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0CAN031404

March 28, 2014

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
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Rockville, MD 20852

SUBJECT: Seismic Hazard and Screening Report (Central Eastern United States (CEUS) Sites), Response to NRC Request for Information (RFI) Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force (NTTF) Review of Insights from the Fukushima Dai-ichi Accident
Arkansas Nuclear One – Units 1 and 2
Docket Nos. 50-313 and 50-368
License Nos. DPR-51 and NPF-6

REFERENCES:

1. NRC letter to Entergy, *RFI Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the NTTF Review of Insights from the Fukushima Dai-ichi Accident*, dated March 12, 2012 (0CNA031208) (ML12053A340)

2. Nuclear Energy Institute (NEI) Letter to NRC, *Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations*, dated April 9, 2013 (ML13101A379)

3. NRC Letter, *Electric Power Research Institute (EPRI) Final Draft Report XXXXXX, "Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima NTTF Recommendation 2.1: Seismic," as an Acceptable Alternative to the March 12, 2012, Information Request for Seismic Reevaluations*, dated May 7, 2013 (ML13106A331)

4. EPRI Report 1025287, *Seismic Evaluation Guidance, Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima NTTF Recommendation 2.1: Seismic*, (ML12333A170)

5. NRC Letter, *Endorsement of EPRI Final Draft Report 1025287, "Seismic Evaluation Guidance,"* dated February 15, 2013, (0CNA021302) (ML12319A074)

6. Entergy Letter to NRC, *Response to NRC RFI Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the NTTF Review of Insights from the Fukushima Dai-ichi Accident – 1.5-Year Response for CEUS Sites*, dated September 12, 2013, (0CAN091301) (ML13255A373)

A010
NRR

Dear Sir or Madam:

On March 12, 2012, the NRC issued Reference 1 to all power reactor licensees. Enclosure 1 of Reference 1 requested each addressee located in the CEUS to submit a seismic hazard evaluation within 1.5 years from the date of Reference 1.

In Reference 2, NEI requested NRC agreement to delay submittal of the final CEUS seismic hazard evaluation so that an update to the 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 (Reference 6), with the remaining seismic hazard and screening information submitted by March 31, 2014. NRC agreed with the proposed path forward in Reference 3.

Reference 4 contains industry guidance and detailed information to be included in the seismic hazard evaluation submittal. NRC endorsed this industry guidance in Reference 5.

The enclosed Seismic Hazard and Screening Reports for Arkansas Nuclear One (ANO) provide the information described in Section 4 of Reference 4 in accordance with the schedule identified in Reference 2.

This letter contains no new regulatory commitments. If you have any questions or require additional information, please contact Stephenie Pyle at 479.858.4704.

I declare under penalty of perjury that the foregoing is true and correct. Executed on March 28, 2014.

Sincerely,

Terry A. Evans for

JGB/nbm

Enclosures: 1. Seismic Hazard and Screening Report for ANO-1
2. Seismic Hazard and Screening Report for ANO-2

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Enclosure 1 to

0CAN031404

Seismic Hazard and Screening Report for ANO-1

Seismic Hazard and Screening Report for Arkansas Nuclear One Unit 1

Table of Contents

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 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 (U.S. NRC, 2012) that requests information to assure that these recommendations are addressed by all U.S. nuclear power plants. The 50.54(f) letter (U.S. NRC, 2012) 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, 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 (U.S. NRC, 2012) pertaining to NTTF Recommendation 2.1 for the Arkansas Nuclear One (ANO) – Unit 1 plant, located in Pope County, Arkansas. In providing this information, Entergy 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, 2013c), 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 ANO – Unit 1 was 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 (U.S. NRC, 2012) and following the guidance provided in the SPID (EPRI, 2013a), 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, ANO – Unit 1 screens-in for a Spent Fuel Pool evaluation and a High Frequency Confirmation. Additionally, based on the results of the screening evaluation, ANO – Unit 1 screens-out of a risk evaluation.

2.0 Seismic Hazard Reevaluation

The Arkansas Nuclear One site is located approximately six miles west-northwest of Russellville, Arkansas, on a peninsula formed by the Dardanelle Reservoir which acts as the water source for each Unit. The Arkansas Nuclear One site is in the center of the Arkansas Valley section of the Ouachita province. The Arkansas Valley lies within the area of outcrop of Paleozoic rocks which occupy essentially the northwestern half of the state. The rocks of the Arkansas Valley are nearly all of sedimentary origin. They include only a few bodies of igneous rock. The beds in the valley consist chiefly of non-fossiliferous shale and sandstone, all of Carboniferous age, and most of them belonging to the lower part of the Pennsylvanian series. The rocks are generally highly carbonaceous and in some places are coal bearing. They contain little or no calcareous material. (Entergy, 2014a), (Entergy, 2014b)

The site is underlain by 8 to 30 ft of moderate to stiff, plastic, red and tan clay with occasional zones of silty clay, which overlies black, dense, horizontally bedded shale and sandstone of the McAlester formation. (Entergy, 2014a)

The nature of the structural features of the Arkansas Valley and their relation to the structure of the adjacent Ouachita and Boston Mountains show that the dominant force in the production of those features was horizontal pressure exerted from the south. It is believed that the folding and thrust faulting developed in post-Paleozoic pre-Cretaceous time due to the subsidence of a land mass to the south which supplied sediments in the place where this land mass once stood. The normal faults were also connected with this episode of deformation. These are believed to have formed either contemporaneously with folding, before folding, or as a result of tension developed after the period of folding. Some normal faults are also believed to have formed during deposition and subsidence of the Pennsylvanian sediments. In the Arkansas Valley, the southward-dipping faults terminate against northward-dipping normal faults. The precise dating of the folds and faults of the Arkansas Valley cannot be done with assurance, but it is known that they are very old geologic structures and probably were formed before Cretaceous time. (Entergy, 2014a)

East-west trending folds are mapped in the area of the site. From about three miles north to three miles south of the site are two anticlines and one syncline. From north to south these structures are as follows: London anticline, Scranton syncline, and the Prairie View anticline. The plant site is located on the Scranton syncline in which the maximum dip rarely exceeds 10 degrees except locally where contorted beds may dip as steeply as 20 degrees. (Entergy, 2014a)

The London anticline extends from about four and one-half miles northwest of the town of London, east to about three miles northwest of the site. This anticline may continue east to connect with the anticline which is mapped northeast of the site to a point three and one-half miles north of Russellville. The south limb of the London anticline is steeper than the north limb. (Entergy, 2014a)

The Scranton syncline, also known as the Ouita syncline, extends from northeast of Russellville, west to a point where it probably dies out about five miles northwest of Scranton. Here it is presumably terminated by the Dublin fault, which is an east-west-trending fault over nine miles west of the site. On the western part of the Scranton syncline the south limb is steeper than the north limb. However, on the eastern portion of the syncline the north limb is steeper than the south limb. (Entergy, 2014a)

The Prairie View anticline is mapped from a point three miles southwest of the town of Scranton, east to at least as far as Russellville. This nearly symmetrical anticline is broken by northward-dipping normal faults. (Entergy, 2014a)

There are a number of old faults mapped in the vicinity of the Arkansas River, particularly to the northwest and west of the site. These are in the main, east-west-trending faults. Of these, the London and Prairie View faults are the closest to the site. The London fault and an accompanying unnamed small branch fault trend east-west about four miles north of the site. A small fault which branches from the unnamed fault lies about two and one-half miles northeast of the site. The London fault is a high-angle south-dipping normal fault. It is best exposed about eight miles northwest of the site at Big Piney Creek where the western part of the fault ends. At this locality, the fault plane dips 58° south and has an apparent displacement of about 20 ft. The fault is also exposed to the east along Flat Rock Creek and in a drainage ditch along a country road about eight miles from the site. The unnamed eastwest-trending fault lies about one mile south of the London fault. The trend of this unnamed fault changes toward the east to generally northwest-southeast and appears to intersect the London fault in the vicinity of the north fork of Mill Creek. This fault is at least pre-Cretaceous in age. (Entergy, 2014a)

The Prairie View fault is concealed under alluvium about six miles west of the site. Another six miles to the west, the fault is exposed. It is an east-west-trending high-angle north-dipping normal fault. This fault extends to the west as far as three miles northwest of Subiaco. The maximum displacement along the fault is 350 ft two miles west of the town of Prairie View. Near the western end of the fault there is about 170 ft of maximum displacement and the fault plane dips about 65° northward. About three miles from the western end of the fault is a small branch fault which is downthrown on the southside and is assumed to be dipping south. The Prairie View anticline is faulted by the Prairie View fault and is similar to the faulted anticlines discussed by Hendricks and Parks. It is their opinion that the faulted anticlines in the Fort Smith district were either faulted then folded, or contemporaneously faulted and folded. Therefore, the Prairie View fault is at least as old as the folding in this area, which is pre-Cretaceous. (Entergy, 2014a)

In summary, the only faults within five miles of the site are the Prairie View fault, and the London fault and its branch faults. The closest fault is only a small branch fault and approaches within about two and one-half miles of the site. The last movement of these faults is believed to have occurred prior to the Cretaceous. (Entergy, 2014a)

Considering the historic seismicity of the site region, Entergy determined that because of the excellent formation conditions and the recent general quiescence of the area that a low

earthquake intensity could be selected. However, considering the New Madrid earthquake, which is the only severe earthquake experienced in the central United States in historic time, an intensity of VII on the Modified Mercalli Intensity Scale of 1931 (Maximum Earthquake) has been assigned for the site. This is considered to be conservative and corresponds to a design spectrum of 0.20g for the SSE. (Entergy, 2014a)

2.1 Regional and Local Geology

The Arkansas Valley is essentially a Paleozoic basin which had its most significant development during the Mississippian and Pennsylvanian. The greatest accumulations occurred during the Lower (Morrowan) and Lower Middle (Atokan) Pennsylvanian. Deformation of the Ouachitas occurred during Mid-Pennsylvanian time. During this time, the Ouachitas were strongly folded, with some thrust faulting, especially in Oklahoma. The Arkansas Valley section lies between the essentially flat-lying rocks of the Boston Mountains on the north and complexly folded strata of the Ouachita Mountains on the south. Its structure, therefore, has some of the characteristics of both its bounding regions, but is generally a region of broad, gentle folds which trend east-west and are only moderately faulted. Faulting is related to the folding and is pre-Cretaceous in age. (Entergy, 2014a) (Entergy, 2014b)

