2.3.4 *Input Spectra*

Consistent with the guidance in Appendix B of the SPID (Reference 3), input Fourier amplitude spectra were defined for a single representative earthquake magnitude (**M** 6.5) using two different assumptions regarding the shape of the seismic source spectrum (single-corner and double-corner). A range of 11 different input amplitudes (median peak ground accelerations (PGA) ranging from 0.01g to 1.50g) were used in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed[1] for the analysis of Braidwood station were the same as those identified in Tables B-4, B-5, B-6 and B-7 of the SPID as appropriate for typical CEUS sites.

2.3.5 *Methodology*

To perform the site response analyses for the Braidwood site, a random vibration theory (RVT) approach was employed. This process utilizes a simple, efficient approach for computing site-specific amplification functions and is consistent with existing NRC guidance and the SPID (Reference 3). The guidance contained in Appendix B of the SPID on incorporating epistemic uncertainty in shear-wave velocities, kappa, non-linear dynamic properties and source spectra for plants with limited at-site information was followed for Braidwood station.

2.3.6 *Amplification Functions*

The results of the site response analysis consist of amplification factors (5% of critical damping pseudo absolute response spectra) which describe the amplification (or de-amplification) of hard reference rock motion as a function of frequency and input reference rock amplitude. The amplification factors are represented in terms of a median amplification value and an associated standard deviation (sigma) for each oscillator frequency and input rock amplitude. Consistent with the SPID (Reference 3) a minimum median amplification value of 0.5 was employed in the present analysis. Figure 2.3.6-1 illustrates the median and +/- 1 standard deviation in the predicted amplification factors developed for the eleven loading levels parameterized by the median reference (hard rock) peak acceleration (0.01g to 1.50g) for profile P1 and the SPID (Reference 3) rock G/G_{max} and hysteretic damping curves. The variability in the amplification factors results from variability in shear-wave velocity, depth to hard rock, and modulus reduction and hysteretic damping curves. To illustrate the effects of nonlinearity at Braidwood station firm rock site, Figure 2.3.6-2 shows the corresponding amplification factors developed with linear site response analyses (model M2). Between the linear and nonlinear (equivalent-linear) analyses, Figures 2.3.6-1 and Figure 2.3.6-2 respectively show only a minor difference for frequencies below about 20 Hz and the 0.5g loading level and below. Above about the 0.5g loading level, the differences increase significantly but only above about 20 Hz. Tabulated values of amplification factors are provided in Tables A-2b1 and A-2b2 in Appendix A.

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[1] Assumptions discussed in Section 2 are priovded by EPRI engineers (Reference 11) in accordance with implementation of the SPID (Reference 3) methodology.

