0.232	0.290	0.266	0.278	0.280	0.374	0.442	0.397	0.425	0.376	0.163	0.138	0.143	0.151	0.074	0.033	0.032	0.036
	5.00E-04	0.222	0.222	0.237	0.292	0.268	0.285	0.290	0.382	0.455	0.386	0.430	0.399	0.184	0.146	0.142	0.157	0.078	0.032	0.030	0.035
	4.00E-04	*0.224*	*0.225*	*0.241*	*0.294*	*0.271*	*0.290*	*0.295*	*0.386*	*0.462*	*0.387*	*0.433*	*0.415*	*0.200*	*0.152*	*0.143*	*0.161*	*0.080*	*0.032*	*0.030*	*0.035*
	3.00E-04	0.228	0.231	0.250	0.301	0.277	0.298	0.304	0.390	0.470	0.393	0.435	0.435	0.225	0.163	0.144	0.166	0.083	0.033	0.030	0.035
	2.00E-04	0.228	0.241	0.261	0.310	0.286	0.309	0.317	0.398	0.482	0.407	0.435	0.455	0.264	0.184	0.149	0.173	0.089	0.034	0.030	0.035
	1.00E-04	0.240	0.264	0.283	0.328	0.304	0.326	0.341	0.408	0.500	0.440	0.431	0.479	0.327	0.240	0.170	0.181	0.099	0.037	0.030	0.036
	7.50E-05	0.246	0.273	0.292	0.337	0.310	0.333	0.351	0.413	0.508	0.454	0.433	0.487	0.347	0.274	0.182	0.185	0.103	0.038	0.029	0.036
	5.00E-05	0.254	0.284	0.300	0.344	0.318	0.337	0.364	0.418	0.515	0.474	0.444	0.496	0.365	0.318	0.204	0.189	0.111	0.040	0.029	0.035
	3.00E-05	0.262	0.283	0.308	0.348	0.325	0.346	0.381	0.430	0.520	0.489	0.452	0.516	0.381	0.343	0.259	0.198	0.121	0.042	0.029	0.034
	2.00E-05	0.269	0.291	0.318	0.359	0.334	0.354	0.394	0.438	0.530	0.501	0.456	0.524	0.396	0.369	0.304	0.217	0.132	0.044	0.029	0.031
	1.00E-05	0.279	0.304	0.335	0.377	0.349	0.364	0.413	0.454	0.550	0.532	0.485	0.544	0.433	0.352	0.357	0.284	0.158	0.050	0.029	0.025
	7.50E-06	0.283	0.308	0.340	0.383	0.353	0.367	0.421	0.460	0.558	0.539	0.496	0.561	0.454	0.374	0.373	0.300	0.169	0.053	0.029	0.023
	5.00E-06	0.288	0.314	0.350	0.392	0.361	0.371	0.429	0.468	0.568	0.551	0.510	0.579	0.464	0.431	0.385	0.317	0.183	0.059	0.030	0.025
	3.00E-06	0.293	0.321	0.359	0.400	0.371	0.378	0.440	0.480	0.578	0.570	0.524	0.605	0.487	0.451	0.400	0.342	0.200	0.071	0.031	0.022
	2.00E-06	0.297	0.326	0.368	0.408	0.376	0.380	0.449	0.489	0.585	0.591	0.536	0.619	0.534	0.457	0.424	0.354	0.219	0.082	0.032	0.020
	1.00E-06	0.304	0.335	0.383	0.420	0.387	0.389	0.461	0.505	0.592	0.624	0.578	0.629	0.515	0.458	0.499	0.371	0.271	0.116	0.035	0.020
	7.50E-07	0.307	0.340	0.390	0.426	0.392	0.392	0.467	0.510	0.591	0.630	0.588	0.638	0.538	0.462	0.525	0.395	0.244	0.130	0.038	0.019
	5.00E-07	0.310	0.344	0.397	0.432	0.400	0.398	0.475	0.517	0.599	0.651	0.608	0.667	0.575	0.408	0.530	0.444	0.250	0.144	0.044	0.019
	3.00E-07	0.334	0.351	0.407	0.441	0.408	0.405	0.485	0.528	0.611	0.665	0.626	0.693	0.612	0.401	0.544	0.485	0.257	0.142	0.054	0.020
	2.00E-07	0.344	0.357	0.417	0.448	0.416	0.410	0.492	0.537	0.624	0.676	0.631	0.704	0.656	0.421	0.531	0.489	0.256	0.146	0.068	0.022
	1.00E-07	0.297	0.366	0.430	0.460	0.428	0.420	0.506	0.554	0.631	0.673	0.662	0.671	0.661	0.450	0.492	0.495	0.303	0.161	0.111	0.028

Table 2.3.6-3: Weighted Average Logarithmic Mean of the 5% Damped Site Amplification for Base-Case Profile C1-PEN

	Period [s]	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.15	0.20	0.30	0.40	0.50	0.75	1.00	1.50	2.00	3.00	5.00	7.50	10.00
	Frequency [Hz]	100.00	50.00	33.33	25.00	20.00	13.33	10.00	6.67	5.00	3.33	2.50	2.00	1.33	1.00	0.67	0.50	0.33	0.20	0.13	0.10
Annual Exceedance Frequency	1.00E-02	1.173	1.029	1.087	1.164	1.081	1.181	1.369	1.934	3.312	3.377	1.717	2.014	2.249	2.483	2.727	1.965	1.450	1.237	1.176	1.150
	7.52E-03	1.090	0.975	1.039	1.118	1.035	1.143	1.330	1.891	3.241	3.354	1.728	2.013	2.248	2.474	2.731	1.962	1.437	1.227	1.157	1.133
	5.00E-03	1.017	0.917	0.983	1.056	0.973	1.068	1.254	1.814	3.111	3.299	1.740	2.011	2.244	2.460	2.726	1.955	1.428	1.208	1.139	1.119
	3.00E-03	0.927	0.851	0.917	0.983	0.903	0.993	1.172	1.722	2.935	3.224	1.747	1.997	2.241	2.438	2.729	1.956	1.424	1.196	1.127	1.115
	2.00E-03	0.842	0.796	0.863	0.923	0.848	0.930	1.103	1.641	2.779	3.162	1.758	1.989	2.236	2.419	2.731	1.967	1.421	1.191	1.125	1.115
	1.00E-03	0.739	0.691	0.755	0.806	0.739	0.817	0.980	1.501	2.499	3.018	1.781	1.974	2.226	2.374	2.743	1.992	1.421	1.183	1.119	1.117
	7.50E-04	0.690	0.649	0.710	0.762	0.700	0.775	0.934	1.437	2.377	2.954	1.787	1.972	2.221	2.357	2.749	2.004	1.422	1.181	1.117	1.118
	5.00E-04	0.626	0.591	0.648	0.697	0.639	0.715	0.867	1.350	2.218	2.821	1.784	1.968	2.209	2.333	2.755	2.022	1.426	1.178	1.115	1.115
	4.00E-04	0.592	0.564	0.617	0.665	0.609	0.686	0.835	1.304	2.131	2.758	1.778	1.966	2.205	2.316	2.762	2.033	1.429	1.176	1.114	1.115
	3.00E-04	0.547	0.526	0.573	0.620	0.568	0.646	0.793	1.245	2.031	2.669	1.770	1.958	2.206	2.298	2.765	2.050	1.432	1.179	1.112	1.115
	2.00E-04	0.478	0.471	0.511	0.563	0.518	0.595	0.736	1.159	1.896	2.549	1.752	1.938	2.209	2.271	2.777	2.073	1.438	1.177	1.111	1.115
	1.00E-04	0.392	0.390	0.430	0.478	0.442	0.519	0.653	1.017	1.664	2.340	1.699	1.895	2.226	2.240	2.794	2.117	1.451	1.174	1.107	1.114
	7.50E-05	0.359	0.363	0.401	0.447	0.416	0.492	0.623	0.963	1.580	2.252	1.668	1.865	2.228	2.229	2.791	2.139	1.458	1.173	1.106	1.114
	5.00E-05	0.322	0.325	0.368	0.411	0.384	0.454	0.577	0.896	1.458	2.127	1.611	1.821	2.229	2.210	2.782	2.172	1.470	1.172	1.105	1.109
	3.00E-05	0.284	0.281	0.326	0.365	0.346	0.413	0.529	0.814	1.325	1.982	1.533	1.748	2.211	2.186	2.759	2.208	1.485	1.172	1.103	1.103
	2.00E-05	0.257	0.252	0.297	0.334	0.318	0.380	0.494	0.757	1.229	1.875	1.469	1.678	2.179	2.163	2.759	2.243	1.499	1.173	1.102	1.091
	1.00E-05	0.212	0.211	0.253	0.286	0.274	0.334	0.441	0.666	1.075	1.709	1.363	1.532	2.074	2.047	2.693	2.325	1.533	1.176	1.099	1.070
	7.50E-06	0.197	0.198	0.238	0.270	0.260	0.317	0.420	0.631	1.012	1.636	1.314	1.479	2.028	2.012	2.647	2.369	1.550	1.178	1.099	1.062
	5.00E-06	0.180	0.180	0.218	0.249	0.241	0.296	0.394	0.585	0.931	1.519	1.237	1.380	1.970	1.964	2.548	2.402	1.571	1.182	1.098	1.070
	3.00E-06	0.159	0.161	0.197	0.225	0.219	0.269	0.362	0.532	0.841	1.377	1.157	1.279	1.895	1.869	2.463	2.390	1.601	1.190	1.098	1.058
	2.00E-06	0.146	0.149	0.183	0.209	0.204	0.251	0.338	0.495	0.778	1.272	1.102	1.211	1.776	1.818	2.356	2.386	1.630	1.198	1.098	1.050
	1.00E-06	0.126	0.128	0.160	0.184	0.181	0.223	0.303	0.436	0.681	1.120	0.995	1.098	1.629	1.642	2.189	2.354	1.679	1.217	1.096	1.039
	7.50E-07	0.118	0.120	0.152	0.175	0.172	0.212	0.290	0.414	0.643	1.059	0.951	1.039	1.582	1.569	2.142	2.323	1.700	1.223	1.096	1.036
	5.00E-07	0.109	0.111	0.141	0.164	0.160	0.198	0.271	0.385	0.595	0.974	0.897	0.972	1.464	1.482	2.033	2.251	1.732	1.231	1.097	1.035
	3.00E-07	0.096	0.101	0.130	0.150	0.147	0.181	0.250	0.350	0.542	0.870	0.830	0.888	1.350	1.375	1.827	2.126	1.739	1.236	1.099	1.035
	2.00E-07	0.079	0.094	0.121	0.141	0.138	0.170	0.235	0.325	0.500	0.804	0.773	0.828	1.279	1.301	1.672	2.003	1.748	1.245	1.103	1.035
	1.00E-07	0.062	0.083	0.109	0.126	0.124	0.151	0.212	0.285	0.434	0.688	0.691	0.742	1.191	1.115	1.450	1.823	1.748	1.270	1.114	1.038

Table 2.3.6-4: Total Logarithmic Standard Deviation of the 5% Damped Site Amplification for Base-Case Profile C1-PEN

	Period [s]	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.15	0.20	0.30	0.40	0.50	0.75	1.00	1.50	2.00	3.00	5.00	7.50	10.00
	Frequency [Hz]	100.00	50.00	33.33	25.00	20.00	13.33	10.00	6.67	5.00	3.33	2.50	2.00	1.33	1.00	0.67	0.50	0.33	0.20	0.13	0.10
Annual Exceedance Frequency	1.00E-02	0.284	0.285	0.272	0.326	0.311	0.309	0.287	0.284	0.358	0.492	0.363	0.317	0.134	0.122	0.156	0.136	0.078	0.050	0.046	0.036
	7.52E-03	0.272	0.269	0.263	0.323	0.304	0.300	0.282	0.290	0.366	0.484	0.367	0.320	0.134	0.123	0.155	0.136	0.074	0.049	0.034	0.024
	5.00E-03	0.255	0.248	0.253	0.320	0.295	0.292	0.279	0.306	0.382	0.471	0.376	0.323	0.136	0.124	0.155	0.136	0.073	0.039	0.033	0.038
	3.00E-03	0.236	0.233	0.248	0.318	0.289	0.287	0.279	0.325	0.399	0.457	0.394	0.332	0.138	0.126	0.154	0.139	0.073	0.039	0.031	0.036
	2.00E-03	0.226	0.229	0.249	0.318	0.288	0.286	0.282	0.343	0.411	0.447	0.406	0.339	0.140	0.128	0.153	0.142	0.073	0.037	0.029	0.038
	1.00E-03	0.225	0.226	0.252	0.320	0.287	0.289	0.292	0.374	0.430	0.432	0.428	0.355	0.151	0.134	0.149	0.149	0.074	0.034	0.032	0.037
	7.50E-04	0.225	0.227	0.253	0.319	0.287	0.292	0.296	0.385	0.440	0.427	0.435	0.363	0.157	0.137	0.148	0.153	0.075	0.033	0.032	0.036
	5.00E-04	0.227	0.230	0.254	0.321	0.289	0.298	0.303	0.397	0.451	0.413	0.442	0.379	0.168	0.142	0.147	0.158	0.078	0.033	0.031	0.035
	4.00E-04	0.230	0.233	0.256	0.322	0.291	0.302	0.308	0.402	0.457	0.412	0.444	0.389	0.176	0.145	0.147	0.162	0.080	0.033	0.031	0.035
	3.00E-04	0.234	0.237	0.261	0.327	0.296	0.309	0.315	0.406	0.465	0.411	0.447	0.404	0.190	0.150	0.148	0.166	0.083	0.034	0.031	0.036
	2.00E-04	0.233	0.246	0.272	0.336	0.303	0.320	0.326	0.411	0.478	0.415	0.454	0.423	0.219	0.159	0.151	0.172	0.087	0.034	0.031	0.036
	1.00E-04	0.244	0.267	0.292	0.354	0.319	0.341	0.344	0.415	0.498	0.434	0.461	0.461	0.276	0.190	0.164	0.180	0.096	0.036	0.030	0.036
	7.50E-05	0.250	0.276	0.301	0.364	0.325	0.349	0.351	0.419	0.506	0.445	0.461	0.473	0.295	0.212	0.173	0.183	0.100	0.038	0.030	0.037
	5.00E-05	0.258	0.288	0.311	0.370	0.332	0.357	0.361	0.424	0.519	0.466	0.463	0.486	0.328	0.243	0.187	0.186	0.107	0.040	0.030	0.036
	3.00E-05	0.266	0.290	0.320	0.373	0.339	0.369	0.374	0.434	0.531	0.493	0.466	0.499	0.357	0.285	0.216	0.190	0.116	0.042	0.030	0.034
	2.00E-05	0.273	0.300	0.331	0.384	0.349	0.380	0.386	0.443	0.540	0.514	0.470	0.507	0.378	0.322	0.262	0.199	0.126	0.044	0.029	0.031
	1.00E-05	0.282	0.317	0.353	0.403	0.366	0.395	0.408	0.454	0.555	0.545	0.490	0.529	0.397	0.338	0.317	0.247	0.148	0.049	0.029	0.026
	7.50E-06	0.286	0.322	0.360	0.410	0.371	0.401	0.417	0.457	0.556	0.558	0.498	0.545	0.406	0.359	0.331	0.281	0.158	0.051	0.030	0.024
	5.00E-06	0.291	0.331	0.372	0.420	0.380	0.409	0.428	0.461	0.559	0.567	0.504	0.554	0.430	0.386	0.345	0.294	0.171	0.057	0.030	0.025
	3.00E-06	0.296	0.341	0.384	0.432	0.393	0.419	0.443	0.469	0.568	0.577	0.521	0.568	0.471	0.401	0.389	0.301	0.185	0.068	0.031	0.022
	2.00E-06	0.301	0.348	0.397	0.442	0.401	0.425	0.455	0.477	0.577	0.588	0.541	0.590	0.470	0.433	0.416	0.320	0.200	0.080	0.032	0.020
	1.00E-06	0.309	0.362	0.415	0.459	0.416	0.436	0.470	0.494	0.596	0.620	0.572	0.620	0.500	0.445	0.458	0.369	0.210	0.114	0.035	0.019
	7.50E-07	0.313	0.369	0.424	0.468	0.423	0.441	0.478	0.501	0.605	0.633	0.580	0.635	0.521	0.446	0.489	0.390	0.216	0.128	0.038	0.019
	5.00E-07	0.318	0.377	0.434	0.477	0.433	0.448	0.487	0.509	0.622	0.645	0.591	0.652	0.529	0.454	0.529	0.410	0.243	0.140	0.043	0.018
	3.00E-07	0.345	0.388	0.447	0.490	0.443	0.455	0.501	0.517	0.635	0.655	0.606	0.659	0.539	0.471	0.528	0.443	0.240	0.138	0.053	0.019
	2.00E-07	0.360	0.397	0.458	0.500	0.451	0.460	0.509	0.524	0.639	0.650	0.611	0.676	0.572	0.478	0.529	0.469	0.252	0.139	0.067	0.021
	1.00E-07	0.314	0.412	0.476	0.517	0.466	0.468	0.522	0.537	0.643	0.660	0.613	0.688	0.638	0.437	0.534	0.506	0.279	0.153	0.110	0.027

Table 2.3.6-5: Weighted Average Logarithmic Mean of the 5% Damped Site Amplification for Base-Case Profile C2-EPRI

	Period [s]	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.15	0.20	0.30	0.40	0.50	0.75	1.00	1.50	2.00	3.00	5.00	7.50	10.00
	Frequency [Hz]	100.00	50.00	33.33	25.00	20.00	13.33	10.00	6.67	5.00	3.33	2.50	2.00	1.33	1.00	0.67	0.50	0.33	0.20	0.13	0.10
Annual Exceedance Frequency	1.00E-02	0.930	0.787	0.807	0.804	0.786	0.960	1.037	1.556	2.805	2.983	1.536	1.848	2.199	2.376	2.662	1.962	1.446	1.231	1.170	1.144
	7.52E-03	0.857	0.737	0.764	0.763	0.744	0.926	1.002	1.515	2.741	2.960	1.546	1.846	2.198	2.369	2.669	1.961	1.435	1.222	1.153	1.128
	5.00E-03	0.793	0.687	0.715	0.711	0.692	0.862	0.937	1.448	2.632	2.910	1.556	1.844	2.197	2.357	2.670	1.957	1.428	1.205	1.135	1.115
	3.00E-03	0.720	0.636	0.665	0.658	0.639	0.802	0.873	1.370	2.483	2.836	1.563	1.832	2.196	2.336	2.674	1.962	1.425	1.193	1.125	1.112
	2.00E-03	0.652	0.595	0.626	0.618	0.600	0.753	0.820	1.303	2.353	2.770	1.573	1.822	2.191	2.318	2.675	1.975	1.424	1.189	1.123	1.113
	1.00E-03	0.573	0.515	0.550	0.538	0.522	0.663	0.725	1.182	2.101	2.606	1.584	1.807	2.182	2.273	2.683	2.003	1.425	1.183	1.118	1.116
	7.50E-04	0.536	0.485	0.519	0.510	0.495	0.628	0.688	1.122	1.984	2.528	1.587	1.804	2.180	2.257	2.688	2.018	1.427	1.181	1.116	1.116
	5.00E-04	0.486	0.442	0.474	0.465	0.449	0.575	0.631	1.039	1.829	2.388	1.583	1.797	2.178	2.236	2.693	2.040	1.433	1.179	1.115	1.114
	4.00E-04	0.459	0.421	0.451	0.443	0.427	0.549	0.604	0.994	1.743	2.326	1.578	1.794	2.181	2.222	2.700	2.055	1.438	1.177	1.114	1.114
	3.00E-04	0.423	0.392	0.417	0.410	0.396	0.513	0.567	0.941	1.644	2.243	1.572	1.781	2.189	2.210	2.704	2.076	1.443	1.180	1.113	1.114
	2.00E-04	0.368	0.349	0.367	0.368	0.357	0.466	0.519	0.865	1.508	2.139	1.555	1.755	2.203	2.192	2.716	2.104	1.452	1.179	1.111	1.114
	1.00E-04	0.299	0.285	0.303	0.306	0.300	0.398	0.451	0.746	1.288	1.966	1.494	1.699	2.221	2.183	2.733	2.161	1.471	1.178	1.108	1.114
	7.50E-05	0.273	0.263	0.281	0.283	0.280	0.375	0.427	0.703	1.214	1.892	1.460	1.669	2.221	2.183	2.728	2.190	1.480	1.177	1.108	1.113
	5.00E-05	0.243	0.234	0.256	0.259	0.257	0.341	0.392	0.650	1.109	1.778	1.405	1.624	2.205	2.172	2.721	2.234	1.496	1.178	1.106	1.109
	3.00E-05	0.213	0.199	0.225	0.229	0.231	0.307	0.357	0.587	0.993	1.632	1.339	1.555	2.161	2.124	2.716	2.289	1.517	1.179	1.105	1.103
	2.00E-05	0.192	0.178	0.203	0.208	0.210	0.281	0.331	0.542	0.910	1.513	1.278	1.502	2.112	2.075	2.680	2.339	1.537	1.182	1.104	1.091
	1.00E-05	0.157	0.147	0.170	0.176	0.178	0.243	0.292	0.471	0.786	1.318	1.182	1.358	2.053	1.971	2.529	2.417	1.584	1.187	1.103	1.071
	7.50E-06	0.146	0.137	0.160	0.165	0.168	0.230	0.277	0.445	0.741	1.246	1.138	1.302	1.998	1.912	2.463	2.441	1.607	1.190	1.102	1.063
	5.00E-06	0.133	0.124	0.145	0.151	0.155	0.213	0.258	0.410	0.684	1.142	1.077	1.229	1.944	1.887	2.343	2.427	1.641	1.196	1.102	1.071
	3.00E-06	0.117	0.110	0.130	0.136	0.139	0.192	0.235	0.372	0.618	1.023	0.990	1.136	1.857	1.862	2.213	2.380	1.689	1.204	1.102	1.060
	2.00E-06	0.108	0.101	0.120	0.126	0.129	0.178	0.219	0.345	0.573	0.941	0.915	1.040	1.763	1.807	2.113	2.326	1.735	1.212	1.103	1.052
	1.00E-06	0.092	0.087	0.104	0.110	0.113	0.157	0.195	0.304	0.497	0.813	0.781	0.886	1.579	1.685	1.975	2.237	1.816	1.231	1.102	1.041
	7.50E-07	0.087	0.081	0.098	0.103	0.106	0.149	0.186	0.289	0.467	0.774	0.741	0.840	1.482	1.583	1.890	2.171	1.820	1.240	1.102	1.039
	5.00E-07	0.079	0.074	0.091	0.096	0.098	0.139	0.174	0.269	0.430	0.708	0.686	0.770	1.323	1.489	1.794	2.071	1.831	1.260	1.103	1.037
	3.00E-07	0.070	0.067	0.082	0.087	0.090	0.127	0.160	0.245	0.387	0.638	0.639	0.686	1.183	1.366	1.640	1.960	1.836	1.286	1.105	1.038
	2.00E-07	0.058	0.062	0.076	0.081	0.083	0.118	0.150	0.228	0.356	0.591	0.585	0.638	1.067	1.303	1.547	1.844	1.826	1.310	1.108	1.039
	1.00E-07	0.045	0.054	0.067	0.072	0.074	0.105	0.135	0.201	0.307	0.520	0.524	0.560	0.928	1.121	1.298	1.609	1.807	1.365	1.118	1.041

Table 2.3.6-6: Total Logarithmic Standard Deviation of the 5% Damped Site Amplification for Base-Case Profile C2-EPRI

	Period [s]	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.15	0.20	0.30	0.40	0.50	0.75	1.00	1.50	2.00	3.00	5.00	7.50	10.00
	Frequency [Hz]	100.00	50.00	33.33	25.00	20.00	13.33	10.00	6.67	5.00	3.33	2.50	2.00	1.33	1.00	0.67	0.50	0.33	0.20	0.13	0.10
Annual Exceedance Frequency	1.00E-02	0.294	0.292	0.266	0.280	0.266	0.273	0.255	0.245	0.347	0.483	0.336	0.323	0.148	0.150	0.132	0.132	0.074	0.047	0.044	0.034
	7.52E-03	0.276	0.269	0.248	0.264	0.247	0.259	0.241	0.246	0.354	0.474	0.340	0.325	0.150	0.151	0.132	0.133	0.072	0.047	0.032	0.023
	5.00E-03	0.252	0.239	0.226	0.244	0.218	0.244	0.225	0.251	0.368	0.461	0.349	0.329	0.152	0.152	0.133	0.134	0.072	0.037	0.033	0.037
	3.00E-03	0.222	0.214	0.213	0.229	0.194	0.239	0.214	0.259	0.387	0.443	0.367	0.340	0.156	0.155	0.132	0.137	0.073	0.038	0.029	0.035
	2.00E-03	0.205	0.204	0.212	0.226	0.188	0.241	0.212	0.268	0.403	0.429	0.376	0.350	0.161	0.158	0.129	0.140	0.072	0.036	0.029	0.037
	1.00E-03	0.198	0.198	0.222	0.229	0.187	0.254	0.219	0.291	0.430	0.401	0.391	0.377	0.176	0.167	0.126	0.146	0.074	0.033	0.031	0.035
	7.50E-04	0.196	0.200	0.230	0.231	0.190	0.262	0.224	0.303	0.443	0.391	0.397	0.390	0.187	0.172	0.125	0.150	0.076	0.032	0.031	0.035
	5.00E-04	0.199	0.204	0.241	0.238	0.196	0.275	0.233	0.318	0.456	0.374	0.406	0.411	0.209	0.181	0.126	0.155	0.080	0.032	0.030	0.034
	4.00E-04	0.202	0.209	0.248	0.241	0.201	0.282	0.238	0.325	0.462	0.374	0.411	0.425	0.224	0.188	0.127	0.158	0.082	0.033	0.030	0.034
	3.00E-04	0.207	0.215	0.259	0.249	0.208	0.293	0.245	0.332	0.467	0.376	0.417	0.440	0.246	0.200	0.130	0.161	0.085	0.033	0.030	0.034
	2.00E-04	0.210	0.227	0.275	0.260	0.220	0.305	0.255	0.342	0.474	0.389	0.425	0.458	0.281	0.222	0.136	0.165	0.091	0.034	0.030	0.035
	1.00E-04	0.226	0.252	0.301	0.278	0.240	0.325	0.271	0.357	0.482	0.425	0.425	0.479	0.333	0.282	0.162	0.171	0.101	0.037	0.029	0.035
	7.50E-05	0.233	0.261	0.311	0.284	0.246	0.332	0.276	0.365	0.487	0.442	0.425	0.488	0.348	0.310	0.176	0.173	0.106	0.039	0.029	0.035
	5.00E-05	0.242	0.274	0.321	0.291	0.255	0.332	0.282	0.375	0.496	0.470	0.427	0.494	0.368	0.344	0.206	0.177	0.113	0.041	0.029	0.035
	3.00E-05	0.252	0.273	0.331	0.295	0.264	0.339	0.293	0.390	0.500	0.494	0.433	0.501	0.393	0.350	0.278	0.186	0.124	0.043	0.029	0.033
	2.00E-05	0.259	0.281	0.342	0.301	0.271	0.346	0.303	0.399	0.502	0.505	0.432	0.517	0.407	0.358	0.316	0.201	0.135	0.045	0.029	0.030
	1.00E-05	0.269	0.294	0.360	0.311	0.282	0.356	0.320	0.414	0.509	0.517	0.463	0.527	0.472	0.363	0.339	0.250	0.158	0.051	0.029	0.025
	7.50E-06	0.272	0.297	0.366	0.315	0.286	0.359	0.327	0.420	0.511	0.522	0.479	0.536	0.478	0.355	0.349	0.275	0.169	0.053	0.029	0.023
	5.00E-06	0.277	0.303	0.377	0.321	0.292	0.364	0.336	0.428	0.517	0.532	0.503	0.560	0.500	0.387	0.350	0.281	0.185	0.058	0.030	0.025
	3.00E-06	0.282	0.310	0.388	0.327	0.298	0.372	0.349	0.438	0.530	0.545	0.515	0.590	0.537	0.453	0.370	0.290	0.203	0.066	0.030	0.022
	2.00E-06	0.286	0.315	0.398	0.332	0.304	0.376	0.360	0.448	0.539	0.559	0.519	0.602	0.561	0.476	0.392	0.303	0.223	0.073	0.031	0.020
	1.00E-06	0.294	0.324	0.414	0.342	0.312	0.386	0.376	0.464	0.562	0.584	0.542	0.624	0.619	0.525	0.463	0.342	0.247	0.093	0.034	0.020
	7.50E-07	0.296	0.328	0.421	0.346	0.315	0.390	0.384	0.470	0.570	0.592	0.552	0.633	0.629	0.521	0.464	0.353	0.239	0.107	0.035	0.020
	5.00E-07	0.300	0.333	0.429	0.352	0.319	0.398	0.395	0.477	0.580	0.604	0.561	0.656	0.619	0.522	0.490	0.373	0.231	0.135	0.038	0.019
	3.00E-07	0.326	0.339	0.440	0.359	0.324	0.405	0.409	0.487	0.591	0.611	0.583	0.631	0.643	0.518	0.521	0.434	0.232	0.164	0.044	0.020
	2.00E-07	0.340	0.344	0.449	0.365	0.328	0.412	0.419	0.492	0.595	0.617	0.585	0.624	0.639	0.538	0.549	0.459	0.239	0.181	0.050	0.021
	1.00E-07	0.294	0.352	0.464	0.375	0.335	0.426	0.437	0.501	0.605	0.645	0.600	0.606	0.658	0.555	0.506	0.487	0.269	0.215	0.069	0.025

Table 2.3.6-7: Weighted Average Logarithmic Mean of the 5% Damped Site Amplification for Base-Case Profile C2-PEN

