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10 CFR 50.54(f)

March 20, 2014
Serial: MNS-14-029

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Duke Energy Carolinas, LLC (Duke Energy
McGuire Nuclear Station (MNS), Units 1 and 2
Docket Nos. 50-369 and 50-370
Renewed License Nos. NPF-9 and NPF-17

Subject: Seismic Hazard and Screening Report (CEUS Sites), Response to NRC 10 CFR 50.54(f) 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

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 No. ML12053A340
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
4. NEI Letter, *Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations*, dated April 9, 2013, ADAMS Accession No. ML13101A379
5. NRC Letter, *Electric Power Research Institute Final Draft Report XXXXXX, Seismic Evaluation Guidance: Augmented Approach for the Resolution of Near-Term Task Force Recommendation 2.1: Seismic, as an Acceptable Alternative to the March 12, 2012, Information Request for Seismic Reevaluations*, dated May 7, 2013, ADAMS Accession No. ML 13106A331

A010
NRR

Ladies and Gentlemen:

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 each addressee located in the Central and Eastern United States (CEUS) to submit a Seismic Hazard Evaluation and Screening Report within 1.5 years from the date of Reference 1.

The Nuclear Energy Institute (NEI) submitted Reference 4 requesting NRC agreement to delay submittal of the CEUS Seismic Hazard Evaluation and Screening Report so that an update to the Electric Power Research Institute (EPRI) ground motion attenuation model could be completed and used to develop that information. NEI proposed that descriptions of subsurface materials and properties and base case velocity profiles be submitted to the NRC by September 12, 2013, with the remaining seismic hazard and screening information submitted by March 31, 2014.

Industry guidance and detailed information to be included in the Seismic Hazard Evaluation and Screening Report submittals is provided by Reference 2. The industry guidance was endorsed by the NRC in a letter dated February 15, 2013 (Reference 3).

The attached report provides the Seismic Hazard Evaluation and Screening Report for MNS as directed by Section 4 of Reference 2 and in accordance with the schedule provided in Reference 4.

There are no regulatory commitments associated with this letter.

Should you have any questions regarding this submittal, please contact George Murphy at 980-875-5715.

I declare under penalty of perjury that the foregoing is true and correct. Executed on March 20, 2014.

Sincerely,

SD Capps

Steven D. Capps

Enclosure:
MNS Seismic Hazard Evaluation and Screening Report

xc:

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Enclosure

MNS Seismic Hazard Evaluation and Screening Report

ENERCON Excellence—Every project. Every day	PROJECT REPORT COVER SHEET	NO. DUKCORP042-PR-002 REV. 0 Page 1 of 34

SEISMIC HAZARD AND SCREENING REPORT

IN RESPONSE TO THE 50.54(f) INFORMATION REQUEST REGARDING FUKUSHIMA NEAR-TERM TASK FORCE RECOMMENDATION 2.1: SEISMIC

for

MCGUIRE NUCLEAR STATION

DUKE ENERGY CAROLINAS

Prepared by: Shana Gibbs (signature) Date: 3/13/14

Shana Gibbs

Reviewed by: (signature) Date: 3/13/2014

Mitchell McKay

Approved by: (signature) Date: 3/13/14

Benjamin Kosbab

PROJECT REPORT REVISION STATUS

REVISION	DATE	DESCRIPTION
0		Initial issue.

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
All	0		

APPENDIX REVISION STATUS

APPENDIX NO.	PAGE NO.	REVISION NO.	APPENDIX NO.	PAGE NO.	REVISION NO.
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1 Introduction

Following the accident at the Fukushima Dai-ichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the Nuclear Regulatory Commission (NRC) 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 (Reference 1) that requests information to assure that these recommendations are addressed by all U.S. nuclear power plants. The 50.54(f) letter (Reference 1) requests that licensees and holders of construction permits under 10 CFR Part 50 (Reference 2) 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 in Attachment 1 of the 50.54(f) letter (Reference 1) pertaining to NTTF Recommendation 2.1: Seismic for the McGuire Nuclear Station (McGuire), located in Mecklenburg County, North Carolina. In providing this information, Duke Energy Carolinas (Duke) 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* (Reference 3). The Augmented Approach, *Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic* (Reference 4), 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 McGuire meet General Design Criterion 2 in Appendix A to 10 CFR Part 50 (Reference 2). The Safe Shutdown Earthquake Ground Motion (SSE) was developed in accordance with General Design Criterion 2 in Appendix A to 10 CFR Part 50 (Reference 2) and used for the design of seismic Category I structures, systems, and components (SSC). (Reference 10, Section 3.1)

In response to the 50.54(f) letter (Reference 1) and following the guidance provided in the SPID (Reference 3), a seismic hazard reevaluation was performed. For screening purposes, a Ground Motion Response Spectrum (GMRS) was developed. The GMRS development and supporting seismic hazard analysis (Sections 2.2, 2.3, and 2.4 of this report) for McGuire was performed by the Electric Power Research Institute (EPRI) (Reference 8). Based on the results of the screening evaluation, McGuire screens in for a risk evaluation and a spent fuel pool integrity evaluation.

2 Seismic Hazard Reevaluation

McGuire is located in northwestern Mecklenburg County, North Carolina, 17 miles north-northwest of Charlotte, North Carolina (Reference 10, Section 2.1). It is bordered on the west by the Catawba River and on the north by Lake Norman which is formed by Cowans Ford Dam adjacent to the site. The site is located in the Charlotte Belt, one of five northeast trending rock belts within the Piedmont Geologic Province. This belt consists of metamorphosed sedimentary and volcanic rocks with igneous rocks emplaced by several intrusive episodes during its early history. There is no evidence of movement along the regional faults since Triassic time or about 180 million years ago. Therefore, it is concluded that there are no identifiable active faults in the region of the site. From an engineering geology standpoint there are no local geologic features which adversely affect the station structures. Where zones of irregular weathering of bedrock occurred, the weathered material was excavated and fill concrete was used under foundation structures, or piles were driven to suitable rock bearing for Category I structures. (Reference 10, Section 2.5)

Historical records indicate that the maximum earthquake intensity experienced at the site was the Charleston earthquake of August 21, 1886 with an estimated site surface intensity between VI-VII Modified Mercalli Scale (MM). The maximum earthquake intensity which has occurred within the region is VII to VIII MM. The original investigation of historical seismic activity in the region estimated that the maximum expected earthquake intensity is between VII and VIII MM. The SSE for foundations on jointed rock and slightly weathered rock is 0.15g (Reference 10, Section 2.5). This value is very conservative, considering the observed surface intensities in the region and the overburden amplification (Reference 10, Former Appendix 2E, Section 4.2).

2.1 Regional and Local Geology

The general site area lies near the center of a region known as the Piedmont Geologic Province. The Piedmont Geologic Province is bordered on the east by the Coastal Plain Province and on the west by the Blue Ridge Province. The Coastal Plain generally consists of poorly consolidated sediments which include gravels, sands, clays, limestones, and marls. The Blue Ridge is a belt of meta-sedimentary rocks of the amphibolite facies in which igneous rocks were emplaced. Several Pre-Triassic faults or structural belts were associated faults described in published literature are located within 75 miles of the site. These structures probably occurred during or immediately following the Appalachian Orogeny at the close of the Paleozoic Era, and there is no evidence of their movement since Triassic time, or 180 million years ago. (Reference 10, Section 2.5)

The station site is located 17 miles northwest of Charlotte, North Carolina. It is bordered on the west by the Catawba River and on the north by Lake Norman which is formed by Cowans Ford Dam adjacent to the site. The site is underlain by metamorphosed sedimentary, volcanic, and intrusive igneous rocks ranging in age from Paleozoic Era to the Triassic Period. There have been no known evidences of unrelieved residual stresses, such as “rock squeeze”, or “pop-ups”, or “rockbursts” in the Piedmont Region.

Furthermore, no evidence of such occurrences was seen in the construction excavations at the McGuire site. Therefore, if unrelieved stresses do exist in the bedrock, they are of no consequence to the stability of the station structures. (Reference 10, Section 2.5)

2.2 PROBABILISTIC SEISMIC HAZARD ANALYSIS

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter (Reference 1) and following the guidance in the SPID (Reference 3), a probabilistic seismic hazard analysis (PSHA) was completed using the recently developed Central and Eastern United States Seismic Source Characterization (CEUS-SSC) for Nuclear Facilities (Reference 5) together with the updated EPRI Ground-Motion Model (GMM) for the CEUS (Reference 6). For the PSHA, a lower-bound moment magnitude of 5.0 was used, as specified in the 50.54(f) letter (Reference 1).

For the PSHA, the CEUS-SSC background seismic sources out to a distance of 400 miles (640 km) around McGuire were included. This distance exceeds the 200 mile (320 km) recommendation contained in NRC Reg. Guide 1.208 (Reference 7) and was chosen for completeness. Background sources included in this site analysis are the following:

1. Atlantic Highly Extended Crust (AHEX)
2. Extended Continental Crust—Atlantic Margin (ECC_AM)
3. Extended Continental Crust—Gulf Coast (ECC_GC)
4. Illinois Basin Extended Basement (IBEB)
5. Mesozoic and younger extended prior – narrow (MESE-N)
6. Mesozoic and younger extended prior – wide (MESE-W)
7. Midcontinent-Craton alternative A (MIDC_A)
8. Midcontinent-Craton alternative B (MIDC_B)
9. Midcontinent-Craton alternative C (MIDC_C)
10. Midcontinent-Craton alternative D (MIDC_D)
11. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
12. Non-Mesozoic and younger extended prior – wide (NMESE-W)
13. Paleozoic Extended Crust narrow (PEZ_N)
14. Paleozoic Extended Crust wide (PEZ_W)
15. Reelfoot Rift (RR)
16. Reelfoot Rift including the Rough Creek Graben (RR-RCG)
17. Study region (STUDY_R)

For sources of large magnitude earthquakes, designated as Repeated Large Magnitude Earthquake (RLME) sources in CEUS-SSC (Reference 5), the following sources lie within 621 miles (1,000 km) of the site and were included in the analysis:

1. Charleston
2. Commerce
3. Eastern Rift Margin Fault northern segment (ERM-N)
4. Eastern Rift Margin Fault southern segment (ERM-S)
5. Marianna
6. New Madrid Fault System (NMFS)
7. Wabash Valley

For each of the above background and RLME sources, the mid-continent version of the updated CEUS EPRI GMM (Reference 6) was used.

2.2.2 Base Rock Seismic Hazard Curves

Consistent with the SPID (Reference 3), base rock seismic hazard curves are not provided as the site amplification approach referred to as Method 3 from NUREG/CR-6728 (Reference 16) has been used. Seismic hazard curves are shown below in Section 2.3.7 at the SSE control point elevation (discussed below in Section 3.2).