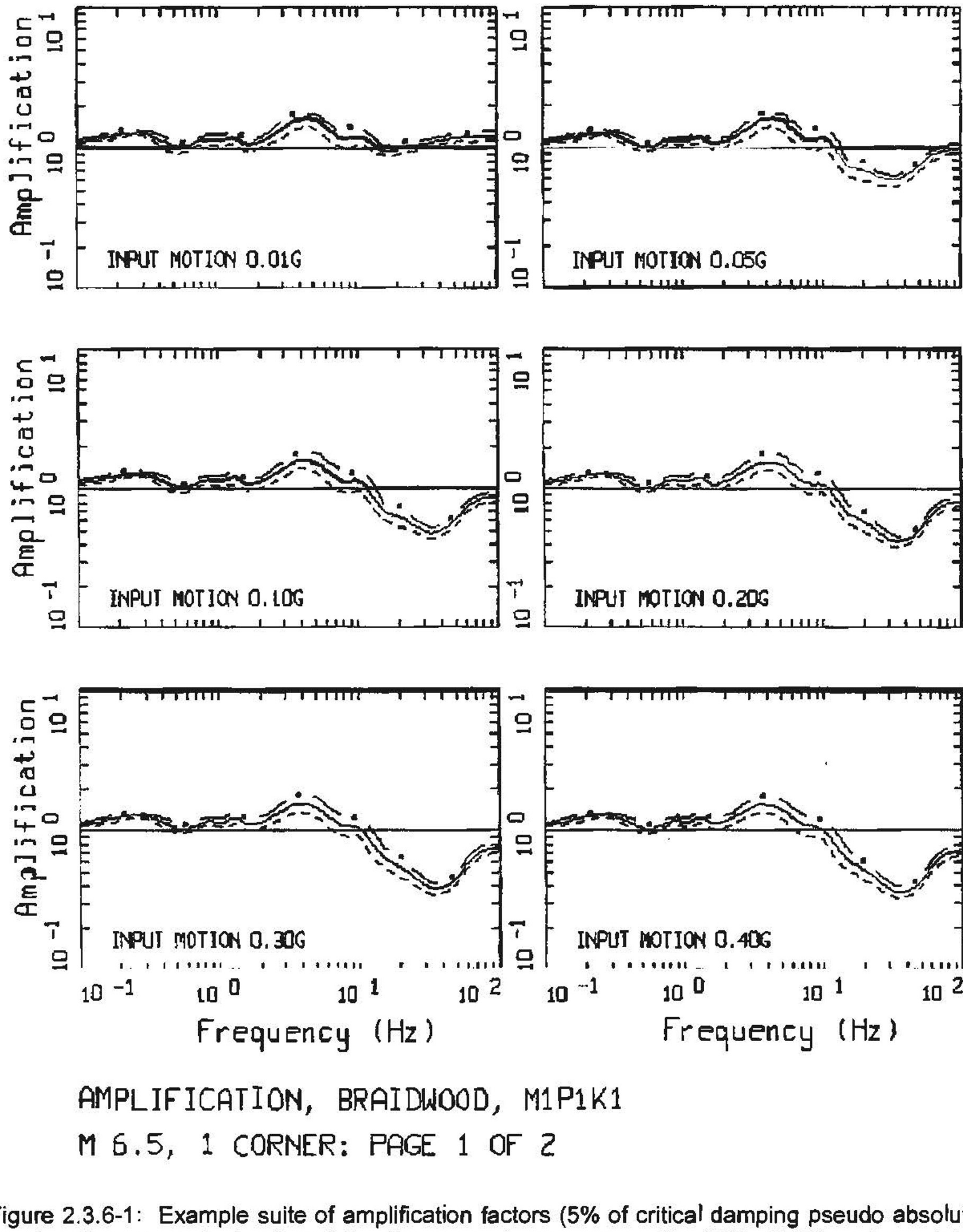
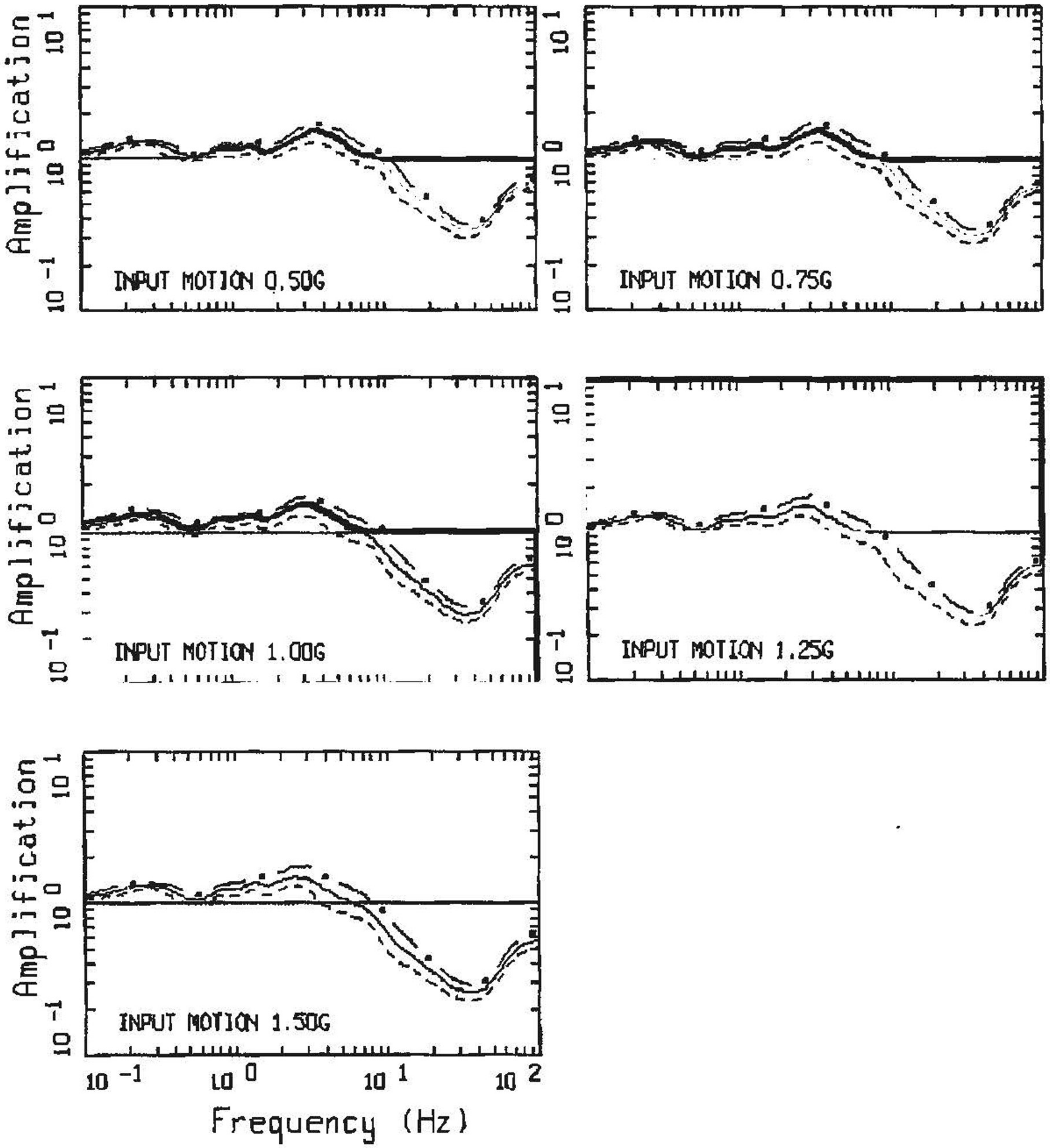