	Period [s]	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.15	0.20	0.30	0.40	0.50	0.75	1.00	1.50	2.00	3.00	5.00	7.50	10.00
	Frequency [Hz]	100.00	50.00	33.33	25.00	20.00	13.33	10.00	6.67	5.00	3.33	2.50	2.00	1.33	1.00	0.67	0.50	0.33	0.20	0.13	0.10
Annual Exceedance Frequency	1.00E-02	1.037	0.888	0.907	0.896	0.863	1.057	1.138	1.684	3.031	3.137	1.584	1.894	2.236	2.406	2.689	1.974	1.452	1.235	1.174	1.147
	7.52E-03	0.960	0.838	0.863	0.853	0.820	1.022	1.102	1.641	2.963	3.111	1.592	1.890	2.233	2.396	2.693	1.971	1.439	1.226	1.155	1.130
	5.00E-03	0.892	0.784	0.812	0.799	0.765	0.953	1.032	1.566	2.844	3.052	1.598	1.883	2.227	2.380	2.689	1.965	1.432	1.207	1.137	1.117
	3.00E-03	0.812	0.727	0.756	0.740	0.705	0.886	0.960	1.476	2.680	2.971	1.597	1.862	2.220	2.354	2.689	1.968	1.429	1.196	1.126	1.114
	2.00E-03	0.736	0.681	0.712	0.694	0.660	0.829	0.900	1.398	2.535	2.905	1.603	1.847	2.212	2.334	2.689	1.980	1.426	1.190	1.124	1.114
	1.00E-03	0.645	0.589	0.625	0.604	0.574	0.728	0.795	1.266	2.270	2.760	1.613	1.821	2.198	2.287	2.696	2.007	1.427	1.184	1.118	1.116
	7.50E-04	0.602	0.554	0.590	0.571	0.544	0.691	0.756	1.208	2.153	2.696	1.616	1.814	2.192	2.268	2.699	2.021	1.428	1.182	1.117	1.117
	5.00E-04	0.546	0.505	0.541	0.523	0.495	0.637	0.698	1.130	2.000	2.568	1.611	1.802	2.180	2.243	2.700	2.041	1.434	1.179	1.115	1.115
	4.00E-04	0.516	0.482	0.516	0.499	0.473	0.609	0.671	1.089	1.917	2.509	1.605	1.794	2.175	2.225	2.705	2.053	1.437	1.178	1.114	1.115
	3.00E-04	0.476	0.450	0.479	0.465	0.440	0.573	0.634	1.039	1.820	2.425	1.598	1.777	2.174	2.205	2.704	2.071	1.441	1.181	1.113	1.115
	2.00E-04	0.417	0.403	0.426	0.421	0.400	0.526	0.585	0.966	1.687	2.310	1.583	1.744	2.173	2.175	2.708	2.095	1.449	1.179	1.111	1.115
	1.00E-04	0.342	0.334	0.358	0.356	0.340	0.456	0.514	0.844	1.460	2.108	1.541	1.686	2.169	2.137	2.705	2.141	1.465	1.177	1.109	1.114
	7.50E-05	0.313	0.310	0.333	0.331	0.319	0.432	0.489	0.798	1.380	2.024	1.514	1.656	2.163	2.122	2.692	2.165	1.473	1.176	1.108	1.114
	5.00E-05	0.280	0.277	0.306	0.305	0.294	0.397	0.451	0.739	1.264	1.904	1.464	1.613	2.150	2.098	2.667	2.200	1.486	1.176	1.106	1.110
	3.00E-05	0.247	0.238	0.272	0.273	0.266	0.360	0.412	0.669	1.140	1.766	1.398	1.546	2.106	2.062	2.624	2.239	1.504	1.177	1.105	1.103
	2.00E-05	0.223	0.214	0.247	0.249	0.243	0.331	0.383	0.620	1.053	1.665	1.340	1.484	2.051	2.024	2.600	2.274	1.521	1.179	1.104	1.092
	1.00E-05	0.184	0.178	0.209	0.213	0.208	0.290	0.340	0.545	0.921	1.499	1.245	1.358	1.955	1.886	2.511	2.336	1.562	1.183	1.102	1.071
	7.50E-06	0.171	0.167	0.197	0.201	0.197	0.274	0.323	0.518	0.870	1.435	1.207	1.313	1.915	1.843	2.419	2.360	1.584	1.186	1.101	1.063
	5.00E-06	0.155	0.151	0.181	0.185	0.182	0.255	0.303	0.481	0.805	1.348	1.159	1.251	1.857	1.788	2.313	2.378	1.615	1.190	1.101	1.071
	3.00E-06	0.137	0.135	0.163	0.167	0.164	0.232	0.278	0.438	0.730	1.231	1.097	1.183	1.782	1.718	2.191	2.358	1.661	1.198	1.101	1.059
	2.00E-06	0.126	0.125	0.151	0.155	0.153	0.216	0.261	0.408	0.673	1.133	1.039	1.134	1.715	1.675	2.085	2.298	1.701	1.206	1.101	1.052
	1.00E-06	0.109	0.107	0.132	0.136	0.134	0.192	0.235	0.361	0.586	0.984	0.936	1.026	1.596	1.567	1.911	2.191	1.768	1.225	1.100	1.041
	7.50E-07	0.102	0.100	0.125	0.129	0.127	0.183	0.225	0.343	0.555	0.925	0.898	0.972	1.547	1.513	1.848	2.120	1.768	1.233	1.100	1.038
	5.00E-07	0.093	0.093	0.116	0.120	0.118	0.171	0.211	0.319	0.515	0.847	0.847	0.904	1.462	1.446	1.759	2.038	1.780	1.252	1.100	1.037
	3.00E-07	0.082	0.084	0.106	0.110	0.108	0.157	0.195	0.291	0.469	0.754	0.773	0.834	1.312	1.353	1.639	1.900	1.783	1.279	1.103	1.037
	2.00E-07	0.068	0.078	0.099	0.103	0.101	0.147	0.184	0.271	0.435	0.691	0.714	0.773	1.215	1.287	1.506	1.829	1.786	1.301	1.105	1.038
	1.00E-07	0.053	0.069	0.089	0.091	0.090	0.132	0.166	0.240	0.383	0.607	0.626	0.680	1.069	1.152	1.307	1.637	1.752	1.355	1.114	1.040

Table 2.3.6-8: Total Logarithmic Standard Deviation of the 5% Damped Site Amplification for Base-Case Profile C2-PEN

	Period [s]	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.15	0.20	0.30	0.40	0.50	0.75	1.00	1.50	2.00	3.00	5.00	7.50	10.00
	Frequency [Hz]	100.00	50.00	33.33	25.00	20.00	13.33	10.00	6.67	5.00	3.33	2.50	2.00	1.33	1.00	0.67	0.50	0.33	0.20	0.13	0.10
Annual Exceedance Frequency	1.00E-02	0.281	0.284	0.262	0.281	0.259	0.274	0.252	0.241	0.345	0.502	0.344	0.324	0.152	0.153	0.136	0.134	0.076	0.048	0.045	0.035
	7.52E-03	0.266	0.265	0.247	0.268	0.242	0.263	0.241	0.243	0.353	0.494	0.349	0.327	0.153	0.153	0.136	0.135	0.073	0.048	0.033	0.024
	5.00E-03	0.245	0.240	0.230	0.251	0.215	0.252	0.228	0.250	0.369	0.481	0.357	0.330	0.155	0.154	0.135	0.136	0.073	0.038	0.033	0.037
	3.00E-03	0.220	0.220	0.221	0.240	0.193	0.249	0.220	0.259	0.389	0.465	0.374	0.340	0.158	0.157	0.134	0.138	0.074	0.039	0.030	0.035
	2.00E-03	0.206	0.212	0.223	0.238	0.188	0.251	0.220	0.269	0.405	0.453	0.385	0.348	0.163	0.160	0.133	0.142	0.073	0.037	0.029	0.037
	1.00E-03	0.201	0.208	0.235	0.242	0.188	0.263	0.228	0.289	0.428	0.433	0.404	0.368	0.175	0.167	0.130	0.148	0.075	0.034	0.032	0.036
	7.50E-04	0.200	0.208	0.242	0.244	0.191	0.269	0.233	0.299	0.440	0.425	0.410	0.379	0.182	0.171	0.129	0.152	0.077	0.033	0.032	0.036
	5.00E-04	0.203	0.212	0.253	0.250	0.196	0.280	0.242	0.314	0.453	0.408	0.416	0.396	0.195	0.178	0.130	0.157	0.080	0.033	0.030	0.035
	4.00E-04	0.206	0.214	0.259	0.254	0.200	0.287	0.246	0.322	0.461	0.405	0.419	0.407	0.204	0.182	0.131	0.159	0.082	0.033	0.030	0.035
	3.00E-04	0.211	0.219	0.270	0.261	0.206	0.297	0.253	0.331	0.469	0.401	0.423	0.419	0.219	0.189	0.132	0.162	0.085	0.034	0.030	0.035
	2.00E-04	0.213	0.228	0.286	0.272	0.216	0.311	0.263	0.346	0.481	0.402	0.433	0.432	0.247	0.201	0.137	0.166	0.090	0.035	0.030	0.035
	1.00E-04	0.228	0.251	0.312	0.293	0.235	0.335	0.279	0.364	0.495	0.413	0.450	0.460	0.295	0.238	0.153	0.170	0.099	0.037	0.030	0.036
	7.50E-05	0.235	0.261	0.322	0.301	0.242	0.345	0.285	0.373	0.500	0.424	0.454	0.471	0.312	0.260	0.163	0.172	0.103	0.038	0.030	0.036
	5.00E-05	0.244	0.274	0.333	0.310	0.252	0.350	0.292	0.384	0.508	0.445	0.458	0.482	0.343	0.291	0.181	0.173	0.110	0.040	0.030	0.035
	3.00E-05	0.255	0.276	0.345	0.319	0.264	0.363	0.304	0.398	0.515	0.472	0.459	0.496	0.367	0.328	0.220	0.175	0.119	0.043	0.029	0.034
	2.00E-05	0.263	0.286	0.359	0.328	0.273	0.374	0.313	0.406	0.520	0.492	0.459	0.506	0.379	0.354	0.270	0.182	0.128	0.045	0.029	0.031
	1.00E-05	0.276	0.304	0.382	0.344	0.286	0.388	0.328	0.422	0.528	0.524	0.471	0.524	0.411	0.338	0.342	0.216	0.150	0.049	0.029	0.025
	7.50E-06	0.281	0.310	0.390	0.349	0.291	0.392	0.334	0.429	0.531	0.537	0.480	0.532	0.426	0.346	0.340	0.244	0.161	0.052	0.029	0.024
	5.00E-06	0.287	0.318	0.404	0.356	0.298	0.398	0.344	0.437	0.536	0.559	0.499	0.545	0.454	0.360	0.350	0.274	0.175	0.056	0.030	0.025
	3.00E-06	0.293	0.328	0.418	0.365	0.306	0.407	0.357	0.447	0.544	0.581	0.515	0.569	0.488	0.383	0.372	0.301	0.194	0.063	0.030	0.022
	2.00E-06	0.298	0.335	0.431	0.371	0.312	0.411	0.367	0.455	0.547	0.595	0.526	0.593	0.515	0.415	0.391	0.306	0.209	0.070	0.031	0.020
	1.00E-06	0.307	0.348	0.452	0.383	0.322	0.420	0.385	0.468	0.558	0.606	0.563	0.617	0.555	0.452	0.429	0.343	0.231	0.090	0.033	0.020
	7.50E-07	0.310	0.354	0.461	0.388	0.326	0.424	0.392	0.473	0.564	0.606	0.577	0.616	0.571	0.456	0.449	0.351	0.213	0.103	0.034	0.019
	5.00E-07	0.314	0.362	0.472	0.394	0.331	0.431	0.404	0.479	0.571	0.608	0.597	0.634	0.596	0.472	0.481	0.374	0.219	0.131	0.037	0.018
	3.00E-07	0.342	0.371	0.487	0.403	0.337	0.438	0.419	0.489	0.579	0.612	0.599	0.656	0.609	0.492	0.513	0.404	0.218	0.162	0.043	0.019
	2.00E-07	0.364	0.379	0.499	0.409	0.343	0.445	0.429	0.497	0.587	0.619	0.596	0.660	0.624	0.489	0.510	0.445	0.236	0.178	0.049	0.020
	1.00E-07	0.321	0.392	0.519	0.422	0.351	0.457	0.447	0.505	0.600	0.632	0.597	0.666	0.638	0.497	0.496	0.483	0.268	0.215	0.067	0.023

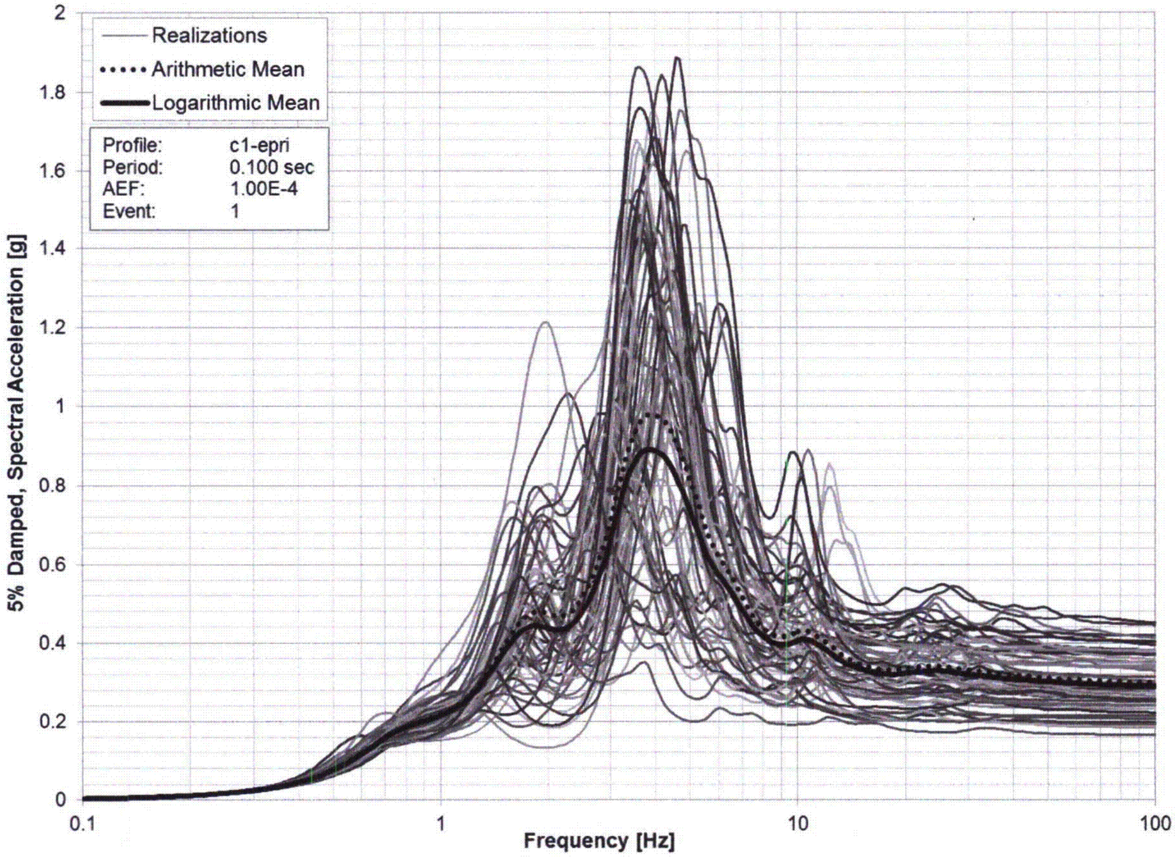


Figure 2.3.6-1: The Computed Surface 5% Damped Acceleration Response Spectrum (Profile: C1-EPRI, CMS Period: 0.1 sec, AFE: 1E-4, and Event: 1)

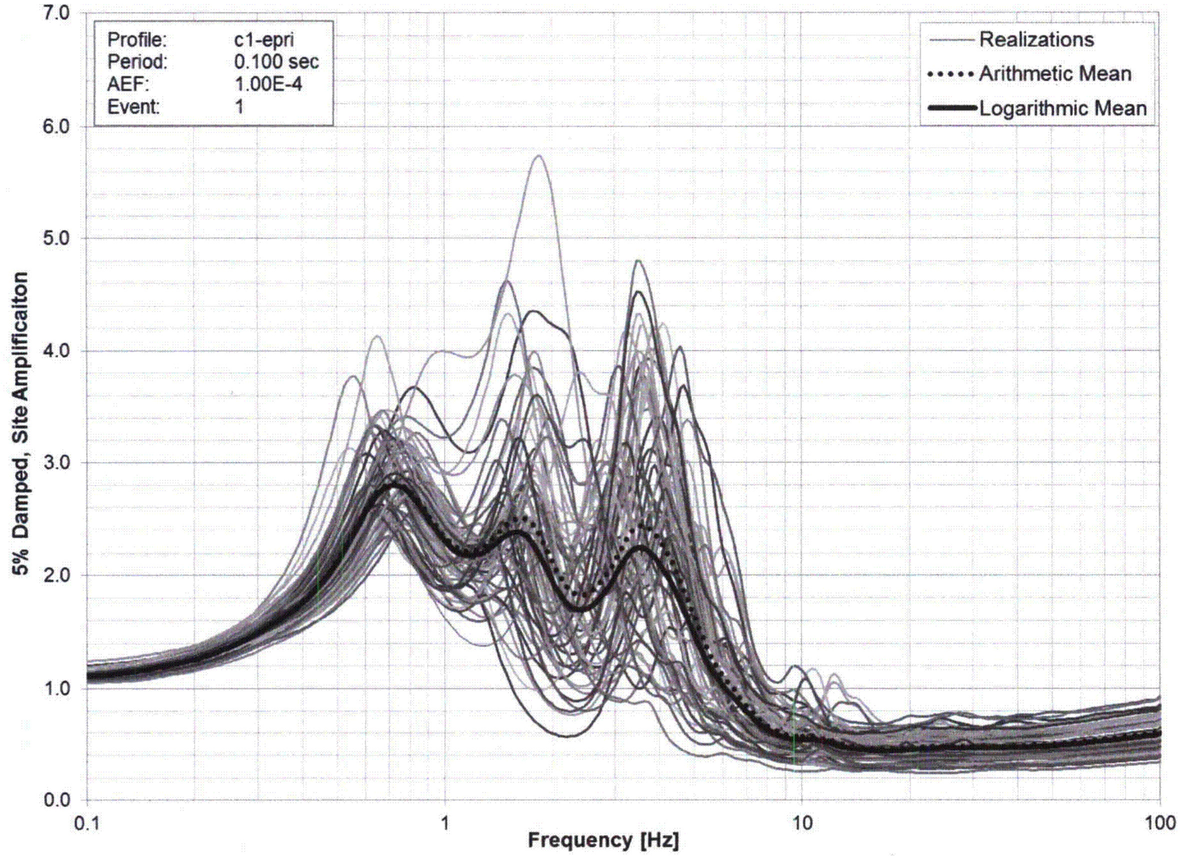


Figure 2.3.6-2: The Individual Realizations and Arithmetic Site Amplification (Profile: C1-EPRI, CMS Period: 0.1 sec, AFE: 1E-4, and Event: 1)

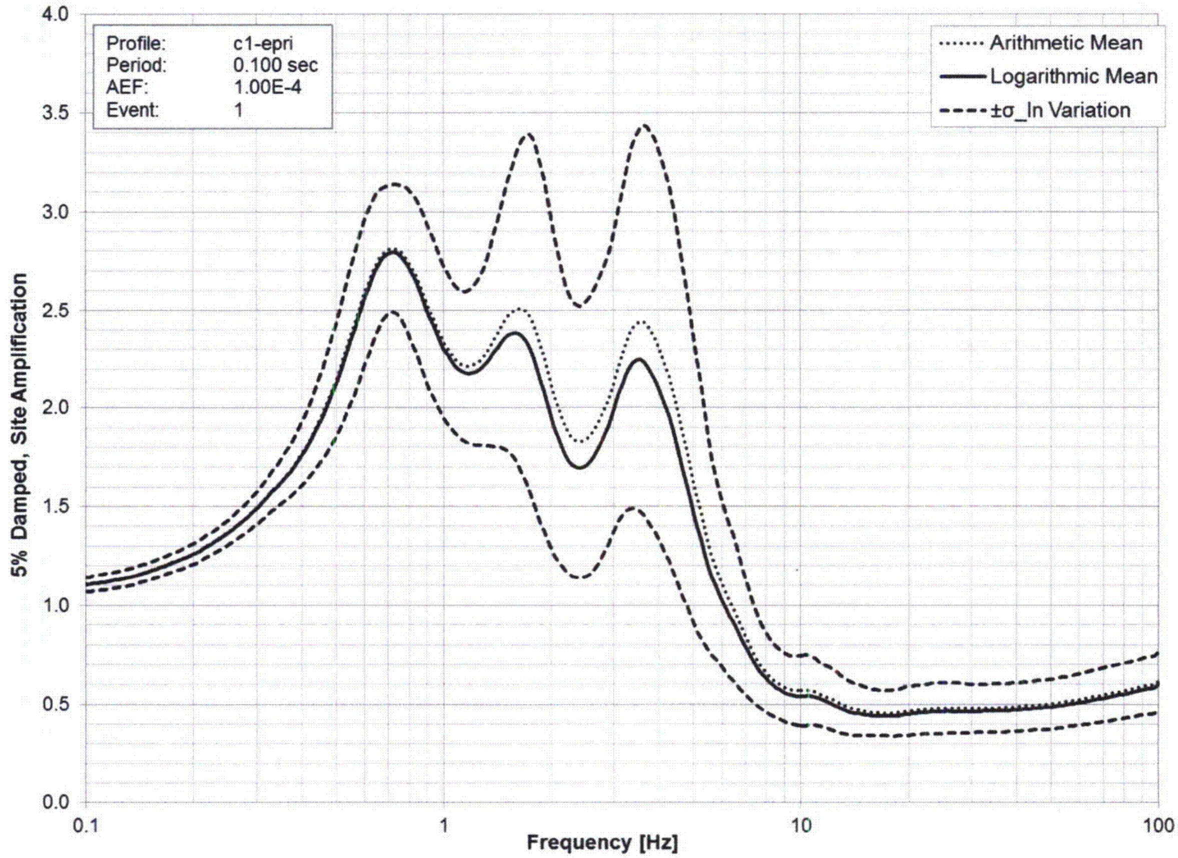


Figure 2.3.6-3: The Arithmetic, Logarithmic and $\pm\sigma_{ln}$ Variation of the Site Amplification (Profile: C1-EPRI, CMS Period: 0.1 sec, AFE: 1E-4, and Event: 1)

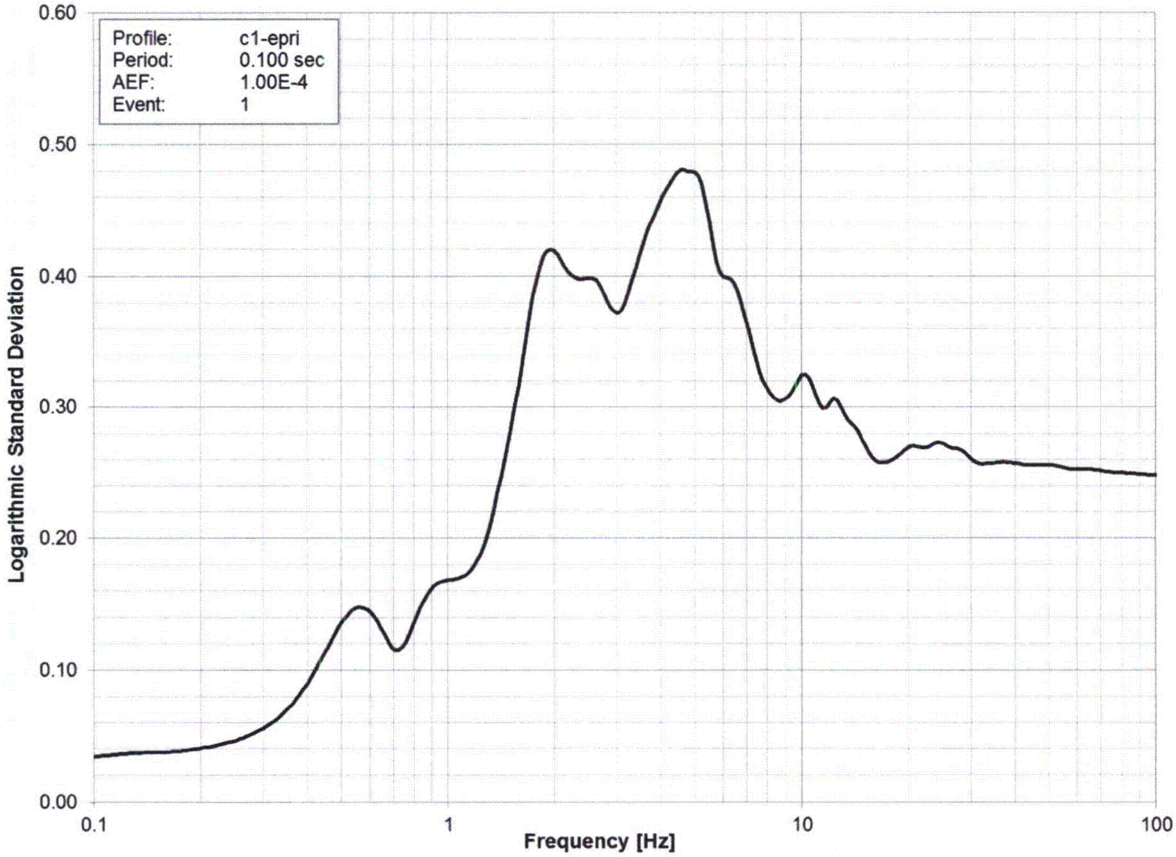


Figure 2.3.6-4: The Logarithmic Standard Deviation of the Site Amplification (Profile: C1-EPRI, CMS Period: 0.1 sec, AFE: 1E-4, and Event: 1)

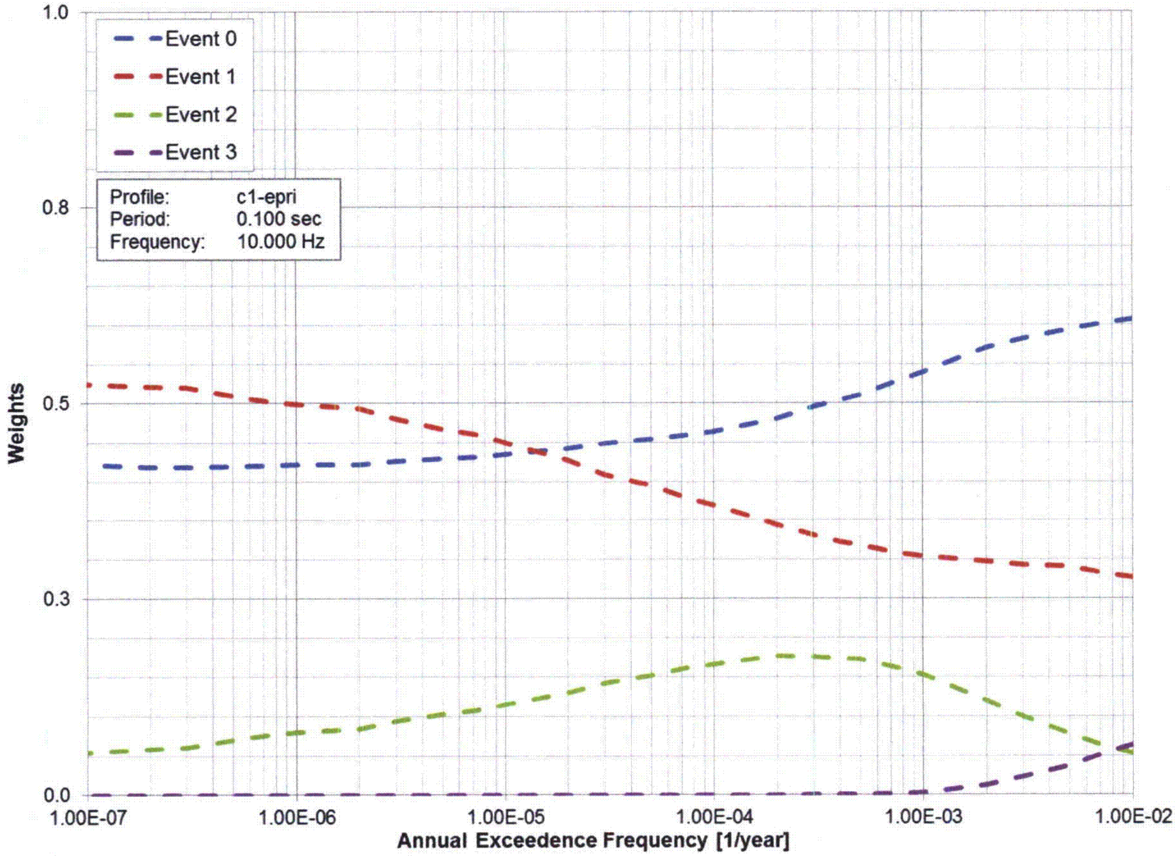


Figure 2.3.6-5: The Weight Factors for the Four Events at the Various MAFE (Profile: C1-EPRI, CMS Period: 0.1 sec) The magnitude and distance of each event varies with MAFE