2.3 SITE RESPONSE EVALUATION

Following the guidance contained in Seismic Enclosure 1 of the 50.54(f) letter (Reference 1) and in the SPID (Reference 3) for nuclear power plant sites that are not founded on hard rock (considered as having a shear-wave velocity of at least 9285 fps (2.83 km/sec), or 9200 fps as approximated in the SPID (Reference 3)), a site response analysis was performed for McGuire.

2.3.1 Description of Subsurface Material

McGuire is located in the Piedmont Physiographic Province of North Carolina. The general site conditions consist of residual soils overlying partially weathered rock grading into hard metamorphic igneous rocks (Reference 9). As depth into partially weathered rock increases the degree of weathering decreases as sound rock, defined as rock quality designation (RQD) of 75% or greater, is encountered.

McGuire consists of two units (1 and 2) with both reactor buildings supported on sound rock. Table 2.3.1-1 shows the single suite of geotechnical properties appropriate for Units 1 and 2.

Table 2.3.1-1 Summary of site geotechnical profile for McGuire (Reference 9)

Depth Range(1) (ft.)	Soil/Rock Description	Density (pcf)	Shear-wave Velocity (fps)	Compressional Wave Velocity (fps)	Poisson's ratio
0-4	Stiff Sandy Micaceous Silt	105	800	1400	0.26
4-10	Stiff to Very Stiff Sandy Micaceous Silt	105	1220	1900	0.15
10-26	Firm to Stiff Micaceous Silt	105	1300	2500	0.50
26-31	Very Dense Fine Sand	135	1600	2950	0.50
31-41	Partially Weathered Rock and Very Soft Granite	150	3250	5500	0.23
41-50	Very Soft to Moderately Hard Diorite RQD = 15% to 80%	172	4750	8900	0.30
50-56.5	Hard Diorite RQD = 80%	172	7200	13400	0.30
56.5-64(2)	See Note 2	172	7200	13400	0.30
64+	See Note 2	172	9200	17212	0.30

(1) Depth begins at Yard Grade Elevation 760 ft. This is the "Ground Surface Elevation".

(2) Note: Boring H-70 terminated at El. 703.4 ft. or 56.5 ft. below Yard Grade. Velocities beyond this depth are not confirmed by tests. V_s = 7,200 fps from 56.5 ft. – 64 ft. is assumed from test at 54.5 ft. V_s = 9,200 fps beginning at 64 ft. below Yard Grade is extrapolated from Measurements at 45.5 ft. and 54.5 ft. below Yard Grade.

(3) The control point elevation is taken to be 43.5 ft. below the Yard Grade Elevation.

The following description of the general geology at the site is taken directly from AMEC Data for Site Amplifications (Reference 9):

> "The four major rock types appearing at the site are dark green meta-gabbro, light gray fine to medium grained granite, black and white fine grained diorite, and black and white coarse grained diorite. The bedrock is generally covered by a soil profile that developed in place from weathering of the rock over geologic time. The general soil profile is typical of residual soils produced by weathering of crystalline rock. The profile shows clayey surface soils grading with depth into sandy micaceous silt (or in some locations micaceous silty sand). The soils are of low to medium plasticity and are primarily ML, MH and some SM classifications in the United Soils Classification System. With increasing depth, the profile transitions to "partially weathered rock" having at least 100 blows per foot standard penetration resistance. The degree of weathering becomes less as the sound rock is approached. Sound rock has a rock quality designation (RQD) of 75 percent or more."

2.3.2 *Development of Base Case Profiles and Nonlinear Material Properties*

Table 2.3.2-1 is not used. Table 2.3.1-1 shows the recommended shear-wave velocities and unit weights verses depth for the best estimate single profile accommodating Unit 1 and Unit 2. In Table 2.3.1-1 depths begin at El. 760 ft. and the Deepest Foundation Elevation (SSE control point) was taken at El. 716.5 ft. El. 716.5 ft. reflects the top of the base of the mat foundation of the reactor buildings. Based on Table 2.3.1-1 and the adopted location of the SSE control point at a depth of 43.5 ft. (13.2 m), the profile consists of 20.5 ft. (6.2 m) of firm rock overlying hard metamorphic basement rock.

Shear-wave velocities for the materials below the bottom of the mat foundation to a depth of 56.5 ft. (17.2 m) were based on downhole measurements (Reference 9). For the material below a depth of 56.5 ft. (17.2 m), shear-wave velocities were based on extrapolations of measurements made in the "sound rock" with the recommended profile reaching hard reference rock conditions at an assumed depth of 64 ft. (19.5 m).

Based on the specified shear-wave velocities reflecting a mixture of predominately measured values as well as assumed values, and considering the recommended shear-wave velocities follow the expected trend of increasing with depth, a scale factor of 1.25 was adopted to reflect upper and lower range base-cases. The scale factor of 1.25 reflects a $\sigma_{\mu ln}$ of about 0.2 based on the SPID (Reference 3) 10^{th} and 90^{th} fractiles which implies a 1.28 scale factor on σ_{μ}.

Using the shear-wave velocities specified in Table 2.3.1-1, three base-profiles were developed using the scale factor of 1.25. The specified shear-wave velocities were taken as the mean or best estimate base-case profile (P1) with lower and upper range base-cases profiles P2 and P3 respectively. The three base-case profiles P1, P2, and P3, have a mean depth below the SSE control point at El. 716.5 ft. of 20.5 ft. (6.2 m) to hard reference rock, randomized ± 4 ft. (± 1.2 m). The base-case profiles (P1, P2, and P3) are shown in Figure 2.3.2-1 and listed in Table 2.3.2-2. The depth randomization reflects ± 20% of the depth and was included to provide a realistic broadening of the fundamental resonance rather than reflect actual random variations to basement shear-wave velocities across a footprint.

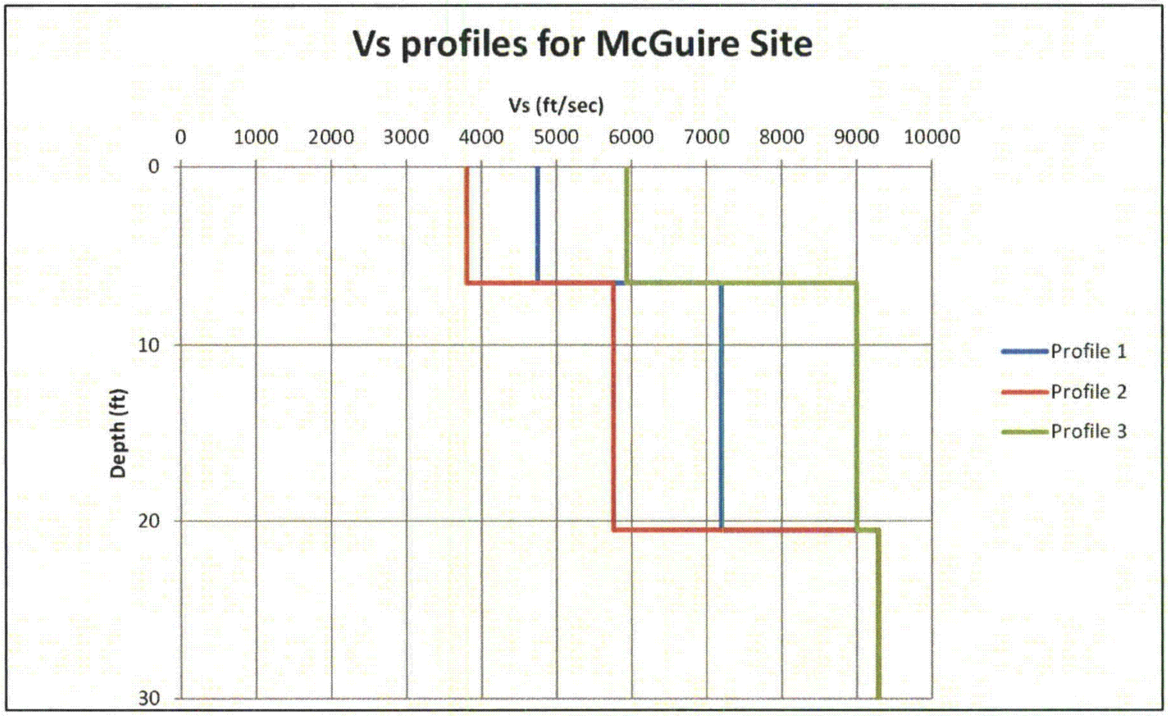


Figure 2.3.2-1 Shear-wave velocity profiles for the McGuire site

Table 2.3.2-2 Layer thicknesses, depths, and shear-wave velocities (V_s) for three profiles, the McGuire site

Profile 1			Profile 2			Profile 3		
Thickness (ft.)	Depth (ft.)	V_s (fps)	Thickness (ft.)	Depth (ft.)	V_s (fps)	Thickness (ft.)	Depth (ft.)	V_s (fps)
	0	4750		0	3800		0	5937
6.5	6.5	4750	6.5	6.5	3800	6.5	6.5	5937
6.5	13.0	7200	6.5	13.0	5760	6.5	13.0	9000
7.0	20.0	7200	7.0	20.0	5760	7.0	20.0	9000
0.5	20.5	7200	0.5	20.5	5760	0.5	20.5	9000
3280.8	3301.3	9285	3280.8	3301.3	9285	3280.8	3301.3	9285

2.3.2.1 Shear Modulus and Damping Curves

No site-specific nonlinear dynamic material properties were determined for the firm rock materials in the initial siting of McGuire. The rock material over the upper 20.5 ft. (6.2 m) was assumed to have behavior that could be modeled as either linear or nonlinear. To represent this potential for either case in the upper 20.5 ft. (6.2 m) of firm rock at the McGuire site, two sets of shear modulus reduction and hysteretic damping curves were used. Consistent with the SPID (Reference 3), the EPRI rock curves (model M1) were considered to be appropriate to represent the upper range nonlinearity likely in the materials at this site and linear analyses (model M2) was assumed to represent an equally plausible alternative rock response across loading level. For the linear analyses, the low strain damping from the EPRI rock curves was used as the constant damping values in the upper 20.5 ft. (6.2 m).

2.3.2.2 Kappa

For the McGuire profile of about 20.5 ft. (6.2 m) of firm rock over hard reference rock, the kappa value of 0.006s for hard rock (Reference 3) dominates profile damping. The 20.5 ft. (6.2 m) of firm rock, based on the low strain damping from the EPRI rock G/G_{max} and hysteretic damping curves, reflects a contribution of only about 0.0003s (Table 2.3.2-3). As a result, the dominant epistemic uncertainty in low strain kappa was assumed to be incorporated in the reference rock hazard.