Since Cretaceous (and probably late Paleozoic) time, erosion has been the primary agent in the development of land forms in the region. No sediments younger than Pennsylvanian are found in the region, except for Quaternary terrace and alluvial deposits along the stream valleys. In a few places, intrusive rocks, mapped by as mid-Cretaceous cut the Paleozoic sediments. In the Arkansas Valley, these rocks consist of scattered dikes and sills of varying composition. None occur at the plant site. (Entergy, 2014a) (Entergy, 2014b)

The site is about six miles northwest from Russellville, and about two miles from the small town of London. The plant is situated on a peninsula formed by the Corps of Engineers' Dardanelle Reservoir. The plant is located on a broad, nearly flat bench adjacent to the floodplain of the Arkansas River. This bench is at about Elevation 353 ft, at the lower of the two Pleistocene terrace levels. Soil on the terrace consists of clay and silty clay, and is from eight to 30 ft thick at the site. The broad floodplain of the Arkansas River is now covered with the waters of the Dardanelle Reservoir in the vicinity of the site. The low hills adjacent to the site are formed by the gently upturned strata along the flanks of the Scranton-Ouita syncline. Relief within the limits of the site area is less than 10 ft. (Entergy, 2014a) (Entergy, 2014b)

2.2 Probabilistic Seismic Hazard Analysis

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter (U.S. NRC, 2012) and following the guidance in the SPID (EPRI, 2013a), 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 (CEUS-SSC, 2012) together with the updated Electric Power

Research Institute (EPRI) Ground-Motion Model (GMM) for the Central and Eastern United States (CEUS) (EPRI, 2013b). For the PSHA, a lower-bound moment magnitude of 5.0 was used, as specified in the 50.54(f) letter (U.S. NRC, 2012). (EPRI, 2013d)

For the PSHA, the CEUS-SSC background seismic sources out to a distance of 400 miles (640 km) around the ANO – Unit 1 site were included. This distance exceeds the 200 mile (320 km) recommendation contained in Reg. Guide 1.208 (U.S. NRC, 2007) and was chosen for completeness. Background sources included in this site analysis are the following (EPRI, 2013d):

1. Extended Continental Crust—Gulf Coast (ECC_GC)
2. Gulf Highly Extended Crust (GHEX)
3. Illinois Basin Extended Basement (IBEB)
4. Mesozoic and younger extended prior – narrow (MESE-N)
5. Mesozoic and younger extended prior – wide (MESE-W)
6. Midcontinent-Craton alternative A (MIDC_A)
7. Midcontinent-Craton alternative B (MIDC_B)
8. Midcontinent-Craton alternative C (MIDC_C)
9. Midcontinent-Craton alternative D (MIDC_D)
10. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
11. Non-Mesozoic and younger extended prior – wide (NMESE-W)
12. Oklahoma Aulacogen (OKA)
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 Repeated Large Magnitude Earthquake (RLME) sources), in NUREG-2115 (CEUS-SSC, 2012) modeled for the CEUS-SSC, the following sources lie within 1,000 km of the site and were included in the analysis (EPRI, 2013d):

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

For each of the above background and RLME sources, the mid-continent version of the updated CEUS EPRI GMM was used. (EPRI, 2013d)

2.2.2 Base Rock Seismic Hazard Curves

Consistent with the SPID (EPRI, 2013a), base rock seismic hazard curves are not provided as the site amplification approach referred to as Method 3 has been used. Seismic hazard curves are shown below in Section 2.3.7 at the SSE control point elevation. (EPRI, 2013d)

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the 50.54(f) Request for Information (U.S. NRC, 2012) and in the SPID (EPRI, 2013a) for nuclear power plant sites that are not founded on hard rock (defined as 2.83 km/sec), a site response analysis was performed for ANO – Unit 1. (EPRI, 2013d)

2.3.1 Description of Subsurface Material

Arkansas Nuclear One – Unit 1 is located on a peninsula formed by the Dardanelle Reservoir about 57 miles (92 km) northwest of Little Rock, Arkansas. The site is situated in the center of the Arkansas Valley in the Ouachita Physiographic Province. The site is founded on Pennsylvania McAlester formation which is hard, dense shale at the top of about 5,000 ft (1,524 m) of firm sedimentary rock. The SSE was specified at an elevation of 326 ft (99.4 m) within the Pennsylvanian shale (Entergy, 2014a).

2.3.2 Development of Base Case Profiles and Nonlinear Material Properties

The basic information used to create the site geologic profile at the ANO – Unit 1 site was taken from plant specific information in the Safety Analysis Report (SAR) (Entergy, 2014a) with the following description (Entergy, 2014a) (Entergy, 2014b):

The reactor containment building is founded on shale of the McAlester Formation with embedment depth of around 26 ft. with tendon galleries of about 36 ft. below grade. Basement rock is estimated to be at a depth of 5,000 ft. The site seismic P-wave varies from 11,000 to 14,500 fps (Entergy, 2014a; Figures 2-21 and 2-30), and Poisson's ratio of 0.18 for 'rock' and 0.25 for 'shale' at the site (Entergy, 2014a, Tables 2-2 and 2-5). The ANO - Unit 1 SAR does not specifically provide a S-wave velocity; however, the ANO – Unit 2 SAR indicates site P-wave velocities form 10,000 to 14,500 fps, and S-wave (not measured but calculated P-wave of 10,000 fps and a Poisson's ration of 0.30) of 5,350 fps. While this information is not identical it is appropriate to use for both units. The site seismic profiles are shown in Figure 2-21 of the SAR (Entergy, 2014a).

The location of the SSE at elevation 326 ft (99.4 m) is within the Pennsylvanian shale with firm sedimentary rocks extending to Precambrian basement at a depth of about 5,000 ft (1,524 m) (Entergy, 2014a).

Shear-wave velocities for the profile were unspecified with compressional-wave velocities listed between 10,000 and 14,500 ft/s (3,048 m/s and 4,419 m/s respectively), likely based on shallow refraction surveys (Entergy, 2014a) (Entergy, 2014b). To develop a mean base-case shear-wave velocity profile, a shallow velocity of 5,300 ft/s (1,616 m/s) was assumed. This value reflects an assumption of a reasonable Poisson ratio of about 0.30 and the lower value of the compressional-wave velocity for the top of the Pennsylvanian McAlester Formation. (EPRI, 2013d)

Provided the materials to basement depth reflect similar sedimentary rocks and age, the shear-wave velocity gradient for sedimentary rock of 0.5 m/m/s (EPRI, 2013a) was assumed to be appropriate for the site. The shallow shear-wave velocity of 5,300 ft/s (1,616 m/s) was taken at the surface of the profile with the velocity gradient applied at that point, resulting in a base-case shear-wave velocity of about 7,772 ft/s (2,369 m/s) at a depth of 5,000 ft (1,524 m). The mean or best estimate base-case profile is shown as profile P1 in Figure 2.3.2-1. (EPRI, 2013d)

Based on the uncertainty in shear-wave velocities due to the lack of measurements, a scale factor of 1.57 was adopted to reflect upper and lower range base-cases. The scale factor of 1.57 reflects a $\sigma_{\mu ln}$ of about 0.35 based on the SPID (EPRI, 2013a) 10th and 90th fractiles which implies a 1.28 scale factor on σ_{μ}. (EPRI, 2013d)

Using the best estimate or mean base-case profile (P1), the depth independent scale factor of 1.57 was applied to develop lower and upper range base-cases profiles P2 and P3 respectively with the stiffest profile (P3) reaching reference rock velocities at a depth of about 1,200 ft (366 m). Base-case profiles P1 and P2 have a mean depth below the SSE of 5,000 ft (1,524 m) to hard reference rock, randomized ±1,500 ft (±457 m). The base-case profiles (P1, P2, and P3) are shown in Figure 2.3.2-1 and listed in Table 2.3.2-1. The depth randomization reflects ±30% of the depth to provide a realistic broadening of the fundamental resonance rather than reflect actual random variations to basement shear-wave velocities across a footprint. (EPRI, 2013d)

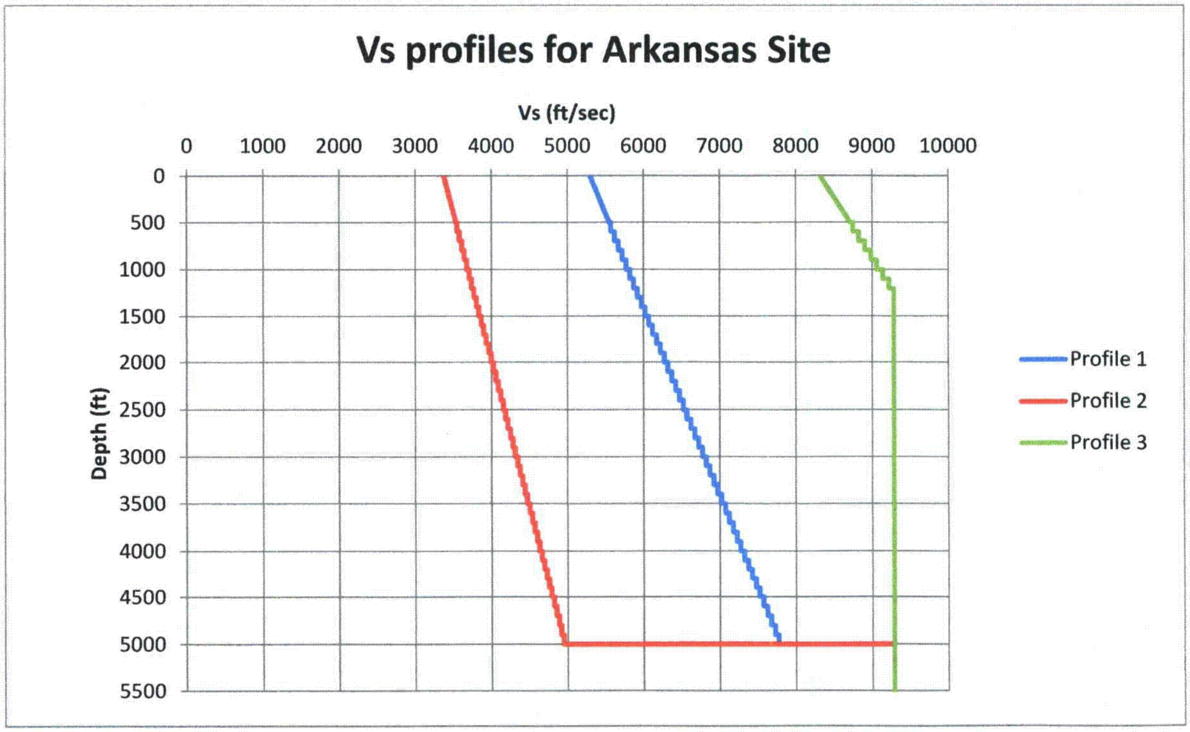

Figure 2.3.2-1. Shear-wave velocity profiles for ANO – Unit 1. (EPRI, 2013d)