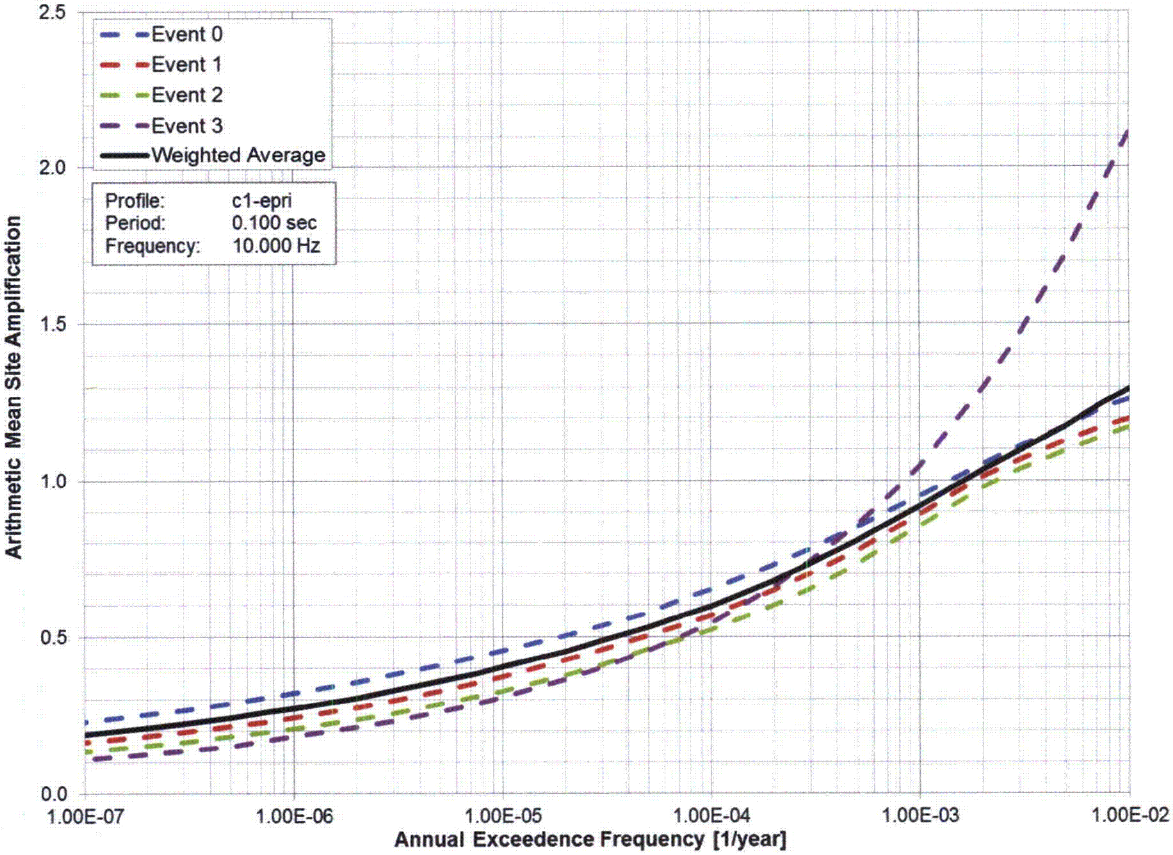


Figure 2.3.6-6: The Weighted Average of the Logarithmic Site Amplification for the Four Events at the Various MAFE (Profile: C1-EPRI, CMS Period: 0.1 sec)

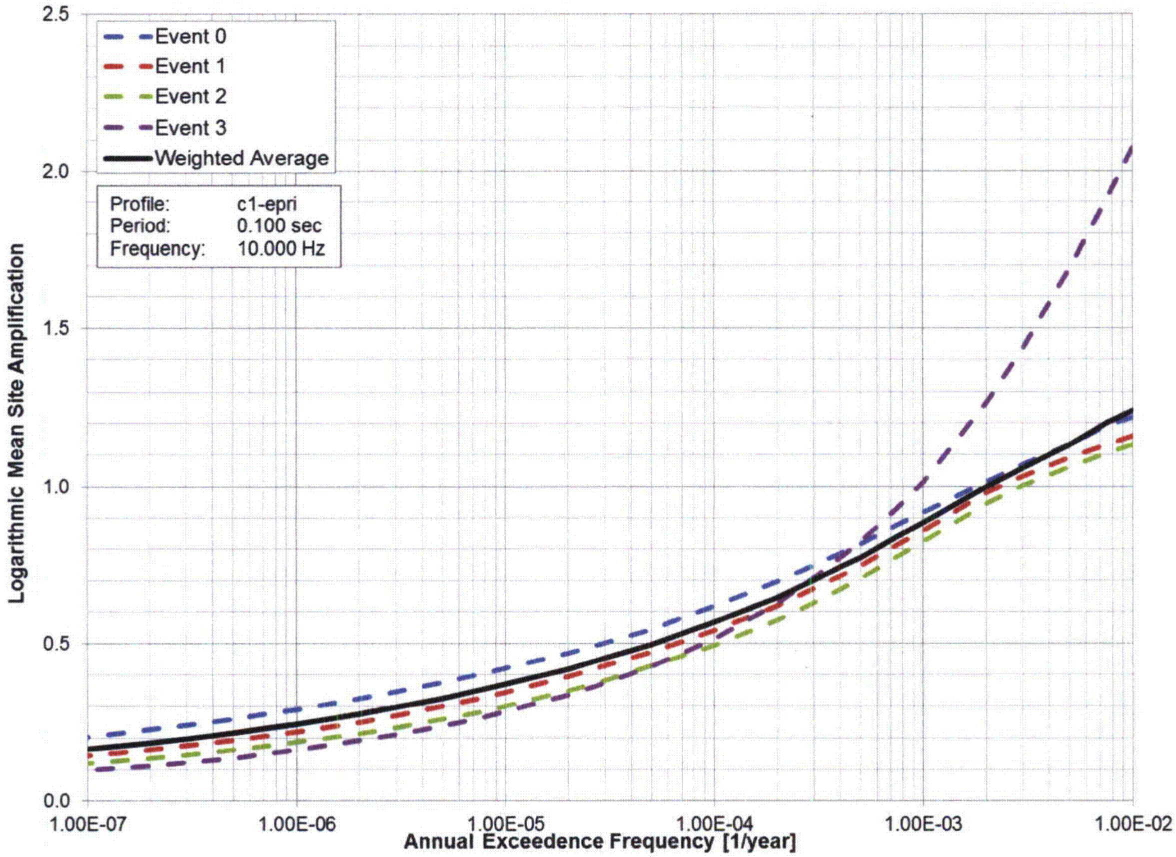


Figure 2.3.6-7: The Total Logarithmic Standard Deviation for the Four Events at the Various MAFE (Profile: C1-EPRI, CMS Period: 0.1 sec)

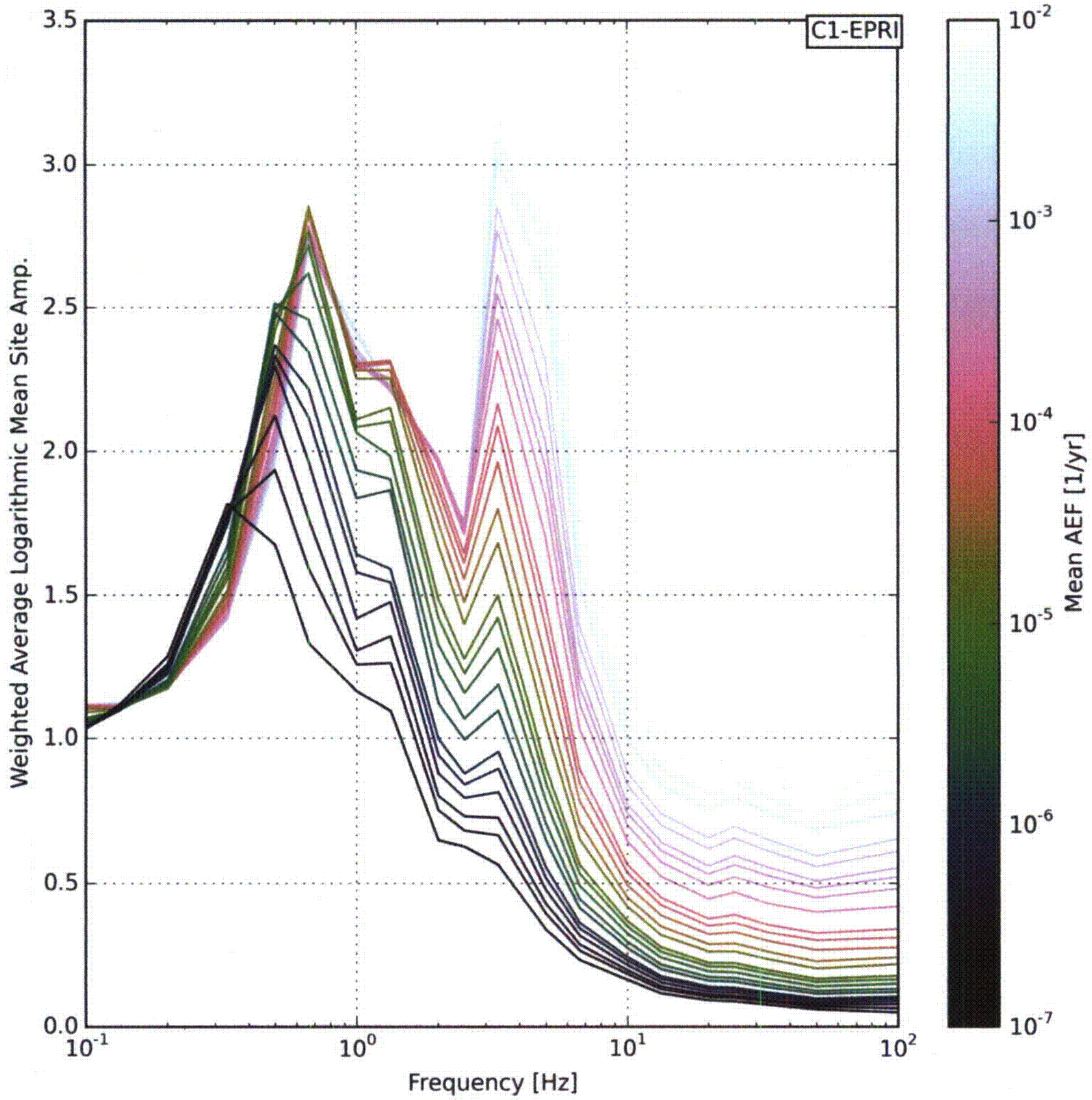


Figure 2.3.6-8: Line Plots of the Weighted Average Logarithmic Site Amplification for the C1-EPRI Profile

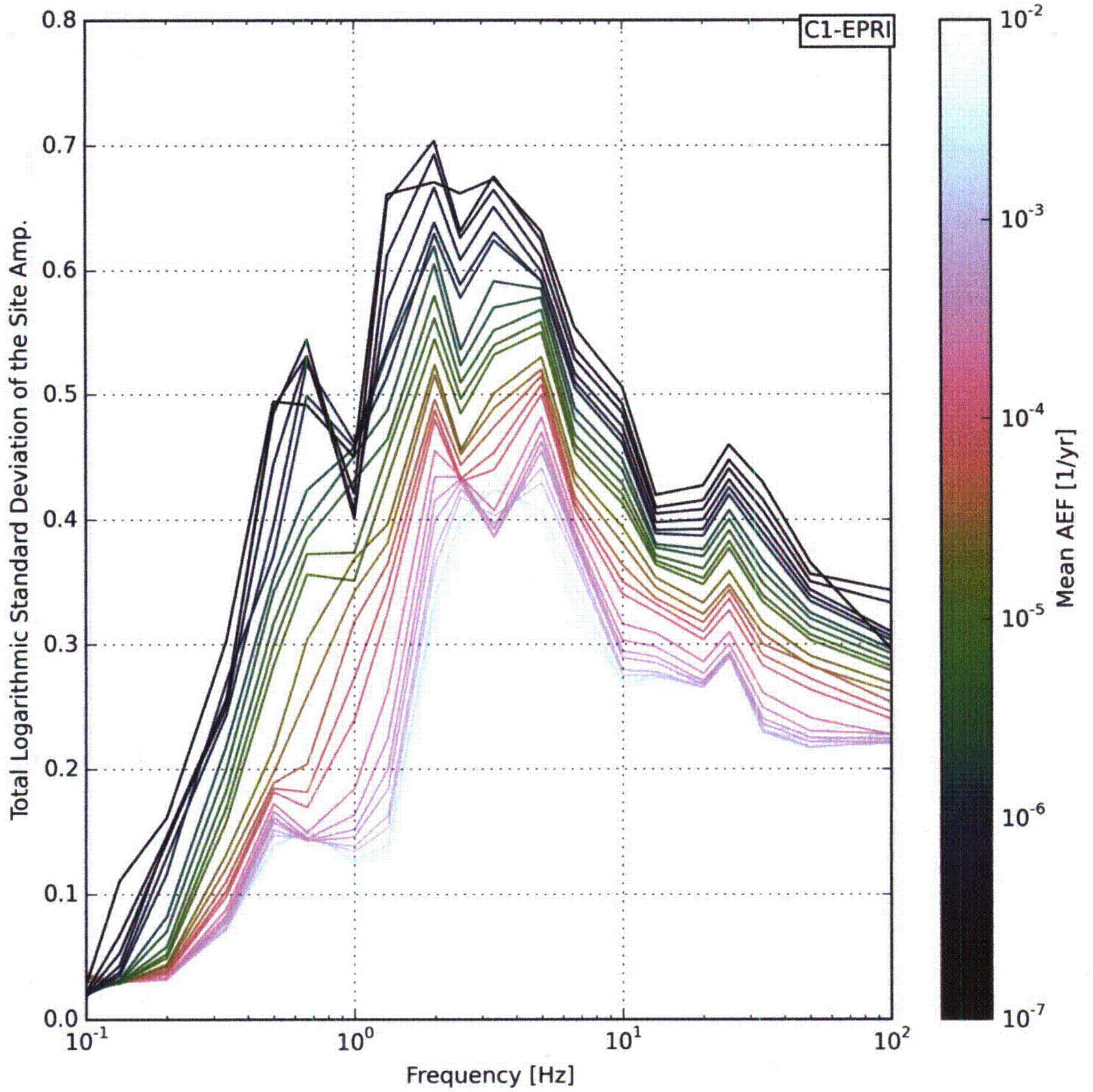


Figure 2.3.6-9: Line Plot of the Total Standard Deviation of the Site Amplification for the C1-EPRI Profile

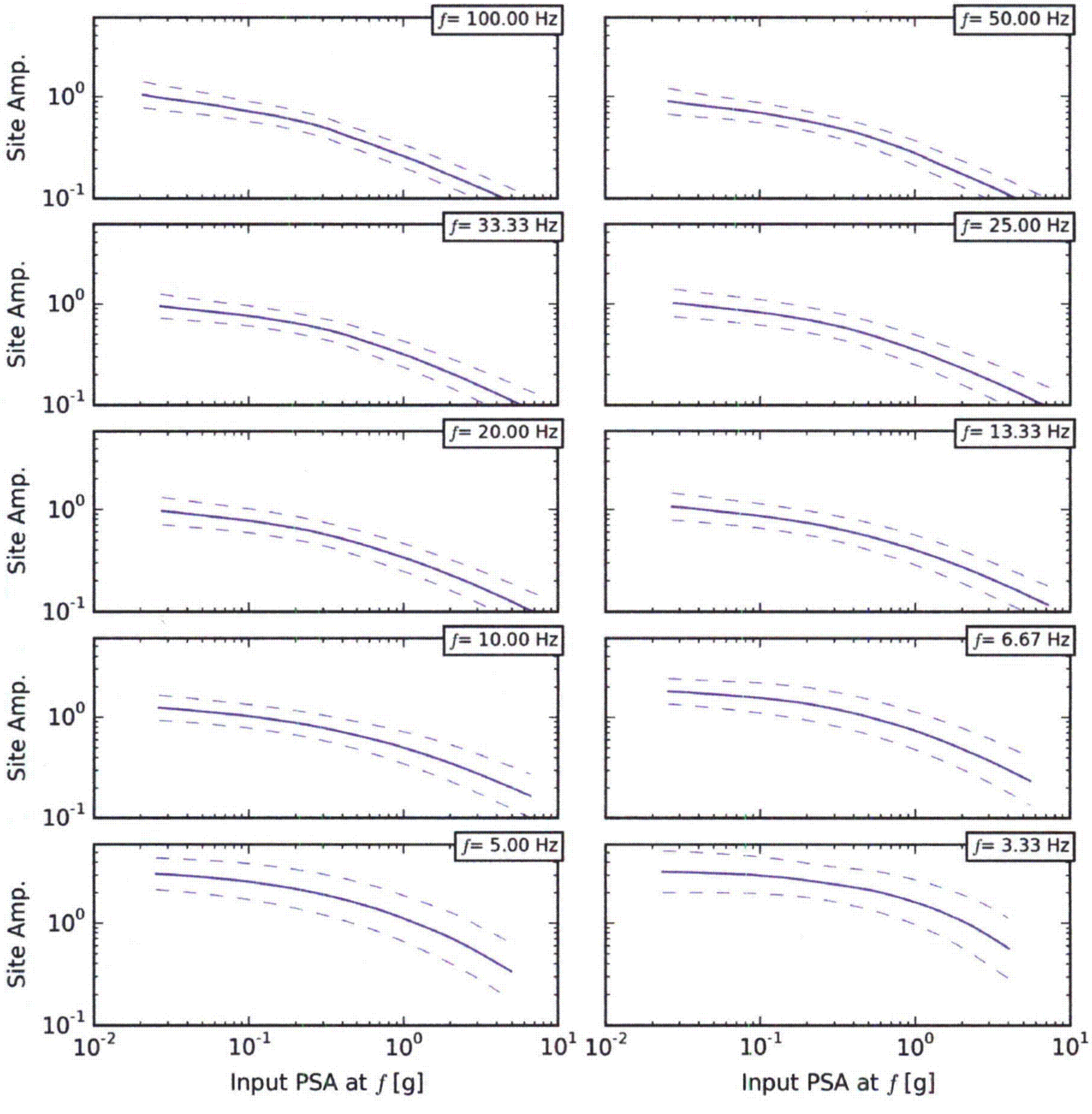


Figure 2.3.6-10: Logarithmic with ±1·σ_{ln} Variation of the C1-EPRI Site Amplification at Frequencies from 100.00 to 3.33 Hz

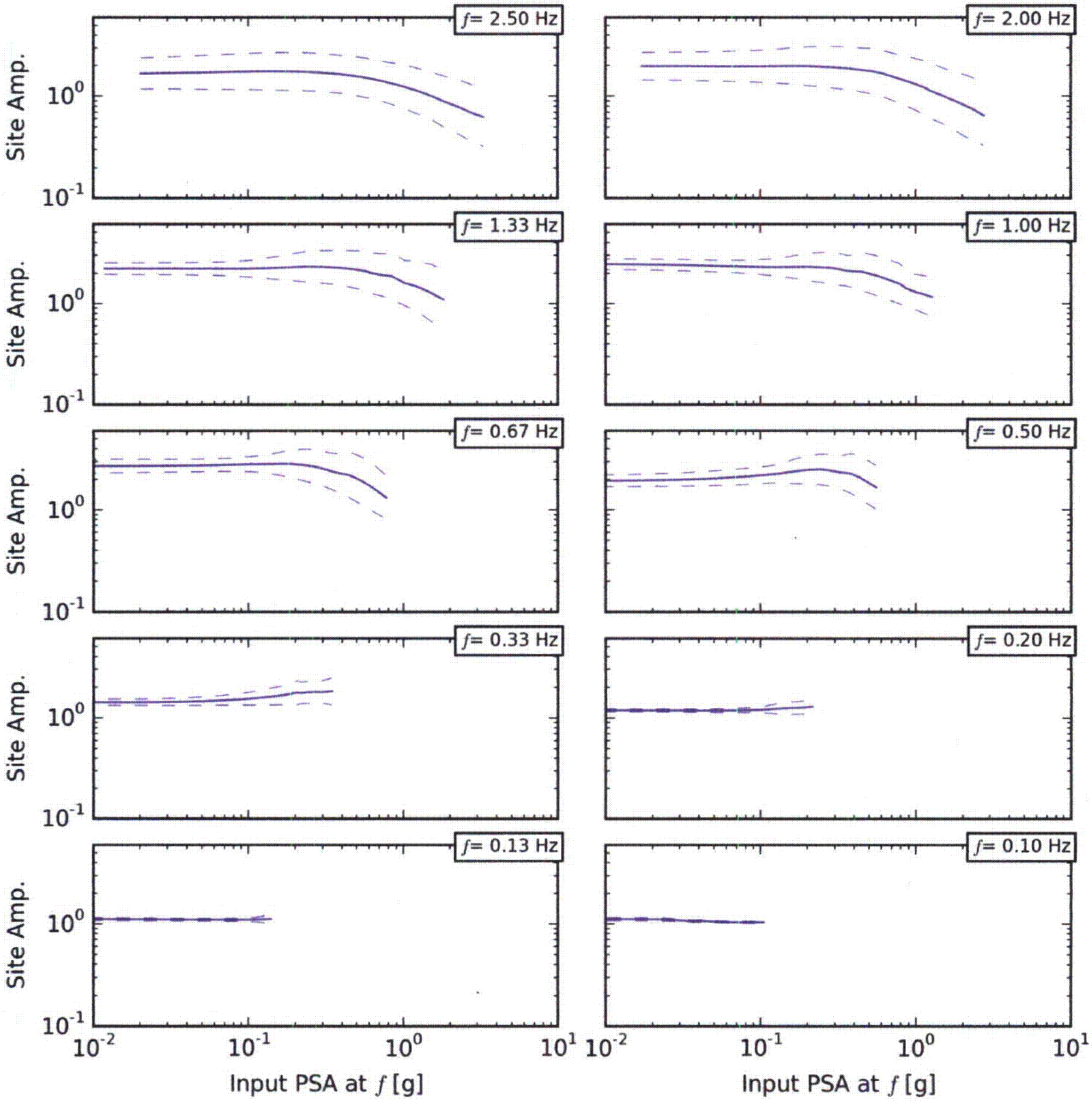


Figure 2.3.6-11: Logarithmic with ±1·σ_{ln} Variation of the C1-EPRI Site Amplification at Frequencies from 2.50 to 0.10 Hz

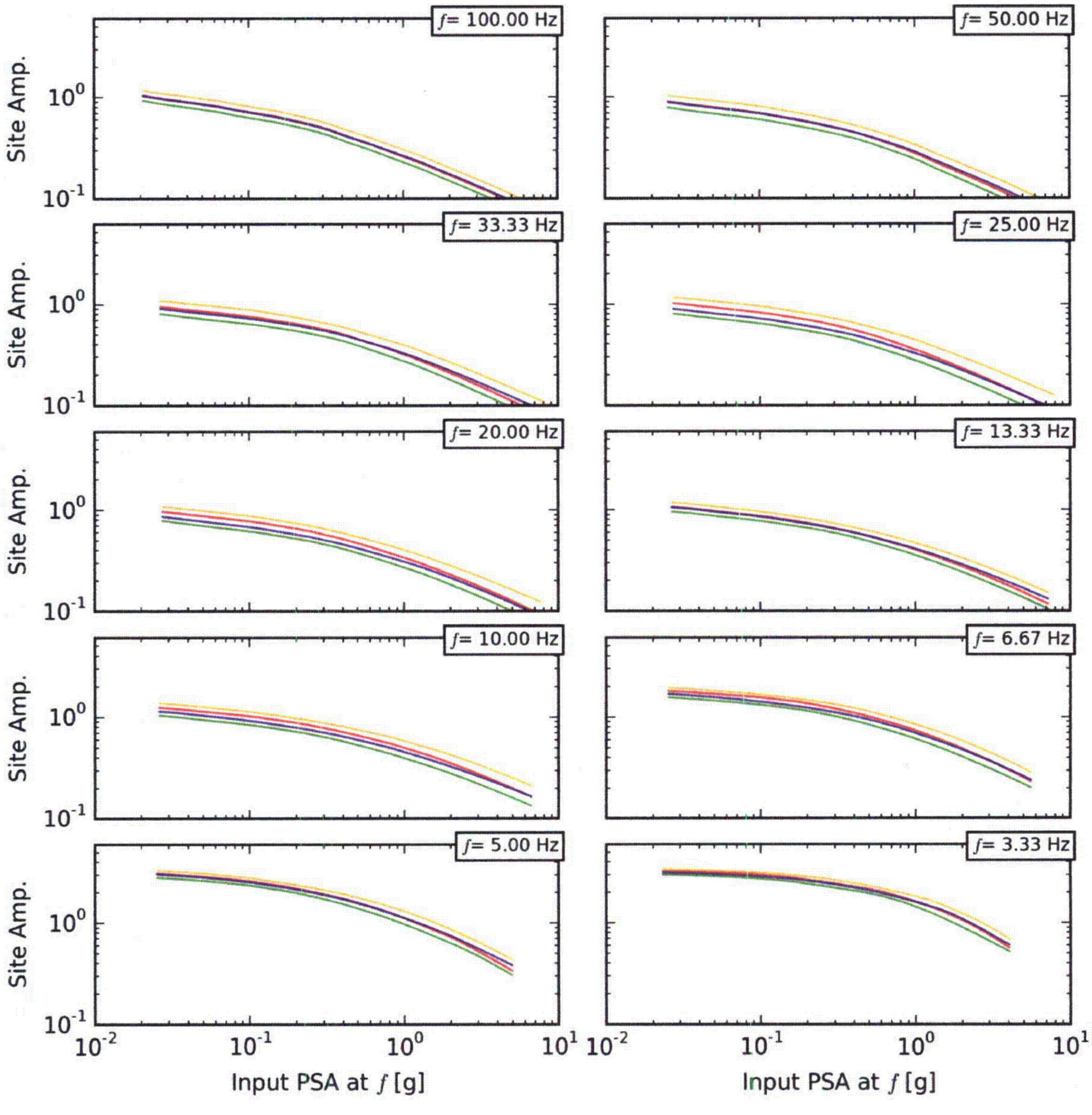


Figure 2.3.6-12: The Logarithmic Mean from the C1-EPRI (red line), C1-PEN (orange line), C2-EPRI (green line), and C2-PEN (blue line) Profiles at Frequencies from 100.00 to 3.33 Hz

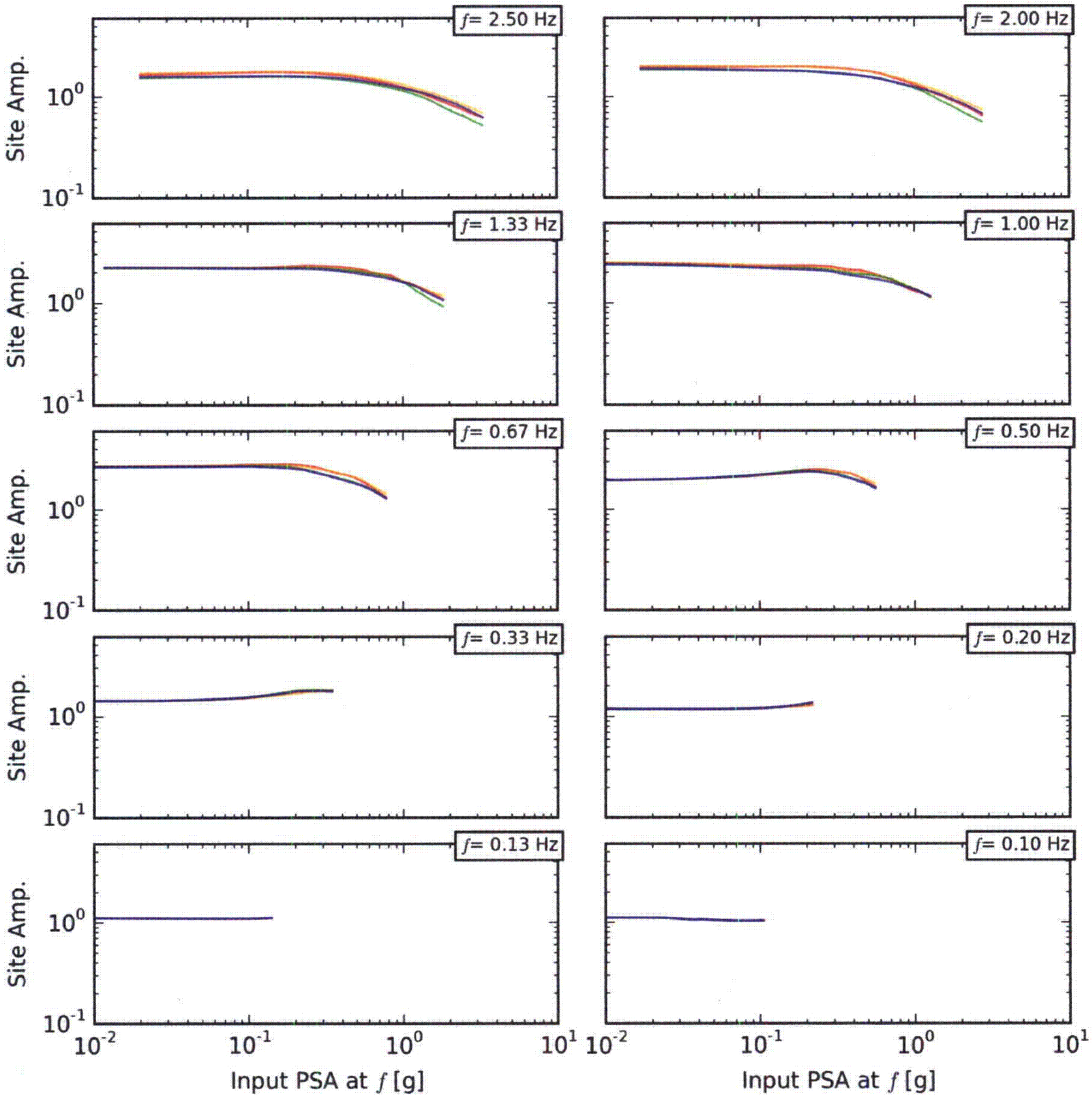


Figure 2.3.6-13: The Logarithmic Mean from the C1-EPRI (red line), C1-PEN (orange line), C2-EPRI (green line), and C2-PEN (blue line) Profiles at Frequencies from 2.50 to 0.10 Hz

2.3.7 Control Point Seismic Hazard Curves

The procedure to develop probabilistic site-specific control point hazard curves used in the present analysis follows the methodology described in McGuire et al. (2001) and Bazzurro and Cornell (2004). This procedure (referred to as "Approach 3") computes a site-specific control point hazard curve for a broad range of spectral accelerations, given the site-specific baserock hazard curve (Section 2.2.2), and site-specific estimates of soil or soft-rock response (i.e., median amplification factors) and associated uncertainties (i.e., sigma in natural log units), presented in the previous section.

The input base rock hazard curves are provided for a suite of 20 spectral frequencies which span the frequency range of 100 – 0.1 Hz. Site response results are provided for the two base case soil profiles and two sets of soil damping ratio and shear modulus reduction curves, described earlier in this report. Given these input baserock hazard curves and the resulting site response analyses, control point hazard curves are developed using Approach 3 at each of the 20 spectral frequencies for the mean and five fractile levels (i.e., 5^{th}, 16^{th}, 50^{th}, 84^{th}, and 95^{th} percentiles), based on the individual combinations of the two soil profiles and two soil curves. Given the assigned weights of 0.67 for Profile C1 and 0.33 for Profile C2 and equal weights for the two sets of soil curves, a weighted average control point hazard curve is computed.