Figure 2.3.6-1: Example suite of amplification factors (5% of critical damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa (K1) at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (Reference 3) (Reference 11)



AMPLIFICATION, BRAIDWOOD, M1P1K1

M 6.5, 1 CORNER: PAGE 2 OF 2

Figure 2.3.6-1: (Continued)

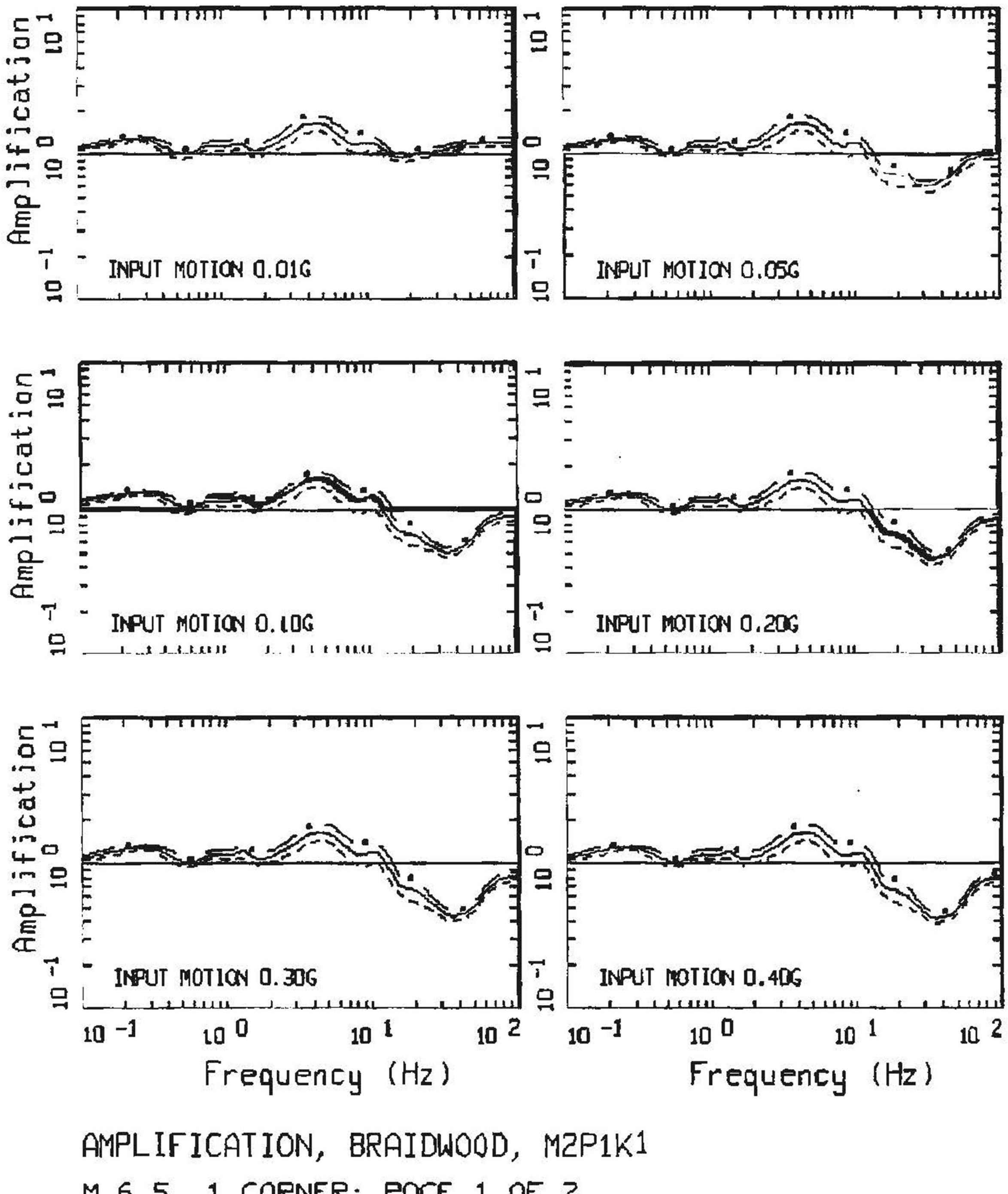