Table 2.3.2-3 Kappa values and weights used for site response analyses

Velocity Profile	Kappa (s)	Weights
P1	0.0062	0.4
P2	0.0063	0.3
P3	0.0062	0.3
G/G_{max} and Hysteretic Damping Curves		
M1		0.5
M2		0.5

2.3.3 *Randomization of Base Case Profiles*

To account for the aleatory variability in dynamic material properties that is expected to occur across a site at the scale of a typical nuclear facility, variability in the assumed shear-wave velocity profiles has been incorporated in the site response calculations. For the McGuire site, random shear-wave velocity profiles were developed from the base case profiles shown in Figure 2.3.2-1. Thirty random velocity profiles were generated for each base case profile. These random velocity profiles were generated using a natural log standard deviation of 0.25 over the upper 50 ft. and a natural log standard deviation of 0.15 below that depth. As specified in the SPID (Reference 3), correlation of shear-wave velocity between layers was modeled using the footprint correlation model. In the correlation model, a limit of +/- 2 standard deviations about the median value in each layer was assumed for the limits on random velocity fluctuations.

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 1.5g) was used in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed for the analysis of the McGuire site were the same as those identified in Tables B-4, B-5, B-6 and B-7 of the SPID (Reference 3) as appropriate for typical CEUS sites.

2.3.5 *Methodology*

To perform the site response analyses for the McGuire 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 (Reference 3) on incorporating epistemic uncertainty in shear-wave velocities, kappa, nonlinear dynamic properties and source spectra for plants with limited at-site information was followed for the McGuire site.

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 EPRI rock G/G_{max} and hysteretic damping curves (model M1). 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 the McGuire 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, Figure 2.3.6-1 and Figure 2.3.6-2 show only a minor difference across structural frequency as well as loading level. Tabulated values of the amplification factors are provided in Appendix A.

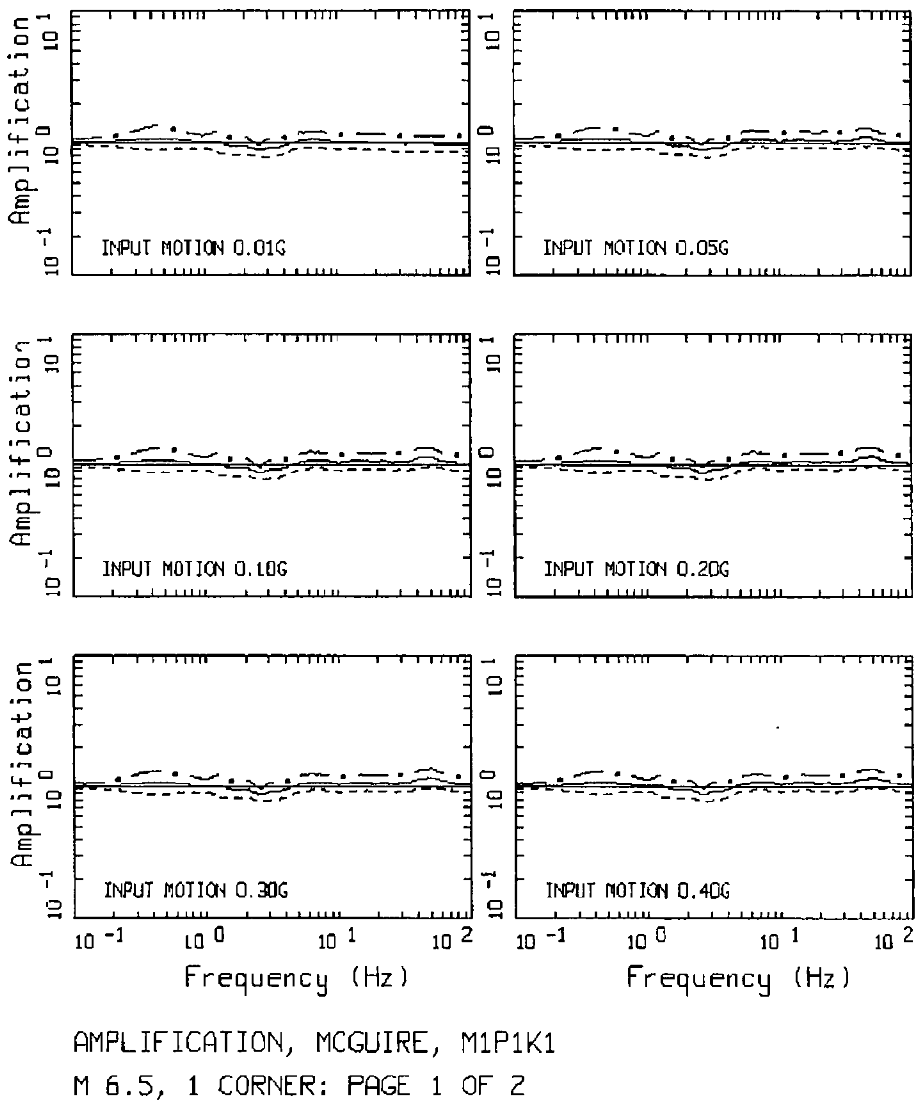
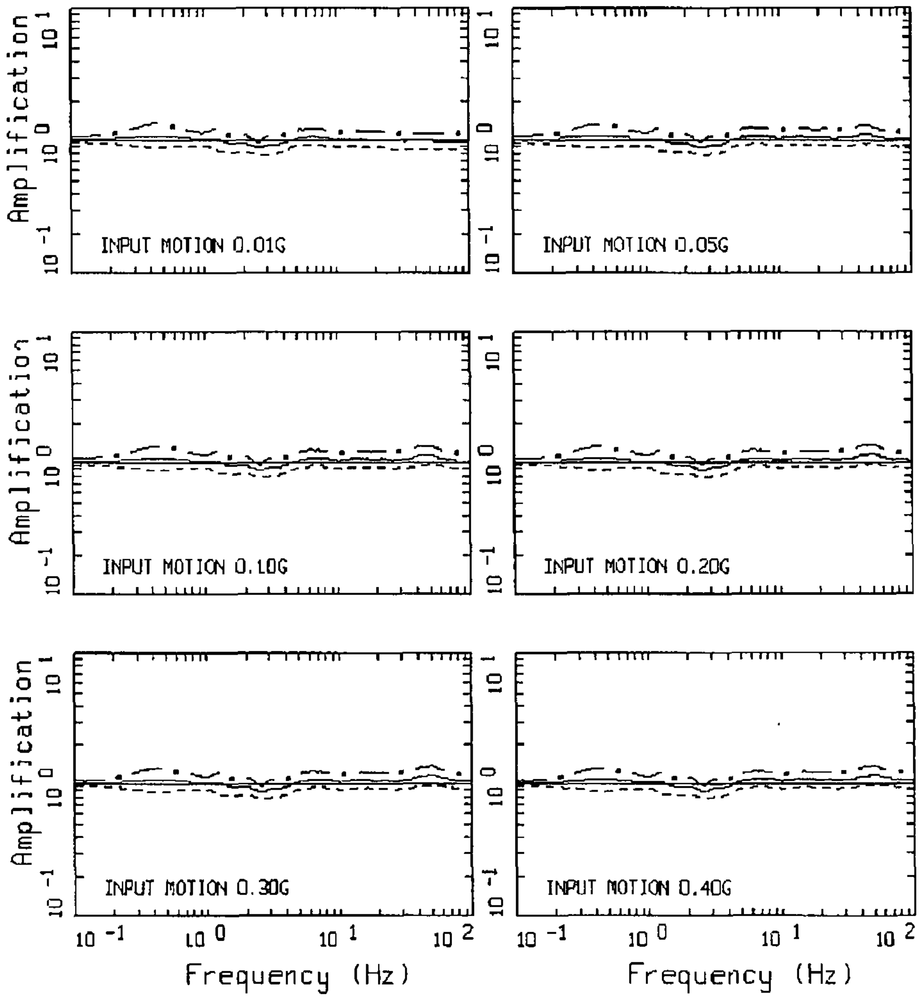


Figure 2.3.6-1 Example suite of amplification factors (5% of critical damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa (K1) at eleven loading levels of hard rock median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