The mean and fractile level control point hazard curves for seven selected spectral frequencies of 100 Hz (PGA), 25 Hz, 10 Hz, 5 Hz, 2.5 Hz, 1 Hz, and 0.5 Hz for the CGS site are shown in Figures 2.3.7-1 through 2.3.7-7. Tabulated values of these control point hazard curves are provided in Tables 2.3.7-1 through 2.3.7-7.

Table 2.3.7-1: The 5% Damped SA at 100 Hz (PGA) Control Point Hazard Curves for the CGS Site

PGA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.000100	9.362E-02	6.169E-02	7.082E-02	8.713E-02	1.122E-01	1.515E-01
0.000113	9.310E-02	6.132E-02	7.039E-02	8.670E-02	1.117E-01	1.503E-01
0.000128	9.245E-02	6.085E-02	6.986E-02	8.614E-02	1.110E-01	1.488E-01
0.000145	9.169E-02	6.031E-02	6.924E-02	8.550E-02	1.101E-01	1.470E-01
0.000164	9.087E-02	5.973E-02	6.857E-02	8.481E-02	1.093E-01	1.451E-01
0.000185	9.002E-02	5.912E-02	6.788E-02	8.409E-02	1.083E-01	1.432E-01
0.000210	8.916E-02	5.851E-02	6.717E-02	8.336E-02	1.074E-01	1.412E-01
0.000237	8.830E-02	5.789E-02	6.646E-02	8.263E-02	1.064E-01	1.392E-01
0.000268	8.744E-02	5.727E-02	6.576E-02	8.190E-02	1.055E-01	1.373E-01
0.000303	8.657E-02	5.665E-02	6.505E-02	8.117E-02	1.046E-01	1.353E-01
0.000343	8.569E-02	5.600E-02	6.432E-02	8.041E-02	1.036E-01	1.334E-01
0.000388	8.475E-02	5.528E-02	6.352E-02	7.962E-02	1.026E-01	1.314E-01
0.000439	8.372E-02	5.444E-02	6.263E-02	7.875E-02	1.016E-01	1.294E-01
0.000497	8.255E-02	5.341E-02	6.157E-02	7.774E-02	1.004E-01	1.272E-01
0.000562	8.117E-02	5.214E-02	6.029E-02	7.658E-02	9.901E-02	1.249E-01
0.000636	7.958E-02	5.061E-02	5.878E-02	7.520E-02	9.750E-02	1.224E-01
0.000719	7.777E-02	4.884E-02	5.702E-02	7.362E-02	9.580E-02	1.198E-01
0.000813	7.575E-02	4.684E-02	5.504E-02	7.180E-02	9.393E-02	1.171E-01
0.000920	7.355E-02	4.466E-02	5.286E-02	6.975E-02	9.192E-02	1.143E-01
0.001041	7.116E-02	4.233E-02	5.047E-02	6.743E-02	8.974E-02	1.114E-01
0.001177	6.860E-02	3.987E-02	4.789E-02	6.483E-02	8.743E-02	1.085E-01
0.001332	6.589E-02	3.732E-02	4.517E-02	6.199E-02	8.499E-02	1.056E-01
0.001507	6.308E-02	3.473E-02	4.236E-02	5.896E-02	8.246E-02	1.028E-01
0.001704	6.023E-02	3.217E-02	3.954E-02	5.585E-02	7.987E-02	9.996E-02
0.001928	5.739E-02	2.970E-02	3.678E-02	5.273E-02	7.726E-02	9.714E-02
0.002181	5.459E-02	2.734E-02	3.412E-02	4.967E-02	7.465E-02	9.436E-02
0.002467	5.183E-02	2.510E-02	3.156E-02	4.665E-02	7.200E-02	9.156E-02
0.002791	4.907E-02	2.296E-02	2.908E-02	4.365E-02	6.927E-02	8.870E-02
0.003157	4.627E-02	2.089E-02	2.666E-02	4.063E-02	6.639E-02	8.574E-02
0.003571	4.341E-02	1.889E-02	2.428E-02	3.757E-02	6.336E-02	8.265E-02
0.004040	4.052E-02	1.695E-02	2.195E-02	3.449E-02	6.019E-02	7.943E-02
0.004570	3.764E-02	1.511E-02	1.970E-02	3.144E-02	5.692E-02	7.613E-02
0.005170	3.482E-02	1.339E-02	1.758E-02	2.850E-02	5.364E-02	7.281E-02
0.005848	3.212E-02	1.181E-02	1.562E-02	2.574E-02	5.044E-02	6.953E-02
0.006615	2.957E-02	1.040E-02	1.384E-02	2.318E-02	4.733E-02	6.632E-02
0.007483	2.719E-02	9.127E-03	1.224E-02	2.083E-02	4.433E-02	6.316E-02
0.008465	2.495E-02	7.995E-03	1.080E-02	1.869E-02	4.140E-02	6.001E-02
0.009576	2.282E-02	6.982E-03	9.503E-03	1.671E-02	3.850E-02	5.682E-02
0.010833	2.079E-02	6.068E-03	8.330E-03	1.488E-02	3.557E-02	5.352E-02
0.012254	1.885E-02	5.243E-03	7.261E-03	1.317E-02	3.262E-02	5.011E-02

PGA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.013862	1.699E-02	4.497E-03	6.290E-03	1.159E-02	2.965E-02	4.661E-02
0.015681	1.521E-02	3.829E-03	5.413E-03	1.013E-02	2.674E-02	4.307E-02
0.017739	1.355E-02	3.235E-03	4.627E-03	8.788E-03	2.392E-02	3.956E-02
0.020066	1.200E-02	2.712E-03	3.927E-03	7.576E-03	2.125E-02	3.613E-02
0.022699	1.055E-02	2.253E-03	3.305E-03	6.480E-03	1.873E-02	3.278E-02
0.025678	9.201E-03	1.852E-03	2.754E-03	5.490E-03	1.638E-02	2.952E-02
0.029047	7.957E-03	1.504E-03	2.268E-03	4.601E-03	1.419E-02	2.633E-02
0.032859	6.814E-03	1.205E-03	1.843E-03	3.810E-03	1.218E-02	2.324E-02
0.037170	5.780E-03	9.516E-04	1.478E-03	3.118E-03	1.035E-02	2.028E-02
0.042048	4.855E-03	7.400E-04	1.168E-03	2.520E-03	8.712E-03	1.749E-02
0.047565	4.038E-03	5.657E-04	9.090E-04	2.012E-03	7.260E-03	1.492E-02
0.053806	3.325E-03	4.238E-04	6.954E-04	1.587E-03	5.991E-03	1.259E-02
0.060867	2.712E-03	3.101E-04	5.212E-04	1.234E-03	4.896E-03	1.052E-02
0.068853	2.192E-03	2.208E-04	3.820E-04	9.473E-04	3.968E-03	8.725E-03
0.077888	1.759E-03	1.526E-04	2.733E-04	7.161E-04	3.194E-03	7.188E-03
0.088108	1.403E-03	1.022E-04	1.904E-04	5.328E-04	2.556E-03	5.888E-03
0.099670	1.109E-03	6.621E-05	1.290E-04	3.889E-04	2.029E-03	4.789E-03
0.112748	8.667E-04	4.136E-05	8.472E-05	2.774E-04	1.593E-03	3.853E-03
0.127542	6.667E-04	2.481E-05	5.365E-05	1.919E-04	1.229E-03	3.055E-03
0.144278	5.020E-04	1.421E-05	3.251E-05	1.277E-04	9.250E-04	2.373E-03
0.163210	3.680E-04	7.699E-06	1.867E-05	8.093E-05	6.736E-04	1.796E-03
0.184625	2.616E-04	3.907E-06	1.007E-05	4.843E-05	4.711E-04	1.319E-03
0.208851	1.798E-04	1.841E-06	5.064E-06	2.720E-05	3.147E-04	9.369E-04
0.236256	1.196E-04	8.003E-07	2.361E-06	1.430E-05	2.004E-04	6.430E-04
0.267257	7.693E-05	3.204E-07	1.021E-06	7.045E-06	1.215E-04	4.256E-04
0.302325	4.785E-05	1.185E-07	4.106E-07	3.262E-06	7.000E-05	2.709E-04
0.341995	2.869E-05	4.074E-08	1.545E-07	1.425E-06	3.830E-05	1.649E-04
0.386871	1.650E-05	1.312E-08	5.471E-08	5.875E-07	1.983E-05	9.554E-05
0.437634	9.059E-06	3.974E-09	1.825E-08	2.285E-07	9.677E-06	5.234E-05
0.495059	4.720E-06	1.132E-09	5.726E-09	8.356E-08	4.436E-06	2.699E-05
0.560020	2.325E-06	3.023E-10	1.683E-09	2.862E-08	1.904E-06	1.304E-05
0.633503	1.079E-06	7.523E-11	4.616E-10	9.152E-09	7.639E-07	5.897E-06
0.716629	4.717E-07	1.738E-11	1.176E-10	2.728E-09	2.859E-07	2.489E-06
0.810663	1.941E-07	3.712E-12	2.778E-11	7.569E-10	9.967E-08	9.797E-07
0.917036	7.559E-08	7.313E-13	6.078E-12	1.956E-10	3.234E-08	3.599E-07
1.037366	2.809E-08	1.330E-13	1.233E-12	4.715E-11	9.769E-09	1.238E-07
1.173485	1.011E-08	2.237E-14	2.325E-13	1.061E-11	2.752E-09	4.022E-08
1.327466	3.585E-09	3.488E-15	4.085E-14	2.236E-12	7.266E-10	1.249E-08
1.501652	1.269E-09	5.062E-16	6.709E-15	4.426E-13	1.812E-10	3.766E-09
1.698694	4.487E-10	6.861E-17	1.036E-15	8.282E-14	4.321E-11	1.122E-09
1.921589	1.562E-10	8.744E-18	1.515E-16	1.478E-14	1.000E-11	3.322E-10
2.173734	5.225E-11	1.056E-18	2.119E-17	2.544E-15	2.279E-12	9.717E-11

PGA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
2.458964	1.639E-11	1.223E-19	2.868E-18	4.274E-16	5.148E-13	2.753E-11
2.781622	4.718E-12	1.377E-20	3.796E-19	7.071E-17	1.144E-13	7.373E-12
3.146617	1.228E-12	1.527E-21	4.951E-20	1.157E-17	2.460E-14	1.824E-12
3.559503	2.857E-13	1.675E-22	6.368E-21	1.864E-18	4.998E-15	4.093E-13
4.026569	5.893E-14	1.818E-23	8.045E-22	2.915E-19	9.383E-16	8.238E-14
4.554923	1.074E-14	1.942E-24	9.907E-23	4.347E-20	1.602E-16	1.475E-14
5.152606	1.727E-15	2.020E-25	1.179E-23	6.070E-21	2.460E-17	2.339E-15
5.828714	2.453E-16	2.050E-26	1.344E-24	7.830E-22	3.384E-18	3.290E-16
6.593533	3.093E-17	1.987E-27	1.451E-25	9.260E-23	4.173E-19	4.118E-17
7.458715	3.488E-18	1.866E-28	1.482E-26	1.003E-23	4.635E-20	4.622E-18
8.437425	3.554E-19	1.736E-29	1.441E-27	1.000E-24	4.676E-21	4.690E-19
9.544557	3.309E-20	1.517E-30	1.308E-28	9.210E-26	4.327E-22	4.355E-20
10.796952	2.855E-21	1.825E-31	1.330E-29	8.312E-27	3.749E-23	3.754E-21
12.213694	2.302E-22	0.000E+00	3.660E-31	5.048E-28	2.860E-24	2.998E-22
13.816336	1.768E-23	0.000E+00	2.791E-32	3.847E-29	2.185E-25	2.298E-23
15.629272	1.286E-24	0.000E+00	1.998E-33	2.750E-30	1.571E-26	1.664E-24
17.680094	8.285E-26	0.000E+00	1.220E-34	1.672E-31	9.715E-28	1.052E-25
20.000000	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Table 2.3.7-2: The 5% damped SA at 25 Hz Control Point Hazard Curves for the CGS Site

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.000100	9.330E-02	6.144E-02	7.058E-02	8.690E-02	1.119E-01	1.508E-01
0.000113	9.282E-02	6.103E-02	7.019E-02	8.650E-02	1.115E-01	1.496E-01
0.000128	9.224E-02	6.054E-02	6.972E-02	8.604E-02	1.109E-01	1.482E-01
0.000145	9.160E-02	6.000E-02	6.920E-02	8.552E-02	1.102E-01	1.467E-01
0.000164	9.091E-02	5.941E-02	6.863E-02	8.497E-02	1.095E-01	1.450E-01
0.000185	9.019E-02	5.882E-02	6.806E-02	8.439E-02	1.087E-01	1.433E-01
0.000210	8.947E-02	5.820E-02	6.747E-02	8.381E-02	1.080E-01	1.415E-01
0.000237	8.874E-02	5.759E-02	6.687E-02	8.322E-02	1.072E-01	1.398E-01
0.000268	8.801E-02	5.697E-02	6.628E-02	8.262E-02	1.064E-01	1.381E-01
0.000303	8.726E-02	5.633E-02	6.565E-02	8.201E-02	1.057E-01	1.364E-01
0.000343	8.647E-02	5.565E-02	6.498E-02	8.137E-02	1.049E-01	1.346E-01
0.000388	8.562E-02	5.489E-02	6.423E-02	8.066E-02	1.040E-01	1.328E-01
0.000439	8.466E-02	5.401E-02	6.333E-02	7.986E-02	1.030E-01	1.309E-01
0.000497	8.355E-02	5.297E-02	6.227E-02	7.892E-02	1.020E-01	1.290E-01
0.000562	8.227E-02	5.174E-02	6.100E-02	7.784E-02	1.008E-01	1.269E-01
0.000636	8.082E-02	5.031E-02	5.951E-02	7.658E-02	9.947E-02	1.247E-01
0.000719	7.919E-02	4.867E-02	5.781E-02	7.515E-02	9.798E-02	1.223E-01
0.000813	7.739E-02	4.684E-02	5.589E-02	7.352E-02	9.636E-02	1.198E-01
0.000920	7.540E-02	4.481E-02	5.377E-02	7.169E-02	9.458E-02	1.173E-01
0.001041	7.324E-02	4.259E-02	5.146E-02	6.966E-02	9.265E-02	1.146E-01
0.001177	7.093E-02	4.021E-02	4.898E-02	6.745E-02	9.059E-02	1.118E-01
0.001332	6.850E-02	3.774E-02	4.639E-02	6.509E-02	8.841E-02	1.090E-01
0.001507	6.599E-02	3.522E-02	4.374E-02	6.262E-02	8.616E-02	1.061E-01
0.001704	6.344E-02	3.272E-02	4.109E-02	6.009E-02	8.385E-02	1.032E-01
0.001928	6.088E-02	3.028E-02	3.849E-02	5.752E-02	8.149E-02	1.003E-01
0.002181	5.831E-02	2.794E-02	3.594E-02	5.492E-02	7.907E-02	9.735E-02
0.002467	5.569E-02	2.568E-02	3.345E-02	5.225E-02	7.657E-02	9.434E-02
0.002791	5.302E-02	2.351E-02	3.099E-02	4.948E-02	7.395E-02	9.121E-02
0.003157	5.027E-02	2.141E-02	2.856E-02	4.660E-02	7.118E-02	8.795E-02
0.003571	4.745E-02	1.938E-02	2.617E-02	4.361E-02	6.827E-02	8.455E-02
0.004040	4.459E-02	1.745E-02	2.383E-02	4.055E-02	6.525E-02	8.105E-02
0.004570	4.174E-02	1.562E-02	2.159E-02	3.751E-02	6.217E-02	7.750E-02
0.005170	3.894E-02	1.392E-02	1.947E-02	3.454E-02	5.908E-02	7.395E-02
0.005848	3.625E-02	1.237E-02	1.749E-02	3.170E-02	5.604E-02	7.045E-02
0.006615	3.367E-02	1.096E-02	1.568E-02	2.900E-02	5.304E-02	6.699E-02
0.007483	3.120E-02	9.681E-03	1.401E-02	2.647E-02	5.009E-02	6.356E-02
0.008465	2.884E-02	8.533E-03	1.248E-02	2.409E-02	4.714E-02	6.011E-02
0.009576	2.656E-02	7.494E-03	1.108E-02	2.183E-02	4.416E-02	5.662E-02
0.010833	2.435E-02	6.552E-03	9.785E-03	1.969E-02	4.114E-02	5.304E-02
0.012254	2.221E-02	5.700E-03	8.595E-03	1.767E-02	3.810E-02	4.942E-02

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.013862	2.016E-02	4.934E-03	7.507E-03	1.577E-02	3.507E-02	4.579E-02
0.015681	1.822E-02	4.249E-03	6.521E-03	1.400E-02	3.212E-02	4.221E-02
0.017739	1.640E-02	3.643E-03	5.637E-03	1.237E-02	2.927E-02	3.875E-02
0.020066	1.471E-02	3.110E-03	4.853E-03	1.089E-02	2.657E-02	3.544E-02
0.022699	1.314E-02	2.644E-03	4.160E-03	9.552E-03	2.402E-02	3.229E-02
0.025678	1.169E-02	2.234E-03	3.548E-03	8.337E-03	2.159E-02	2.927E-02
0.029047	1.034E-02	1.875E-03	3.006E-03	7.232E-03	1.928E-02	2.637E-02
0.032859	9.083E-03	1.559E-03	2.528E-03	6.230E-03	1.709E-02	2.360E-02
0.037170	7.918E-03	1.283E-03	2.107E-03	5.325E-03	1.503E-02	2.094E-02
0.042048	6.852E-03	1.043E-03	1.740E-03	4.517E-03	1.310E-02	1.845E-02
0.047565	5.887E-03	8.373E-04	1.424E-03	3.803E-03	1.134E-02	1.613E-02
0.053806	5.025E-03	6.640E-04	1.154E-03	3.181E-03	9.748E-03	1.401E-02
0.060867	4.263E-03	5.193E-04	9.257E-04	2.642E-03	8.331E-03	1.210E-02
0.068853	3.595E-03	4.002E-04	7.344E-04	2.180E-03	7.081E-03	1.040E-02
0.077888	3.013E-03	3.033E-04	5.752E-04	1.785E-03	5.986E-03	8.878E-03
0.088108	2.509E-03	2.256E-04	4.438E-04	1.447E-03	5.031E-03	7.541E-03
0.099670	2.074E-03	1.644E-04	3.367E-04	1.162E-03	4.202E-03	6.365E-03
0.112748	1.702E-03	1.171E-04	2.507E-04	9.221E-04	3.483E-03	5.335E-03
0.127542	1.384E-03	8.143E-05	1.828E-04	7.214E-04	2.863E-03	4.436E-03
0.144278	1.114E-03	5.515E-05	1.303E-04	5.549E-04	2.329E-03	3.654E-03
0.163210	8.860E-04	3.632E-05	9.053E-05	4.185E-04	1.870E-03	2.975E-03
0.184625	6.940E-04	2.322E-05	6.115E-05	3.083E-04	1.479E-03	2.389E-03
0.208851	5.343E-04	1.436E-05	4.002E-05	2.210E-04	1.150E-03	1.888E-03
0.236256	4.034E-04	8.579E-06	2.533E-05	1.539E-04	8.752E-04	1.464E-03
0.267257	2.980E-04	4.939E-06	1.547E-05	1.038E-04	6.515E-04	1.112E-03
0.302325	2.152E-04	2.733E-06	9.094E-06	6.777E-05	4.732E-04	8.250E-04
0.341995	1.516E-04	1.453E-06	5.148E-06	4.275E-05	3.347E-04	5.973E-04
0.386871	1.041E-04	7.415E-07	2.805E-06	2.608E-05	2.302E-04	4.212E-04
0.437634	6.954E-05	3.636E-07	1.472E-06	1.538E-05	1.538E-04	2.889E-04
0.495059	4.521E-05	1.714E-07	7.441E-07	8.765E-06	9.961E-05	1.926E-04
0.560020	2.857E-05	7.778E-08	3.631E-07	4.829E-06	6.254E-05	1.246E-04
0.633503	1.753E-05	3.401E-08	1.709E-07	2.570E-06	3.800E-05	7.823E-05
0.716629	1.045E-05	1.433E-08	7.756E-08	1.320E-06	2.235E-05	4.765E-05
0.810663	6.056E-06	5.816E-09	3.392E-08	6.537E-07	1.272E-05	2.818E-05
0.917036	3.416E-06	2.271E-09	1.428E-08	3.122E-07	7.022E-06	1.621E-05
1.037366	1.879E-06	8.519E-10	5.778E-09	1.439E-07	3.761E-06	9.076E-06
1.173485	1.011E-06	3.065E-10	2.246E-09	6.406E-08	1.961E-06	4.963E-06
1.327466	5.337E-07	1.057E-10	8.396E-10	2.764E-08	9.974E-07	2.658E-06
1.501652	2.776E-07	3.499E-11	3.025E-10	1.160E-08	4.968E-07	1.399E-06
1.698694	1.427E-07	1.113E-11	1.054E-10	4.751E-09	2.430E-07	7.251E-07
1.921589	7.284E-08	3.422E-12	3.575E-11	1.909E-09	1.171E-07	3.717E-07
2.173734	3.700E-08	1.022E-12	1.184E-11	7.543E-10	5.579E-08	1.889E-07

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
2.458964	1.878E-08	2.981E-13	3.856E-12	2.940E-10	2.635E-08	9.556E-08
2.781622	9.537E-09	8.557E-14	1.239E-12	1.133E-10	1.238E-08	4.822E-08
3.146617	4.855E-09	2.425E-14	3.932E-13	4.336E-11	5.796E-09	2.429E-08
3.559503	2.474E-09	6.804E-15	1.237E-13	1.651E-11	2.713E-09	1.222E-08
4.026569	1.260E-09	1.891E-15	3.862E-14	6.280E-12	1.270E-09	6.133E-09
4.554923	6.382E-10	5.214E-16	1.202E-14	2.398E-12	5.929E-10	3.060E-09
5.152606	3.202E-10	1.429E-16	3.743E-15	9.218E-13	2.758E-10	1.512E-09
5.828714	1.583E-10	3.897E-17	1.172E-15	3.568E-13	1.272E-10	7.366E-10
6.593533	7.671E-11	1.061E-17	3.709E-16	1.392E-13	5.793E-11	3.520E-10
7.458715	3.627E-11	2.891E-18	1.188E-16	5.445E-14	2.590E-11	1.642E-10
8.437425	1.666E-11	7.895E-19	3.862E-17	2.128E-14	1.133E-11	7.455E-11
9.544557	7.411E-12	2.164E-19	1.270E-17	8.250E-15	4.818E-12	3.278E-11
10.796952	3.180E-12	5.961E-20	4.205E-18	3.155E-15	1.989E-12	1.392E-11
12.213694	1.313E-12	1.649E-20	1.393E-18	1.183E-15	7.936E-13	5.698E-12
13.816336	5.210E-13	4.586E-21	4.585E-19	4.326E-16	3.052E-13	2.241E-12
15.629272	1.981E-13	1.280E-21	1.489E-19	1.537E-16	1.130E-13	8.456E-13
17.680094	7.213E-14	3.578E-22	4.748E-20	5.281E-17	4.017E-14	3.059E-13
20.000000	2.514E-14	9.991E-23	1.477E-20	1.752E-17	1.370E-14	1.059E-13

Table 2.3.7-3: The 5% Damped SA at 10 Hz Control Point Hazard Curves for the CGS Site

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.000100	9.413E-02	6.189E-02	7.105E-02	8.743E-02	1.128E-01	1.525E-01
0.000113	9.383E-02	6.172E-02	7.086E-02	8.718E-02	1.124E-01	1.517E-01
0.000128	9.340E-02	6.148E-02	7.058E-02	8.684E-02	1.118E-01	1.505E-01
0.000145	9.286E-02	6.117E-02	7.023E-02	8.641E-02	1.111E-01	1.490E-01
0.000164	9.222E-02	6.081E-02	6.982E-02	8.590E-02	1.103E-01	1.473E-01
0.000185	9.154E-02	6.042E-02	6.937E-02	8.534E-02	1.094E-01	1.454E-01
0.000210	9.082E-02	6.001E-02	6.890E-02	8.477E-02	1.085E-01	1.434E-01
0.000237	9.009E-02	5.959E-02	6.842E-02	8.418E-02	1.075E-01	1.414E-01
0.000268	8.936E-02	5.918E-02	6.794E-02	8.359E-02	1.066E-01	1.395E-01
0.000303	8.862E-02	5.876E-02	6.746E-02	8.300E-02	1.057E-01	1.375E-01
0.000343	8.789E-02	5.834E-02	6.698E-02	8.241E-02	1.047E-01	1.356E-01
0.000388	8.715E-02	5.790E-02	6.649E-02	8.180E-02	1.038E-01	1.337E-01
0.000439	8.637E-02	5.742E-02	6.596E-02	8.117E-02	1.028E-01	1.316E-01
0.000497	8.551E-02	5.687E-02	6.535E-02	8.047E-02	1.018E-01	1.296E-01
0.000562	8.453E-02	5.619E-02	6.463E-02	7.965E-02	1.008E-01	1.274E-01
0.000636	8.338E-02	5.534E-02	6.375E-02	7.868E-02	9.957E-02	1.249E-01
0.000719	8.203E-02	5.429E-02	6.268E-02	7.754E-02	9.828E-02	1.221E-01
0.000813	8.047E-02	5.304E-02	6.142E-02	7.621E-02	9.682E-02	1.192E-01
0.000920	7.872E-02	5.160E-02	5.996E-02	7.469E-02	9.519E-02	1.160E-01
0.001041	7.673E-02	4.994E-02	5.828E-02	7.294E-02	9.333E-02	1.127E-01
0.001177	7.451E-02	4.804E-02	5.635E-02	7.095E-02	9.119E-02	1.093E-01
0.001332	7.202E-02	4.591E-02	5.416E-02	6.869E-02	8.874E-02	1.057E-01
0.001507	6.931E-02	4.358E-02	5.174E-02	6.618E-02	8.599E-02	1.020E-01
0.001704	6.642E-02	4.110E-02	4.916E-02	6.350E-02	8.300E-02	9.827E-02
0.001928	6.346E-02	3.858E-02	4.650E-02	6.072E-02	7.989E-02	9.455E-02
0.002181	6.049E-02	3.608E-02	4.385E-02	5.793E-02	7.673E-02	9.088E-02
0.002467	5.760E-02	3.368E-02	4.129E-02	5.519E-02	7.362E-02	8.730E-02
0.002791	5.480E-02	3.141E-02	3.884E-02	5.255E-02	7.059E-02	8.384E-02
0.003157	5.213E-02	2.927E-02	3.651E-02	5.003E-02	6.766E-02	8.050E-02
0.003571	4.957E-02	2.727E-02	3.432E-02	4.760E-02	6.484E-02	7.728E-02
0.004040	4.711E-02	2.539E-02	3.224E-02	4.527E-02	6.209E-02	7.414E-02
0.004570	4.471E-02	2.360E-02	3.024E-02	4.299E-02	5.939E-02	7.104E-02
0.005170	4.234E-02	2.187E-02	2.828E-02	4.072E-02	5.666E-02	6.791E-02
0.005848	3.994E-02	2.018E-02	2.634E-02	3.842E-02	5.384E-02	6.467E-02
0.006615	3.748E-02	1.851E-02	2.439E-02	3.606E-02	5.090E-02	6.130E-02
0.007483	3.498E-02	1.686E-02	2.245E-02	3.364E-02	4.784E-02	5.779E-02
0.008465	3.245E-02	1.525E-02	2.051E-02	3.119E-02	4.471E-02	5.419E-02
0.009576	2.996E-02	1.370E-02	1.863E-02	2.876E-02	4.156E-02	5.057E-02
0.010833	2.752E-02	1.225E-02	1.684E-02	2.637E-02	3.846E-02	4.700E-02
0.012254	2.518E-02	1.091E-02	1.513E-02	2.405E-02	3.543E-02	4.352E-02