Figure 2.3.6-2: Example suite of amplification factors (5% of critical damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), linear site response (model M2), and base-case kappa (K1) at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (Reference 3) (Reference 11)

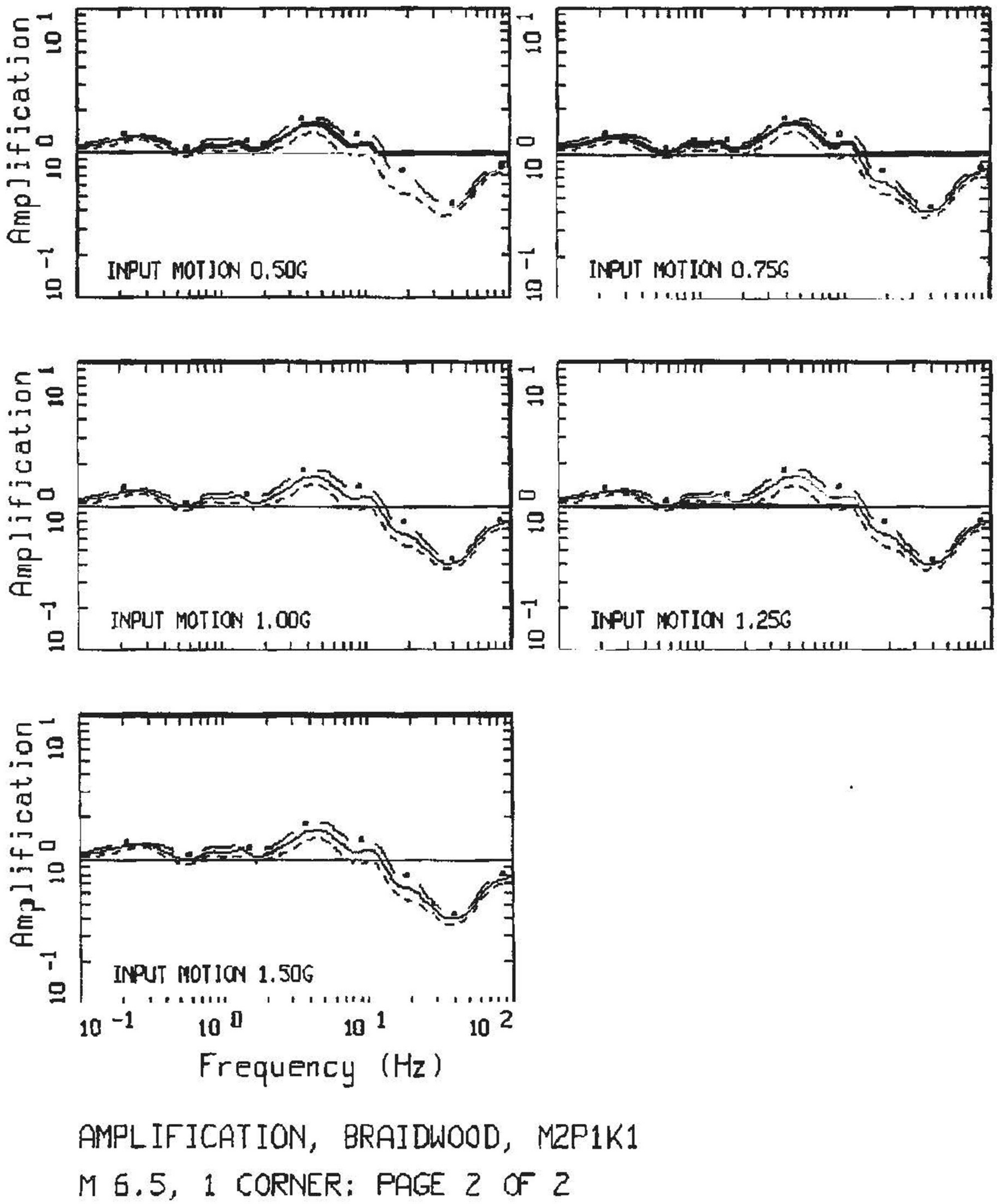


Figure 2.3.6-2: (Continued)