AMPLIFICATION, MCGUIRE, M1P1K1

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Figure 2.3.6-1 continued

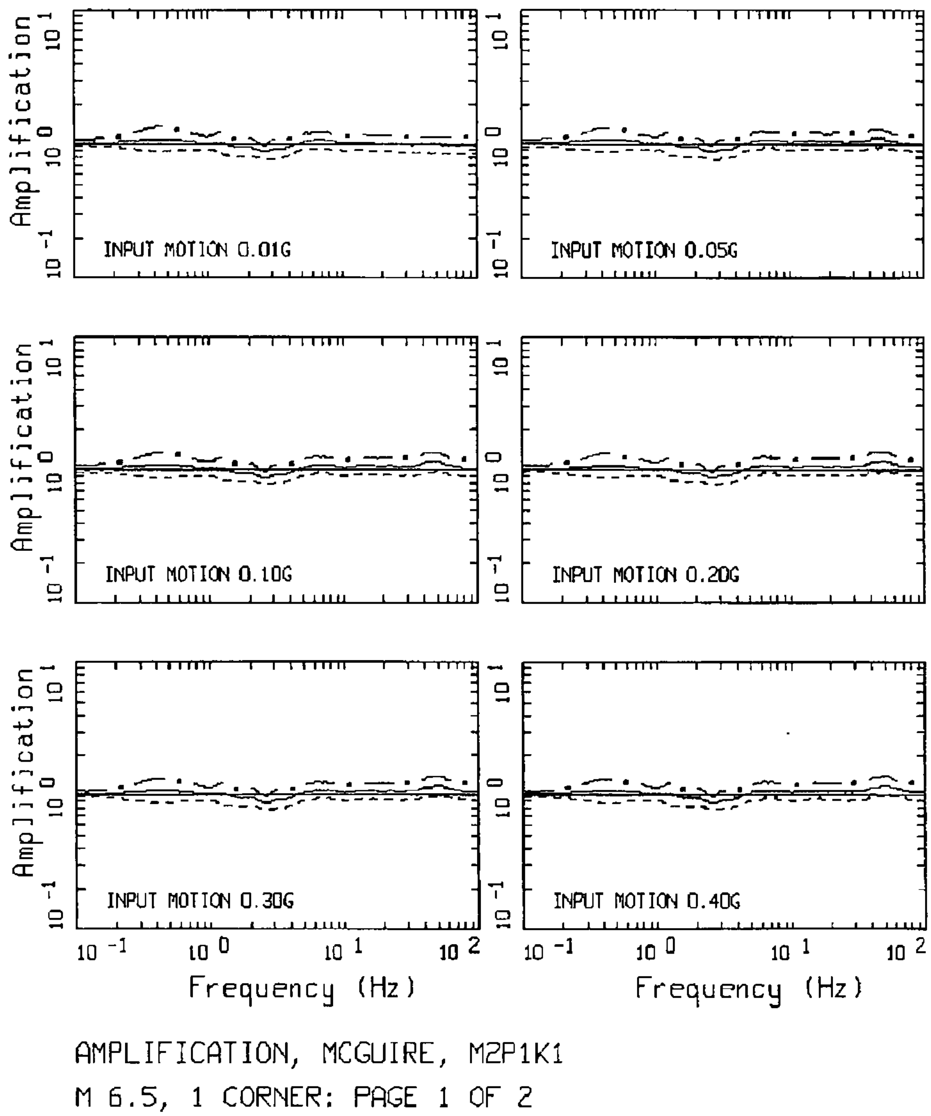
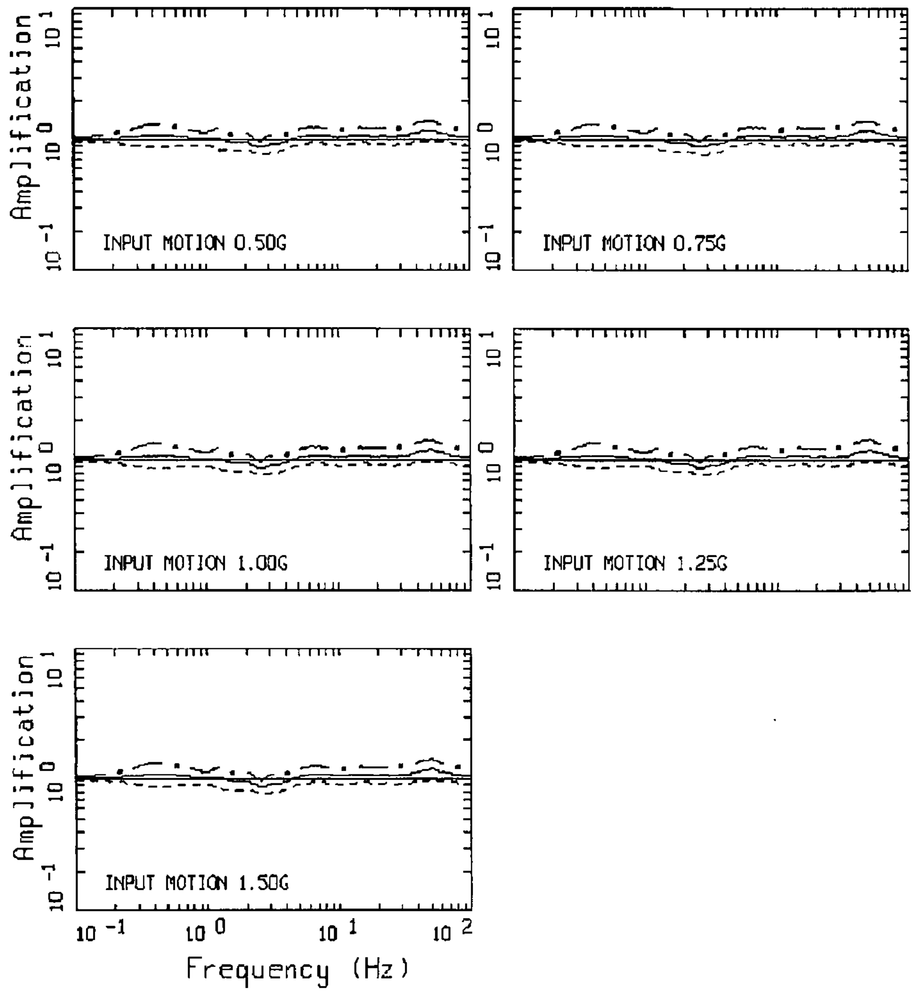


Figure 2.3.6-2 Example suite of amplification factors (5% of critical damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), linear site response (model M2), and base-case kappa (K1) at eleven loading levels of hard rock median peak acceleration values from 0.01g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



AMPLIFICATION, MCGUIRE, M2P1K1
M 6.5, 1 CORNER: PAGE 2 OF 2

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 from NUREG/CR-6728 (Reference 16)) 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 McGuire 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.

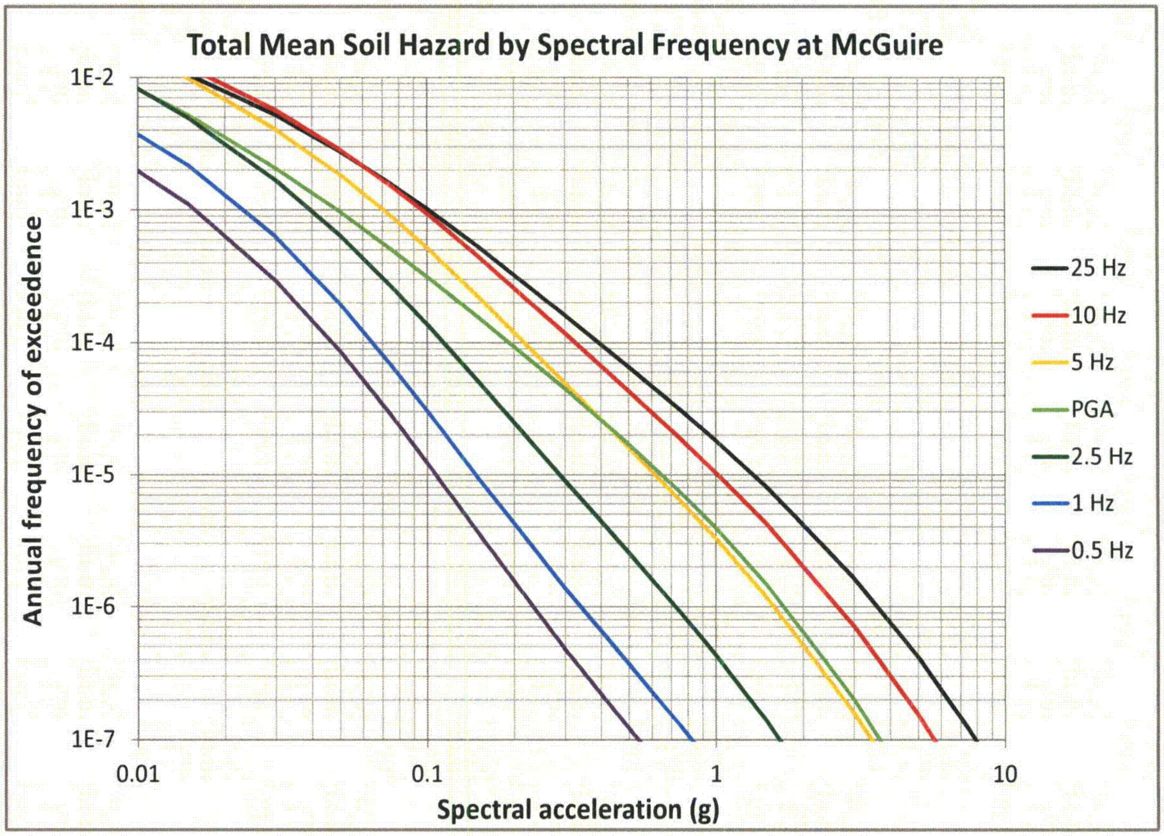


Figure 2.3.7-1 Control point mean hazard curves for spectral frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 Hz (PGA) at McGuire (5% of critical damping)

2.4 CONTROL POINT RESPONSE SPECTRA

The control point mean hazard curves described above have been used to develop uniform hazard response spectra (UHRS) and the 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 NRC Reg. Guide 1.208 (Reference 7). Figure 2.4-1 shows the control point UHRS and GMRS. Table 2.4-1 shows the UHRS and GMRS spectral accelerations for each of the seven frequencies.

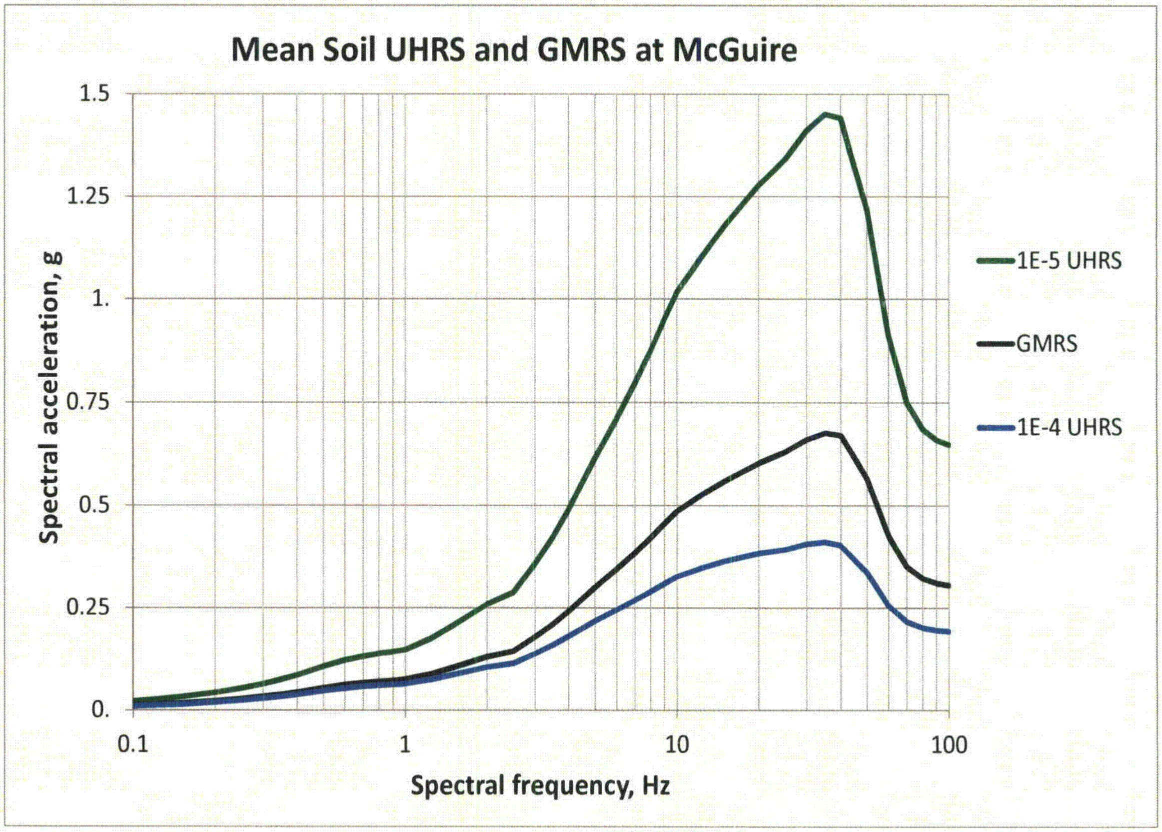


Figure 2.4-1 Plots of 1E-4 and 1E-5 uniform hazard spectra and GMRS at control point for McGuire (5% of critical damping response spectra)

Table 2.4-1 UHRS and GMRS at control point for McGuire (5% of critical damping response spectra)