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.013862	2.294E-02	9.670E-03	1.354E-02	2.183E-02	3.251E-02	4.017E-02
0.015681	2.082E-02	8.546E-03	1.206E-02	1.970E-02	2.972E-02	3.695E-02
0.017739	1.882E-02	7.528E-03	1.069E-02	1.770E-02	2.707E-02	3.389E-02
0.020066	1.696E-02	6.608E-03	9.438E-03	1.584E-02	2.456E-02	3.098E-02
0.022699	1.522E-02	5.778E-03	8.304E-03	1.411E-02	2.220E-02	2.823E-02
0.025678	1.361E-02	5.028E-03	7.273E-03	1.253E-02	1.998E-02	2.561E-02
0.029047	1.210E-02	4.348E-03	6.339E-03	1.107E-02	1.788E-02	2.312E-02
0.032859	1.069E-02	3.732E-03	5.490E-03	9.727E-03	1.590E-02	2.074E-02
0.037170	9.392E-03	3.176E-03	4.722E-03	8.495E-03	1.405E-02	1.849E-02
0.042048	8.196E-03	2.680E-03	4.032E-03	7.372E-03	1.233E-02	1.638E-02
0.047565	7.105E-03	2.243E-03	3.418E-03	6.358E-03	1.076E-02	1.443E-02
0.053806	6.125E-03	1.862E-03	2.877E-03	5.450E-03	9.334E-03	1.264E-02
0.060867	5.252E-03	1.535E-03	2.404E-03	4.646E-03	8.064E-03	1.101E-02
0.068853	4.482E-03	1.256E-03	1.997E-03	3.938E-03	6.939E-03	9.555E-03
0.077888	3.806E-03	1.021E-03	1.646E-03	3.321E-03	5.948E-03	8.249E-03
0.088108	3.215E-03	8.217E-04	1.347E-03	2.783E-03	5.077E-03	7.087E-03
0.099670	2.701E-03	6.544E-04	1.093E-03	2.318E-03	4.311E-03	6.058E-03
0.112748	2.255E-03	5.143E-04	8.779E-04	1.916E-03	3.639E-03	5.150E-03
0.127542	1.869E-03	3.982E-04	6.974E-04	1.571E-03	3.051E-03	4.351E-03
0.144278	1.538E-03	3.033E-04	5.471E-04	1.277E-03	2.539E-03	3.652E-03
0.163210	1.255E-03	2.268E-04	4.232E-04	1.027E-03	2.095E-03	3.041E-03
0.184625	1.012E-03	1.661E-04	3.219E-04	8.161E-04	1.711E-03	2.508E-03
0.208851	8.068E-04	1.190E-04	2.401E-04	6.390E-04	1.381E-03	2.046E-03
0.236256	6.339E-04	8.298E-05	1.751E-04	4.918E-04	1.099E-03	1.647E-03
0.267257	4.900E-04	5.634E-05	1.247E-04	3.713E-04	8.607E-04	1.307E-03
0.302325	3.721E-04	3.714E-05	8.641E-05	2.743E-04	6.625E-04	1.022E-03
0.341995	2.774E-04	2.377E-05	5.830E-05	1.982E-04	5.004E-04	7.850E-04
0.386871	2.027E-04	1.476E-05	3.825E-05	1.398E-04	3.704E-04	5.920E-04
0.437634	1.451E-04	8.904E-06	2.441E-05	9.622E-05	2.683E-04	4.378E-04
0.495059	1.017E-04	5.221E-06	1.515E-05	6.454E-05	1.899E-04	3.169E-04
0.560020	6.969E-05	2.977E-06	9.150E-06	4.219E-05	1.313E-04	2.244E-04
0.633503	4.668E-05	1.651E-06	5.373E-06	2.685E-05	8.852E-05	1.552E-04
0.716629	3.055E-05	8.900E-07	3.067E-06	1.663E-05	5.820E-05	1.048E-04
0.810663	1.953E-05	4.664E-07	1.703E-06	1.002E-05	3.729E-05	6.906E-05
0.917036	1.220E-05	2.374E-07	9.187E-07	5.876E-06	2.330E-05	4.444E-05
1.037366	7.450E-06	1.174E-07	4.818E-07	3.353E-06	1.419E-05	2.792E-05
1.173485	4.449E-06	5.635E-08	2.459E-07	1.865E-06	8.440E-06	1.714E-05
1.327466	2.602E-06	2.632E-08	1.222E-07	1.011E-06	4.901E-06	1.029E-05
1.501652	1.492E-06	1.196E-08	5.922E-08	5.354E-07	2.782E-06	6.045E-06
1.698694	8.394E-07	5.301E-09	2.800E-08	2.769E-07	1.545E-06	3.478E-06
1.921589	4.643E-07	2.294E-09	1.293E-08	1.401E-07	8.404E-07	1.963E-06
2.173734	2.529E-07	9.703E-10	5.842E-09	6.933E-08	4.484E-07	1.089E-06

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
2.458964	1.359E-07	4.011E-10	2.580E-09	3.362E-08	2.350E-07	5.951E-07
2.781622	7.225E-08	1.622E-10	1.115E-09	1.599E-08	1.213E-07	3.211E-07
3.146617	3.813E-08	6.412E-11	4.722E-10	7.472E-09	6.181E-08	1.716E-07
3.559503	2.003E-08	2.482E-11	1.959E-10	3.437E-09	3.117E-08	9.102E-08
4.026569	1.050E-08	9.407E-12	7.978E-11	1.560E-09	1.561E-08	4.806E-08
4.554923	5.498E-09	3.494E-12	3.195E-11	7.008E-10	7.783E-09	2.529E-08
5.152606	2.876E-09	1.274E-12	1.261E-11	3.125E-10	3.867E-09	1.326E-08
5.828714	1.501E-09	4.568E-13	4.919E-12	1.387E-10	1.915E-09	6.920E-09
6.593533	7.789E-10	1.613E-13	1.902E-12	6.130E-11	9.442E-10	3.584E-09
7.458715	4.005E-10	5.629E-14	7.309E-13	2.703E-11	4.623E-10	1.836E-09
8.437425	2.031E-10	1.945E-14	2.798E-13	1.187E-11	2.240E-10	9.269E-10
9.544557	1.012E-10	6.676E-15	1.069E-13	5.179E-12	1.070E-10	4.591E-10
10.796952	4.931E-11	2.281E-15	4.077E-14	2.239E-12	5.015E-11	2.224E-10
12.213694	2.341E-11	7.764E-16	1.548E-14	9.548E-13	2.299E-11	1.050E-10
13.816336	1.080E-11	2.632E-16	5.843E-15	4.002E-13	1.027E-11	4.811E-11
15.629272	4.823E-12	8.881E-17	2.183E-15	1.641E-13	4.461E-12	2.137E-11
17.680094	2.082E-12	2.975E-17	8.042E-16	6.567E-14	1.876E-12	9.172E-12
20.000000	8.661E-13	9.865E-18	2.911E-16	2.556E-14	7.626E-13	3.797E-12

Table 2.3.7-4: The 5% Damped SA at 5 Hz Control Point Hazard Curves for the CGS Site

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.000100	9.491E-02	6.188E-02	7.104E-02	8.741E-02	1.128E-01	1.527E-01
0.000113	9.491E-02	6.188E-02	7.104E-02	8.741E-02	1.128E-01	1.527E-01
0.000128	9.490E-02	6.188E-02	7.104E-02	8.740E-02	1.128E-01	1.527E-01
0.000145	9.489E-02	6.187E-02	7.103E-02	8.740E-02	1.128E-01	1.527E-01
0.000164	9.488E-02	6.186E-02	7.102E-02	8.739E-02	1.128E-01	1.526E-01
0.000185	9.484E-02	6.185E-02	7.100E-02	8.736E-02	1.127E-01	1.525E-01
0.000210	9.477E-02	6.182E-02	7.097E-02	8.732E-02	1.126E-01	1.524E-01
0.000237	9.465E-02	6.177E-02	7.092E-02	8.725E-02	1.125E-01	1.520E-01
0.000268	9.449E-02	6.170E-02	7.083E-02	8.715E-02	1.123E-01	1.516E-01
0.000303	9.424E-02	6.159E-02	7.071E-02	8.700E-02	1.120E-01	1.510E-01
0.000343	9.394E-02	6.146E-02	7.056E-02	8.681E-02	1.117E-01	1.502E-01
0.000388	9.357E-02	6.130E-02	7.038E-02	8.659E-02	1.112E-01	1.492E-01
0.000439	9.317E-02	6.112E-02	7.017E-02	8.634E-02	1.107E-01	1.481E-01
0.000497	9.272E-02	6.092E-02	6.995E-02	8.606E-02	1.102E-01	1.470E-01
0.000562	9.225E-02	6.072E-02	6.971E-02	8.577E-02	1.096E-01	1.457E-01
0.000636	9.177E-02	6.050E-02	6.947E-02	8.548E-02	1.091E-01	1.444E-01
0.000719	9.128E-02	6.029E-02	6.922E-02	8.517E-02	1.085E-01	1.432E-01
0.000813	9.078E-02	6.007E-02	6.897E-02	8.485E-02	1.079E-01	1.419E-01
0.000920	9.026E-02	5.983E-02	6.869E-02	8.451E-02	1.073E-01	1.405E-01
0.001041	8.968E-02	5.956E-02	6.839E-02	8.414E-02	1.066E-01	1.391E-01
0.001177	8.904E-02	5.925E-02	6.803E-02	8.370E-02	1.059E-01	1.375E-01
0.001332	8.828E-02	5.887E-02	6.759E-02	8.316E-02	1.051E-01	1.358E-01
0.001507	8.737E-02	5.839E-02	6.705E-02	8.250E-02	1.042E-01	1.337E-01
0.001704	8.629E-02	5.778E-02	6.636E-02	8.166E-02	1.030E-01	1.313E-01
0.001928	8.498E-02	5.704E-02	6.551E-02	8.063E-02	1.017E-01	1.285E-01
0.002181	8.343E-02	5.610E-02	6.447E-02	7.938E-02	1.001E-01	1.254E-01
0.002467	8.163E-02	5.495E-02	6.319E-02	7.787E-02	9.816E-02	1.220E-01
0.002791	7.956E-02	5.355E-02	6.166E-02	7.606E-02	9.595E-02	1.183E-01
0.003157	7.721E-02	5.189E-02	5.985E-02	7.397E-02	9.341E-02	1.143E-01
0.003571	7.459E-02	4.997E-02	5.777E-02	7.158E-02	9.054E-02	1.101E-01
0.004040	7.175E-02	4.784E-02	5.547E-02	6.894E-02	8.738E-02	1.058E-01
0.004570	6.875E-02	4.553E-02	5.300E-02	6.612E-02	8.402E-02	1.014E-01
0.005170	6.568E-02	4.315E-02	5.044E-02	6.320E-02	8.054E-02	9.704E-02
0.005848	6.260E-02	4.076E-02	4.787E-02	6.025E-02	7.703E-02	9.270E-02
0.006615	5.957E-02	3.842E-02	4.534E-02	5.735E-02	7.356E-02	8.847E-02
0.007483	5.664E-02	3.615E-02	4.288E-02	5.452E-02	7.018E-02	8.438E-02
0.008465	5.380E-02	3.398E-02	4.052E-02	5.179E-02	6.690E-02	8.043E-02
0.009576	5.105E-02	3.191E-02	3.825E-02	4.915E-02	6.372E-02	7.661E-02
0.010833	4.838E-02	2.992E-02	3.604E-02	4.658E-02	6.062E-02	7.287E-02
0.012254	4.575E-02	2.798E-02	3.388E-02	4.405E-02	5.755E-02	6.919E-02

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.013862	4.312E-02	2.608E-02	3.173E-02	4.152E-02	5.448E-02	6.550E-02
0.015681	4.046E-02	2.418E-02	2.957E-02	3.897E-02	5.138E-02	6.177E-02
0.017739	3.778E-02	2.231E-02	2.740E-02	3.639E-02	4.823E-02	5.799E-02
0.020066	3.508E-02	2.044E-02	2.522E-02	3.379E-02	4.504E-02	5.418E-02
0.022699	3.238E-02	1.861E-02	2.307E-02	3.119E-02	4.185E-02	5.036E-02
0.025678	2.973E-02	1.684E-02	2.096E-02	2.865E-02	3.867E-02	4.659E-02
0.029047	2.716E-02	1.514E-02	1.894E-02	2.617E-02	3.555E-02	4.291E-02
0.032859	2.469E-02	1.353E-02	1.702E-02	2.378E-02	3.252E-02	3.934E-02
0.037170	2.235E-02	1.203E-02	1.522E-02	2.151E-02	2.959E-02	3.593E-02
0.042048	2.015E-02	1.064E-02	1.355E-02	1.937E-02	2.679E-02	3.269E-02
0.047565	1.808E-02	9.366E-03	1.200E-02	1.736E-02	2.415E-02	2.962E-02
0.053806	1.616E-02	8.202E-03	1.058E-02	1.548E-02	2.166E-02	2.674E-02
0.060867	1.437E-02	7.145E-03	9.280E-03	1.373E-02	1.934E-02	2.404E-02
0.068853	1.271E-02	6.192E-03	8.098E-03	1.211E-02	1.719E-02	2.150E-02
0.077888	1.119E-02	5.336E-03	7.027E-03	1.062E-02	1.520E-02	1.915E-02
0.088108	9.792E-03	4.571E-03	6.062E-03	9.262E-03	1.337E-02	1.696E-02
0.099670	8.522E-03	3.894E-03	5.201E-03	8.025E-03	1.171E-02	1.494E-02
0.112748	7.377E-03	3.298E-03	4.437E-03	6.916E-03	1.020E-02	1.311E-02
0.127542	6.354E-03	2.779E-03	3.766E-03	5.928E-03	8.851E-03	1.145E-02
0.144278	5.446E-03	2.329E-03	3.181E-03	5.055E-03	7.643E-03	9.944E-03
0.163210	4.644E-03	1.941E-03	2.672E-03	4.289E-03	6.567E-03	8.597E-03
0.184625	3.939E-03	1.607E-03	2.233E-03	3.618E-03	5.613E-03	7.390E-03
0.208851	3.321E-03	1.322E-03	1.853E-03	3.034E-03	4.770E-03	6.316E-03
0.236256	2.782E-03	1.078E-03	1.527E-03	2.528E-03	4.027E-03	5.364E-03
0.267257	2.314E-03	8.719E-04	1.249E-03	2.090E-03	3.376E-03	4.524E-03
0.302325	1.910E-03	6.984E-04	1.011E-03	1.714E-03	2.809E-03	3.789E-03
0.341995	1.564E-03	5.537E-04	8.107E-04	1.394E-03	2.318E-03	3.149E-03
0.386871	1.269E-03	4.338E-04	6.426E-04	1.123E-03	1.896E-03	2.597E-03
0.437634	1.020E-03	3.356E-04	5.033E-04	8.953E-04	1.536E-03	2.123E-03
0.495059	8.115E-04	2.560E-04	3.890E-04	7.058E-04	1.231E-03	1.719E-03
0.560020	6.381E-04	1.923E-04	2.964E-04	5.497E-04	9.753E-04	1.377E-03
0.633503	4.954E-04	1.422E-04	2.224E-04	4.224E-04	7.630E-04	1.091E-03
0.716629	3.794E-04	1.032E-04	1.642E-04	3.199E-04	5.888E-04	8.538E-04
0.810663	2.861E-04	7.344E-05	1.191E-04	2.384E-04	4.476E-04	6.584E-04
0.917036	2.123E-04	5.123E-05	8.471E-05	1.747E-04	3.348E-04	5.000E-04
1.037366	1.548E-04	3.497E-05	5.910E-05	1.256E-04	2.462E-04	3.734E-04
1.173485	1.108E-04	2.334E-05	4.036E-05	8.850E-05	1.776E-04	2.738E-04
1.327466	7.773E-05	1.522E-05	2.696E-05	6.110E-05	1.257E-04	1.969E-04
1.501652	5.346E-05	9.692E-06	1.760E-05	4.126E-05	8.719E-05	1.389E-04
1.698694	3.599E-05	6.025E-06	1.122E-05	2.724E-05	5.920E-05	9.582E-05
1.921589	2.371E-05	3.654E-06	6.985E-06	1.757E-05	3.932E-05	6.470E-05
2.173734	1.528E-05	2.162E-06	4.243E-06	1.107E-05	2.554E-05	4.272E-05

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
2.458964	9.625E-06	1.247E-06	2.515E-06	6.808E-06	1.621E-05	2.757E-05
2.781622	5.928E-06	7.020E-07	1.454E-06	4.087E-06	1.005E-05	1.739E-05
3.146617	3.568E-06	3.850E-07	8.195E-07	2.394E-06	6.083E-06	1.072E-05
3.559503	2.100E-06	2.059E-07	4.504E-07	1.369E-06	3.597E-06	6.451E-06
4.026569	1.208E-06	1.073E-07	2.414E-07	7.631E-07	2.077E-06	3.798E-06
4.554923	6.795E-07	5.454E-08	1.262E-07	4.152E-07	1.171E-06	2.185E-06
5.152606	3.741E-07	2.701E-08	6.429E-08	2.205E-07	6.457E-07	1.231E-06
5.828714	2.018E-07	1.304E-08	3.196E-08	1.144E-07	3.480E-07	6.786E-07
6.593533	1.067E-07	6.137E-09	1.550E-08	5.793E-08	1.836E-07	3.672E-07
7.458715	5.549E-08	2.816E-09	7.331E-09	2.867E-08	9.496E-08	1.952E-07
8.437425	2.840E-08	1.260E-09	3.387E-09	1.389E-08	4.824E-08	1.023E-07
9.544557	1.435E-08	5.498E-10	1.528E-09	6.592E-09	2.412E-08	5.289E-08
10.796952	7.188E-09	2.343E-10	6.741E-10	3.072E-09	1.190E-08	2.711E-08
12.213694	3.578E-09	9.749E-11	2.912E-10	1.408E-09	5.813E-09	1.381E-08
13.816336	1.777E-09	3.967E-11	1.233E-10	6.365E-10	2.818E-09	7.007E-09
15.629272	8.825E-10	1.580E-11	5.133E-11	2.847E-10	1.361E-09	3.551E-09
17.680094	4.394E-10	6.178E-12	2.105E-11	1.264E-10	6.562E-10	1.799E-09
20.000000	2.193E-10	2.373E-12	8.521E-12	5.581E-11	3.162E-10	9.113E-10

Table 2.3.7-5: The 5% Damped SA at 2.5 Hz Control Point Hazard Curves for the CGS Site

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.000100	9.485E-02	6.185E-02	7.100E-02	8.736E-02	1.125E-01	1.561E-01
0.000113	9.480E-02	6.182E-02	7.097E-02	8.732E-02	1.125E-01	1.559E-01
0.000128	9.471E-02	6.176E-02	7.091E-02	8.724E-02	1.124E-01	1.555E-01
0.000145	9.457E-02	6.168E-02	7.082E-02	8.714E-02	1.123E-01	1.551E-01
0.000164	9.438E-02	6.158E-02	7.070E-02	8.698E-02	1.121E-01	1.544E-01
0.000185	9.414E-02	6.144E-02	7.054E-02	8.679E-02	1.118E-01	1.535E-01
0.000210	9.385E-02	6.128E-02	7.035E-02	8.656E-02	1.115E-01	1.526E-01
0.000237	9.352E-02	6.110E-02	7.014E-02	8.631E-02	1.112E-01	1.514E-01
0.000268	9.318E-02	6.090E-02	6.992E-02	8.603E-02	1.108E-01	1.502E-01
0.000303	9.282E-02	6.070E-02	6.968E-02	8.574E-02	1.105E-01	1.489E-01
0.000343	9.244E-02	6.048E-02	6.944E-02	8.544E-02	1.101E-01	1.477E-01
0.000388	9.206E-02	6.027E-02	6.920E-02	8.513E-02	1.097E-01	1.464E-01
0.000439	9.166E-02	6.004E-02	6.894E-02	8.482E-02	1.093E-01	1.450E-01
0.000497	9.123E-02	5.980E-02	6.866E-02	8.448E-02	1.089E-01	1.436E-01
0.000562	9.076E-02	5.953E-02	6.836E-02	8.410E-02	1.083E-01	1.421E-01
0.000636	9.019E-02	5.921E-02	6.799E-02	8.365E-02	1.077E-01	1.405E-01
0.000719	8.949E-02	5.883E-02	6.755E-02	8.310E-02	1.069E-01	1.387E-01
0.000813	8.862E-02	5.833E-02	6.698E-02	8.242E-02	1.059E-01	1.365E-01
0.000920	8.752E-02	5.771E-02	6.628E-02	8.156E-02	1.046E-01	1.340E-01
0.001041	8.618E-02	5.693E-02	6.540E-02	8.049E-02	1.030E-01	1.311E-01
0.001177	8.456E-02	5.595E-02	6.429E-02	7.917E-02	1.011E-01	1.278E-01
0.001332	8.262E-02	5.473E-02	6.294E-02	7.757E-02	9.880E-02	1.241E-01
0.001507	8.035E-02	5.324E-02	6.131E-02	7.565E-02	9.618E-02	1.200E-01
0.001704	7.774E-02	5.146E-02	5.936E-02	7.338E-02	9.320E-02	1.156E-01
0.001928	7.480E-02	4.940E-02	5.712E-02	7.079E-02	8.988E-02	1.109E-01
0.002181	7.160E-02	4.710E-02	5.463E-02	6.792E-02	8.630E-02	1.059E-01
0.002467	6.822E-02	4.464E-02	5.197E-02	6.485E-02	8.254E-02	1.008E-01
0.002791	6.475E-02	4.210E-02	4.922E-02	6.170E-02	7.869E-02	9.576E-02
0.003157	6.130E-02	3.956E-02	4.647E-02	5.852E-02	7.486E-02	9.074E-02
0.003571	5.793E-02	3.709E-02	4.379E-02	5.541E-02	7.110E-02	8.587E-02
0.004040	5.468E-02	3.472E-02	4.120E-02	5.241E-02	6.747E-02	8.119E-02
0.004570	5.156E-02	3.247E-02	3.872E-02	4.951E-02	6.395E-02	7.671E-02
0.005170	4.857E-02	3.032E-02	3.634E-02	4.672E-02	6.057E-02	7.241E-02
0.005848	4.568E-02	2.827E-02	3.405E-02	4.401E-02	5.725E-02	6.826E-02
0.006615	4.284E-02	2.629E-02	3.181E-02	4.134E-02	5.396E-02	6.421E-02
0.007483	4.002E-02	2.435E-02	2.959E-02	3.867E-02	5.065E-02	6.020E-02
0.008465	3.720E-02	2.244E-02	2.736E-02	3.597E-02	4.728E-02	5.621E-02
0.009576	3.437E-02	2.055E-02	2.513E-02	3.324E-02	4.386E-02	5.221E-02
0.010833	3.155E-02	1.869E-02	2.291E-02	3.050E-02	4.040E-02	4.824E-02
0.012254	2.877E-02	1.688E-02	2.073E-02	2.780E-02	3.696E-02	4.432E-02

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.013862	2.608E-02	1.514E-02	1.863E-02	2.516E-02	3.360E-02	4.049E-02
0.015681	2.350E-02	1.349E-02	1.664E-02	2.264E-02	3.038E-02	3.681E-02
0.017739	2.107E-02	1.195E-02	1.478E-02	2.026E-02	2.732E-02	3.330E-02
0.020066	1.881E-02	1.052E-02	1.305E-02	1.803E-02	2.447E-02	2.999E-02
0.022699	1.672E-02	9.200E-03	1.147E-02	1.598E-02	2.182E-02	2.690E-02
0.025678	1.479E-02	8.006E-03	1.004E-02	1.410E-02	1.939E-02	2.403E-02
0.029047	1.304E-02	6.930E-03	8.746E-03	1.240E-02	1.717E-02	2.139E-02
0.032859	1.146E-02	5.968E-03	7.587E-03	1.085E-02	1.516E-02	1.898E-02
0.037170	1.003E-02	5.116E-03	6.554E-03	9.470E-03	1.335E-02	1.680E-02
0.042048	8.750E-03	4.366E-03	5.638E-03	8.238E-03	1.173E-02	1.483E-02
0.047565	7.612E-03	3.711E-03	4.832E-03	7.144E-03	1.028E-02	1.306E-02
0.053806	6.604E-03	3.143E-03	4.127E-03	6.180E-03	8.987E-03	1.148E-02
0.060867	5.715E-03	2.655E-03	3.515E-03	5.332E-03	7.840E-03	1.007E-02
0.068853	4.935E-03	2.237E-03	2.986E-03	4.590E-03	6.826E-03	8.824E-03
0.077888	4.251E-03	1.880E-03	2.530E-03	3.940E-03	5.927E-03	7.709E-03
0.088108	3.653E-03	1.577E-03	2.139E-03	3.373E-03	5.132E-03	6.717E-03
0.099670	3.130E-03	1.320E-03	1.803E-03	2.878E-03	4.428E-03	5.833E-03
0.112748	2.674E-03	1.103E-03	1.516E-03	2.446E-03	3.807E-03	5.046E-03
0.127542	2.276E-03	9.180E-04	1.270E-03	2.070E-03	3.259E-03	4.348E-03
0.144278	1.930E-03	7.615E-04	1.060E-03	1.744E-03	2.778E-03	3.730E-03
0.163210	1.629E-03	6.291E-04	8.809E-04	1.463E-03	2.358E-03	3.187E-03
0.184625	1.370E-03	5.171E-04	7.289E-04	1.222E-03	1.992E-03	2.709E-03
0.208851	1.146E-03	4.226E-04	6.002E-04	1.015E-03	1.676E-03	2.293E-03
0.236256	9.536E-04	3.431E-04	4.914E-04	8.390E-04	1.403E-03	1.931E-03
0.267257	7.893E-04	2.765E-04	3.998E-04	6.895E-04	1.168E-03	1.617E-03
0.302325	6.491E-04	2.209E-04	3.229E-04	5.630E-04	9.670E-04	1.347E-03
0.341995	5.300E-04	1.749E-04	2.586E-04	4.564E-04	7.955E-04	1.114E-03
0.386871	4.293E-04	1.370E-04	2.052E-04	3.669E-04	6.492E-04	9.156E-04
0.437634	3.447E-04	1.060E-04	1.610E-04	2.922E-04	5.252E-04	7.463E-04
0.495059	2.739E-04	8.097E-05	1.247E-04	2.302E-04	4.207E-04	6.030E-04
0.560020	2.151E-04	6.091E-05	9.528E-05	1.790E-04	3.331E-04	4.821E-04
0.633503	1.668E-04	4.505E-05	7.161E-05	1.373E-04	2.603E-04	3.810E-04
0.716629	1.274E-04	3.271E-05	5.287E-05	1.036E-04	2.005E-04	2.971E-04
0.810663	9.582E-05	2.327E-05	3.828E-05	7.689E-05	1.519E-04	2.283E-04
0.917036	7.080E-05	1.620E-05	2.714E-05	5.598E-05	1.131E-04	1.726E-04
1.037366	5.135E-05	1.102E-05	1.883E-05	3.995E-05	8.269E-05	1.283E-04
1.173485	3.653E-05	7.321E-06	1.277E-05	2.791E-05	5.927E-05	9.356E-05
1.327466	2.547E-05	4.744E-06	8.455E-06	1.909E-05	4.163E-05	6.694E-05
1.501652	1.741E-05	2.998E-06	5.468E-06	1.277E-05	2.864E-05	4.697E-05
1.698694	1.166E-05	1.847E-06	3.453E-06	8.350E-06	1.931E-05	3.232E-05
1.921589	7.655E-06	1.109E-06	2.130E-06	5.344E-06	1.275E-05	2.180E-05
2.173734	4.932E-06	6.506E-07	1.284E-06	3.349E-06	8.258E-06	1.444E-05

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
2.458964	3.121E-06	3.725E-07	7.568E-07	2.056E-06	5.249E-06	9.386E-06
2.781622	1.942E-06	2.086E-07	4.367E-07	1.239E-06	3.277E-06	6.002E-06
3.146617	1.190E-06	1.143E-07	2.471E-07	7.328E-07	2.013E-06	3.777E-06
3.559503	7.190E-07	6.147E-08	1.373E-07	4.264E-07	1.217E-06	2.342E-06
4.026569	4.290E-07	3.245E-08	7.496E-08	2.443E-07	7.264E-07	1.434E-06
4.554923	2.531E-07	1.684E-08	4.029E-08	1.379E-07	4.279E-07	8.671E-07
5.152606	1.479E-07	8.610E-09	2.134E-08	7.689E-08	2.492E-07	5.188E-07
5.828714	8.566E-08	4.338E-09	1.115E-08	4.236E-08	1.437E-07	3.075E-07
6.593533	4.925E-08	2.157E-09	5.759E-09	2.307E-08	8.203E-08	1.807E-07
7.458715	2.814E-08	1.059E-09	2.939E-09	1.244E-08	4.646E-08	1.054E-07
8.437425	1.598E-08	5.138E-10	1.484E-09	6.639E-09	2.611E-08	6.105E-08
9.544557	9.033E-09	2.464E-10	7.408E-10	3.510E-09	1.456E-08	3.515E-08
10.796952	5.082E-09	1.168E-10	3.660E-10	1.839E-09	8.068E-09	2.012E-08
12.213694	2.846E-09	5.469E-11	1.789E-10	9.545E-10	4.439E-09	1.145E-08
13.816336	1.587E-09	2.530E-11	8.643E-11	4.911E-10	2.426E-09	6.477E-09
15.629272	8.816E-10	1.155E-11	4.128E-11	2.505E-10	1.318E-09	3.643E-09
17.680094	4.873E-10	5.206E-12	1.949E-11	1.266E-10	7.109E-10	2.036E-09
20.000000	2.678E-10	2.314E-12	9.102E-12	6.349E-11	3.807E-10	1.130E-09

Table 2.3.7-6: The 5% Damped SA at 1 Hz Control Point Hazard Curves for the CGS Site

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.000010	9.458E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000011	9.458E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000013	9.458E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000015	9.458E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000017	9.458E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000020	9.458E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000023	9.457E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000027	9.457E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000031	9.456E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000035	9.455E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000040	9.454E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000046	9.453E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000053	9.452E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000061	9.451E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000071	9.450E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000081	9.449E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000093	9.448E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000107	9.446E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.549E-01
0.000123	9.442E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.548E-01
0.000142	9.433E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.544E-01
0.000163	9.420E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.538E-01
0.000187	9.404E-02	6.166E-02	7.079E-02	8.710E-02	1.122E-01	1.531E-01
0.000215	9.382E-02	6.161E-02	7.074E-02	8.704E-02	1.122E-01	1.523E-01
0.000248	9.335E-02	6.139E-02	7.048E-02	8.676E-02	1.118E-01	1.510E-01
0.000285	9.239E-02	6.081E-02	6.981E-02	8.603E-02	1.108E-01	1.487E-01
0.000327	9.098E-02	5.989E-02	6.876E-02	8.487E-02	1.093E-01	1.457E-01
0.000376	8.940E-02	5.885E-02	6.757E-02	8.356E-02	1.076E-01	1.423E-01
0.000433	8.781E-02	5.781E-02	6.636E-02	8.224E-02	1.059E-01	1.389E-01
0.000498	8.624E-02	5.678E-02	6.518E-02	8.093E-02	1.043E-01	1.356E-01
0.000572	8.471E-02	5.576E-02	6.402E-02	7.965E-02	1.026E-01	1.324E-01
0.000658	8.320E-02	5.477E-02	6.288E-02	7.839E-02	1.010E-01	1.292E-01
0.000756	8.172E-02	5.380E-02	6.176E-02	7.715E-02	9.939E-02	1.262E-01
0.000870	8.027E-02	5.284E-02	6.066E-02	7.592E-02	9.781E-02	1.232E-01
0.001000	7.882E-02	5.188E-02	5.956E-02	7.470E-02	9.624E-02	1.203E-01
0.001150	7.723E-02	5.081E-02	5.836E-02	7.335E-02	9.450E-02	1.172E-01
0.001322	7.500E-02	4.926E-02	5.665E-02	7.139E-02	9.198E-02	1.133E-01
0.001520	7.177E-02	4.695E-02	5.417E-02	6.854E-02	8.830E-02	1.081E-01
0.001748	6.811E-02	4.431E-02	5.135E-02	6.525E-02	8.407E-02	1.025E-01
0.002009	6.449E-02	4.172E-02	4.857E-02	6.201E-02	7.988E-02	9.692E-02
0.002310	6.093E-02	3.918E-02	4.583E-02	5.878E-02	7.574E-02	9.149E-02