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 Section B-6.0 of the SPID (Reference 3). This procedure (referred to as Method 3) computes a site-specific control point hazard curve for a broad range of spectral accelerations given the site-specific bedrock hazard curve and site-specific estimates of soil or soft-rock response and associated uncertainties. This process is repeated for each of the seven spectral frequencies for which ground motion equations are available. The dynamic response of the materials below the control point was represented by the frequency- and amplitude-dependent amplification functions (median values and standard deviations) developed and described in the previous section. The resulting control point mean hazard curves for Braidwood are shown in Figure 2.3.7-1 for the seven spectral frequencies for which ground motion equations are defined. Tabulated values of mean and fractile seismic hazard curves and site response amplification functions are provided in Appendix A.

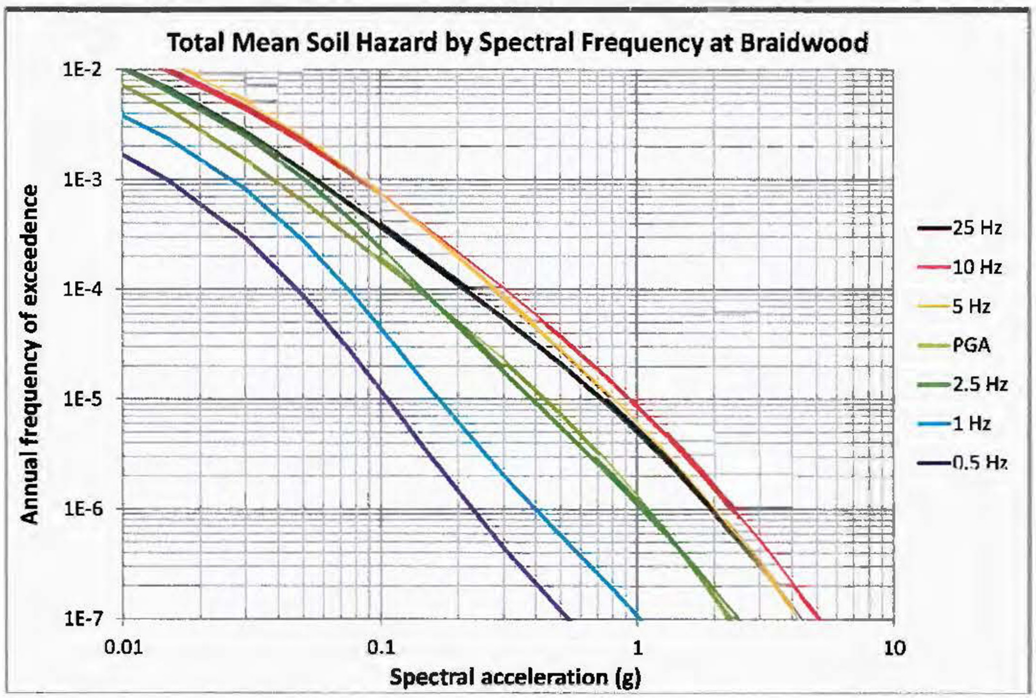


Figure 2.3.7-1: Control point mean hazard curves for spectral frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 Hz (PGA) at Braidwood (5% of critical damping) (Reference 11)

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 spectral frequency for the 1E-4 and 1E-5 per year hazard levels.

The 1E-4 and 1E-5 UHRS, along with a Design Factor (DF), are used to compute the GMRS at the control point using the criteria in Regulatory Guide 1.208 (Reference 15). Table 2.4-1 shows the UHRS and GMRS spectral accelerations for a range of spectral frequencies.

Table 2.4-1: UHRS and GMRS at the control point for Braidwood (5% of critical damping) (Reference 11)