Freq (Hz)	1E-4 UHRS (g)	1E-5 UHRS (g)	GMRS (g)
100	1.92E-01	6.48E-01	3.05E-01
90	1.95E-01	6.60E-01	3.10E-01
80	2.01E-01	6.86E-01	3.22E-01
70	2.16E-01	7.50E-01	3.51E-01
60	2.56E-01	9.10E-01	4.24E-01
50	3.37E-01	1.22E+00	5.65E-01
40	4.03E-01	1.44E+00	6.70E-01
35	4.11E-01	1.45E+00	6.76E-01
30	4.06E-01	1.41E+00	6.60E-01
25	3.93E-01	1.34E+00	6.29E-01
20	3.84E-01	1.28E+00	6.03E-01
15	3.65E-01	1.18E+00	5.59E-01
12.5	3.49E-01	1.11E+00	5.28E-01
10	3.26E-01	1.02E+00	4.86E-01
9	3.09E-01	9.50E-01	4.55E-01
8	2.90E-01	8.75E-01	4.21E-01
7	2.68E-01	7.96E-01	3.84E-01
6	2.45E-01	7.11E-01	3.44E-01
5	2.17E-01	6.16E-01	3.00E-01
4	1.80E-01	4.91E-01	2.41E-01
3.5	1.59E-01	4.24E-01	2.09E-01
3	1.37E-01	3.58E-01	1.77E-01
2.5	1.14E-01	2.88E-01	1.43E-01
2	1.05E-01	2.58E-01	1.29E-01
1.5	8.66E-02	2.06E-01	1.04E-01
1.25	7.49E-02	1.75E-01	8.86E-02
1	6.47E-02	1.47E-01	7.49E-02
0.9	6.25E-02	1.42E-01	7.24E-02
0.8	6.05E-02	1.38E-01	7.00E-02
0.7	5.77E-02	1.31E-01	6.69E-02
0.6	5.35E-02	1.22E-01	6.20E-02
0.5	4.70E-02	1.07E-01	5.44E-02
0.4	3.76E-02	8.55E-02	4.35E-02
0.35	3.29E-02	7.48E-02	3.81E-02
0.3	2.82E-02	6.41E-02	3.26E-02
0.25	2.35E-02	5.35E-02	2.72E-02
0.2	1.88E-02	4.28E-02	2.18E-02
0.15	1.41E-02	3.21E-02	1.63E-02
0.125	1.17E-02	2.67E-02	1.36E-02
0.1	9.39E-03	2.14E-02	1.09E-02

3

Plant Design Basis Ground Motion

The current licensing basis SSE is based on an evaluation of the maximum earthquake potential considering regional and local geology and seismic history (Reference 10, Former Appendix 2E). Historical records indicate that the maximum earthquake intensity experienced at the site was the Charleston earthquake of August 31, 1886 with an estimated site surface intensity between VI and VII MM (Reference 10, Former Appendix 2E, Section 4.1). Since there is an absence of geologic structure that can be related to earthquakes, it is necessary to presume that the observed epicentral intensities of historical earthquakes in the region could occur anywhere within the region or even in the immediate vicinity of the site (Reference 10, Former Appendix 2E, Section 4.2).

3.1 SSE Description of Spectral Shape

The McGuire SSE is defined in terms of a PGA and a design response spectrum shape. Considering a site design intensity between VII and VIII (7.5), the maximum horizontal ground acceleration is defined with 15% of gravity (0.15g) as the anchor point for the SSE (Reference 10, Section 2.5). The site design response spectrum for the McGuire SSE is based on a Newmark-type spectral shape (Reference 10, Former Appendix 2E, Section 4.4).

For the purposes of NTTF 2.1: Seismic screening, the spectral acceleration values for the McGuire horizontal SSE (5% of critical damping) are shown as a function of frequency in Table 3.1-1 and plotted in Figure 3.1-1. The SSE acceleration values are based on data from Former Appendix 2E Figure 2E-4 of the McGuire Updated Final Safety Analysis Report (UFSAR) (Reference 10).

Table 3.1-1 Horizontal SSE for McGuire (5% of critical damping response spectrum)

Frequency (Hz)	Spectral Acceleration (g)
0.33	0.06
2	0.36
6	0.36
35/PGA	0.15

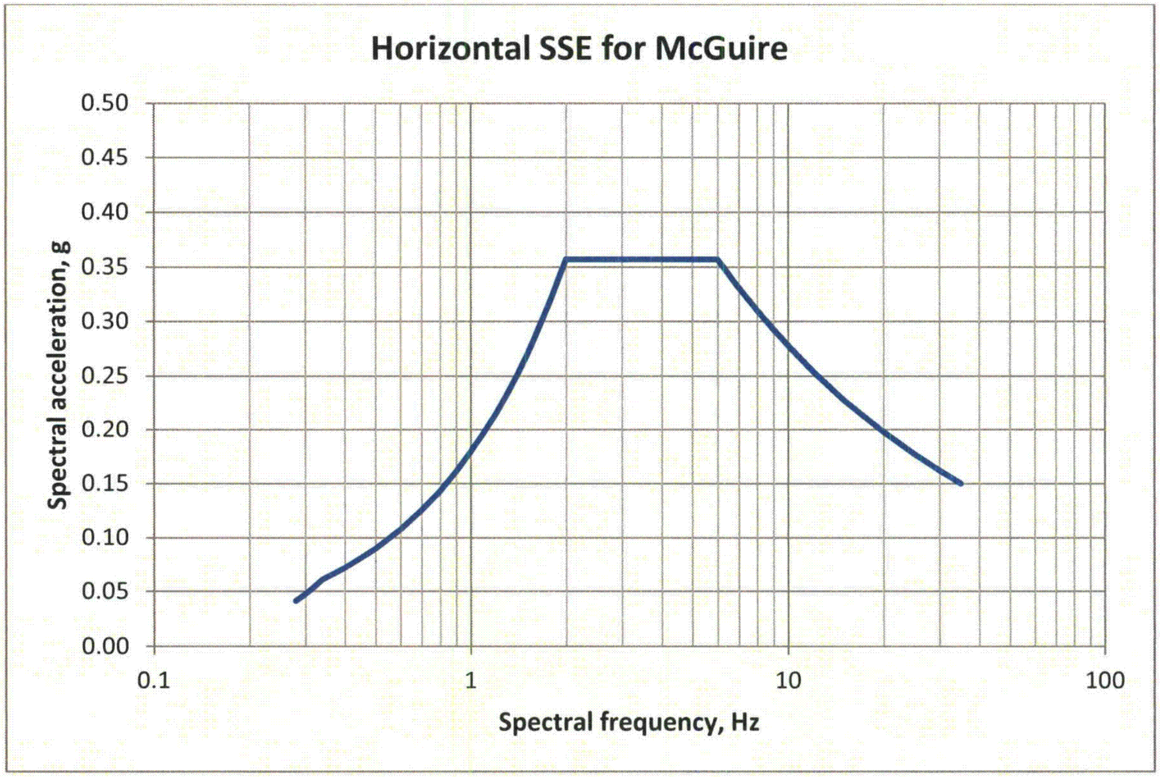


Figure 3.1-1 Horizontal SSE for McGuire (5% of critical damping response spectrum)

3.2 CONTROL POINT ELEVATION

The McGuire UFSAR defines the SSE control point at the top of sound rock (Reference 10, Section 3.7). Since the elevation at the top of sound rock varies throughout the site (Reference 9, page 8) and all major Category 1 structures are founded on sound rock (Reference 10, Section 3.7), the SSE control point elevation is taken to be at EL. 716.5, which is at the base of the mat foundation of the Reactor Buildings. This definition of the control point is consistent with the approach described in the SPID (Reference 3, Section 2.4.2).

4

Screening Evaluation

In accordance with the SPID, Section 3 (Reference 3), a screening evaluation was performed for McGuire 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 for McGuire. Therefore, McGuire screens in for a risk evaluation.

4.2 High Frequency Screening (> 10 Hz)

Above 10 Hz, the GMRS exceeds the SSE for McGuire. The high frequency exceedances can be addressed in the risk evaluation discussed in Section 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 for McGuire. Therefore, McGuire screens in for a spent fuel pool integrity evaluation.

5

Interim Actions and Assessments

As described in Section 4, the GMRS developed in response to the NTTF 2.1: Seismic portion of the 10 CFR 50.54(f) Request for Information dated March 12, 2012 (Reference 1) exceeds the design basis SSE. The NRC 50.54(f) letter (Reference 1) requests: "interim evaluation and actions taken or planned to address the higher seismic hazard relative to the design basis, as appropriate, prior to completion of the risk evaluation." These evaluations and actions are discussed below.

Consistent with NRC letter dated February 20, 2014 (Reference 17), the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of McGuire. Therefore, the results do not call into question the operability or functionality of SSCs and are not reportable pursuant to 10 CFR 50.72, "Immediate notification requirements for operating nuclear power reactors" (Reference 2, Section 50.72) and 10 CFR 50.73, "Licensee event report system" (Reference 2, Section 50.73).

5.1 Expedited Seismic Evaluation Program

An expedited seismic evaluation process (ESEP) is being performed at McGuire in accordance with the methodology in EPRI 3002000704 (Reference 4) as proposed in a letter to the NRC dated April 9, 2013 (Reference 11) and agreed to by the NRC in a letter dated May 7, 2013 (Reference 12). Duke plans to submit a report on the ESEP to the NRC in December 2014 (Reference 15), in accordance with the schedule in the Nuclear Energy Institute (NEI) April 9, 2013 letter to the NRC (Reference 11).

5.2 Seismic Risk Estimates

The NRC letter (Reference 17) also requests that licensees provide an interim evaluation or actions to address the higher seismic hazard relative to the design basis while the expedited approach and risk evaluations are conducted. In response to that request, the NEI letter dated March 12, 2014 (Reference 14) provides seismic core damage risk estimates using the updated seismic hazards for the operating nuclear plants in the CEUS. These risk estimates continue to support the following conclusions of the NRC GI-199 Safety/Risk Assessment (Reference 13):

> "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."

McGuire is included in the March 12, 2014 risk estimates (Reference 14). Using the methodology described in the NEI letter (Reference 14), the seismic core damage risk

estimates for all plants were shown to be below 1E-4/year; thus, the above conclusions apply.

5.3 INDIVIDUAL PLANT EXAMINATION OF EXTERNAL EVENTS

An evaluation of beyond-design-basis ground motions was performed for McGuire as part of the IPEEE program. The SPRA methodology was utilized to perform the IPEEE seismic evaluation for McGuire (Reference 21). The results of the SPRA determined the SCDF for McGuire to be less than the Commission's Safety Goal subsidiary objective of 1E-4/year (References 22 and 13). The McGuire IPEEE seismic evaluation (Reference 21) concluded that there are no fundamental weaknesses or vulnerabilities with regard to severe accident risk, including seismic, and confirmed that the plant poses no undue risk to the public health and safety. Additionally, improvements were made to the plant based on the McGuire IPEEE seismic evaluation, as confirmed in the NTTF 2.3 seismic walkdown report (Reference 19), to enhance the McGuire seismic margin.