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 3 profiles, ANO – Unit 1 site. (EPRI, 2013d)

Profile 1			Profile 2			Profile 3		
thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)
	0	5,302		0	3,378		0	8,325
10.0	10.0	5,302	10.0	10.0	3,378	10.0	10.0	8,325
10.0	20.0	5,307	10.0	20.0	3,381	10.0	20.0	8,332
10.0	30.0	5,312	10.0	30.0	3,384	10.0	30.0	8,340
10.0	40.0	5,317	10.0	40.0	3,387	10.0	40.0	8,348
10.0	50.0	5,322	10.0	50.0	3,390	10.0	50.0	8,356
10.0	60.0	5,327	10.0	60.0	3,393	10.0	60.0	8,364
10.0	70.0	5,332	10.0	70.0	3,397	10.0	70.0	8,372
10.0	80.0	5,337	10.0	80.0	3,400	10.0	80.0	8,379
10.0	90.0	5,342	10.0	90.0	3,403	10.0	90.0	8,387
10.0	100.0	5,347	10.0	100.0	3,406	10.0	100.0	8,395
10.0	110.0	5,352	10.0	110.0	3,409	10.0	110.0	8,403
10.0	120.0	5,357	10.0	120.0	3,413	10.0	120.0	8,411
10.0	130.0	5,362	10.0	130.0	3,416	10.0	130.0	8,419
10.0	140.0	5,367	10.0	140.0	3,419	10.0	140.0	8,427
10.0	150.0	5,372	10.0	150.0	3,422	10.0	150.0	8,434
10.0	160.0	5,377	10.0	160.0	3,425	10.0	160.0	8,442
10.0	170.0	5,382	10.0	170.0	3,428	10.0	170.0	8,450
10.0	180.0	5,387	10.0	180.0	3,432	10.0	180.0	8,458
10.0	190.0	5,392	10.0	190.0	3,435	10.0	190.0	8,466
10.0	200.0	5,397	10.0	200.0	3,438	10.0	200.0	8,474
10.0	210.0	5,402	10.0	210.0	3,441	10.0	210.0	8,481
10.0	220.0	5,407	10.0	220.0	3,444	10.0	220.0	8,489
10.0	230.0	5,412	10.0	230.0	3,448	10.0	230.0	8,497
10.0	240.0	5,417	10.0	240.0	3,451	10.0	240.0	8,505
10.0	250.0	5,422	10.0	250.0	3,454	10.0	250.0	8,513
10.0	260.0	5,427	10.0	260.0	3,457	10.0	260.0	8,521
10.0	270.0	5,432	10.0	270.0	3,460	10.0	270.0	8,529
10.0	280.0	5,437	10.0	280.0	3,464	10.0	280.0	8,536
10.0	290.0	5,442	10.0	290.0	3,467	10.0	290.0	8,544
10.0	300.0	5,447	10.0	300.0	3,470	10.0	300.0	8,552
10.0	310.0	5,452	10.0	310.0	3,473	10.0	310.0	8,560
10.0	320.0	5,457	10.0	320.0	3,476	10.0	320.0	8,568
10.0	330.0	5,462	10.0	330.0	3,479	10.0	330.0	8,576
10.0	340.0	5,467	10.0	340.0	3,483	10.0	340.0	8,584
10.0	350.0	5,472	10.0	350.0	3,486	10.0	350.0	8,591
10.0	360.0	5,477	10.0	360.0	3,489	10.0	360.0	8,599
10.0	370.0	5,482	10.0	370.0	3,492	10.0	370.0	8,607

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 3 profiles, ANO – Unit 1 site. (EPRI, 2013d)

Profile 1			Profile 2			Profile 3		
thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)
10.0	380.0	5,487	10.0	380.0	3,495	10.0	380.0	8,615
10.0	390.0	5,492	10.0	390.0	3,499	10.0	390.0	8,623
10.0	400.0	5,497	10.0	400.0	3,502	10.0	400.0	8,631
10.0	410.0	5,502	10.0	410.0	3,505	10.0	410.0	8,638
10.0	420.0	5,507	10.0	420.0	3,508	10.0	420.0	8,646
10.0	430.0	5,512	10.0	430.0	3,511	10.0	430.0	8,654
10.0	440.0	5,517	10.0	440.0	3,514	10.0	440.0	8,662
10.0	450.0	5,522	10.0	450.0	3,518	10.0	450.0	8,670
10.0	460.0	5,527	10.0	460.0	3,521	10.0	460.0	8,678
10.0	470.0	5,532	10.0	470.0	3,524	10.0	470.0	8,686
10.0	480.0	5,537	10.0	480.0	3,527	10.0	480.0	8,693
10.0	490.0	5,542	10.0	490.0	3,530	10.0	490.0	8,701
10.0	500.0	5,547	10.0	500.0	3,534	10.0	500.0	8,709
100.0	600.0	5,572	100.0	600.0	3,550	100.0	600.0	8,748
100.0	700.0	5,622	100.0	700.0	3,581	100.0	700.0	8,827
100.0	800.0	5,672	100.0	800.0	3,613	100.0	800.0	8,905
100.0	899.9	5,722	100.0	899.9	3,645	100.0	899.9	8,984
100.0	999.9	5,772	100.0	999.9	3,677	100.0	999.9	9,062
100.0	1,099.9	5,822	100.0	1,099.9	3,709	100.0	1,099.9	9,141
100.0	1,199.9	5,872	100.0	1,199.9	3,741	100.0	1,199.9	9,219
100.0	1,299.9	5,922	100.0	1,299.9	3,772	100.0	1,299.9	9,285
100.0	1,399.9	5,972	100.0	1,399.9	3,804	100.0	1,399.9	9,285
100.0	1,499.9	6,022	100.0	1,499.9	3,836	100.0	1,499.9	9,285
100.0	1,599.9	6,072	100.0	1,599.9	3,868	100.0	1,599.9	9,285
100.0	1,699.9	6,122	100.0	1,699.9	3,900	100.0	1,699.9	9,285
100.0	1,799.9	6,172	100.0	1,799.9	3,932	100.0	1,799.9	9,285
100.0	1,899.9	6,222	100.0	1,899.9	3,964	100.0	1,899.9	9,285
100.0	1,999.9	6,272	100.0	1,999.9	3,995	100.0	1,999.9	9,285
100.0	2,099.9	6,322	100.0	2,099.9	4,027	100.0	2,099.9	9,285
100.0	2,199.9	6,372	100.0	2,199.9	4,059	100.0	2,199.9	9,285
100.0	2,299.9	6,422	100.0	2,299.9	4,091	100.0	2,299.9	9,285
100.0	2,399.9	6,472	100.0	2,399.9	4,123	100.0	2,399.9	9,285
100.0	2,499.9	6,522	100.0	2,499.9	4,155	100.0	2,499.9	9,285
100.0	2,599.9	6,572	100.0	2,599.9	4,186	100.0	2,599.9	9,285
100.0	2,699.9	6,622	100.0	2,699.9	4,218	100.0	2,699.9	9,285
100.0	2,799.8	6,672	100.0	2,799.8	4,250	100.0	2,799.8	9,285
100.0	2,899.8	6,722	100.0	2,899.8	4,282	100.0	2,899.8	9,285
100.0	2,999.8	6,772	100.0	2,999.8	4,314	100.0	2,999.8	9,285

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 3 profiles, ANO – Unit 1 site. (EPRI, 2013d)

Profile 1			Profile 2			Profile 3		
thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)
100.0	3,099.8	6,822	100.0	3,099.8	4,346	100.0	3,099.8	9,285
100.0	3,199.8	6,872	100.0	3,199.8	4,378	100.0	3,199.8	9,285
100.0	3,299.8	6,922	100.0	3,299.8	4,409	100.0	3,299.8	9,285
100.0	3,399.8	6,972	100.0	3,399.8	4,441	100.0	3,399.8	9,285
100.0	3,499.8	7,022	100.0	3,499.8	4,473	100.0	3,499.8	9,285
100.0	3,599.8	7,072	100.0	3,599.8	4,505	100.0	3,599.8	9,285
100.0	3,699.8	7,122	100.0	3,699.8	4,537	100.0	3,699.8	9,285
100.0	3,799.8	7,172	100.0	3,799.8	4,569	100.0	3,799.8	9,285
100.0	3,899.8	7,222	100.0	3,899.8	4,600	100.0	3,899.8	9,285
100.0	3,999.8	7,272	100.0	3,999.8	4,632	100.0	3,999.8	9,285
100.0	4,099.8	7,322	100.0	4,099.8	4,664	100.0	4,099.8	9,285
100.0	4,199.8	7,372	100.0	4,199.8	4,696	100.0	4,199.8	9,285
100.0	4,299.8	7,422	100.0	4,299.8	4,728	100.0	4,299.8	9,285
100.0	4,399.8	7,472	100.0	4,399.8	4,760	100.0	4,399.8	9,285
100.0	4,499.8	7,522	100.0	4,499.8	4,792	100.0	4,499.8	9,285
100.0	4,599.8	7,572	100.0	4,599.8	4,823	100.0	4,599.8	9,285
100.0	4,699.8	7,622	100.0	4,699.8	4,855	100.0	4,699.8	9,285
100.0	4,799.7	7,672	100.0	4,799.7	4,887	100.0	4,799.7	9,285
100.0	4,899.7	7,722	100.0	4,899.7	4,919	100.0	4,899.7	9,285
100.0	4,999.7	7,772	100.0	4,999.7	4,951	100.0	4,999.7	9,285
3,280.8	8,280.6	9,285	3,280.8	8,280.6	9,285	3,280.8	8,280.6	9,285

2.3.2.1 Shear Modulus and Damping Curves

Nonlinear dynamic material properties were not available for ANO - Unit 1 for sedimentary rocks. The rock material over the upper 500 ft (150 m) was assumed to have behavior that could be modeled as either linear or non-linear. To represent this potential for either case in the upper 500 ft of sedimentary rock at the ANO - Unit 1 site, two sets of shear modulus reduction and hysteretic damping curves were used. Consistent with the SPID (EPRI, 2013a), 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 were used as the constant damping values in the upper 500 ft. (EPRI, 2013d)