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
100	1.39E-01	4.35E-01	2.08E-01
90	1.40E-01	4.40E-01	2.10E-01
80	1.40E-01	4.46E-01	2.12E-01
70	1.42E-01	4.55E-01	2.16E-01
60	1.45E-01	4.70E-01	2.23E-01
50	1.52E-01	5.01E-01	2.37E-01
40	1.67E-01	5.60E-01	2.64E-01
35	1.79E-01	6.05E-01	2.85E-01
30	1.93E-01	6.58E-01	3.09E-01
25	2.12E-01	7.27E-01	3.41E-01
20	2.29E-01	7.68E-01	3.62E-01
15	2.66E-01	8.63E-01	4.09E-01
12.5	2.84E-01	9.08E-01	4.32E-01
10	3.01E-01	9.33E-01	4.47E-01
9	3.00E-01	9.22E-01	4.42E-01
8	2.94E-01	8.95E-01	4.30E-01
7	2.84E-01	8.59E-01	4.13E-01
6	2.78E-01	8.32E-01	4.01E-01
5	2.72E-01	7.99E-01	3.86E-01
4	2.49E-01	7.05E-01	3.44E-01
3.5	2.28E-01	6.34E-01	3.10E-01
3	1.88E-01	5.15E-01	2.53E-01
2.5	1.44E-01	3.88E-01	1.91E-01
2	1.19E-01	3.09E-01	1.53E-01
1.5	9.52E-02	2.33E-01	1.17E-01
1.25	8.77E-02	2.06E-01	1.04E-01
1	7.51E-02	1.68E-01	8.58E-02

Table 2.4-1: (Continued)

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
0.9	7.25E-02	1.62E-01	8.28E-02
0.8	6.88E-02	1.54E-01	7.87E-02
0.7	6.23E-02	1.40E-01	7.12E-02
0.6	5.44E-02	1.22E-01	6.22E-02
0.5	4.74E-02	1.06E-01	5.42E-02
0.4	3.79E-02	8.50E-02	4.34E-02
0.35	3.32E-02	7.43E-02	3.80E-02
0.3	2.84E-02	6.37E-02	3.25E-02
0.25	2.37E-02	5.31E-02	2.71E-02
0.2	1.90E-02	4.25E-02	2.17E-02
0.15	1.42E-02	3.19E-02	1.63E-02
0.125	1.18E-02	2.66E-02	1.36E-02
0.1	9.48E-03	2.12E-02	1.08E-02

The 1E-4 and 1E-5 UHRS are used to compute the GMRS at the control point and are shown in Figure 2.4-1.

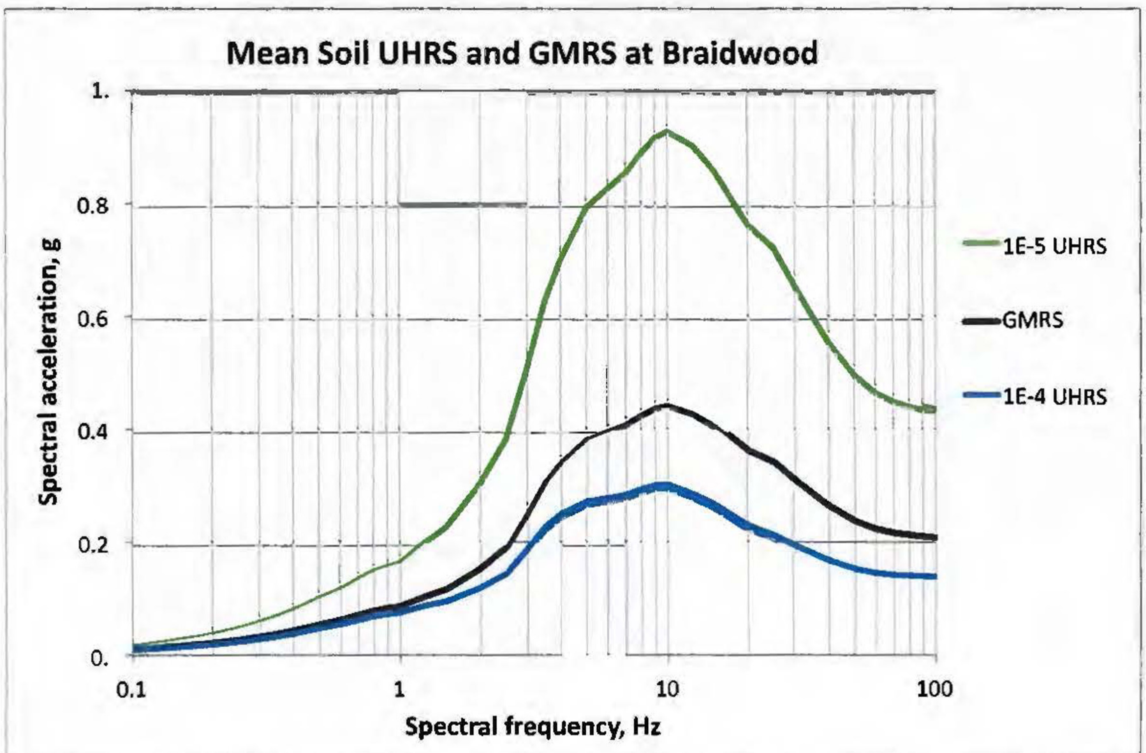


Figure 2.4-1: Plots of 1E-4 and 1E-5 UHRS and GMRS at control point for Braidwood (5% of critical damping response spectra) (Reference 11)