5.4 WALKDOWNS TO ADDRESS NRC FUKUSHIMA NTTF RECOMMENDATION 2.3

Walkdowns have been completed for McGuire in accordance with the EPRI seismic walkdown guidance (Reference 18); including inaccessible items (References 19 and 20). Potentially adverse seismic conditions (PASC) found were entered into the corrective action program (CAP) for resolution. None of the PASC items challenged operability of the plant. There were no vulnerabilities identified under IPEEE, however, previously identified IPEEE enhancements were reviewed and found to be complete. Duke confirmed through the walkdowns that the existing monitoring and maintenance procedures keep the plant consistent with the licensing basis (References 19 and 20).

6

Conclusions

In accordance with the 50.54(f) letter (Reference 1), a seismic hazard and screening evaluation was performed for McGuire. A GMRS was developed solely for the purpose of screening for additional evaluations in accordance with the SPID (Reference 3).

Based on the results of the screening evaluation, McGuire screens in for a risk evaluation and a spent fuel pool integrity evaluation.

7 References

1. NRC (E. Leeds and M. Johnson) Letter to All Power Reactor Licensees et al., *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 No. ML12053A340.

2. Title 10 Code of Federal Regulations Part 50.

3. EPRI 1025287, *Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*, Palo Alto, CA, February 2013.

4. EPRI 3002000704, *Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*, Palo Alto, CA, May 2013.

5. EPRI 1021097 (NUREG-2115), *Central and Eastern United States Seismic Source Characterization for Nuclear Facilities*, Palo Alto, CA, January 2012.

6. EPRI 3002000717, *EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project*, Palo Alto, CA, June 2013.

7. NRC Regulatory Guide 1.208, *A performance-based approach to define the site-specific earthquake ground motion*, 2007.

8. EPRI RSM-092513-030, *McGuire Seismic Hazard and Screening Report*, dated October 31, 2013.

9. AMEC Project No. 6234-12-0031, *Data for Site Amplifications – McGuire Phase 2 EPRI Seismic Attenuation and GMRS Project, McGuire Nuclear Station,* dated July 26, 2012.

10. Duke Energy Company, *McGuire Nuclear Station, Units 1 and 2, Updated Final Safety Analysis Report (UFSAR),* Revision 17.

11. NEI (A. R. Pietrangelo) Letter to the NRC, *Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations,* dated April 9, 2013, ADAMS Accession No. ML13101A379.

12. NRC (E. Leeds) Letter to NEI (J. Pollock), *Electric Power Research Institute Final Draft Report XXXXXX, "Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic," as an Acceptable Alternative to the March 12, 2012, Information Request for Seismic Reevaluations*, dated May 7, 2013, ADAMS Accession No. ML13106A331.

13. NRC Memorandum (from P. Hiland to B. Sheron), "Safety/Risk Assessment Results for Generic Issue 199, Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants," dated September 2, 2010, ADAMS Accession No. ML100270582.

14. NEI (A. R. Pietrangelo) Letter to the NRC, *Seismic Risk Evaluations for Plants in the Central and Eastern United States,* dated March 12, 2014.

15. Duke Energy (B. Waldrep) Letter to the NRC, *Duke Energy Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident*, dated April 26, 2013, ADAMS Accession No. ML13121A061.

16. NUREG/CR-6728, *Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk- Consistent Ground Motion Spectra Guidelines*, October 2001.

17. NRC (E. Leeds) Letter to All Power Reactor Licensees et al., *Supplemental Information Related to Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Seismic Hazard Reevaluations for Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident*, dated February 20, 2014, ADAMS Accession No. ML14030A046.

18. EPRI 1025286, *Seismic Walkdown Guidance for Resolution of Fukushima Near-Term Task Force Recommendation 2.3: Seismic*, Palo Alto, CA, June 2012.

19. Duke Energy Carolinas (S. Capps) Letter to the NRC, *McGuire Nuclear Station (MNS), Units 1 and 2, Seismic Walkdown Information Requested by 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,* dated November 26, 2012, ADAMS Accession No. ML13003A339.

20. Duke Energy Carolinas (S. Capps) Letter to the NRC, *McGuire Nuclear Station (MNS), Unit 1, Response to NRC Request for Information Pursuant to Title 10 Code of Federal Regulations 50.54(f) Regarding Seismic Aspects of Recommendation 2.3 of the Near Term Task Force Review of Insights from the Fukushima Dai-ichi Accident*, dated June 20, 2013, ADAMS Accession No. ML13190A272.

21. Duke Power Company (T. McMeekin) Letter to the NRC, *McGuire Nuclear Station, Units 1 and 2, Individual Plant Examination of External Events (IPEEE) Submittal,* dated June 1, 1994.

22. NRC (F. Rinaldi) Letter to Duke Energy Corporation (H. Barron), *Review of McGuire Nuclear Station, Units 1 and 2 - Individual Plant Examination of External Events Submittal (TAC Nos. M83639 and M83640),* dated February 16, 1999.

A

Additional Tables

Table A-1a Mean and fractile seismic hazard curves for PGA at McGuire, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.21E-02	3.33E-02	4.43E-02	5.27E-02	6.00E-02	6.54E-02
0.001	4.15E-02	2.35E-02	3.42E-02	4.19E-02	4.98E-02	5.50E-02
0.005	1.58E-02	7.03E-03	1.08E-02	1.53E-02	1.95E-02	2.92E-02
0.01	8.18E-03	3.28E-03	4.77E-03	7.45E-03	1.04E-02	1.90E-02
0.015	5.16E-03	1.82E-03	2.64E-03	4.43E-03	6.83E-03	1.38E-02
0.03	2.07E-03	5.20E-04	7.77E-04	1.49E-03	2.96E-03	7.13E-03
0.05	9.66E-04	1.79E-04	2.80E-04	5.91E-04	1.40E-03	3.90E-03
0.075	5.06E-04	7.66E-05	1.27E-04	2.80E-04	7.13E-04	2.19E-03
0.1	3.14E-04	4.37E-05	7.45E-05	1.72E-04	4.31E-04	1.38E-03
0.15	1.56E-04	2.07E-05	3.79E-05	8.85E-05	2.16E-04	6.64E-04
0.3	4.50E-05	5.66E-06	1.16E-05	2.84E-05	6.73E-05	1.57E-04
0.5	1.70E-05	1.98E-06	4.31E-06	1.13E-05	2.72E-05	5.27E-05
0.75	7.41E-06	7.77E-07	1.72E-06	4.90E-06	1.21E-05	2.25E-05
1.	3.92E-06	3.63E-07	8.23E-07	2.53E-06	6.54E-06	1.21E-05
1.5	1.46E-06	1.07E-07	2.53E-07	8.72E-07	2.46E-06	4.83E-06
3.	2.03E-07	7.55E-09	2.10E-08	9.79E-08	3.23E-07	7.77E-07
5.	3.50E-08	7.34E-10	2.22E-09	1.32E-08	5.20E-08	1.55E-07
7.5	7.02E-09	1.77E-10	3.63E-10	2.13E-09	9.51E-09	3.47E-08
10.	1.99E-09	1.16E-10	1.64E-10	5.66E-10	2.57E-09	1.05E-08

Table A-1b Mean and fractile seismic hazard curves for 25 Hz at McGuire, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.68E-02	4.13E-02	5.05E-02	5.75E-02	6.36E-02	6.83E-02
0.001	4.82E-02	3.19E-02	4.13E-02	4.83E-02	5.58E-02	6.09E-02
0.005	2.39E-02	1.27E-02	1.79E-02	2.35E-02	2.88E-02	3.84E-02
0.01	1.48E-02	7.03E-03	1.02E-02	1.40E-02	1.82E-02	2.76E-02
0.015	1.05E-02	4.70E-03	6.83E-03	9.79E-03	1.32E-02	2.13E-02
0.03	5.21E-03	2.01E-03	2.92E-03	4.56E-03	6.83E-03	1.25E-02
0.05	2.78E-03	9.11E-04	1.32E-03	2.29E-03	3.84E-03	7.55E-03
0.075	1.57E-03	4.37E-04	6.45E-04	1.20E-03	2.25E-03	4.77E-03
0.1	1.02E-03	2.49E-04	3.79E-04	7.34E-04	1.49E-03	3.28E-03
0.15	5.30E-04	1.11E-04	1.74E-04	3.63E-04	7.77E-04	1.79E-03
0.3	1.62E-04	2.88E-05	5.05E-05	1.11E-04	2.35E-04	5.27E-04
0.5	6.51E-05	1.13E-05	2.13E-05	4.77E-05	9.93E-05	1.87E-04
0.75	3.10E-05	5.20E-06	1.02E-05	2.35E-05	4.98E-05	8.23E-05
1.	1.80E-05	2.88E-06	5.83E-06	1.38E-05	2.92E-05	4.70E-05
1.5	7.99E-06	1.15E-06	2.46E-06	6.09E-06	1.32E-05	2.10E-05
3.	1.65E-06	1.87E-07	4.13E-07	1.18E-06	2.80E-06	4.77E-06
5.	4.19E-07	3.47E-08	8.00E-08	2.72E-07	7.13E-07	1.34E-06
7.5	1.21E-07	7.23E-09	1.77E-08	7.03E-08	2.07E-07	4.31E-07
10.	4.56E-08	2.10E-09	5.42E-09	2.39E-08	7.77E-08	1.74E-07

Table A-1c Mean and fractile seismic hazard curves for 10 Hz at McGuire, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.10E-02	4.98E-02	5.42E-02	6.09E-02	6.73E-02	7.13E-02
0.001	5.36E-02	4.07E-02	4.70E-02	5.42E-02	6.00E-02	6.45E-02
0.005	2.80E-02	1.67E-02	2.16E-02	2.80E-02	3.42E-02	3.95E-02
0.01	1.72E-02	9.11E-03	1.23E-02	1.69E-02	2.16E-02	2.72E-02
0.015	1.20E-02	6.00E-03	8.12E-03	1.16E-02	1.53E-02	2.04E-02
0.03	5.65E-03	2.49E-03	3.37E-03	5.27E-03	7.45E-03	1.11E-02
0.05	2.85E-03	1.07E-03	1.51E-03	2.49E-03	3.95E-03	6.36E-03
0.075	1.52E-03	4.90E-04	7.13E-04	1.25E-03	2.19E-03	3.79E-03
0.1	9.36E-04	2.64E-04	4.01E-04	7.34E-04	1.38E-03	2.49E-03
0.15	4.49E-04	1.07E-04	1.69E-04	3.37E-04	6.73E-04	1.29E-03
0.3	1.18E-04	2.22E-05	3.95E-05	8.60E-05	1.82E-04	3.37E-04
0.5	4.29E-05	7.34E-06	1.42E-05	3.23E-05	6.83E-05	1.16E-04
0.75	1.89E-05	3.01E-06	6.00E-06	1.44E-05	3.09E-05	5.05E-05
1.	1.04E-05	1.53E-06	3.14E-06	7.89E-06	1.72E-05	2.80E-05
1.5	4.20E-06	5.42E-07	1.16E-06	3.09E-06	7.03E-06	1.16E-05
3.	7.19E-07	6.93E-08	1.53E-07	4.83E-07	1.21E-06	2.25E-06
5.	1.55E-07	1.05E-08	2.46E-08	9.24E-08	2.60E-07	5.42E-07
7.5	3.89E-08	1.87E-09	4.63E-09	2.04E-08	6.45E-08	1.51E-07
10.	1.32E-08	5.42E-10	1.32E-09	6.17E-09	2.19E-08	5.42E-08