2.3.2.2 Kappa

Base-case kappa estimates were determined using Section B-5.1.3.1 of the SPID (EPRI, 2013a) for a firm CEUS rock site. Kappa for a firm rock site with at least 3,000 ft (1 km) of sedimentary rock may be estimated from the average S-wave velocity over the upper 100 ft (V_{s100}) of the subsurface profile. For the ANO – Unit 1 site, with at least 3,000 ft (1 km) of firm rock, the corresponding average shear-wave velocities over the top 100 ft (31 m) were 5,325 ft/s (1,623 m/s) (P1), 3,391 ft/s (1,034 m/s) (P2), and 8,360 ft/s (2,548 m/s) (P3). The corresponding kappa estimates were 0.014 s, 0.023 s, and 0.009 s respectively. The range of kappa from 0.009 s to 0.023 s reflects a reasonable assessment of epistemic uncertainty. The suite of kappa estimates and associated weights are listed in Table 2.3.2-2. (EPRI, 2013d)

Table 2.3.2-2. Kappa Values and Weights Used for Site Response Analyses. (EPRI, 2013d)

Velocity Profile	Kappa(s)
P1	0.014
P2	0.023
P3	0.009
	Weights
P1	0.4
P2	0.3
P3	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 ANO – Unit 1 site, random shear wave velocity profiles were developed from the base case profiles shown in Figure 2.3.2-1. Consistent with the discussion in Appendix B of the SPID (EPRI, 2013a), the velocity randomization procedure made use of random field models which describe the statistical correlation between layering and shear wave velocity. The default randomization parameters developed in (Toro,1997) for United States Geological Survey "A" site conditions were used for this site. 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 0.15 below that depth. As specified in the SPID (EPRI, 2013a), 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. (EPRI, 2013d)

2.3.4 Input Spectra

Consistent with the guidance in Appendix B of the SPID (EPRI, 2013a), 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) were used in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed for the analysis of the ANO – Unit 1 site were the same as those identified in Tables B-4, B-5, B-6 and B-7 of the SPID (EPRI, 2013a) as appropriate for typical CEUS sites. (EPRI, 2013d)

2.3.5 Methodology

To perform the site response analyses for the ANO – Unit 1site, 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 (EPRI, 2013a). The guidance contained in Appendix B of the SPID (EPRI, 2013a) 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 the ANO – Unit 1 site. (EPRI, 2013d)

2.3.6 Amplification Functions

The results of the site response analysis consist of amplification factors (5% damped 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 (EPRI, 2013a) 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 (EPRI, 2013a) 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 the ANO – Unit 1 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 0.5g loading level and below. Above about the 0.5g loading level, the differences increase significantly but only above about 20 Hz. Tabular data for Figure 2.3.6-1 and Figure 2.3.6-2 is provided For Information Only in Appendix A. (EPRI, 2013d)

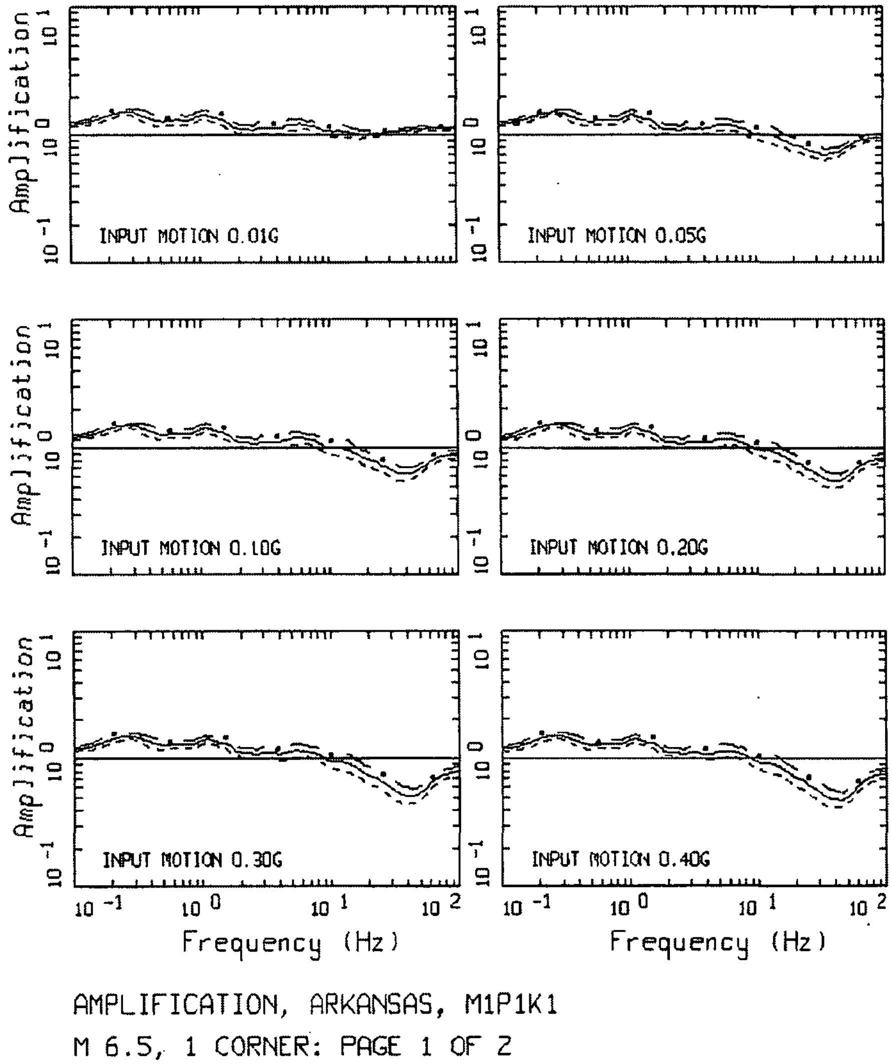

Figure 2.3.6-1. Example suite of amplification factors (5% damping pseudo-absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa (K1) at eleven loading levels of hard-rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (EPRI, 2013a). (EPRI, 2013d)

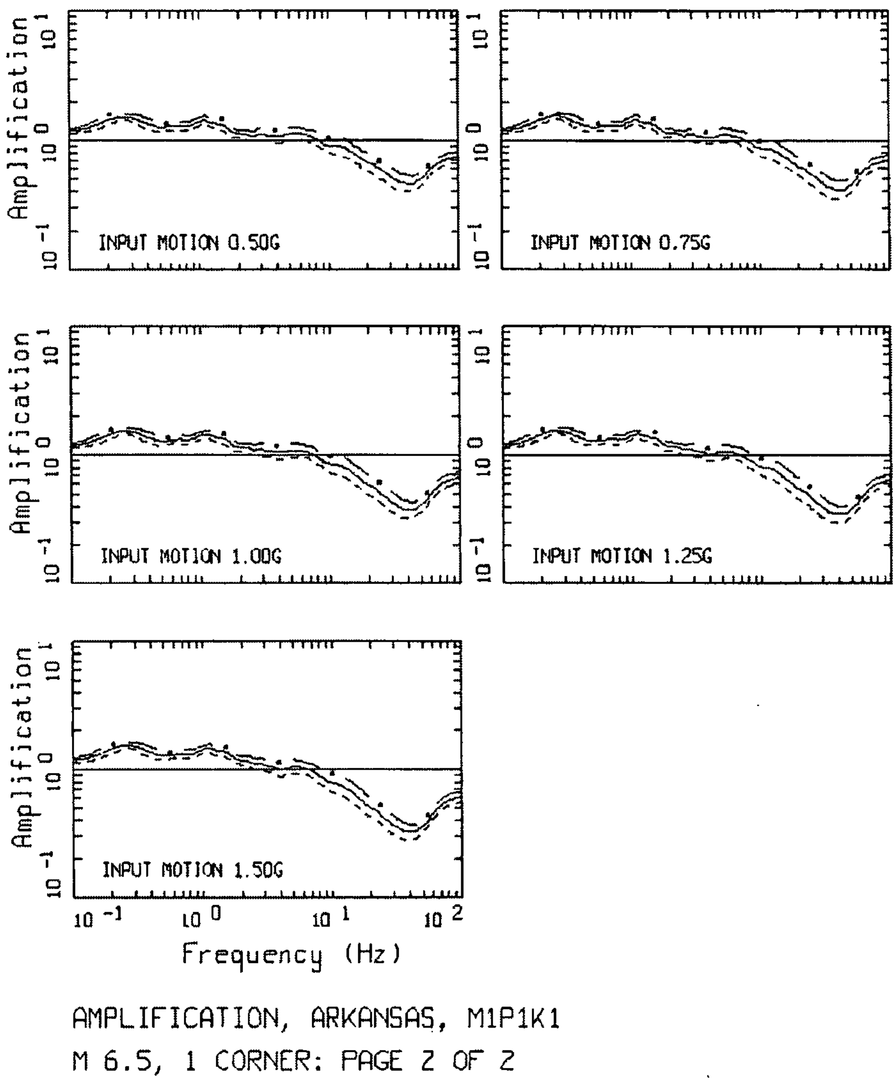

Figure 2.3.6-1.(cont.)