3 Plant Design Basis and Beyond Design Basis Evaluation Ground Motion

The recommended safe shutdown earthquake (SSE) was initially defined as the occurrence of an Intensity MM VII event near the site. This near field event would produce maximum horizontal ground accelerations of 0.13g. However, at the time of the review of the construction permit application, the NRC considered the occurrence of an earthquake of Intensity MM VIII to be equally probable (a lower order of probability) at any place in the eastern Central Stable Region. The NRC also took the position that, based on the postulated occurrence of an Intensity MM VIII at the site, a safe shutdown earthquake of 0.20g at the bedrock-till interface was adequately conservative for the Braidwood station. (Reference 10)

Seismic design of Braidwood station is based upon a ground surface acceleration of 0.26g and Regulatory Guide 1.60 response spectra shape for SSE. The following description is provided in Section 3.7.1.1 of the UFSAR (Reference 10) for the design response spectra for the design basis of Braidwood station:

> "During the review of the FSAR for an Operating License, the Byron/Braidwood seismic design was reevaluated using the Regulatory Guide 1.60 spectra without the application of a deconvolution analysis. Attachment 3.7A contains the specific NRC questions / responses on seismic design. These questions and responses document the historical evolution of certain aspects of the Byron/Braidwood seismic design. Attachment 3.7A also provides the details and results of this reevaluation. It is concluded that the present seismic design of Byron / Braidwood is conservative. Based on the reevaluation described in Attachment 3.7A, the Byron / Braidwood seismic design basis is acceptable and will therefore be used for all future seismic evaluations."

Based on the above summary description of Braidwood station seismic design, the following is concluded:

- The seismic design is based on ground surface acceleration of 0.26g and Regulatory Guide 1.60 response spectra shape.
- The seismic design also satisfies 0.20g and Regulatory Guide 1.60 response spectra shape at the bedrock-soil interface. Per Subsection 3.7.1.2 of the UFSAR (Reference 10), the bedrock-soil interface is on an average 38 feet below the grade elevation.

The reevaluation criteria used for Braidwood considering a 0.2g PGA Regulatory Guide 1.60 response spectra shape at the bedrock-soil interface was accepted by the NRC and therefore is used for the GMRS comparison.

3.1 SSE DESCRIPTION OF SPECTRAL SHAPE

The SSE is defined in terms of a PGA and a design response spectrum. The SSE is a 0.20g PGA Regulatory Guide 1.60 spectrum as described above. Table 3.1-1 shows the spectral acceleration values as a function of frequency for the 5% of critical damping horizontal SSE, and Figure 3.1-1 plots the horizontal SSE response spectra.

Table 3.1-1: Horizontal Safe Shutdown Earthquake response spectrum for Braidwood (5% of critical damping) (Reference 14)

Frequency (Hz)	Spectral Acceleration (g)
0.35	0.124
0.5	0.167
1	0.295
1.25	0.354
2	0.521
2.5	0.626
3	0.610
4	0.586
5	0.567
6	0.553
7	0.541
8	0.531
9	0.522
10	0.483
12	0.422
12.5	0.410
13	0.398
15	0.358
20	0.289
25	0.246
28	0.226
30	0.215
33	0.200
40	0.200
50	0.200
100	0.200