Table A-1d Mean and fractile seismic hazard curves for 5 Hz at McGuire, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.14E-02	4.98E-02	5.50E-02	6.17E-02	6.83E-02	7.23E-02
0.001	5.41E-02	4.01E-02	4.63E-02	5.42E-02	6.17E-02	6.64E-02
0.005	2.63E-02	1.46E-02	1.98E-02	2.60E-02	3.33E-02	3.73E-02
0.01	1.49E-02	7.45E-03	1.05E-02	1.46E-02	1.95E-02	2.29E-02
0.015	9.77E-03	4.63E-03	6.64E-03	9.51E-03	1.31E-02	1.57E-02
0.03	4.04E-03	1.69E-03	2.42E-03	3.79E-03	5.58E-03	7.45E-03
0.05	1.84E-03	6.54E-04	9.65E-04	1.64E-03	2.68E-03	3.84E-03
0.075	9.00E-04	2.72E-04	4.19E-04	7.55E-04	1.36E-03	2.10E-03
0.1	5.17E-04	1.40E-04	2.19E-04	4.19E-04	7.89E-04	1.29E-03
0.15	2.24E-04	5.20E-05	8.60E-05	1.72E-04	3.47E-04	5.91E-04
0.3	4.95E-05	9.37E-06	1.72E-05	3.73E-05	7.89E-05	1.32E-04
0.5	1.60E-05	2.64E-06	5.12E-06	1.23E-05	2.64E-05	4.25E-05
0.75	6.41E-06	9.11E-07	1.90E-06	4.83E-06	1.07E-05	1.74E-05
1.	3.25E-06	4.13E-07	8.85E-07	2.35E-06	5.50E-06	9.11E-06
1.5	1.17E-06	1.23E-07	2.72E-07	8.00E-07	1.98E-06	3.52E-06
3.	1.61E-07	9.93E-09	2.49E-08	9.24E-08	2.76E-07	5.58E-07
5.	2.93E-08	1.15E-09	3.05E-09	1.38E-08	4.98E-08	1.13E-07
7.5	6.39E-09	2.42E-10	5.27E-10	2.46E-09	1.05E-08	2.64E-08
10.	1.98E-09	1.53E-10	2.07E-10	7.03E-10	3.09E-09	8.60E-09

Table A-1e Mean and fractile seismic hazard curves for 2.5 Hz at McGuire, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.71E-02	4.37E-02	4.90E-02	5.75E-02	6.45E-02	6.93E-02
0.001	4.67E-02	3.19E-02	3.79E-02	4.63E-02	5.58E-02	6.09E-02
0.005	1.70E-02	8.98E-03	1.20E-02	1.64E-02	2.22E-02	2.60E-02
0.01	8.25E-03	3.90E-03	5.35E-03	7.89E-03	1.11E-02	1.38E-02
0.015	4.90E-03	2.10E-03	2.96E-03	4.56E-03	6.73E-03	8.85E-03
0.03	1.68E-03	5.58E-04	8.47E-04	1.49E-03	2.49E-03	3.52E-03
0.05	6.42E-04	1.72E-04	2.72E-04	5.20E-04	1.01E-03	1.53E-03
0.075	2.69E-04	5.91E-05	9.93E-05	2.04E-04	4.31E-04	7.03E-04
0.1	1.38E-04	2.68E-05	4.63E-05	9.79E-05	2.22E-04	3.84E-04
0.15	5.11E-05	8.47E-06	1.55E-05	3.47E-05	8.23E-05	1.46E-04
0.3	9.01E-06	1.11E-06	2.25E-06	5.91E-06	1.49E-05	2.64E-05
0.5	2.54E-06	2.32E-07	5.27E-07	1.57E-06	4.31E-06	8.00E-06
0.75	9.16E-07	6.09E-08	1.53E-07	5.27E-07	1.60E-06	3.09E-06
1.	4.30E-07	2.16E-08	5.83E-08	2.29E-07	7.55E-07	1.53E-06
1.5	1.38E-07	4.37E-09	1.34E-08	6.26E-08	2.42E-07	5.27E-07
3.	1.50E-08	2.80E-10	7.77E-10	4.56E-09	2.46E-08	6.45E-08
5.	2.26E-09	1.25E-10	1.64E-10	5.42E-10	3.33E-09	1.02E-08
7.5	4.23E-10	9.24E-11	1.16E-10	1.72E-10	6.26E-10	1.98E-09
10.	1.17E-10	9.11E-11	1.01E-10	1.53E-10	2.42E-10	6.17E-10

Table A-1f Mean and fractile seismic hazard curves for 1 Hz at McGuire, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	4.08E-02	2.32E-02	3.05E-02	4.19E-02	5.05E-02	5.58E-02
0.001	2.79E-02	1.40E-02	1.95E-02	2.84E-02	3.52E-02	4.13E-02
0.005	7.74E-03	3.14E-03	4.70E-03	7.34E-03	1.07E-02	1.36E-02
0.01	3.73E-03	1.11E-03	1.82E-03	3.33E-03	5.58E-03	7.55E-03
0.015	2.16E-03	5.12E-04	8.98E-04	1.84E-03	3.37E-03	4.90E-03
0.03	6.29E-04	9.79E-05	1.87E-04	4.70E-04	1.02E-03	1.74E-03
0.05	1.96E-04	2.25E-05	4.63E-05	1.27E-04	3.33E-04	6.17E-04
0.075	6.79E-05	6.45E-06	1.38E-05	3.90E-05	1.16E-04	2.25E-04
0.1	3.03E-05	2.57E-06	5.58E-06	1.62E-05	5.20E-05	1.02E-04
0.15	9.44E-06	6.93E-07	1.53E-06	4.63E-06	1.60E-05	3.28E-05
0.3	1.38E-06	6.36E-08	1.62E-07	6.00E-07	2.29E-06	5.35E-06
0.5	3.70E-07	9.65E-09	2.88E-08	1.32E-07	5.91E-07	1.55E-06
0.75	1.29E-07	1.92E-09	6.54E-09	3.68E-08	2.01E-07	5.75E-07
1.	5.91E-08	6.26E-10	2.13E-09	1.36E-08	8.72E-08	2.72E-07
1.5	1.83E-08	1.90E-10	4.56E-10	3.05E-09	2.42E-08	8.60E-08
3.	1.93E-09	1.01E-10	1.49E-10	2.53E-10	1.92E-09	8.72E-09
5.	2.91E-10	9.11E-11	1.01E-10	1.53E-10	3.05E-10	1.29E-09
7.5	5.53E-11	9.11E-11	1.01E-10	1.53E-10	1.55E-10	3.05E-10
10.	1.56E-11	9.11E-11	9.11E-11	1.53E-10	1.53E-10	1.69E-10

Table A-1g Mean and fractile seismic hazard curves for 0.5 Hz at McGuire, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	2.30E-02	1.31E-02	1.77E-02	2.25E-02	2.84E-02	3.33E-02
0.001	1.44E-02	7.66E-03	1.02E-02	1.38E-02	1.84E-02	2.29E-02
0.005	4.17E-03	1.16E-03	1.95E-03	3.79E-03	6.45E-03	8.35E-03
0.01	1.97E-03	3.09E-04	6.17E-04	1.57E-03	3.33E-03	4.90E-03
0.015	1.10E-03	1.20E-04	2.60E-04	7.77E-04	1.92E-03	3.14E-03
0.03	2.94E-04	1.77E-05	4.25E-05	1.62E-04	5.12E-04	1.05E-03
0.05	8.60E-05	3.57E-06	8.85E-06	3.73E-05	1.49E-04	3.37E-04
0.075	2.83E-05	9.24E-07	2.35E-06	9.93E-06	4.83E-05	1.15E-04
0.1	1.22E-05	3.47E-07	9.24E-07	3.68E-06	2.07E-05	4.98E-05
0.15	3.61E-06	8.47E-08	2.35E-07	9.24E-07	5.75E-06	1.53E-05
0.3	4.78E-07	6.45E-09	1.98E-08	9.65E-08	6.45E-07	2.35E-06
0.5	1.22E-07	8.60E-10	2.84E-09	1.79E-08	1.42E-07	6.45E-07
0.75	4.25E-08	2.32E-10	6.17E-10	4.31E-09	4.25E-08	2.25E-07
1.	1.98E-08	1.53E-10	2.57E-10	1.51E-09	1.72E-08	1.04E-07
1.5	6.46E-09	1.04E-10	1.53E-10	3.79E-10	4.37E-09	3.23E-08
3.	7.73E-10	9.11E-11	1.01E-10	1.53E-10	3.95E-10	3.33E-09
5.	1.31E-10	9.11E-11	1.01E-10	1.53E-10	1.57E-10	5.50E-10
7.5	2.78E-11	9.11E-11	9.11E-11	1.53E-10	1.53E-10	1.92E-10
10.	8.48E-12	9.11E-11	9.11E-11	1.53E-10	1.53E-10	1.53E-10