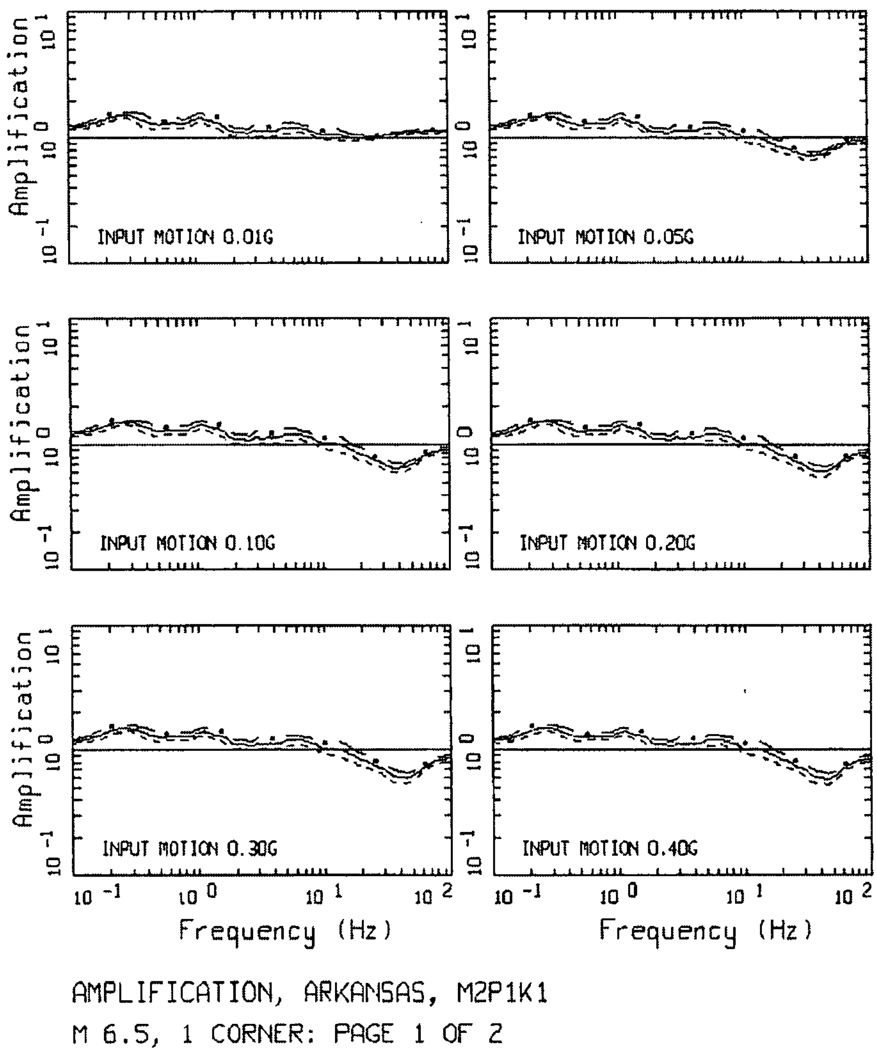

Figure 2.3.6-2. Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), linear site response (model M2), and base-case kappa (K1) at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (EPRI, 2013a). (EPRI, 2013d)

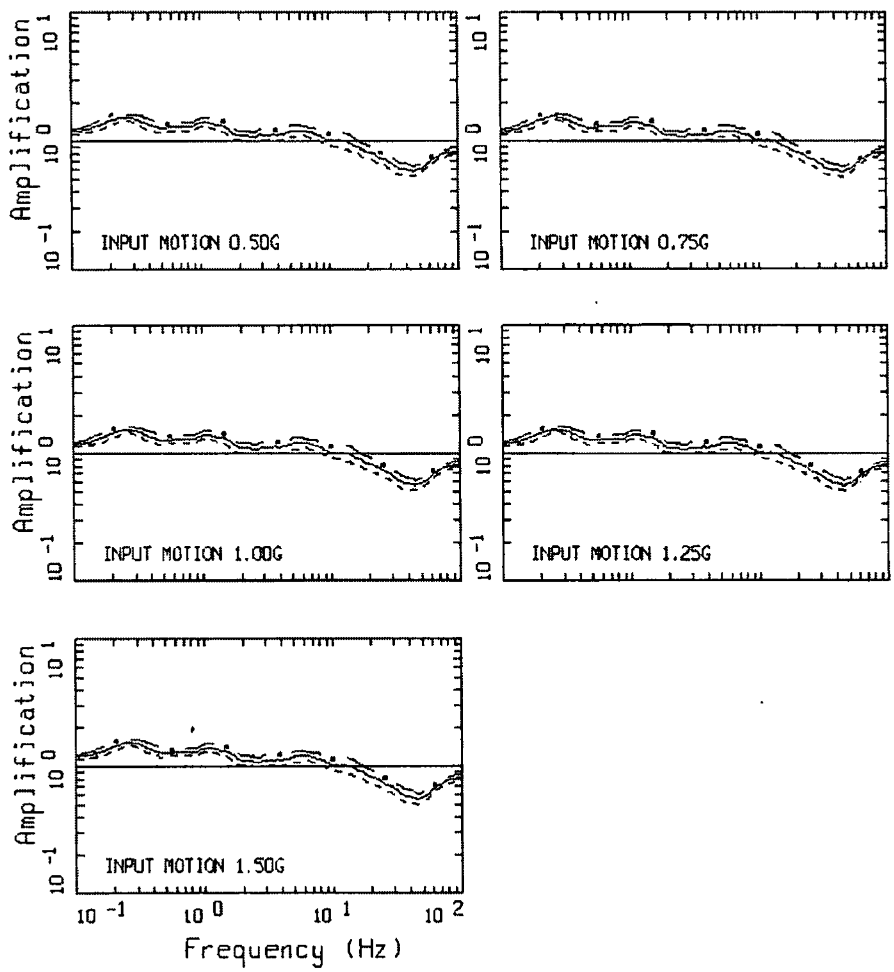

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Figure 2.3.6-2.(cont.)

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 (EPRI, 2013a). 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 ANO – Unit 1 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. (EPRI, 2013d)

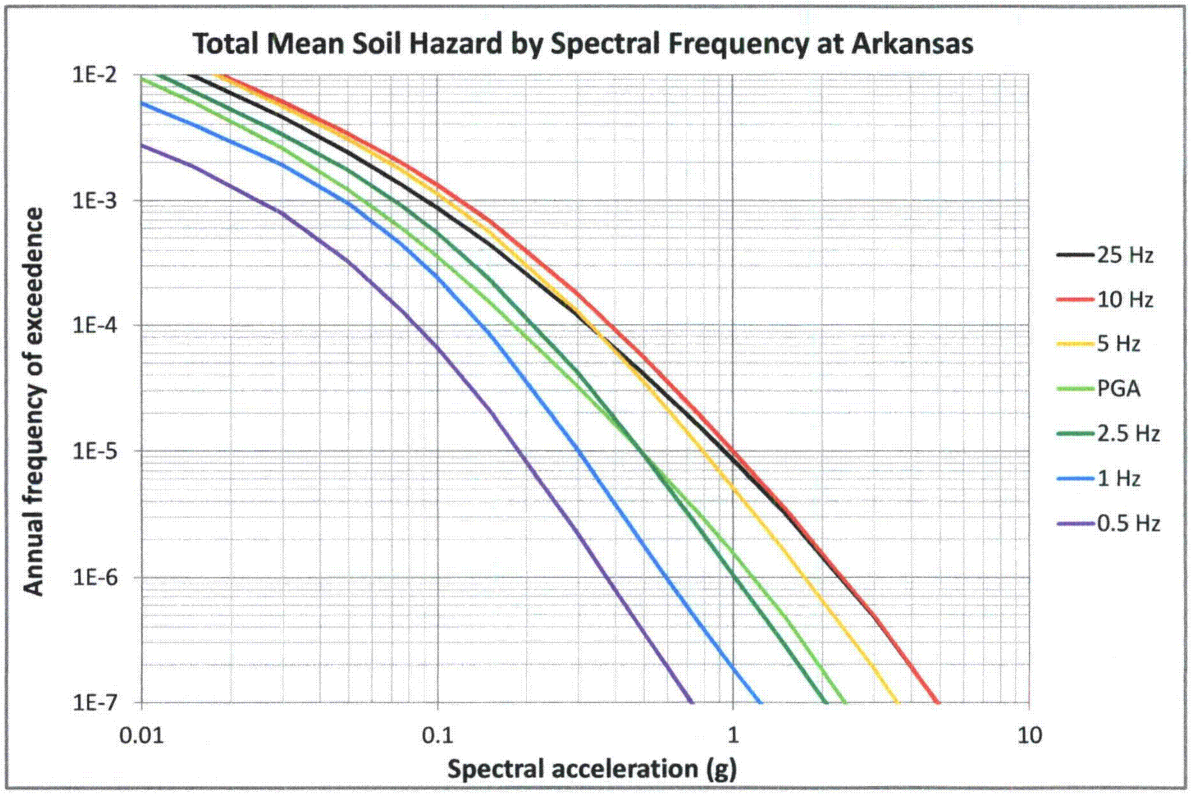

Figure 2.3.7-1. Control point mean hazard curves for spectral frequencies of 0.5, 1.0, 2.5, 5.0, 10, 25 and PGA (100 Hz) at ANO – Unit 1. (EPRI, 2013d)

2.4 Control Point Response Spectrum

The control point 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 10^{-4} and 10^{-5} per year hazard levels. Table 2.4-1 shows the UHRS and GMRS accelerations for a range of spectral frequencies. (EPRI, 2013d)

Table 2.4-1. UHRS and GMRS for ANO – Unit 1. (EPRI, 2013d)

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
100	1.82E-01	4.88E-01	2.40E-01
90	1.82E-01	4.91E-01	2.42E-01
80	1.83E-01	4.97E-01	2.44E-01
70	1.86E-01	5.09E-01	2.50E-01
60	1.96E-01	5.42E-01	2.65E-01
50	2.20E-01	6.22E-01	3.03E-01
40	2.59E-01	7.42E-01	3.61E-01
35	2.79E-01	8.02E-01	3.89E-01
30	3.02E-01	8.67E-01	4.21E-01
25	3.26E-01	9.32E-01	4.53E-01
20	3.54E-01	9.85E-01	4.82E-01
15	3.81E-01	1.03E+00	5.06E-01
12.5	3.90E-01	1.03E+00	5.10E-01
10	3.86E-01	1.00E+00	4.96E-01
9	3.80E-01	9.71E-01	4.83E-01
8	3.76E-01	9.46E-01	4.72E-01
7	3.64E-01	9.06E-01	4.53E-01
6	3.50E-01	8.54E-01	4.29E-01
5	3.32E-01	7.91E-01	3.99E-01
4	2.92E-01	6.90E-01	3.48E-01
3.5	2.71E-01	6.36E-01	3.22E-01
3	2.44E-01	5.67E-01	2.87E-01
2.5	2.11E-01	4.87E-01	2.47E-01
2	1.91E-01	4.35E-01	2.21E-01
1.5	1.73E-01	3.84E-01	1.96E-01
1.25	1.57E-01	3.43E-01	1.76E-01
1	1.41E-01	3.01E-01	1.55E-01
0.9	1.28E-01	2.76E-01	1.42E-01
0.8	1.20E-01	2.59E-01	1.33E-01
0.7	1.13E-01	2.47E-01	1.27E-01
0.6	1.00E-01	2.20E-01	1.13E-01
0.5	8.46E-02	1.88E-01	9.62E-02
0.4	6.77E-02	1.51E-01	7.70E-02
0.35	5.92E-02	1.32E-01	6.74E-02
0.3	5.08E-02	1.13E-01	5.77E-02
0.25	4.23E-02	9.41E-02	4.81E-02
0.2	3.38E-02	7.53E-02	3.85E-02
0.15	2.54E-02	5.65E-02	2.89E-02
0.125	2.12E-02	4.71E-02	2.41E-02
0.1	1.69E-02	3.76E-02	1.92E-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. (EPRI, 2013d)