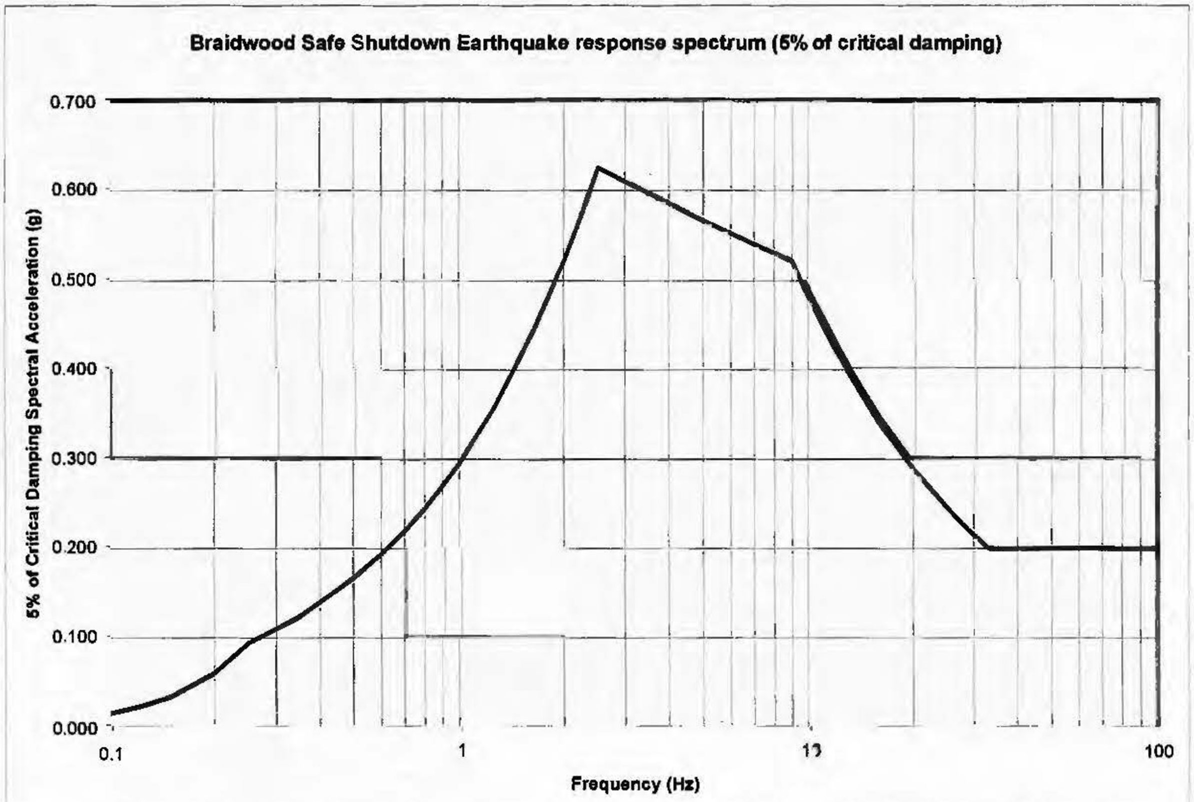


Figure 3.1-1: Braidwood Safe Shutdown Earthquake horizontal response spectrum (5% of critical damping)

3.2 CONTROL POINT ELEVATION

In accordance with Section 2.4.2 of the SPID (Reference 3), the licensing design basis definition of the SSE control point for Braidwood station is used for comparison to the GMRS. Section 3.7A of the site UFSAR (Reference 10), states that the 0.20g Regulatory Guide 1.60 (Reference 13) SSE site response spectra is specified at the bedrock-till interface (EL. 562 feet).

4
Screening Evaluation

Following completion of the seismic hazard reevaluation, as requested in the 50.54(f) letter (Reference 1), a screening process is needed to determine if a risk assessment is needed. The horizontal GMRS determined from the hazard reevaluation is used to characterize the amplitude of the new seismic hazard at each of the nuclear power plant sites. The screening compares the GMRS with the 5% of critical damping horizontal SSE, and is performed in accordance with SPID Section 3, as described below.

4.1 Risk Evaluation Screening (1 to 10 Hz)

In the frequency range of 1 Hz to 10 Hz, the SSE exceeds the GMRS. Therefore, a risk evaluation will not be performed.

4.2 High Frequency Screening (>10 Hz)

For a portion of the frequency range above 10 Hz, the GMRS exceeds the SSE. Therefore, a high frequency confirmation will be performed.

Section 3.4 of the SPID (Reference 3) discusses high-frequency exceedances. It discusses the impact of high-frequency ground motion on plant components and identifies the component groups that are sensitive to high-frequency vibration. A two-phase test program is described, which is currently ongoing, that will develop data to support the high-frequency confirmation.

The SPID concludes that high-frequency vibration is not damaging, in general, to components with strain- or stress-based failure modes, based on EPRI Report NP-7498 (Reference 22). But components, such as relays, subject to electrical functionality failure modes have unknown acceleration sensitivity for frequencies above 16 Hz.

EPRI Report 1015108 (Reference 20) provides evidence that supports the conclusion that high-frequency motions are not damaging to the majority of nuclear plant components, excluding relays and other electrical devices whose output signals may be affected by high-frequency vibration. EPRI Report 1015109 (Reference 21) provides guidance for identifying and evaluating potentially high-frequency sensitive components. Guidance from these documents is considered in the SPID (Reference 3) report for identifying components that are sensitive to high-frequency vibration. Component types listed in Table 2-1 of EPRI Report 3002000706 (Reference 23) will require high-frequency confirmation. Those component types are:

- Electro-mechanical relays
- Circuit breakers
- Control switches
- Process switches and sensors
- Electro-mechanical contactors
- Auxiliary contacts
- Transfer switches
- Potentiometers

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

In the 1 Hz to 10 Hz part of the response spectrum, the SSE exceeds the GMRS. Therefore, a spent fuel pool evaluation will not be performed.