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.002656	5.706E-02	3.645E-02	4.281E-02	5.518E-02	7.116E-02	8.570E-02
0.003054	5.266E-02	3.338E-02	3.933E-02	5.097E-02	6.588E-02	7.923E-02
0.003511	4.819E-02	3.028E-02	3.579E-02	4.665E-02	6.046E-02	7.269E-02
0.004037	4.402E-02	2.742E-02	3.251E-02	4.262E-02	5.539E-02	6.660E-02
0.004642	4.020E-02	2.483E-02	2.952E-02	3.892E-02	5.074E-02	6.100E-02
0.005337	3.671E-02	2.248E-02	2.680E-02	3.555E-02	4.648E-02	5.587E-02
0.006136	3.351E-02	2.034E-02	2.433E-02	3.245E-02	4.255E-02	5.116E-02
0.007055	3.052E-02	1.836E-02	2.203E-02	2.955E-02	3.887E-02	4.676E-02
0.008111	2.755E-02	1.644E-02	1.981E-02	2.666E-02	3.521E-02	4.245E-02
0.009326	2.457E-02	1.453E-02	1.760E-02	2.373E-02	3.151E-02	3.817E-02
0.010723	2.173E-02	1.274E-02	1.552E-02	2.095E-02	2.799E-02	3.409E-02
0.012328	1.914E-02	1.111E-02	1.361E-02	1.841E-02	2.474E-02	3.032E-02
0.014175	1.672E-02	9.574E-03	1.180E-02	1.606E-02	2.170E-02	2.674E-02
0.016298	1.451E-02	8.159E-03	1.010E-02	1.391E-02	1.888E-02	2.338E-02
0.018738	1.253E-02	6.911E-03	8.598E-03	1.199E-02	1.636E-02	2.036E-02
0.021544	1.080E-02	5.838E-03	7.298E-03	1.033E-02	1.416E-02	1.771E-02
0.024771	9.281E-03	4.895E-03	6.158E-03	8.850E-03	1.223E-02	1.536E-02
0.028480	7.908E-03	4.043E-03	5.132E-03	7.512E-03	1.053E-02	1.328E-02
0.032745	6.686E-03	3.287E-03	4.222E-03	6.315E-03	9.026E-03	1.144E-02
0.037649	5.630E-03	2.650E-03	3.452E-03	5.284E-03	7.728E-03	9.842E-03
0.043288	4.732E-03	2.131E-03	2.815E-03	4.410E-03	6.606E-03	8.461E-03
0.049770	3.963E-03	1.706E-03	2.283E-03	3.662E-03	5.625E-03	7.267E-03
0.057224	3.294E-03	1.355E-03	1.832E-03	3.009E-03	4.754E-03	6.234E-03
0.065793	2.715E-03	1.065E-03	1.454E-03	2.445E-03	3.982E-03	5.329E-03
0.075646	2.219E-03	8.330E-04	1.146E-03	1.966E-03	3.301E-03	4.510E-03
0.086975	1.794E-03	6.481E-04	8.981E-04	1.563E-03	2.699E-03	3.754E-03
0.100000	1.438E-03	5.023E-04	7.009E-04	1.231E-03	2.184E-03	3.080E-03
0.114976	1.144E-03	3.871E-04	5.444E-04	9.629E-04	1.750E-03	2.500E-03
0.132194	8.982E-04	2.944E-04	4.185E-04	7.458E-04	1.380E-03	1.995E-03
0.151991	6.933E-04	2.199E-04	3.175E-04	5.707E-04	1.067E-03	1.559E-03
0.174753	5.293E-04	1.623E-04	2.387E-04	4.331E-04	8.147E-04	1.202E-03
0.200923	4.016E-04	1.189E-04	1.782E-04	3.268E-04	6.182E-04	9.205E-04
0.231013	3.019E-04	8.603E-05	1.315E-04	2.444E-04	4.654E-04	6.996E-04
0.265609	2.236E-04	6.084E-05	9.494E-05	1.800E-04	3.462E-04	5.252E-04
0.305386	1.633E-04	4.200E-05	6.706E-05	1.305E-04	2.547E-04	3.899E-04
0.351119	1.185E-04	2.864E-05	4.686E-05	9.415E-05	1.867E-04	2.884E-04
0.403702	8.606E-05	1.950E-05	3.268E-05	6.782E-05	1.370E-04	2.134E-04
0.464159	6.239E-05	1.325E-05	2.274E-05	4.870E-05	1.003E-04	1.577E-04
0.533670	4.490E-05	8.926E-06	1.567E-05	3.462E-05	7.286E-05	1.157E-04
0.613591	3.181E-05	5.896E-06	1.060E-05	2.415E-05	5.207E-05	8.363E-05
0.705481	2.202E-05	3.785E-06	6.973E-06	1.640E-05	3.635E-05	5.915E-05
0.811131	1.483E-05	2.345E-06	4.435E-06	1.079E-05	2.467E-05	4.078E-05

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.932604	9.702E-06	1.398E-06	2.720E-06	6.873E-06	1.624E-05	2.735E-05
1.072268	6.171E-06	8.023E-07	1.611E-06	4.241E-06	1.040E-05	1.788E-05
1.232847	3.831E-06	4.452E-07	9.253E-07	2.547E-06	6.486E-06	1.142E-05
1.417475	2.328E-06	2.404E-07	5.183E-07	1.494E-06	3.956E-06	7.143E-06
1.629751	1.386E-06	1.271E-07	2.843E-07	8.582E-07	2.361E-06	4.370E-06
1.873819	8.065E-07	6.589E-08	1.526E-07	4.814E-07	1.374E-06	2.607E-06
2.154435	4.562E-07	3.338E-08	7.980E-08	2.624E-07	7.766E-07	1.510E-06
2.477078	2.500E-07	1.641E-08	4.040E-08	1.383E-07	4.244E-07	8.466E-07
2.848037	1.324E-07	7.773E-09	1.967E-08	7.003E-08	2.237E-07	4.588E-07
3.274549	6.794E-08	3.525E-09	9.169E-09	3.407E-08	1.138E-07	2.410E-07
3.764938	3.393E-08	1.526E-09	4.088E-09	1.594E-08	5.619E-08	1.234E-07
4.328762	1.662E-08	6.309E-10	1.746E-09	7.207E-09	2.708E-08	6.213E-08
4.977026	8.067E-09	2.498E-10	7.182E-10	3.172E-09	1.286E-08	3.100E-08
5.722369	3.914E-09	9.512E-11	2.861E-10	1.370E-09	6.068E-09	1.545E-08
6.579331	1.912E-09	3.507E-11	1.113E-10	5.863E-10	2.866E-09	7.734E-09
7.564636	9.431E-10	1.260E-11	4.256E-11	2.502E-10	1.360E-09	3.893E-09
8.697490	4.693E-10	4.441E-12	1.613E-11	1.071E-10	6.492E-10	1.969E-09
10.000005	2.350E-10	1.543E-12	6.090E-12	4.606E-11	3.112E-10	9.969E-10

Table 2.3.7-7: The 5% Damped SA at 0.5 Hz Control Point Hazard Curves for the CGS Site

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.000010	9.476E-02	6.178E-02	7.093E-02	8.727E-02	1.124E-01	1.555E-01
0.000011	9.476E-02	6.178E-02	7.093E-02	8.727E-02	1.124E-01	1.555E-01
0.000013	9.476E-02	6.178E-02	7.093E-02	8.727E-02	1.124E-01	1.555E-01
0.000015	9.476E-02	6.178E-02	7.093E-02	8.727E-02	1.124E-01	1.555E-01
0.000017	9.472E-02	6.176E-02	7.090E-02	8.724E-02	1.124E-01	1.554E-01
0.000020	9.460E-02	6.169E-02	7.082E-02	8.714E-02	1.122E-01	1.550E-01
0.000023	9.443E-02	6.158E-02	7.069E-02	8.698E-02	1.120E-01	1.545E-01
0.000027	9.423E-02	6.146E-02	7.056E-02	8.681E-02	1.118E-01	1.539E-01
0.000031	9.403E-02	6.133E-02	7.042E-02	8.664E-02	1.116E-01	1.533E-01
0.000035	9.383E-02	6.121E-02	7.028E-02	8.646E-02	1.114E-01	1.526E-01
0.000040	9.363E-02	6.109E-02	7.014E-02	8.629E-02	1.111E-01	1.520E-01
0.000046	9.344E-02	6.097E-02	7.000E-02	8.612E-02	1.109E-01	1.514E-01
0.000053	9.324E-02	6.085E-02	6.986E-02	8.595E-02	1.107E-01	1.508E-01
0.000061	9.304E-02	6.073E-02	6.972E-02	8.577E-02	1.105E-01	1.502E-01
0.000071	9.284E-02	6.061E-02	6.958E-02	8.560E-02	1.102E-01	1.496E-01
0.000081	9.263E-02	6.047E-02	6.943E-02	8.542E-02	1.100E-01	1.490E-01
0.000093	9.231E-02	6.028E-02	6.920E-02	8.518E-02	1.096E-01	1.481E-01
0.000107	9.169E-02	5.989E-02	6.876E-02	8.479E-02	1.089E-01	1.465E-01
0.000123	9.067E-02	5.926E-02	6.804E-02	8.418E-02	1.078E-01	1.439E-01
0.000142	8.942E-02	5.849E-02	6.715E-02	8.343E-02	1.064E-01	1.408E-01
0.000163	8.807E-02	5.765E-02	6.620E-02	8.262E-02	1.049E-01	1.375E-01
0.000187	8.646E-02	5.660E-02	6.502E-02	8.150E-02	1.031E-01	1.339E-01
0.000215	8.408E-02	5.495E-02	6.322E-02	7.953E-02	1.005E-01	1.296E-01
0.000248	8.077E-02	5.259E-02	6.067E-02	7.653E-02	9.682E-02	1.242E-01
0.000285	7.701E-02	4.986E-02	5.775E-02	7.300E-02	9.268E-02	1.184E-01
0.000327	7.326E-02	4.717E-02	5.484E-02	6.947E-02	8.854E-02	1.127E-01
0.000376	6.969E-02	4.461E-02	5.207E-02	6.609E-02	8.457E-02	1.072E-01
0.000433	6.628E-02	4.218E-02	4.943E-02	6.287E-02	8.078E-02	1.020E-01
0.000498	6.304E-02	3.989E-02	4.693E-02	5.981E-02	7.715E-02	9.699E-02
0.000572	5.996E-02	3.772E-02	4.456E-02	5.690E-02	7.369E-02	9.227E-02
0.000658	5.703E-02	3.567E-02	4.231E-02	5.413E-02	7.039E-02	8.778E-02
0.000756	5.424E-02	3.373E-02	4.016E-02	5.149E-02	6.723E-02	8.350E-02
0.000870	5.155E-02	3.187E-02	3.810E-02	4.895E-02	6.415E-02	7.937E-02
0.001000	4.875E-02	2.997E-02	3.595E-02	4.629E-02	6.088E-02	7.508E-02
0.001150	4.554E-02	2.786E-02	3.348E-02	4.326E-02	5.700E-02	7.017E-02
0.001322	4.207E-02	2.563E-02	3.081E-02	3.998E-02	5.271E-02	6.485E-02
0.001520	3.870E-02	2.348E-02	2.823E-02	3.681E-02	4.852E-02	5.969E-02
0.001748	3.556E-02	2.149E-02	2.584E-02	3.384E-02	4.462E-02	5.489E-02
0.002009	3.257E-02	1.961E-02	2.359E-02	3.102E-02	4.091E-02	5.031E-02
0.002310	2.960E-02	1.777E-02	2.137E-02	2.820E-02	3.726E-02	4.575E-02

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.002656	2.670E-02	1.599E-02	1.923E-02	2.546E-02	3.372E-02	4.129E-02
0.003054	2.402E-02	1.435E-02	1.726E-02	2.292E-02	3.045E-02	3.718E-02
0.003511	2.160E-02	1.288E-02	1.549E-02	2.063E-02	2.748E-02	3.346E-02
0.004037	1.943E-02	1.156E-02	1.390E-02	1.857E-02	2.481E-02	3.012E-02
0.004642	1.747E-02	1.037E-02	1.247E-02	1.671E-02	2.239E-02	2.711E-02
0.005337	1.570E-02	9.294E-03	1.118E-02	1.502E-02	2.019E-02	2.438E-02
0.006136	1.404E-02	8.268E-03	9.971E-03	1.345E-02	1.811E-02	2.185E-02
0.007055	1.244E-02	7.244E-03	8.797E-03	1.192E-02	1.607E-02	1.944E-02
0.008111	1.092E-02	6.257E-03	7.683E-03	1.047E-02	1.413E-02	1.718E-02
0.009326	9.545E-03	5.358E-03	6.661E-03	9.155E-03	1.238E-02	1.514E-02
0.010723	8.295E-03	4.528E-03	5.701E-03	7.940E-03	1.083E-02	1.332E-02
0.012328	7.154E-03	3.755E-03	4.791E-03	6.812E-03	9.471E-03	1.171E-02
0.014175	6.136E-03	3.073E-03	3.975E-03	5.800E-03	8.274E-03	1.028E-02
0.016298	5.255E-03	2.503E-03	3.284E-03	4.926E-03	7.226E-03	9.020E-03
0.018738	4.491E-03	2.033E-03	2.704E-03	4.171E-03	6.301E-03	7.918E-03
0.021544	3.813E-03	1.636E-03	2.202E-03	3.495E-03	5.460E-03	6.947E-03
0.024771	3.205E-03	1.296E-03	1.763E-03	2.885E-03	4.689E-03	6.089E-03
0.028480	2.678E-03	1.018E-03	1.397E-03	2.358E-03	4.005E-03	5.335E-03
0.032745	2.233E-03	7.966E-04	1.104E-03	1.922E-03	3.415E-03	4.673E-03
0.037649	1.858E-03	6.229E-04	8.708E-04	1.562E-03	2.900E-03	4.078E-03
0.043288	1.534E-03	4.848E-04	6.835E-04	1.256E-03	2.432E-03	3.516E-03
0.049770	1.250E-03	3.741E-04	5.318E-04	9.932E-04	2.001E-03	2.977E-03
0.057224	1.006E-03	2.862E-04	4.102E-04	7.749E-04	1.618E-03	2.480E-03
0.065793	8.000E-04	2.166E-04	3.136E-04	5.991E-04	1.289E-03	2.034E-03
0.075646	6.277E-04	1.617E-04	2.374E-04	4.597E-04	1.011E-03	1.643E-03
0.086975	4.873E-04	1.195E-04	1.782E-04	3.507E-04	7.830E-04	1.309E-03
0.100000	3.753E-04	8.750E-05	1.329E-04	2.662E-04	6.014E-04	1.034E-03
0.114976	2.853E-04	6.312E-05	9.778E-05	1.999E-04	4.559E-04	8.010E-04
0.132194	2.128E-04	4.445E-05	7.050E-05	1.476E-04	3.389E-04	6.050E-04
0.151991	1.562E-04	3.068E-05	4.998E-05	1.075E-04	2.481E-04	4.477E-04
0.174753	1.140E-04	2.098E-05	3.517E-05	7.786E-05	1.805E-04	3.286E-04
0.200923	8.287E-05	1.428E-05	2.464E-05	5.618E-05	1.310E-04	2.403E-04
0.231013	5.964E-05	9.580E-06	1.705E-05	4.007E-05	9.424E-05	1.742E-04
0.265609	4.205E-05	6.238E-06	1.147E-05	2.791E-05	6.672E-05	1.241E-04
0.305386	2.904E-05	3.924E-06	7.499E-06	1.897E-05	4.649E-05	8.695E-05
0.351119	1.991E-05	2.426E-06	4.835E-06	1.276E-05	3.226E-05	6.060E-05
0.403702	1.373E-05	1.509E-06	3.135E-06	8.635E-06	2.252E-05	4.249E-05
0.464159	9.500E-06	9.477E-07	2.046E-06	5.864E-06	1.576E-05	2.988E-05
0.533670	6.508E-06	5.924E-07	1.325E-06	3.942E-06	1.090E-05	2.079E-05
0.613591	4.354E-06	3.616E-07	8.357E-07	2.583E-06	7.347E-06	1.414E-05
0.705481	2.818E-06	2.126E-07	5.078E-07	1.633E-06	4.785E-06	9.314E-06
0.811131	1.762E-06	1.197E-07	2.956E-07	9.927E-07	3.005E-06	5.937E-06

PSA [g]	Mean AFE	5th Fractile AFE	16th Fractile AFE	50th Fractile AFE	84th Fractile AFE	95th Fractile AFE
0.932604	1.068E-06	6.462E-08	1.653E-07	5.821E-07	1.827E-06	3.675E-06
1.072268	6.321E-07	3.367E-08	8.946E-08	3.314E-07	1.082E-06	2.223E-06
1.232847	3.675E-07	1.707E-08	4.717E-08	1.844E-07	6.286E-07	1.322E-06
1.417475	2.110E-07	8.481E-09	2.440E-08	1.008E-07	3.600E-07	7.760E-07
1.629751	1.199E-07	4.146E-09	1.243E-08	5.430E-08	2.036E-07	4.507E-07
1.873819	6.752E-08	1.996E-09	6.241E-09	2.884E-08	1.138E-07	2.590E-07
2.154435	3.763E-08	9.463E-10	3.085E-09	1.509E-08	6.278E-08	1.472E-07
2.477078	2.072E-08	4.407E-10	1.498E-09	7.771E-09	3.412E-08	8.254E-08
2.848037	1.125E-08	2.007E-10	7.122E-10	3.925E-09	1.824E-08	4.562E-08
3.274549	6.021E-09	8.910E-11	3.305E-10	1.942E-09	9.570E-09	2.481E-08
3.764938	3.173E-09	3.844E-11	1.494E-10	9.397E-10	4.926E-09	1.326E-08
4.328762	1.646E-09	1.608E-11	6.570E-11	4.443E-10	2.486E-09	6.969E-09
4.977026	8.407E-10	6.521E-12	2.809E-11	2.053E-10	1.230E-09	3.597E-09
5.722369	4.226E-10	2.561E-12	1.168E-11	9.265E-11	5.961E-10	1.823E-09
6.579331	2.092E-10	9.745E-13	4.721E-12	4.084E-11	2.833E-10	9.073E-10
7.564636	1.020E-10	3.592E-13	1.855E-12	1.759E-11	1.319E-10	4.433E-10
8.697490	4.903E-11	1.282E-13	7.088E-13	7.391E-12	6.027E-11	2.128E-10
10.000005	2.323E-11	4.438E-14	2.634E-13	3.036E-12	2.701E-11	1.003E-10

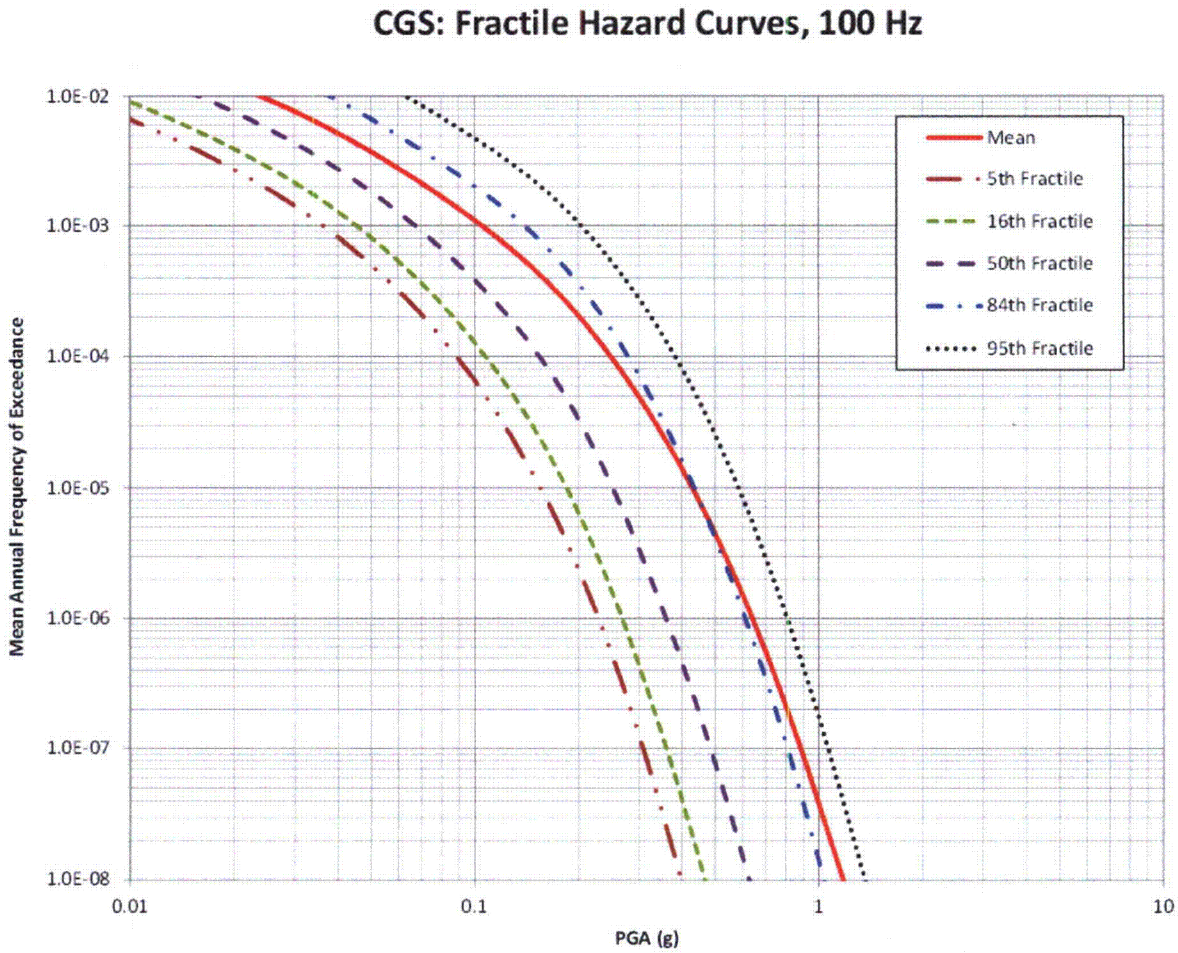


Figure 2.3.7-1: Control Point Mean and 5th, 16th, 50th, 84th, and 95th Percentile Fractile Hazard Curves for Spectral Frequency 5% Damped SA at 100 Hz (PGA) at the CGS Site

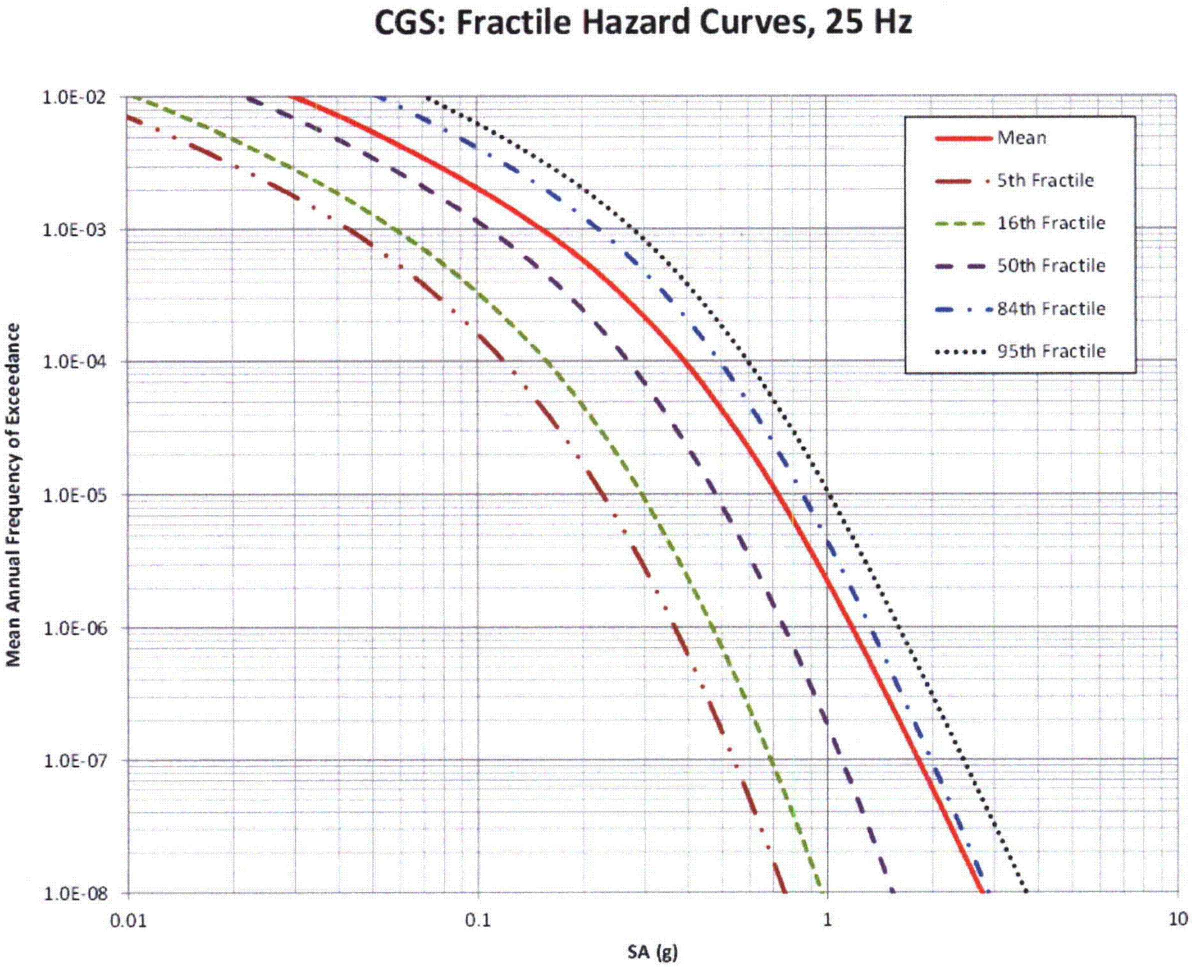


Figure 2.3.7-2: Control Point Mean and 5th, 16th, 50th, 84th, and 95th Percentile Fractile Hazard Curves for the Spectral Frequency 5% Damped SA at 25 Hz at the CGS Site

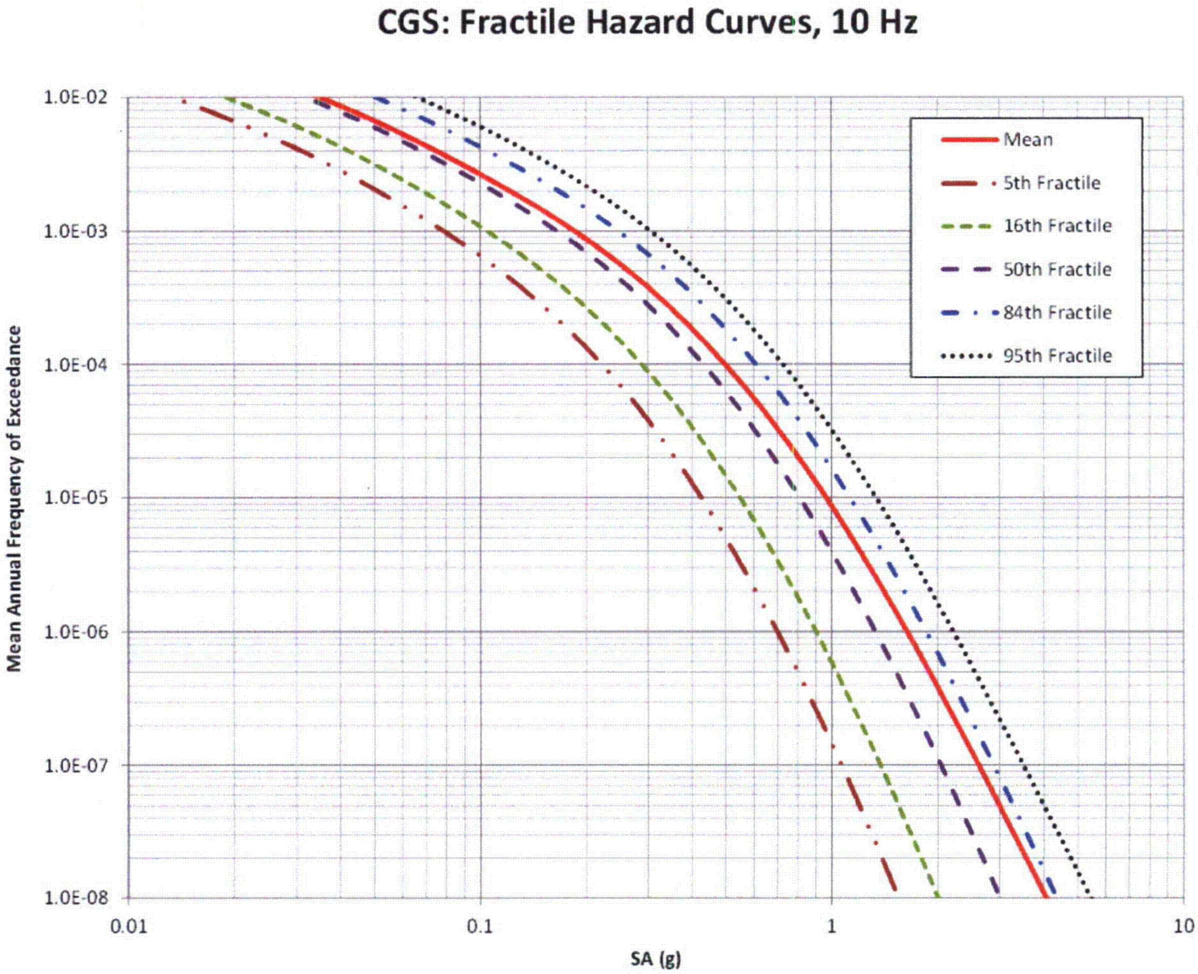


Figure 2.3.7-3: Control Point Mean and 5th, 16th, 50th, 84th, and 95th Percentile Fractile Hazard Curves for the Spectral Frequency 5% Damped SA at 10 Hz at the CGS Site