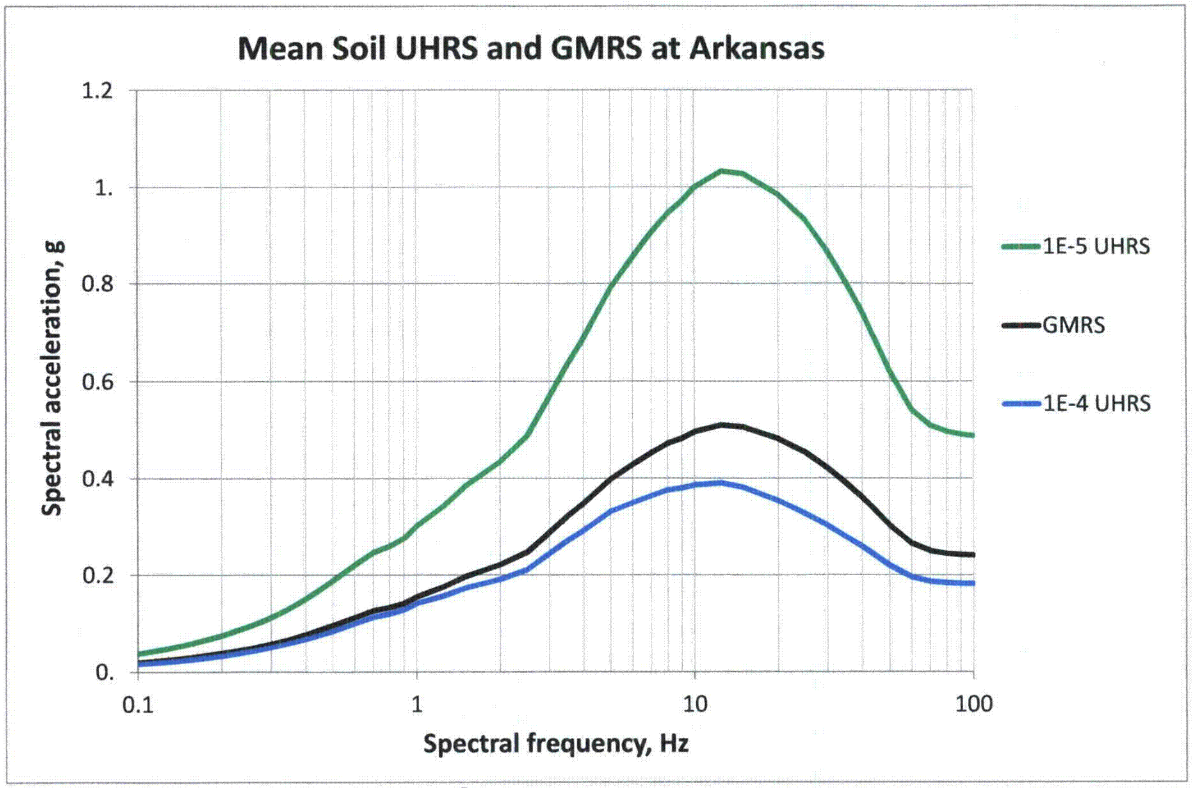

Figure 2.4-1. UHRS for 10^{-4} and 10^{-5} and GMRS at control point for ANO – Unit 1 (5%-damped response spectra). (EPRI, 2013d)

3.0 Plant Design Basis and Beyond Design Basis Evaluation Ground Motion

The design bases for ANO – Unit 1 are identified in the Updated Final Safety Analysis Report (Entergy, 2014a).and other pertinent documents.

An evaluation for beyond design basis (BDB) ground motions was performed in the Individual Plant Examination of External Events (IPEEE). The IPEEE capacity response spectrum is included below for screening purposes.

3.1 Safe Shutdown Earthquake Description of Spectral Shape

The SSEs for ANO – Unit 1 were developed in accordance with 10 CFR Part 100, Appendix A through an evaluation of the maximum earthquake potential for the region surrounding the site. Considering the historic seismicity of the site region, Entergy determined that because of the excellent formation conditions and the recent general quiescence of the area that a low earthquake intensity could be selected. However, considering the New Madrid earthquake, which is the only severe earthquake experienced in the central United States in historic time, an

intensity of VII on the Modified Mercalli Intensity Scale of 1931 has been assigned for the site. This is considered to be conservative and corresponds to a design spectrum of 0.20g for the SSE. (Entergy, 2014a)

The SSE is defined in terms of a PGA and a design response spectrum. Table 3.1-1 shows the spectral acceleration (SA) values as a function of frequency for the 5% damped horizontal SSE. (EPRI, 2013d)

Table 3.1-1. SSE for ANO – Unit 1. (EPRI, 2013d)

Freq. (Hz)	SA (g)
0.5	0.10
1.0	0.17
2.5	0.29
5.0	0.31
10	0.24
25	0.20
100	0.20

3.2 Control Point Elevation

The SSE control point elevation is at Elevation 326 ft. It is defined to be at the bottom of the foundation of the highest safety-related building, which is the Reactor Building. The bottom of the foundation for the Reactor Building is at 326 ft within the Pennsylvanian shale (Entergy, 2014a).

3.3 IPEEE Description and Capacity Response Spectrum

A "modified" full-scope Seismic Margin Assessment (SMA) was performed to support the IPEEE for ANO – Unit 1. The results of the IPEEE were submitted to the NRC (Entergy, 1996). Results of the NRC review are documented in reference (U.S. NRC, 2001).

The ANO – Unit 1 Seismic IPEEE was performed using the Seismic Margins assessment option per the EPRI methodology of EPRI-6041 (EPRI, 1991). With this method, a seismic margins earthquake (SME) was postulated and the items needed for safe shutdown were then evaluated for the SME demand. Components and structures that were determined to have sufficient capacity to survive the SME without loss of function were screened-out. Items that did not screen were subjected to a more detailed evaluation, including calculation of a high-confidence of low-probability of failure (HCLPF) PGA for that item. A 0.30 PGA earthquake level and the NUREG/CR-0098 (U.S. NRC, 1978) median response spectra shape were used.

The IPEEE was reviewed for adequacy utilizing the guidance provided in Section 3.3 of the SPID (EPRI, 2013a). The IPEEE Adequacy Determination according to SPID (EPRI, 2013a) Section 3.3.1 is included in Appendix B.

The results of the review have shown, in accordance with the criteria established in SPID (EPRI, 2013a) Section 3.3, that the IPEEE is adequate to support screening of the updated seismic hazard for ANO – Unit 1. The review also concluded that the risk insights obtained from the IPEEE are still valid under the current plant configuration.

The Safety-related structures at ANO – Unit 1 are founded on rock. As stated in NUREG 1407 Section 3.2.1, a plant in the full scope category that is located on a rock site is not required to perform a soil failure evaluation.

The 5% damped horizontal IPEEE HCLPF Spectrum (IHS) spectral acceleration for ANO – Unit 1 is provided in Table 3.3-1. The SSE and the IHS are shown in Figure 3.3-1.

Table 3.3-1. IHS for ANO – Unit 1 IPEEE (Entergy1996).

Freq. (Hz)	HIS (g)
0.5	0.15
1.0	0.29
2.2	0.64
8.0	0.64
10	0.57
25	0.35
33	0.30
100	0.30

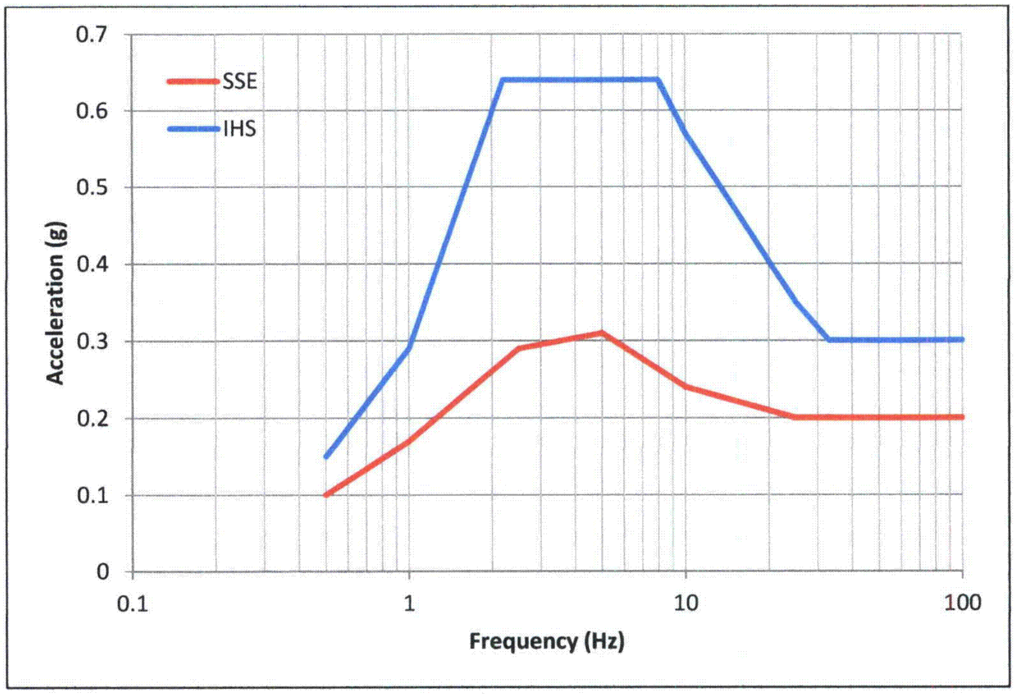

Figure 3.3-1. SSE and IHS Response Spectra for ANO – Unit 1.

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 IHS exceeds the GMRS for ANO – Unit 1. Based on this comparison, a risk evaluation will not be performed.

4.2 High Frequency Screening (> 10 Hz)

For a portion of the range above 10 Hz, the GMRS exceeds the SSE. Therefore, ANO – Unit 1 screens-in for a High Frequency Confirmation.

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, ANO – Unit 1 screens-in for a Spent Fuel Pool evaluation.