Table A- 2 Amplification functions for McGuire, 5% of critical damping

PGA	Median AF	Sigma ln(AF)	25 Hz	Median AF	Sigma ln(AF)	10 Hz	Median AF	Sigma ln(AF)	5 Hz	Median AF	Sigma ln(AF)
1.00E-02	9.89E-01	1.29E-01	1.30E-02	1.00E+00	1.27E-01	1.90E-02	1.03E+00	1.29E-01	2.09E-02	1.04E+00	1.32E-01
4.95E-02	1.02E+00	1.23E-01	1.02E-01	1.04E+00	1.28E-01	9.99E-02	1.04E+00	1.29E-01	8.24E-02	1.05E+00	1.31E-01
9.64E-02	1.04E+00	1.22E-01	2.13E-01	1.05E+00	1.28E-01	1.85E-01	1.05E+00	1.29E-01	1.44E-01	1.05E+00	1.31E-01
1.94E-01	1.05E+00	1.22E-01	4.43E-01	1.05E+00	1.28E-01	3.56E-01	1.05E+00	1.28E-01	2.65E-01	1.05E+00	1.31E-01
2.92E-01	1.05E+00	1.22E-01	6.76E-01	1.05E+00	1.29E-01	5.23E-01	1.05E+00	1.28E-01	3.84E-01	1.05E+00	1.31E-01
3.91E-01	1.06E+00	1.23E-01	9.09E-01	1.05E+00	1.29E-01	6.90E-01	1.05E+00	1.28E-01	5.02E-01	1.05E+00	1.31E-01
4.93E-01	1.06E+00	1.23E-01	1.15E+00	1.05E+00	1.30E-01	8.61E-01	1.05E+00	1.28E-01	6.22E-01	1.05E+00	1.31E-01
7.41E-01	1.06E+00	1.23E-01	1.73E+00	1.05E+00	1.31E-01	1.27E+00	1.05E+00	1.28E-01	9.13E-01	1.05E+00	1.31E-01
1.01E+00	1.06E+00	1.24E-01	2.36E+00	1.05E+00	1.32E-01	1.72E+00	1.05E+00	1.28E-01	1.22E+00	1.05E+00	1.31E-01
1.28E+00	1.06E+00	1.24E-01	3.01E+00	1.06E+00	1.34E-01	2.17E+00	1.05E+00	1.29E-01	1.54E+00	1.05E+00	1.31E-01
1.55E+00	1.07E+00	1.24E-01	3.63E+00	1.06E+00	1.35E-01	2.61E+00	1.05E+00	1.29E-01	1.85E+00	1.05E+00	1.31E-01

2.5 Hz	Median AF	Sigma ln(AF)	1 Hz	Median AF	Sigma ln(AF)	0.5 Hz	Median AF	Sigma ln(AF)
2.18E-02	8.90E-01	1.23E-01	1.27E-02	1.02E+00	9.81E-02	8.25E-03	1.10E+00	2.04E-01
7.05E-02	8.91E-01	1.23E-01	3.43E-02	1.01E+00	9.82E-02	1.96E-02	1.10E+00	2.02E-01
1.18E-01	8.92E-01	1.22E-01	5.51E-02	1.01E+00	9.82E-02	3.02E-02	1.10E+00	2.01E-01
2.12E-01	8.93E-01	1.22E-01	9.63E-02	1.01E+00	9.82E-02	5.11E-02	1.09E+00	2.00E-01
3.04E-01	8.93E-01	1.22E-01	1.36E-01	1.01E+00	9.83E-02	7.10E-02	1.09E+00	2.00E-01
3.94E-01	8.93E-01	1.22E-01	1.75E-01	1.01E+00	9.83E-02	9.06E-02	1.09E+00	2.00E-01
4.86E-01	8.93E-01	1.22E-01	2.14E-01	1.01E+00	9.83E-02	1.10E-01	1.09E+00	2.00E-01
7.09E-01	8.93E-01	1.22E-01	3.10E-01	1.01E+00	9.83E-02	1.58E-01	1.09E+00	2.00E-01
9.47E-01	8.94E-01	1.22E-01	4.12E-01	1.01E+00	9.83E-02	2.09E-01	1.09E+00	2.00E-01
1.19E+00	8.94E-01	1.22E-01	5.18E-01	1.01E+00	9.83E-02	2.62E-01	1.09E+00	2.00E-01
1.43E+00	8.94E-01	1.22E-01	6.19E-01	1.01E+00	9.84E-02	3.12E-01	1.09E+00	2.00E-01

Tables A2-b1 and A2-b2 are tabular versions of the typical amplification factors provided in Figures 2.3.6-1 and 2.3.6-2. Values are provided for two input motion levels at approximately 1E-5 and 1E-5 mean annual frequency of exceedance. These tables concentrate on the frequency range of 0.5 Hz to 25 Hz, with values up to 100 Hz included, and a single value at 0.1 Hz included for completeness. These factors are unverified and are provided for information only. The figures should be considered the governing information.

Table A2-b1. Median AFs and sigmas for Model 1, Profile 1, for 2 PGA levels

M1P1K1	Rock PGA=0.194			M1P1K1	PGA=0.741		
Freq (Hz)	Soil SA	Median AF	Sigma ln(AF)	Freq (Hz)	Soil SA	Median AF	Sigma ln(AF)
100.0	0.201	1.037	0.137	100.0	0.779	1.051	0.138
87.1	0.208	1.043	0.136	87.1	0.810	1.059	0.137
75.9	0.220	1.057	0.134	75.9	0.871	1.075	0.134
66.1	0.246	1.082	0.136	66.1	0.997	1.104	0.136
57.5	0.296	1.117	0.149	57.5	1.239	1.138	0.151
50.1	0.369	1.158	0.166	50.1	1.565	1.178	0.169
43.7	0.430	1.141	0.170	43.7	1.814	1.155	0.174
38.0	0.460	1.109	0.163	38.0	1.911	1.122	0.167
33.1	0.469	1.068	0.153	33.1	1.913	1.079	0.158
28.8	0.468	1.065	0.146	28.8	1.874	1.073	0.149
25.1	0.462	1.043	0.141	25.1	1.818	1.049	0.144
21.9	0.454	1.074	0.139	21.9	1.754	1.080	0.140
19.1	0.443	1.062	0.136	19.1	1.686	1.067	0.138
16.6	0.430	1.072	0.135	16.6	1.612	1.077	0.136
14.5	0.415	1.084	0.135	14.5	1.537	1.088	0.136
12.6	0.399	1.069	0.137	12.6	1.458	1.072	0.137
11.0	0.381	1.048	0.137	11.0	1.379	1.050	0.138
9.5	0.364	1.046	0.135	9.5	1.302	1.048	0.135
8.3	0.344	1.070	0.140	8.3	1.218	1.072	0.140
7.2	0.327	1.086	0.135	7.2	1.147	1.087	0.135
6.3	0.308	1.091	0.142	6.3	1.074	1.092	0.142
5.5	0.287	1.062	0.143	5.5	0.992	1.063	0.143
4.8	0.270	1.021	0.128	4.8	0.927	1.022	0.128
4.2	0.251	0.980	0.138	4.2	0.857	0.981	0.138
3.6	0.233	0.936	0.150	3.6	0.792	0.936	0.149
3.2	0.217	0.924	0.154	3.2	0.732	0.925	0.154
2.8	0.197	0.885	0.141	2.8	0.662	0.885	0.141
2.4	0.184	0.896	0.122	2.4	0.615	0.896	0.122
2.1	0.176	0.941	0.153	2.1	0.585	0.942	0.153
1.8	0.157	0.939	0.144	1.8	0.520	0.940	0.144
1.6	0.138	0.951	0.144	1.6	0.454	0.952	0.144
1.4	0.124	0.996	0.175	1.4	0.407	0.995	0.174
1.2	0.113	1.023	0.175	1.2	0.366	1.022	0.174
1.0	0.101	1.021	0.124	1.0	0.328	1.020	0.124
0.91	0.093	1.023	0.117	0.91	0.297	1.023	0.117
0.79	0.085	1.034	0.136	0.79	0.269	1.033	0.135
0.69	0.076	1.049	0.154	0.69	0.241	1.048	0.154
0.60	0.068	1.064	0.173	0.60	0.211	1.063	0.172
0.52	0.058	1.077	0.193	0.52	0.181	1.075	0.192
0.46	0.049	1.083	0.206	0.46	0.151	1.082	0.206
0.10	0.002	1.018	0.059	0.10	0.006	1.017	0.051

Table A2-b2. Median AFs and sigmas for Model 2, Profile 1, for 2 PGA levels

M2P1K1	PGA=0.194			M2P1K1	PGA=0.741		
Freq (Hz)	Soil SA	Median AF	Sigma ln(AF)	Freq (Hz)	Soil SA	Median AF	Sigma ln(AF)
100.0	0.201	1.038	0.138	100.0	0.778	1.051	0.139
87.1	0.208	1.044	0.137	87.1	0.810	1.059	0.138
75.9	0.220	1.057	0.135	75.9	0.872	1.076	0.136
66.1	0.246	1.082	0.137	66.1	1.000	1.107	0.141
57.5	0.297	1.118	0.152	57.5	1.245	1.143	0.158
50.1	0.370	1.159	0.169	50.1	1.569	1.181	0.175
43.7	0.430	1.142	0.172	43.7	1.813	1.155	0.175
38.0	0.460	1.110	0.164	38.0	1.906	1.120	0.166
33.1	0.469	1.068	0.154	33.1	1.907	1.075	0.155
28.8	0.468	1.065	0.146	28.8	1.868	1.070	0.147
25.1	0.462	1.043	0.141	25.1	1.813	1.046	0.142
21.9	0.454	1.074	0.139	21.9	1.750	1.077	0.139
19.1	0.443	1.062	0.136	19.1	1.682	1.065	0.137
16.6	0.430	1.072	0.135	16.6	1.609	1.075	0.135
14.5	0.415	1.084	0.135	14.5	1.535	1.087	0.135
12.6	0.399	1.069	0.137	12.6	1.456	1.071	0.137
11.0	0.381	1.048	0.137	11.0	1.378	1.049	0.137
9.5	0.364	1.046	0.135	9.5	1.301	1.047	0.135
8.3	0.343	1.070	0.140	8.3	1.217	1.071	0.140
7.2	0.327	1.086	0.135	7.2	1.147	1.087	0.135
6.3	0.308	1.091	0.142	6.3	1.074	1.092	0.142
5.5	0.287	1.062	0.143	5.5	0.991	1.063	0.142
4.8	0.270	1.021	0.128	4.8	0.927	1.022	0.128
4.2	0.251	0.980	0.138	4.2	0.857	0.981	0.138
3.6	0.233	0.936	0.150	3.6	0.792	0.936	0.149
3.2	0.217	0.924	0.154	3.2	0.732	0.925	0.154
2.8	0.197	0.885	0.141	2.8	0.662	0.885	0.141
2.4	0.184	0.896	0.122	2.4	0.615	0.896	0.122
2.1	0.176	0.941	0.153	2.1	0.585	0.941	0.153
1.8	0.157	0.939	0.144	1.8	0.520	0.940	0.144
1.6	0.138	0.951	0.144	1.6	0.454	0.952	0.144
1.4	0.124	0.996	0.175	1.4	0.407	0.995	0.174
1.2	0.113	1.023	0.175	1.2	0.366	1.022	0.174
1.0	0.101	1.021	0.124	1.0	0.328	1.020	0.124
0.91	0.093	1.023	0.117	0.91	0.297	1.023	0.117
0.79	0.085	1.034	0.136	0.79	0.269	1.033	0.135
0.69	0.076	1.049	0.154	0.69	0.241	1.048	0.154
0.60	0.068	1.064	0.173	0.60	0.211	1.063	0.172
0.52	0.058	1.077	0.193	0.52	0.181	1.075	0.192
0.46	0.049	1.083	0.206	0.46	0.151	1.082	0.206
0.10	0.002	1.018	0.059	0.10	0.006	1.017	0.051