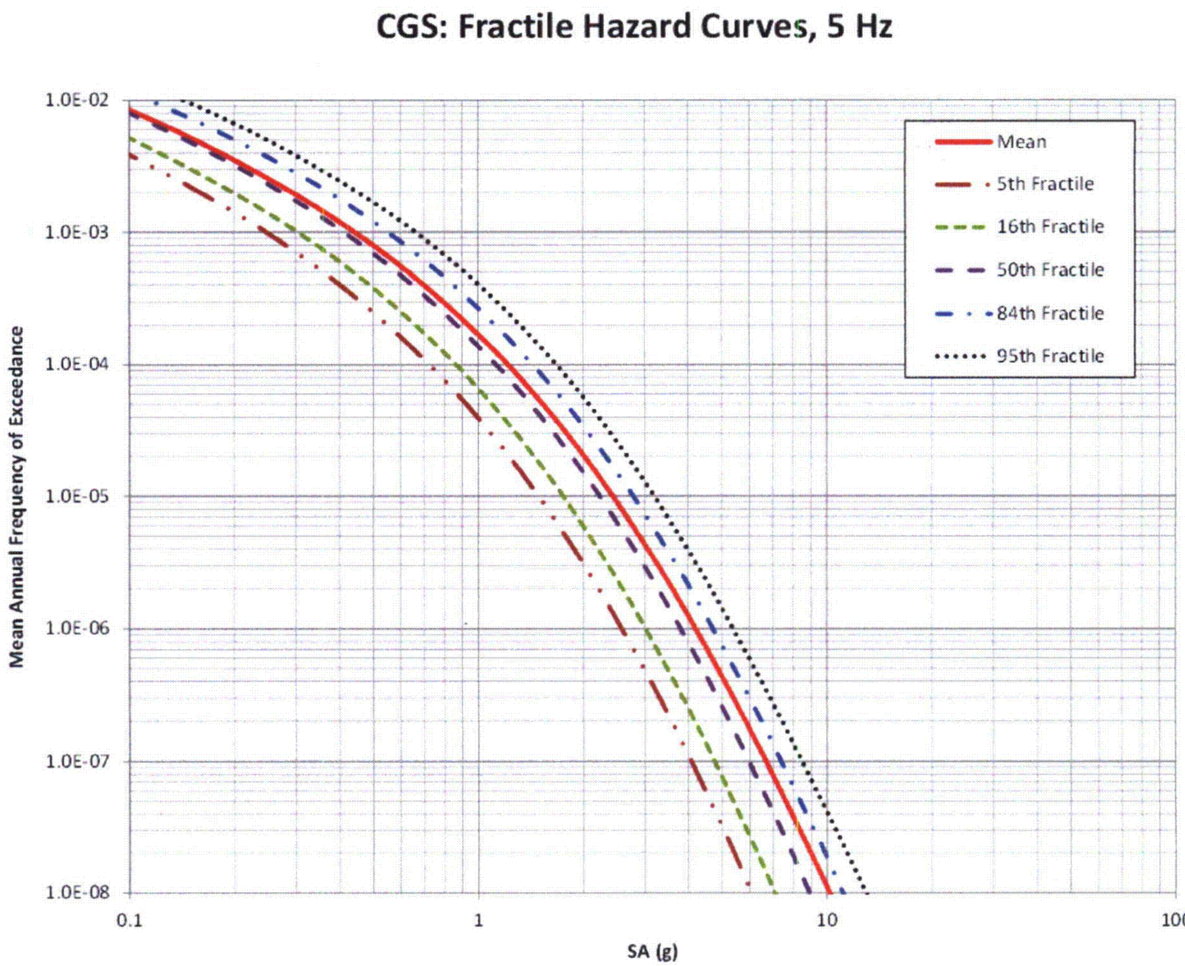


Figure 2.3.7-4: Control Point Mean and 5th, 16th, 50th, 84th, and 95th Percentile Fractile Hazard Curves for the Spectral Frequency 5% Damped SA at 5 Hz at the CGS Site

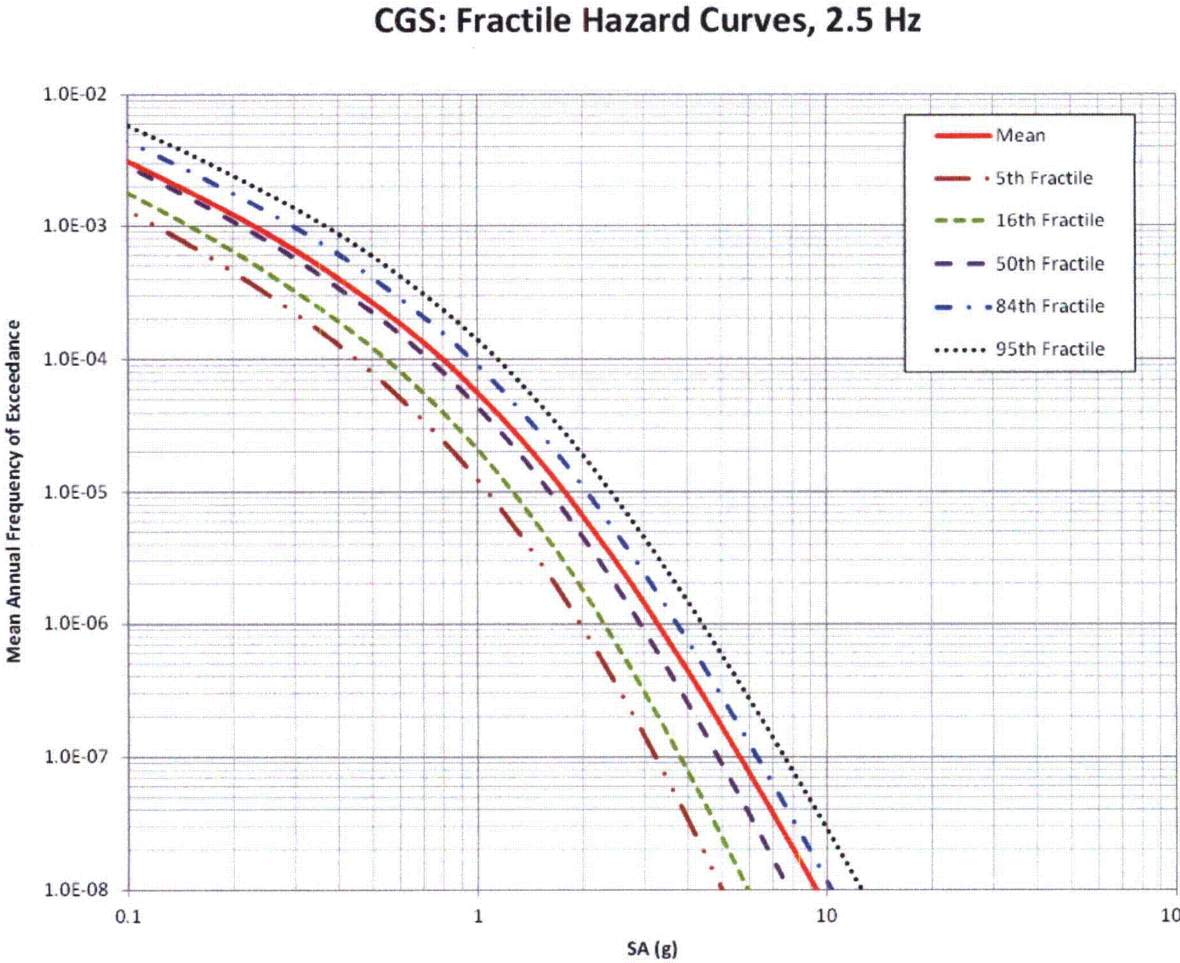


Figure 2.3.7-5: Control Point Mean and 5th, 16th, 50th, 84th, and 95th Percentile Fractile Hazard Curves for the Spectral Frequency 5% Damped SA at 2.5 Hz at the CGS Site

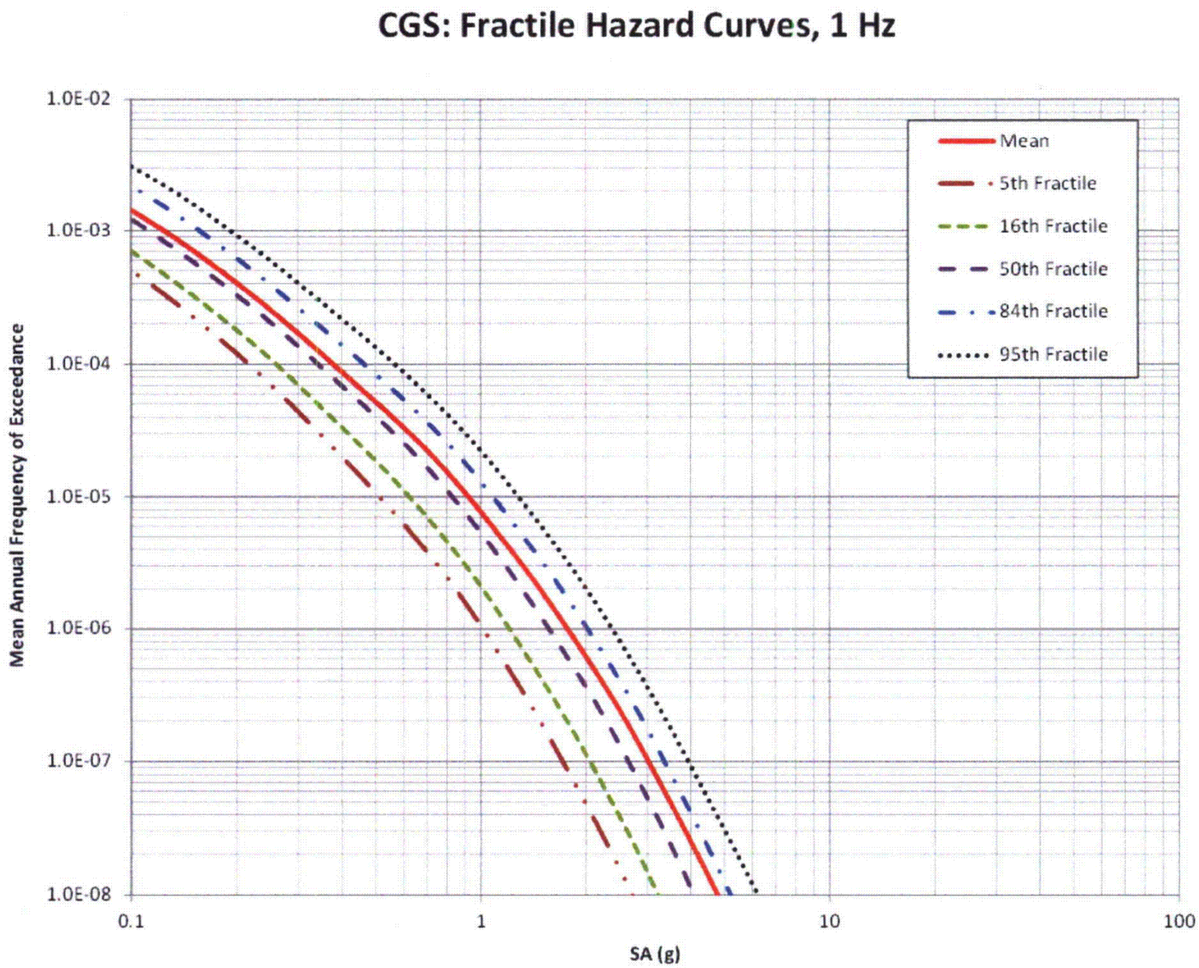


Figure 2.3.7-6: Control Point Mean and 5th, 16th, 50th, 84th, and 95th Percentile Fractile Hazard Curves for the Spectral Frequency 5% Damped SA at 1 Hz at the CGS Site

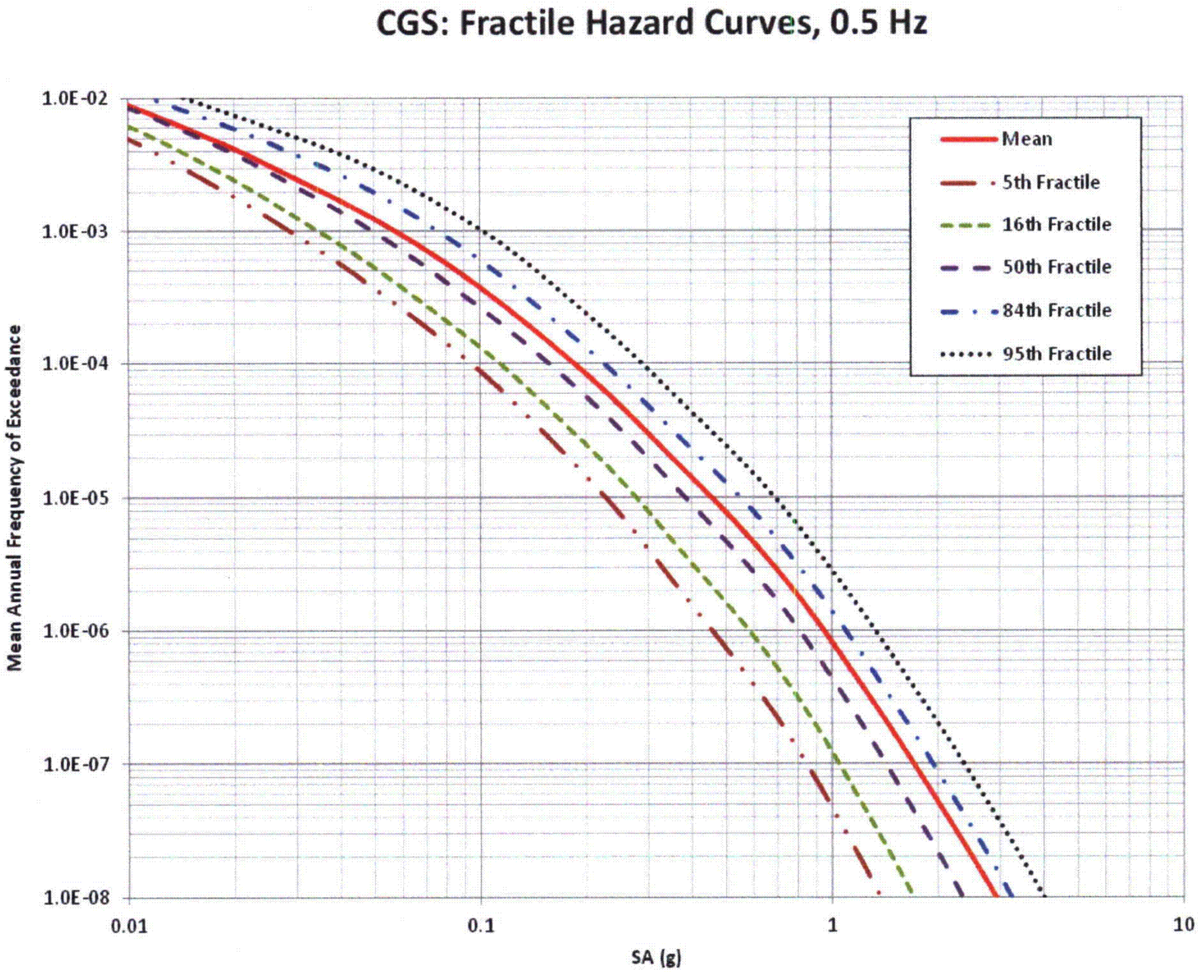


Figure 2.3.7-7: Control Point Mean and 5th, 16th, 50th, 84th, and 95th Percentile Fractile Hazard Curves for the Spectral Frequency 5% Damped SA at 0.5 Hz at the CGS Site

2.4 Control Point Response Spectra

The control point hazard curves described above have been used to develop uniform hazard response spectra (UHRS) and the ground motion response spectrum (GMRS). The UHRS were obtained through linear interpolation in log-log space to estimate the spectral acceleration at each of the 20 oscillator frequencies for the 10^{-4} and 10^{-5} per year hazard levels.

The control point UHRS for 10^{-4} and 10^{-5} hazard levels, along with a design factor (DF) are used to compute the GMRS at the control point using the criteria in Regulatory Guide 1.208 (USNRC, 2007). Table 2.4-1 shows the UHRS and GMRS spectral accelerations and these spectra which are also plotted in Figure 2.4-1.

Table 2.4-1: 5% Damped UHRS for 10^{-4} and 10^{-5} Hazard Levels and GMRS at Control Point for the CGS Site

Frequency (Hz)	Mean UHRS [g] (AFE=10^{-4})	Mean UHRS [g] (AFE=10^{-5})	GMRS [g]
100.000	0.2484	0.4288	0.2484
50.000	0.2951	0.5057	0.2951
33.333	0.3471	0.6242	0.3471
25.000	0.3916	0.7238	0.3916
20.000	0.3595	0.6537	0.3595
13.333	0.4341	0.8088	0.4341
10.000	0.4978	0.9638	0.5067
6.667	0.7427	1.4240	0.7501
5.000	1.2160	2.4340	1.2711
3.333	1.3236	2.8030	1.4474
2.500	0.7958	1.7767	0.9078
2.000	0.7360	1.7620	0.8878
1.333	0.5313	1.3565	0.6748
1.000	0.3781	0.9234	0.4634
0.667	0.3089	0.7104	0.3609
0.500	0.1851	0.4552	0.2281
0.333	0.0837	0.1917	0.0974
0.200	0.0435	0.0912	0.0472
0.133	0.0262	0.0540	0.0280
0.100	0.0196	0.0397	0.0207

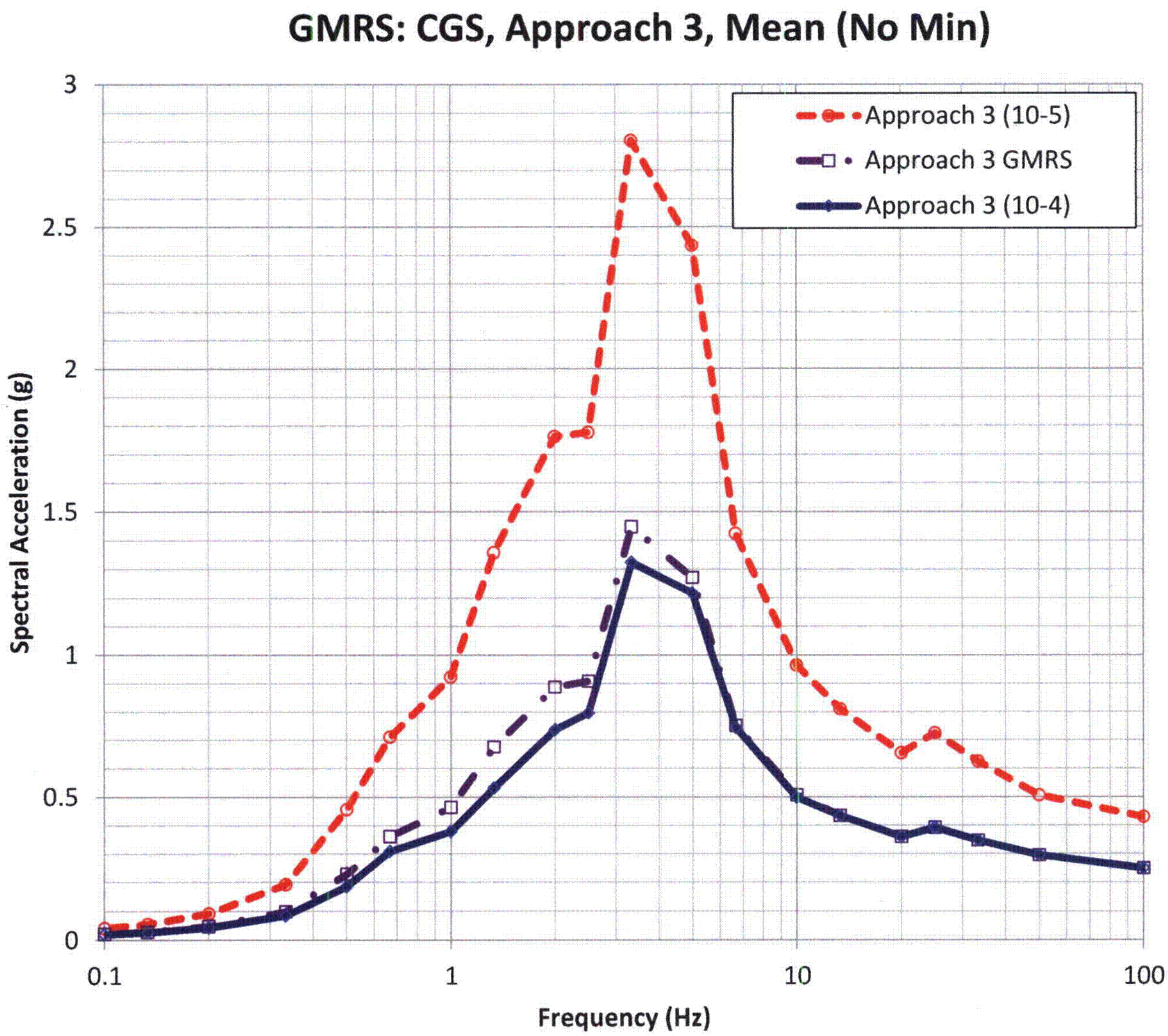


Figure 2.4-1: Control Point UHRS for 10^{-4} and 10^{-5} Hazard Levels and GMRS at Control Point for the CGS Site

3.0 Plant Design Basis and Beyond Design Basis Evaluation Ground Motion

The seismic design basis for CGS is identified in Section 3.7 of the Final Safely Analysis Report (EN, 2013b) and other pertinent documents (EN, 1993, 2003, & 2011).

3.1 SSE Description of Spectral Shape

The SSE was developed in accordance with Appendix A of 10 CFR Part 100 through an evaluation of the maximum earthquake potential for the region surrounding the site. The original investigation of historical seismic activity in the region is described in the FSAR (EN, 1998 and 2013b).

The design response spectrum is based on Newmark-Hall spectrum shape, and hence similar but not identical to Regulatory Guide (RG) 1.60 (NRC, 1973) generic response spectra. However, after the RG 1.60 response spectrum became available, a confirmatory seismic analysis was performed using the RG 1.60 response spectrum scaled to 0.25 g peak ground acceleration to verify that the the structural responses from use of the two spectra were within 10% of each other at almost all locations (see FSAR Section 3.7.1.1). Additionally, Section 3.7.2.5 of the FSAR notes that, for primary metal containment, the RPV, the RPV pedestal, and the sacrificial shield wall, the RG spectrum was used for determination of seismic demands and development of in-structure response spectra.

The original 5% damped horizontal response spectrum and the RG 1.60 response spectrum are shown in Figure 3.1-1 and tabulated in Table 3.1-1.

For analysis of the structures, a set of synthetic time histories was generated and used in the seismic analysis. The response spectra from the time histories enveloped the Operating Basis Earthquake (OBE) response spectra (half of SSE) by a large margin. A typical comparison of the time history response spectrum with SSE spectrum is shown in Figure 3.1-2 (Figure 3.7-8 of the updated FSAR). The response spectrum method of analysis was used for seismic analysis of the Seismic Category I structures. However, time history analyses of the structures were also performed to develop in-structure response spectra for Seismic Category I systems and components in these structures.

Table 3.1-1: The 5% Damped Horizontal SSE for CGS and the RG 1.60 with PGA of 0.25 g

SSE	
Frequency [Hz]	SA [g]
0.40	0.12
2.05	0.60
6.10	0.60
18.9	0.25
100.0	0.25

RG 1.60	
Frequency [Hz]	SA [g]
0.10	0.019
0.25	0.118
2.50	0.783
9.00	0.653
33.00	0.250

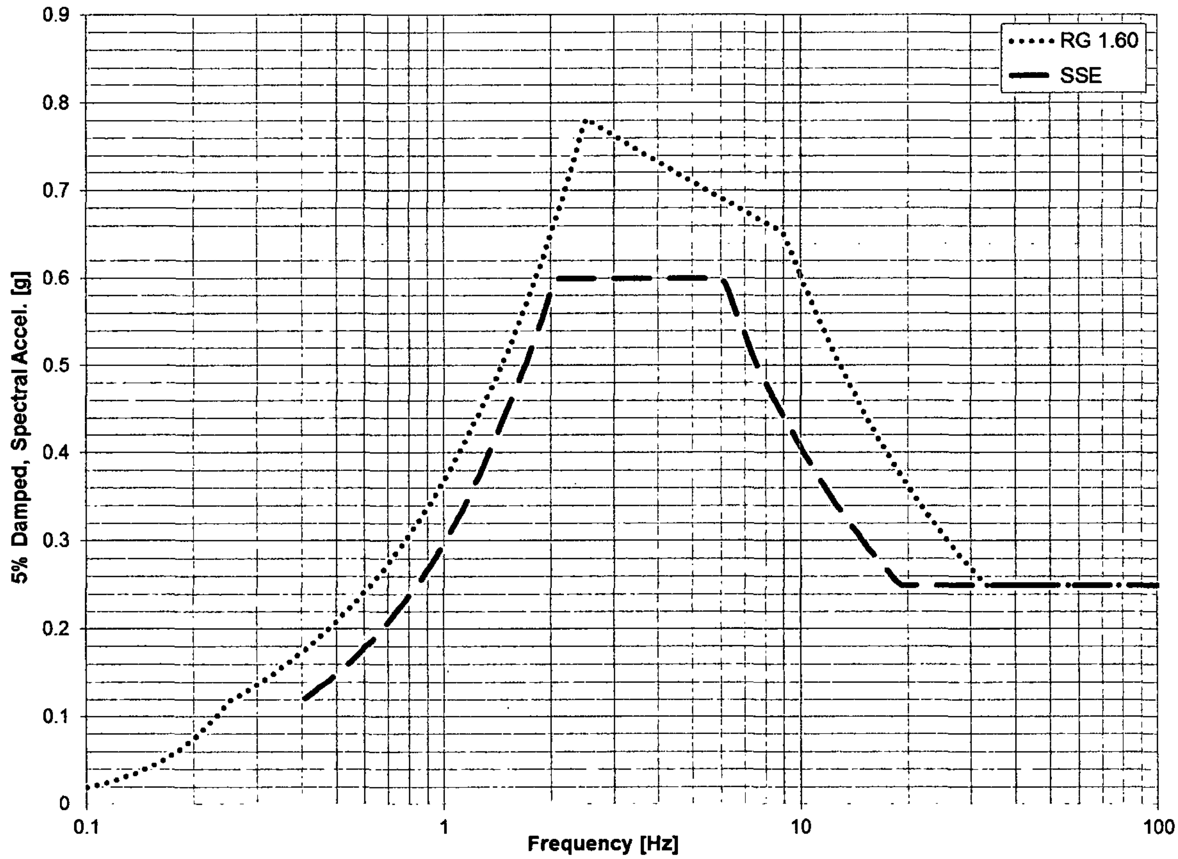


Figure 3.1-1: The 5% Damped Horizontal SSE for CGS and RG 1.60 with PGA 0.25 g (Source: FSAR Figure 3.7-3; EN, 2013b)

Note: RG 1.60 spectrum was used for design of SSCs associated with the primary containment structure.

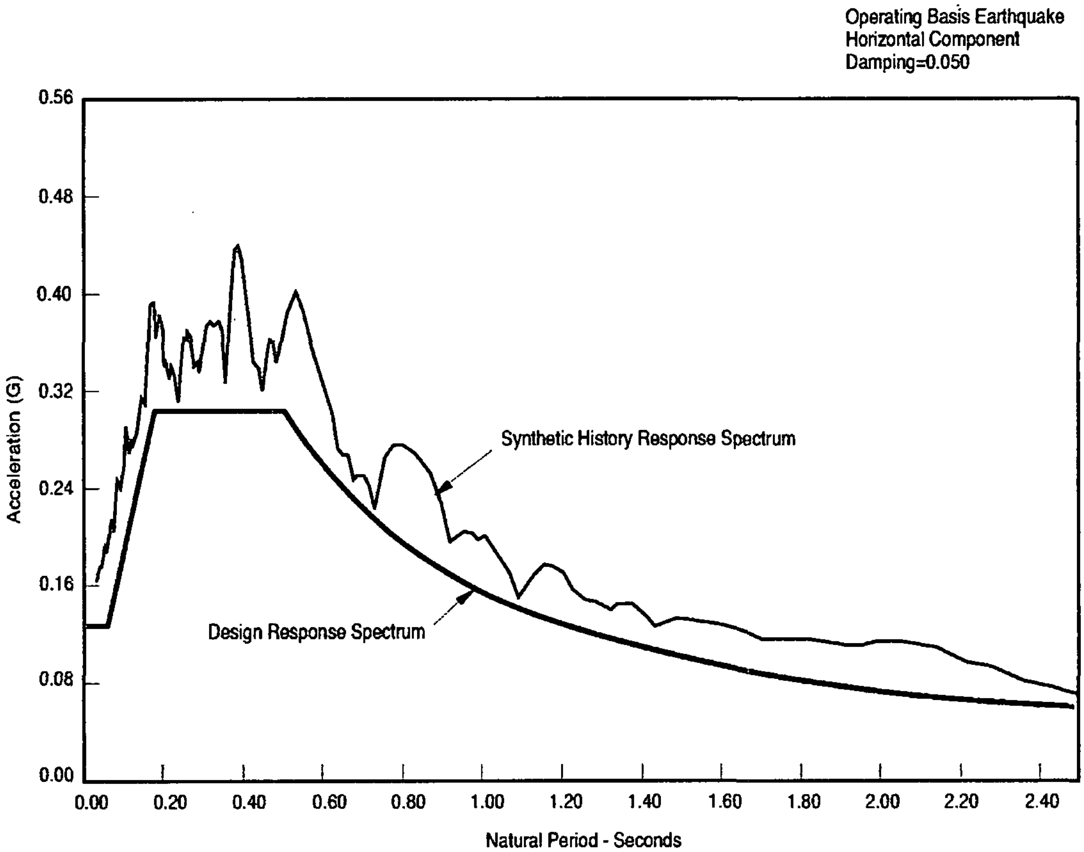


Figure 3.1-2: The 5% Damped SA of the Time Series Used for Analysis (Source: FSAR Figure 3.7-8; EN, 2013b)

3.2 Control Point Elevation

The CGS site is a soil site with a thickness of about 525 ft. All Seismic Category I structures are supported by a soil layer with embedment depth ranging from 4 ft to 21.5 ft (FSAR Table 3.7-2, EN, 2013b). For seismic analyses of the structures, the SSE control point elevation is defined at the basemat level of the structures attached to soil springs for SSI analysis. Given the previous analysis and the recommendations of the SPID document (EPRI, 2013a) for soil sites, the control point elevation is considered to be at the surface of the finished grade (El. 441 ft). This location has therefore been used to compute the GMRS.