5.0 Interim Actions

Based on the screening evaluation, the expedited seismic evaluation described in EPRI 3002000704 (EPRI, 2013c) will be performed as proposed in a letter to NRC (ML13101A379) dated April 9, 2013 (NEI, 2013a) and agreed to by NRC (ML13106A331) in a letter dated May 7, 2013 (U.S. NRC, 2013).

Consistent with NRC letter (ML14030A046) dated February 20, 2014 (U.S. NRC, 2014), the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of ANO – Unit 1. 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," 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 (U.S. NRC, 2010):

> 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.

ANO – Unit 1 is included in the March 12, 2014 risk estimates (NEI, 2014). Using the methodology described in the NEI letter, all plants were shown to be below 10^{-4}/year; thus, the above conclusions apply.

In accordance with the Near-Term Task Force Recommendation 2.3, ANO – Unit 1 performed seismic walkdowns using the guidance in EPRI Report 1025286 (EPRI, 2012). The seismic walkdowns were completed and captured in Fukushima Seismic Walkdown Report (Entergy, 2013). The goal of the walkdowns was to verify current plant configuration with the existing licensing basis, to verify the current maintenance plans, and to identify any vulnerabilities. The walkdown also verified that any vulnerabilities identified in the IPEEE (Entergy, 1996) were adequately addressed. The results of the walkdown, including any identified corrective actions, confirm that ANO – Unit 1 can adequately respond to a seismic event.

6.0 Conclusions

In accordance with the 50.54(f) request for information (U.S. NRC, 2012), a seismic hazard and screening evaluation was performed for Arkansas Nuclear One – Unit 1. 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, ANO – Unit 1 screens-in for a High Frequency Confirmation and a Spent Fuel Pool evaluation. Additionally, based on the results of the screening evaluation, ANO – Unit 1 screens-out of a risk evaluation.

7.0 References

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10 CFR Part 50.72. Title 10, Code of Federal Regulations, Part 50.72, "Immediate Notification Requirements for Operating Nuclear Power Reactors," U.S. Nuclear Regulatory Commission, Washington DC.

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Appendix A

Tabulated Data

Table A-1a. Mean and Fractile Seismic Hazard Curves for 100 Hz (PGA) at ANO – Unit 1. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.02E-02	4.31E-02	6.64E-02	8.12E-02	9.51E-02	9.93E-02
0.001	6.09E-02	2.76E-02	4.77E-02	6.09E-02	7.66E-02	8.72E-02
0.005	1.83E-02	7.77E-03	1.16E-02	1.69E-02	2.29E-02	3.84E-02
0.01	9.30E-03	3.73E-03	5.35E-03	8.23E-03	1.20E-02	2.25E-02
0.015	6.06E-03	2.10E-03	3.05E-03	5.27E-03	8.23E-03	1.51E-02
0.03	2.60E-03	5.50E-04	8.60E-04	1.92E-03	4.25E-03	7.34E-03
0.05	1.22E-03	1.77E-04	2.92E-04	6.93E-04	2.16E-03	4.19E-03
0.075	6.12E-04	7.45E-05	1.27E-04	2.96E-04	9.93E-04	2.32E-03
0.1	3.57E-04	4.07E-05	7.34E-05	1.67E-04	5.20E-04	1.38E-03
0.15	1.55E-04	1.74E-05	3.42E-05	7.66E-05	2.04E-04	5.75E-04
0.3	3.21E-05	3.47E-06	7.77E-06	1.92E-05	4.50E-05	1.04E-04
0.5	9.43E-06	7.89E-07	2.01E-06	5.91E-06	1.51E-05	2.92E-05
0.75	3.38E-06	1.82E-07	5.42E-07	1.98E-06	5.66E-06	1.11E-05
1.	1.55E-06	5.35E-08	1.84E-07	8.23E-07	2.68E-06	5.42E-06
1.5	4.76E-07	7.03E-09	3.19E-08	1.98E-07	8.12E-07	1.82E-06
3.	4.66E-08	2.39E-10	9.11E-10	1.02E-08	7.23E-08	2.10E-07
5.	6.22E-09	1.42E-10	1.84E-10	8.35E-10	8.12E-09	3.01E-08
7.5	1.02E-09	1.32E-10	1.60E-10	2.13E-10	1.20E-09	5.12E-09
10.	2.51E-10	1.21E-10	1.32E-10	1.82E-10	3.57E-10	1.36E-09

Table A-1b. Mean and Fractile Seismic Hazard Curves for 25 Hz at ANO – Unit 1. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.59E-02	5.58E-02	7.34E-02	8.72E-02	9.93E-02	9.93E-02
0.001	6.98E-02	3.90E-02	5.83E-02	7.03E-02	8.23E-02	9.37E-02
0.005	2.62E-02	1.21E-02	1.84E-02	2.46E-02	3.19E-02	5.12E-02
0.01	1.45E-02	6.64E-03	9.24E-03	1.32E-02	1.79E-02	3.19E-02
0.015	9.81E-03	4.25E-03	5.91E-03	8.85E-03	1.27E-02	2.22E-02
0.03	4.61E-03	1.49E-03	2.16E-03	3.90E-03	6.73E-03	1.07E-02
0.05	2.41E-03	5.42E-04	8.35E-04	1.79E-03	4.01E-03	6.54E-03
0.075	1.36E-03	2.25E-04	3.68E-04	8.60E-04	2.39E-03	4.25E-03
0.1	8.75E-04	1.25E-04	2.10E-04	4.98E-04	1.51E-03	3.01E-03
0.15	4.45E-04	5.66E-05	1.01E-04	2.35E-04	6.93E-04	1.62E-03
0.3	1.19E-04	1.51E-05	2.96E-05	6.73E-05	1.64E-04	3.84E-04
0.5	4.05E-05	5.20E-06	1.10E-05	2.64E-05	6.00E-05	1.13E-04
0.75	1.65E-05	1.98E-06	4.50E-06	1.15E-05	2.60E-05	4.56E-05
1.	8.51E-06	9.37E-07	2.22E-06	5.91E-06	1.40E-05	2.39E-05
1.5	3.19E-06	2.80E-07	7.13E-07	2.13E-06	5.42E-06	9.51E-06
3.	4.77E-07	2.19E-08	6.54E-08	2.57E-07	8.60E-07	1.64E-06
5.	9.36E-08	2.25E-09	7.66E-09	3.90E-08	1.67E-07	3.57E-07
7.5	2.19E-08	3.95E-10	1.16E-09	6.83E-09	3.73E-08	9.11E-08
10.	7.14E-09	2.01E-10	3.57E-10	1.82E-09	1.15E-08	3.09E-08

Table A-1c. Mean and Fractile Seismic Hazard Curves for 10 Hz at ANO – Unit 1. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	9.37E-02	7.34E-02	8.00E-02	9.37E-02	9.93E-02	9.93E-02
0.001	8.10E-02	5.75E-02	6.83E-02	8.12E-02	9.37E-02	9.93E-02
0.005	3.41E-02	1.79E-02	2.46E-02	3.37E-02	4.31E-02	5.35E-02
0.01	1.86E-02	9.24E-03	1.25E-02	1.79E-02	2.35E-02	3.23E-02
0.015	1.25E-02	6.09E-03	8.23E-03	1.18E-02	1.62E-02	2.25E-02
0.03	6.11E-03	2.57E-03	3.57E-03	5.58E-03	8.47E-03	1.16E-02
0.05	3.41E-03	1.10E-03	1.62E-03	2.96E-03	5.20E-03	7.45E-03
0.075	2.02E-03	5.05E-04	7.77E-04	1.57E-03	3.33E-03	5.12E-03
0.1	1.34E-03	2.76E-04	4.37E-04	9.37E-04	2.29E-03	3.79E-03
0.15	6.90E-04	1.13E-04	1.87E-04	4.19E-04	1.16E-03	2.22E-03
0.3	1.78E-04	2.46E-05	4.50E-05	1.02E-04	2.57E-04	5.83E-04
0.5	5.54E-05	7.55E-06	1.51E-05	3.52E-05	7.89E-05	1.67E-04
0.75	2.06E-05	2.68E-06	5.75E-06	1.40E-05	3.14E-05	5.83E-05
1.	1.00E-05	1.16E-06	2.64E-06	7.03E-06	1.60E-05	2.84E-05
1.5	3.47E-06	3.01E-07	7.66E-07	2.35E-06	5.91E-06	1.05E-05
3.	4.83E-07	1.67E-08	5.58E-08	2.57E-07	8.72E-07	1.72E-06
5.	9.34E-08	1.21E-09	4.98E-09	3.57E-08	1.67E-07	3.79E-07
7.5	2.20E-08	2.32E-10	6.54E-10	6.09E-09	3.73E-08	9.65E-08
10.	7.22E-09	1.82E-10	2.39E-10	1.60E-09	1.16E-08	3.28E-08

Table A-1d. Mean and Fractile Seismic Hazard Curves for 5.0 Hz at ANO – Unit 1. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	9.55E-02	7.55E-02	8.23E-02	9.65E-02	9.93E-02	9.93E-02
0.001	8.43E-02	6.00E-02	6.93E-02	8.47E-02	9.93E-02	9.93E-02
0.005	3.61E-02	1.79E-02	2.49E-02	3.52E-02	4.77E-02	5.50E-02
0.01	1.89E-02	8.98E-03	1.25E-02	1.82E-02	2.57E-02	3.01E-02
0.015	1.23E-02	5.83E-03	8.00E-03	1.18E-02	1.67E-02	2.01E-02
0.03	5.64E-03	2.35E-03	3.33E-03	5.35E-03	8.00E-03	9.93E-03
0.05	3.08E-03	9.65E-04	1.49E-03	2.72E-03	4.70E-03	6.36E-03
0.075	1.78E-03	4.25E-04	6.73E-04	1.40E-03	2.92E-03	4.31E-03
0.1	1.14E-03	2.22E-04	3.63E-04	8.00E-04	1.92E-03	3.23E-03
0.15	5.60E-04	8.47E-05	1.44E-04	3.33E-04	8.98E-04	1.90E-03
0.3	1.29E-04	1.53E-05	2.80E-05	6.45E-05	1.69E-04	4.98E-04
0.5	3.54E-05	3.95E-06	8.00E-06	1.92E-05	4.70E-05	1.20E-04
0.75	1.16E-05	1.23E-06	2.68E-06	7.03E-06	1.72E-05	3.52E-05
1.	5.13E-06	4.90E-07	1.15E-06	3.28E-06	8.12E-06	1.53E-05
1.5	1.58E-06	1.15E-07	3.01E-07	1.01E-06	2.68E-06	4.98E-06
3.	1.85E-07	5.75E-09	1.95E-08	9.24E-08	3.23E-07	6.83E-07
5.	3.21E-08	5.20E-10	1.72E-09	1.10E-08	5.35E-08	1.34E-07
7.5	6.96E-09	1.92E-10	3.14E-10	1.67E-09	1.05E-08	3.14E-08
10.	2.17E-09	1.55E-10	1.87E-10	4.77E-10	3.01E-09	1.01E-08