3.3 IPEEE Description and Capacity Response Spectrum

Section 5.0 summarizes the Individual Plant Examination of External Events (IPEEE) and post-IPEEE seismic PRA assessment and provides the plant-level high-confidence low-probability of failure (HCLPF) capacity spectrum for the CGS.

4.0 Screening Evaluation

In accordance with SPID (EPRI, 2013a) Section 3, a screening evaluation was performed as described below.

4.1 Risk Evaluation Screening (1 to 10 Hz)

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds the SSE. Therefore, CGS screens in for a risk evaluation.

4.2 High Frequency Screening (> 10 Hz)

For the range above 10 Hz, the GMRS exceeds the SSE. The high frequency exceedances will be addressed in the risk evaluation discussed in 4.1 above.

4.3 Spent Fuel Pool Evaluation Screening (1 to 10 Hz)

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds the SSE. Therefore, CGS screens in for a spent fuel pool evaluation.

5.0 Interim Actions

Based on the screening evaluation, the expedited seismic evaluation described in EPRI (2013b) is planned.

Consistent with NRC letter dated February 20, 2014, (NRC, 2014a) the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of CGS. Therefore, the results do not call into question the operability or functionality of SSCs and are not reportable pursuant to10 CFR 50.72, "Immediate notification requirements for operating nuclear power reactors," and 10 CFR 50.73, "Licensee event report system"..

The NRC letter also requests that licensees provide an interim evaluation or actions to demonstrate that the plant can cope with the reevaluated hazard while the expedited approach and risk evaluations are conducted. In response to that request, NEI letter dated March 12, 2014 (NEI, 2014), provides seismic core damage risk estimates using the updated seismic hazards for the operating nuclear plants in the Central and Eastern United States. These risk estimates continue to support the following conclusions of the NRC GI-199 Safety/Risk Assessment (NRC, 2010b):

> Overall seismic core damage risk estimates are consistent with the Commission's Safety Goal Policy Statement because they are within the subsidiary objective of 10^{-4}/year for core damage frequency. The GI-199 Safety/Risk Assessment, based in part on information from the U.S. Nuclear Regulatory Commission's (NRC's) Individual Plant Examination of External Events (IPEEE) program, indicates that no concern exists regarding adequate protection and that the current seismic design of operating reactors provides a safety margin to withstand potential earthquakes exceeding the original design basis.

CGS is a western plant, and hence it was not included in the March 12, 2014 risk estimates (NEI, 2014). In any case, using the GI-199 Appendix A methodology and based on CGS's most recently reported SCDF value of 4.9×10^{-6}/year, the CGS's plant-level HCLPF capacity is estimated to be 0.395 g (PGA value). It is noted that the 4.9×10^{-6}/year SCDF value is the third SCDF update since the original IPEEE Seismic PRA; one SCDF update because of Seismic PRA update in 2004, and two more SCDF updates due to revision of plant models for internal events (EN, 2011). Integration of the plant- level fragility (corresponding to 0.395 g PGA HCLPF capacity) with the latest PGA seismic hazard results in revised SCDF estimate as 8.5×10^{-7} per year, which is about two orders of magnitude smaller than the 10^{-4} per year maximum seismic risk threshold considered in GI-199 (see further discussion below under the heading "*IPEEE and Post-IPEEE Seismic PRA Assessments*").

Additional information is provided below about the recent 2.3 Seismic Walkdowns, and historical Seismic PRA assessments to demonstrate that: (a) CGS' plant-level HCLPF capacity spectrum well exceeds its seismic design basis spectrum; and (b) CGS plant continues to have a very low seismic risk when the latest PSHA results are factored in.

2.3 Seismic Walkdowns and IPEEE Information

The 2.3 Seismic Walkdowns were performed at CGS during 2013 for a broad range of safety related equipment and the walkdown summary is documented in CGS' final walkdown report (EN, 2013a). The NRC, in letter dated March 11, 2014 (NRC, 2014b), determined that sufficient information was provided to be responsive to Enclosure 3 of the 50.54(f) letter. This concluded the NRC's efforts associated with 2.3 Seismic for CGS. The letter reported that CGS had no significant degraded, non-conforming or unanalyzed conditions that warranted any modification[s] to the plant. CGS had no as-found conditions that would prevent SSCs from performing their required safety functions.

CGS' 2.3 Seismic Walkdown report also noted that all the IPEEE identified issues have been resolved. Based on the NRC staff's review of the report, the staff concluded that the licensee's identification of plant-specific vulnerabilities (including anomalies, outliers and other findings) identified by the IPEEE program, as well as actions taken to eliminate or reduce them, meets the intent of Section 7 (IPEEE vulnerabilities) of the walkdown guidance.

Expedited Seismic Evaluation Process

The Expedited Seismic Evaluation Process (ESEP) walkdowns and seismic margin evaluations for CGS will be initiated later in 2015. The seismic demand used in the ESEP will be 2 x CGS SSE in-structure response spectra (ISRS). It is noted that the plant-level HCLPF capacity spectrum well exceeds the plant SSE spectrum (by a factor of approximately 1.5 to 1.7), and the new PGA hazard curve is enveloped by the PGA hazard curve used in the past Seismic PRA assessments. The combination of these two factors suggests that very few expedited seismic equipment list (ESEL) items, if any, will require upgrade/modifications to achieve seismic margin of at least 2 x SSE.

IPEEE and Post-IPEEE Seismic PRA Assessments

As part of the response to IPEEE-Seismic, CGS performed a full scope seismic PRA assessment in the mid 1990's (EN, 1995). This assessment was performed using the 10,000-year uniform hazard spectrum shape, scaled up to 0.50 g PGA, for use as the RLE spectrum. This ground motion is two times the CGS SSE. In its IPEEE-Seismic report, CGS reported an SCDF value of 2.1×10^{-5} per year using the PGA hazard curve that was developed in 1994. The IPEEE report was reviewed by the NRC and the identified vulnerabilities were resolved.

During CGS' license amendment application for license renewal, three subsequent updates were performed on the original IPEEE Seismic PRA. In 2004, several fragility calculations were updated, resulting in a revised SCDF value of 6.67×10^{-6} per year (the PGA hazard curve from 1994 was the same, albeit extended to cover low annual probabilities of exceedance) (NRC, 2010a). In 2007 and 2010, the plant systems models for Seismic PRA and internal events were successively updated, which led to further reduction of SCDF to 5.24×10^{-6}/year and 4.9×10^{-6} per year, respectively (NRC, 2010a; EN, 2011). Section 5.3.2 of NUREG-1437, Supplement No. 47 (NRC, 2012b), documents NRC's review and acceptance of this decreasing trend in SCDF values. It was also noted in this section that the plant-specific PGA hazard curve based on USGS 2008 work was more benign than the PGA hazard curve that was used for CGS' Seismic PRA studies, thus indicating that the SCDF would be even lower than 4.9×10^{-6} per year if the USGS hazard results were to be used.

The GI-199 methodology was used to estimate the plant-level PGA HCLPF capacity based on the most recently reported SCDF value of 4.9×10^{-6} per year. The HCLPF capacity was determined to be 0.395 g (about 1.6-times higher than the SSE PGA value), and the corresponding HCLPF Capacity Spectrum is provided in Table 5-1 and shown in Figure 5-1.

Table 5-1: CGS Plant-Level HCLPF Capacity Spectrum Calculated Using the 2010 Seismic PRA Results

Frequency [Hz]	5% Damped, Spectral Acceleration [g]
0.500	0.283
0.980	0.608
1.937	0.881
3.214	1.007
4.770	1.034
6.861	0.963
9.720	0.810
19.985	0.522
29.709	0.396
49.765	0.395

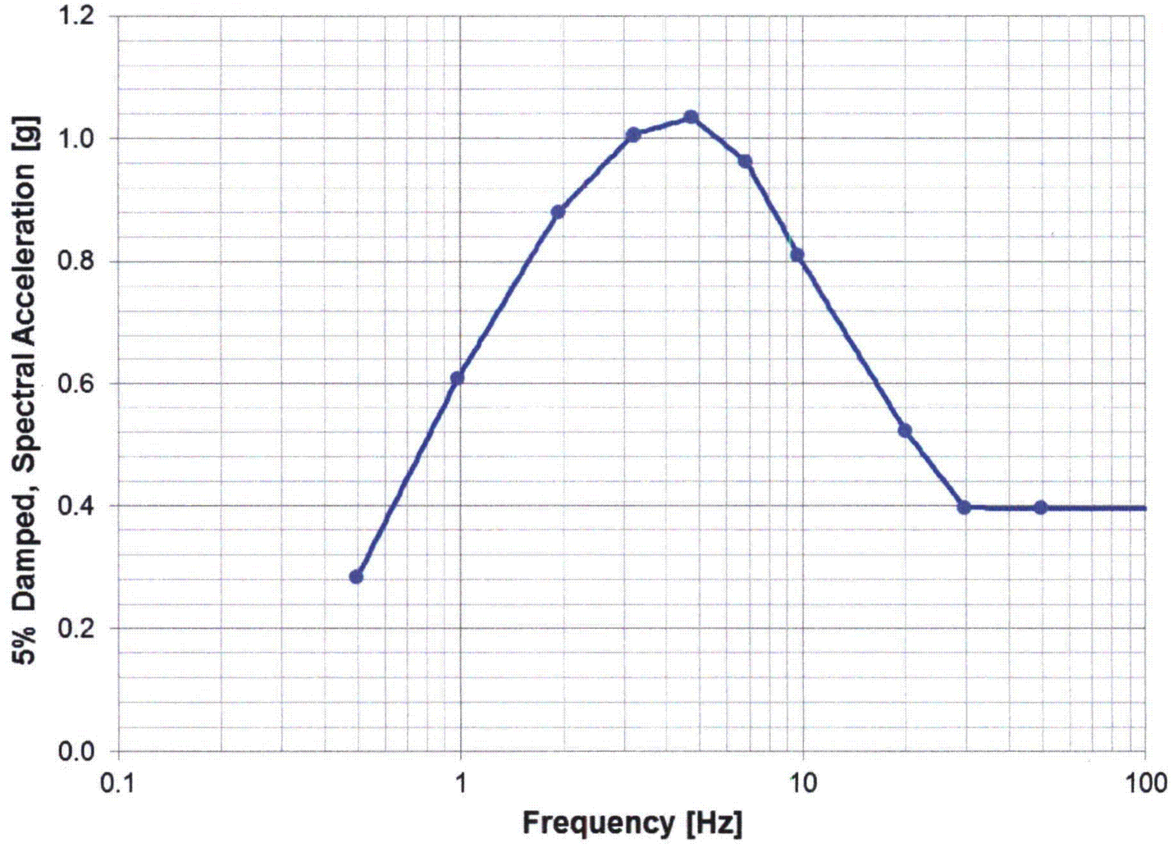


Figure 5-1: CGS Plant-Level HCLPF Capacity Spectrum Calculated Using the 2010 Seismic PRA Results

As seen in Figure 5-2, the latest PGA hazard curve is lower than the PGA hazard curve considered for CGS's earlier Seismic PRA studies (this is similar to how the old hazard curve exceeded the 2008 USGS hazard curve as well). Using the calculated 0.395 g plant-level (PGA) HCLPF capacity based on the 2010 Seismic PRA and the latest PGA hazard curve developed for this report, the revised SCDF for CGS is estimated to be about 8.5×10^{-7} per year. As a result of being "screened in" in this report (see Section 4), the new SCDF value will, however, be more rigorously determined by carrying out new Seismic PRA that will be based on new seismic analyses and fragility analyses considering GMRS as the RLE spectrum. In any case, the (rather low) estimated value of 8.5×10^{-7} per year is indicative of the plant's low seismic risk profile (and suggests that very few, if any, seismic upgrades will be needed as a result of the new Seismic PRA).

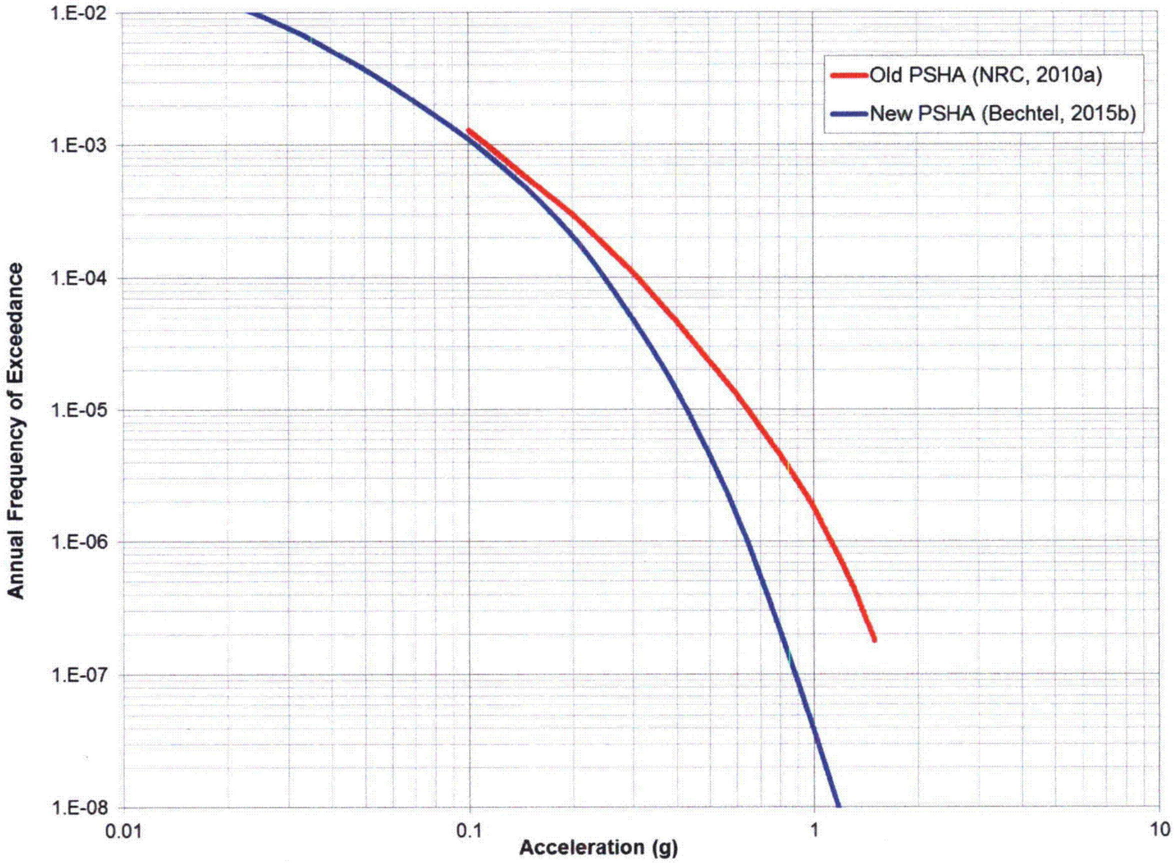


Figure 5-2: Comparison of New PGA Hazard Curve with that Used in Earlier CGS Seismic PRAs

6.0 Conclusions

In accordance with the 50.54(f) request for information, a seismic hazard and screening evaluation was performed for CGS. A GMRS was developed solely for the purpose of screening for additional evaluations in accordance with the SPID (EPRI, 2013a).

Based on the results of the screening evaluation, CGS screens in for a risk evaluation, a Spent Fuel Pool evaluation, and a High Frequency evaluation as part of the risk evaluation.

As discussed in Section 5, previous Seismic PRA evaluations have already shown that the seismic core damage risk is low for CGS, and is expected remain low when new Seismic PRA evaluation is completed.

7.0 References

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Appendix 2.2A

Hanford Sitewide Probabilistic Seismic Hazard Analysis Analytical Process: SSHAC Level 3

The Hanford Probabilistic Seismic Hazard Analysis (PSHA) was conducted using processes that are appropriate for a Study Level 3, as presented in the guidance advanced by the SSHAC in NUREG/CR-6372, *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts*—known informally as the Senior Seismic Hazard Analysis Committee (SSHAC) Guidelines—as well as the detailed implementation guidance provided in NUREG-2117, *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies.*

The input to the PSHA to calculate the hazard at the baserock horizon consists of a seismic source characterization (SSC) model and a ground motion characterization (GMC) model. The SSC model defines the location and average rates of all potential future earthquakes of different magnitudes up to the maximum considered physically possible within each source. The GMC model predicts the expected distribution (defined by a logarithmic mean value and an associated logarithmic standard deviation) of spectral accelerations at a site due to a particular earthquake scenario. The PSHA calculations calculate the resulting ground motions from all possible earthquake scenarios and from sampling the full distribution of ground motion amplitudes, to obtain estimates of the total rate at which each level of acceleration is expected to be exceeded at the site.

The quantity of data available regarding earthquake occurrence and ground motion generation in any region is never sufficient to unambiguously define the SSC and GMC models. One reason for this is that the completeness of the data, and sometimes its quality as well, are such that different experts assessing the data arrive at diverse interpretations, all of which may be technically defensible. Another reason is that the PSHA calculations will always consider earthquake scenarios for which no data at all are available, such as large-magnitude earthquakes at short distances from the site. These are examples of what is referred to as epistemic uncertainty, which reflects lack of knowledge regarding earthquake processes in general and in the study region in particular. This uncertainty is incorporated in the PSHA calculations.

The SSHAC Level 3 process as given in current regulatory guidance defines clear roles and responsibilities for all participants. All technical assessments including the final hazard model and documentation are developed by Technical Integration (TI) Teams that perform this work in two stages: evaluation and integration. In the evaluation stage, the TI Teams assess available data, methods, and models both for their inherent quality and reliability, and specifically for their applicability to the region and site under consideration. In the integration phase, the TI Teams construct logic trees that capture the center, the body, and the range of technically defensible interpretations. The work is conducted under the continuous observation of the Participatory

Peer Review Panel (PPRP), which is charged with performing both technical and process reviews. The PPRP is responsible for reviewing the activities of the TI Teams to ensure that the project satisfactorily considers available data, methods, and models; captures the center, body, and range of technically defensible interpretations; and adequately documents the technical bases of all decisions. PPRP concurrence that these goals have been met is the key indicator of successful compliance with the requirements of a SSHAC Level 3 process.

The Hanford PSHA was conducted from April 2012 to October 2014. The project included a kick-off meeting in April 2012 conducted at PNNL facilities in Richland, Washington, and a tour of the Hanford region. Three workshops were held in Walnut Creek, California. Workshop 1 identified significant seismic hazard issues and data available to address those issues. Workshop 2 reviewed the databases assembled by the teams and discussed alternative models that related to the seismic source or ground motion models for the project. Workshop 3 provided an opportunity for the technical integration teams to present their preliminary SSC and GMC models to the PPRP and receive feedback. Hazard feedback based on hazard calculations using the preliminary models was also provided at Workshop 3. Seven working meetings (four for seismic source characterization and three for ground motion characterization) were held in Oakland, California, over the course of the project to facilitate interaction between the team members; due to family circumstance preventing travel, the first GMC Working Meeting was conducted as a conference call. As is typical of SSHAC Level 3 projects, the total number of participants entailed a large group of about 50 individuals.

Appendix 2.2B
Hanford Sitewide Probabilistic Seismic Hazard Analysis
PPRP Closure Letter

November 15, 2014

Mr. Robert W. Bryce
Hanford PSHA Project Manager
Pacific Northwest National Laboratory
902 Battelle Boulevard
P.O. Box 999, MSIN K6-75
Richland, WA 99352

Subject: Hanford Site-Wide Probabilistic Seismic Hazard Analysis Participatory Peer Review Panel Closure Letter

Dear Mr. Bryce:

Consistent with the requirements for a SSHAC[1] Level 3 study, the Hanford Site-Wide (HSW) Probabilistic Seismic Hazard Analysis (PSHA) Participatory Peer Review Panel (hereafter "PPRP" and "Panel") is pleased to issue this PPRP Closure Letter containing our findings with respect to the HSW PSHA SSHAC Level 3 project. The Panel participated in the study following implementation guidance for a SSHAC Level 3[2] study. The Panel was actively engaged in all phases and activities of the Project's implementation, including final development of the Project Plan and planning of the evaluation and integration activities, which are the core of the SSHAC assessment process.

Consistent with regulatory guidance for SSHAC projects, the role of the PPRP is to conduct a review of both the *process* followed and the *technical* assessments made by the Technical Integration (TI) Teams. Accordingly, this letter documents the activities that the PPRP has undertaken in its review of the PSHA, its review of the adequacy of the process followed, and its findings relative to the technical adequacy of the PSHA.

PPRP Activities for the PSHA Review

The notion of a participatory peer review process entails the continual review of a project from its start to its completion. Thus, proper implementation requires adequate opportunities during the conduct of the study for the PPRP to understand the data being used, the analyses performed for the study, the TI Team's evaluations and integration of the technical bases for its assessments, and the completeness and clarity of the

[1]Budnitz, R.J., G. Apostolakis, D.M. Boore, L.S. Cluff, K.L. Coppersmith, C.A. Cornell, and P.A. Morris (1997). *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and the Use of Experts (known as the "Senior Seismic Hazard Analysis Committee Report", or "SSHAC Guideline")*, NUREG/CR-6372, U.S. Nuclear Regulatory Commission, TIC; 235076, Washington, D.C.

[2]USNRC (2012). *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*, NUREG-2117, U.S. Nuclear Regulatory Commission, Washington, D.C.

documentation. Participatory review also involves opportunities for the PPRP to provide its reviews and comments in written form during the conduct of the project, such that the suggestions and recommendations made by the Panel can be considered by the TI Teams in a timely fashion prior to completion of the work. Written comments by the PPRP serve to document the review process and provide a vehicle for ensuring that all aspects of the SSHAC process have been adequately conducted.

The activities of the PPRP for the HSW PSHA are summarized in the table below, which include written reviews during various stages of the project.

Date	PPRP Activity
April 23, 2012	Kick-off Meeting and Site Tour: All PPRP members attended in person
May 25, 2012	Submittal of PPRP written review comments on Kick-off Meeting
July 23-27, 2012	SSHAC Workshop No. 1: All PPRP members attended in person as observers
August 11, 2012	Submittal of PPRP written review comments on SSHAC Workshop No. 1
September 11, 2012	GMC Working Meeting No. 1a: PPRP representative attended via teleconference as an observer
September 17-19, 2012	SSC Working Meeting No. 1: PPRP representatives attended in person as observers
October 24, 2012	GMC Working Meeting No. 1b: PPRP representatives attended via teleconference as observers
December 3-8, 2012	SSHAC Workshop No. 2: All PPRP members attended in person as observers
January 3, 2013	Submittal of PPRP written review comments on SSHAC Workshop No. 2
February 18-21, 2013	GMC Working Meeting No. 2: PPRP representatives attended in person as observers
February 25-28, 2013	SSC Working Meeting No. 2: PPRP representatives attended in person as observers
August 13-16, 2013	GMC and SSC Working Meetings No. 3: PPRP representatives attended via teleconference and in person as observers
September 17, 2013	Quaternary Geologic Studies Field Trip: PPRP representative attended in person as an observer
November 11-15, 2013	SSHAC Workshop No. 3: All PPRP members attended in person as active participants
December 7, 2014	Submittal of PPRP written review comments on SSHAC Workshop No. 3
January 13-16, 2014	SSC Working Meeting No. 4: PPRP representatives attended via teleconference and in person as observers
January 13-17, 2014	GMC Working Meeting No. 4: PPRP representative attended in person as an observer
March 6-7, 2014	PPRP Briefing Meeting on changes made to the GMC and SSC models following Workshop No. 3 and on the PPRP written review comments on Workshop No. 3: All PRPP members attended in person as active participants
June 16, 2014	Submittal of PPRP written review comments on HSW PSHA Draft Report No. 1
June 18, 2014	Teleconference with TI Teams to discuss PPRP written review comments on partially complete HSW PSHA draft report: All PRPP members attended

June 30, 2014	Submittal of PPRP written review comments on HSW PSHA Draft Report No. 2 and on TI Teams' responses to PPRP written review comments on PSHA Draft Report No. 1
October 23, 2014	Submittal of PPRP written review comments on HSW PSHA Draft Report No. 3 and on TI Teams' responses to PPRP written review comments on PSHA Draft Report No. 2
November 11, 2014	Submittal of PPRP written review comments on HSW PSHA Draft Report No. 4 and on TI Teams' responses to PPRP written review comments on PSHA Draft Report No. 3
November 16, 2014	Submittal of HSW PSHA PPRP Closure Letter

The activities listed above are those that were related directly to the conduct of the HSW PSHA and the development of the HSW PSHA report. Prior to the HSW PSHA work activities, the Panel was provided with the Mid-Columbia Project PSHA report and other documents related to Hanford Site seismic hazards. Although those documents provided a useful background for the Panel, this letter does not address these activities, because they lie outside of the SSHAC Level 3 process for the new HSW PSHA.

The Panel concludes that its ongoing review and feedback interactions with the TI Teams during the conduct the HSW PSHA project activities fully met the expectations for a SSHAC Level 3 study. From the presentation of the plans for conducting the HSW PSHA at the outset of the project to the completion of the HSW PSHA report, the TI Teams provided multiple and effective communications to the PPRP. Conference calls and written communications allowed the PPRP to fully understand the technical support for the TI Teams' assessments. The TI Teams provided written responses to PPRP comments documenting that all comments had been adequately considered during the conduct of the work and its documentation.

SSHAC *Process* Review

As explained in NUREG-2117 (USNRC, 2012), the SSHAC process consists of two important activities, described as follows:

> "The fundamental goal of a SSHAC process is to carry out properly and document completely the activities of evaluation and integration, defined as:
>
> - *Evaluation*: The consideration of the complete set of data, models, and methods proposed by the larger technical community that are relevant to the hazard analysis.
> - *Integration*: Representing the center, body, and range of technically defensible interpretations in light of the evaluation process (i.e., informed by the assessment of existing data, models, and methods)."

These activities are essential to any SSHAC Level study and to both refinements to existing studies as well as new PSHAs (such as the HSW PSHA).

During the *Evaluation* phase of the HSW PSHA, the TI Teams considered new data, models, and methods that have become available in the technical community since the previous HSW PSHA project was completed in 1995. Importantly, the TI Teams also evaluated new site-specific data and methods for conducting site-response analysis, which is included as part of the HWS PSHA project as guidelines that ensure that there is a proper interface between the reference-rock hazard and the site-response analyses that will be conducted by the engineering consultants. The Panel concludes that the TI Teams conducted an adequate evaluation process and that this process has been sufficiently documented in the PSHA report.

During the *Integration* phase of the project, SSC and GMC models and site-response methodological guidance were developed for purposes of the HSW-specific PSHA. SSHAC guidelines require that the technical bases for the PSHA model be documented thoroughly in the PSHA report. The PSHA document demonstrates the consideration by the TI Teams of the existence of seismic-source and ground-motion data and models that have become available since the previous HSW PSHA model was developed. The site-response guidelines entailed developing shear-wave velocity profiles for the Saddle Mountain Basalts and conducting a site-response analysis in light of models and methods that have been identified by the U.S. Nuclear Regulatory Agency and used in recent analyses for nuclear facilities. Documentation in the PSHA report confirms that the GMC TI Team was aware of the applicable site-specific data, as well as models and methods for building the profiles, accounting for uncertainties, and carrying out the site-response analysis in order to develop these guidelines.

Based on the review of the *Evaluation* and *Integration* activities conducted by the TI Teams, as well as the documentation of these activities in the PSHA report, the PPRP concludes that the SSHAC process has been adequately conducted.

SSHAC *Technical* Review

The role of the PPRP in the review of the technical aspects of the project is specified in NUREG-2117 (USNRC, 2012) as follows:

> "The PPRP fulfills two parallel roles, the first being technical review. This means that the PPRP is charged with ensuring that the full range of data, models, and methods have been duly considered in the assessment and also that all technical decisions are adequately justified and documented.
>
> The responsibility of the PPRP is to provide clear and timely feedback to the TI/TFI and project manager to ensure that any technical or process deficiencies are identified at the earliest possible stage so that they can be corrected. More commonly, the PPRP provides its perspectives and advice regarding the manner in which ongoing activities can be improved or carried out more effectively. In terms of technical review, a key responsibility of the PPRP is to highlight any data, models or proponents that have not been

considered. Beyond completeness, it is not within the remit of the PPRP to judge the weighting of the logic-trees in detail but rather to judge the justification provided for the models included or excluded, and for the weights applied to the logic-tree branches."

Consistent with this USNRC guidance, the PPRP reviewed at multiple times during the project the TI Teams' analyses and evaluations of data, models, and methods. These reviews included conference calls, post-workshop meetings, written comments, and the review of drafts of the PSHA report. Through these reviews, the PPRP communicated feedback to the TI Teams regarding data and approaches that did not appear to have been considered, suggestions for methods being used within the technical community, and recommendations for ways that the documentation could be improved to include more discussion of the technical bases for the assessments.

Examples of PPRP feedback regarding the technical aspects of the project can be found in the written comments provided at various times to the TI Teams.

The TI Teams were responsive to the questions, comments, and suggestions made by the PPRP relative to the technical aspects of the project. Therefore, the Panel concludes that the technical aspects of the projects have been adequately addressed.

Conclusion

On the basis of the PPRP's review of the HSW PSHA, the Panel concludes that both the process and technical aspects of the assessment fully meet accepted guidance and current expectations for a SSHAC Level 3 study.

We appreciate the opportunity to provide our review of the project.

Sincerely,

HSW PSHA PPRP Members

Kenneth W. Campbell
Chair

Brian S.-J. Chiou

William R. Lettis

William U. Savage

J. Carl Stepp