Table A-1e. Mean and Fractile Seismic Hazard Curves for 2.5 Hz at ANO – Unit 1. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	9.00E-02	6.73E-02	7.55E-02	8.98E-02	9.93E-02	9.93E-02
0.001	7.37E-02	4.77E-02	5.75E-02	7.34E-02	9.11E-02	9.93E-02
0.005	2.44E-02	1.18E-02	1.57E-02	2.32E-02	3.33E-02	4.01E-02
0.01	1.17E-02	5.42E-03	7.34E-03	1.10E-02	1.60E-02	1.98E-02
0.015	7.39E-03	3.23E-03	4.50E-03	7.03E-03	1.02E-02	1.29E-02
0.03	3.35E-03	1.04E-03	1.62E-03	3.05E-03	5.05E-03	6.73E-03
0.05	1.74E-03	3.52E-04	6.09E-04	1.40E-03	2.92E-03	4.31E-03
0.075	9.27E-04	1.31E-04	2.35E-04	6.09E-04	1.62E-03	2.80E-03
0.1	5.49E-04	6.00E-05	1.11E-04	3.01E-04	9.37E-04	1.95E-03
0.15	2.35E-04	1.84E-05	3.57E-05	1.01E-04	3.57E-04	9.65E-04
0.3	4.12E-05	2.13E-06	4.70E-06	1.38E-05	5.05E-05	1.64E-04
0.5	9.27E-06	3.73E-07	9.65E-07	3.33E-06	1.16E-05	3.09E-05
0.75	2.61E-06	8.12E-08	2.46E-07	1.05E-06	3.63E-06	8.47E-06
1.	1.04E-06	2.53E-08	8.72E-08	4.31E-07	1.60E-06	3.57E-06
1.5	2.82E-07	4.19E-09	1.72E-08	1.10E-07	4.70E-07	1.08E-06
3.	2.84E-08	2.72E-10	7.89E-10	6.93E-09	4.50E-08	1.29E-07
5.	4.43E-09	1.82E-10	1.98E-10	7.45E-10	5.91E-09	2.07E-08
7.5	8.72E-10	1.32E-10	1.82E-10	2.19E-10	1.04E-09	4.07E-09
10.	2.52E-10	1.21E-10	1.32E-10	1.82E-10	3.52E-10	1.21E-09

Table A-1f. Mean and Fractile Seismic Hazard Curves for 1.0 Hz at ANO – Unit 1. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.70E-02	3.63E-02	4.77E-02	6.73E-02	8.47E-02	9.51E-02
0.001	4.59E-02	2.04E-02	2.96E-02	4.56E-02	6.09E-02	7.23E-02
0.005	1.18E-02	4.63E-03	6.83E-03	1.10E-02	1.64E-02	2.13E-02
0.01	5.95E-03	2.01E-03	3.19E-03	5.50E-03	8.60E-03	1.13E-02
0.015	4.00E-03	1.10E-03	1.87E-03	3.63E-03	6.09E-03	8.00E-03
0.03	1.92E-03	2.84E-04	5.75E-04	1.55E-03	3.28E-03	4.77E-03
0.05	9.45E-04	7.89E-05	1.79E-04	6.26E-04	1.74E-03	2.88E-03
0.075	4.54E-04	2.42E-05	5.91E-05	2.39E-04	8.35E-04	1.60E-03
0.1	2.42E-04	9.79E-06	2.46E-05	1.07E-04	4.31E-04	9.37E-04
0.15	8.57E-05	2.49E-06	6.54E-06	3.01E-05	1.40E-04	3.57E-04
0.3	1.01E-05	1.84E-07	5.75E-07	2.80E-06	1.42E-05	4.25E-05
0.5	1.77E-06	2.01E-08	7.77E-08	4.77E-07	2.49E-06	7.23E-06
0.75	4.57E-07	2.88E-09	1.36E-08	1.10E-07	6.73E-07	1.98E-06
1.	1.86E-07	7.45E-10	3.68E-09	3.79E-08	2.68E-07	8.47E-07
1.5	5.52E-08	2.16E-10	6.09E-10	7.77E-09	7.13E-08	2.64E-07
3.	6.63E-09	1.44E-10	1.82E-10	4.77E-10	5.91E-09	2.96E-08
5.	1.17E-09	1.32E-10	1.46E-10	1.82E-10	8.00E-10	4.50E-09
7.5	2.58E-10	1.21E-10	1.32E-10	1.82E-10	2.42E-10	9.51E-10
10.	8.12E-11	1.21E-10	1.32E-10	1.82E-10	1.82E-10	3.52E-10

Table A-1g. Mean and Fractile Seismic Hazard Curves for 0.5 Hz at ANO – Unit 1. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	3.27E-02	1.62E-02	2.25E-02	3.19E-02	4.31E-02	5.20E-02
0.001	1.92E-02	8.72E-03	1.25E-02	1.82E-02	2.60E-02	3.28E-02
0.005	4.97E-03	1.51E-03	2.49E-03	4.56E-03	7.45E-03	9.79E-03
0.01	2.75E-03	4.83E-04	9.79E-04	2.39E-03	4.50E-03	6.26E-03
0.015	1.86E-03	2.07E-04	4.77E-04	1.49E-03	3.28E-03	4.77E-03
0.03	7.82E-04	3.42E-05	9.65E-05	4.43E-04	1.49E-03	2.64E-03
0.05	3.24E-04	7.03E-06	2.16E-05	1.27E-04	5.83E-04	1.32E-03
0.075	1.35E-04	1.77E-06	5.75E-06	3.79E-05	2.16E-04	6.00E-04
0.1	6.59E-05	6.26E-07	2.07E-06	1.44E-05	9.37E-05	3.01E-04
0.15	2.10E-05	1.27E-07	4.63E-07	3.33E-06	2.53E-05	9.51E-05
0.3	2.17E-06	5.58E-09	2.76E-08	2.35E-07	2.07E-06	9.11E-06
0.5	3.56E-07	5.05E-10	2.60E-09	3.05E-08	3.14E-07	1.55E-06
0.75	8.87E-08	1.92E-10	4.63E-10	5.35E-09	7.13E-08	4.07E-07
1.	3.54E-08	1.82E-10	2.16E-10	1.53E-09	2.42E-08	1.62E-07
1.5	1.04E-08	1.32E-10	1.82E-10	3.42E-10	5.12E-09	4.37E-08
3.	1.26E-09	1.21E-10	1.32E-10	1.82E-10	4.07E-10	3.79E-09
5.	2.27E-10	1.21E-10	1.32E-10	1.82E-10	1.82E-10	5.83E-10
7.5	5.06E-11	1.21E-10	1.32E-10	1.82E-10	1.82E-10	2.13E-10
10.	1.61E-11	1.21E-10	1.32E-10	1.82E-10	1.82E-10	1.82E-10

Table A-2. Amplification Functions for ANO – Unit 1. (EPRI, 2013d)

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	1.08E+00	4.75E-02	1.30E-02	9.47E-01	5.76E-02	1.90E-02	1.02E+00	9.03E-02	2.09E-02	1.17E+00	9.85E-02
4.95E-02	9.08E-01	6.43E-02	1.02E-01	7.27E-01	1.11E-01	9.99E-02	9.80E-01	1.06E-01	8.24E-02	1.16E+00	1.04E-01
9.64E-02	8.49E-01	7.06E-02	2.13E-01	6.89E-01	1.24E-01	1.85E-01	9.67E-01	1.09E-01	1.44E-01	1.15E+00	1.05E-01
1.94E-01	8.00E-01	7.61E-02	4.43E-01	6.59E-01	1.32E-01	3.56E-01	9.50E-01	1.12E-01	2.65E-01	1.14E+00	1.08E-01
2.92E-01	7.74E-01	7.92E-02	6.76E-01	6.41E-01	1.35E-01	5.23E-01	9.37E-01	1.14E-01	3.84E-01	1.13E+00	1.09E-01
3.91E-01	7.56E-01	8.13E-02	9.09E-01	6.27E-01	1.38E-01	6.90E-01	9.26E-01	1.17E-01	5.02E-01	1.12E+00	1.11E-01
4.93E-01	7.42E-01	8.27E-02	1.15E+00	6.16E-01	1.41E-01	8.61E-01	9.16E-01	1.18E-01	6.22E-01	1.11E+00	1.12E-01
7.41E-01	7.18E-01	8.48E-02	1.73E+00	5.94E-01	1.45E-01	1.27E+00	8.96E-01	1.21E-01	9.13E-01	1.10E+00	1.15E-01
1.01E+00	7.00E-01	8.61E-02	2.36E+00	5.77E-01	1.47E-01	1.72E+00	8.79E-01	1.24E-01	1.22E+00	1.08E+00	1.17E-01
1.28E+00	6.85E-01	8.65E-02	3.01E+00	5.61E-01	1.50E-01	2.17E+00	8.64E-01	1.26E-01	1.54E+00	1.07E+00	1.18E-01
1.55E+00	6.74E-01	8.65E-02	3.63E+00	5.49E-01	1.51E-01	2.61E+00	8.51E-01	1.26E-01	1.85E+00	1.06E+00	1.19E-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	1.09E+00	8.96E-02	1.27E-02	1.39E+00	1.12E-01	8.25E-03	1.25E+00	1.19E-01			
7.05E-02	1.08E+00	8.90E-02	3.43E-02	1.38E+00	1.07E-01	1.96E-02	1.24E+00	1.15E-01			
1.18E-01	1.08E+00	8.87E-02	5.51E-02	1.37E+00	1.05E-01	3.02E-02	1.24E+00	1.14E-01			
2.12E-01	1.08E+00	8.88E-02	9.63E-02	1.37E+00	1.03E-01	5.11E-02	1.24E+00	1.13E-01			
3.04E-01	1.07E+00	8.89E-02	1.36E-01	1.37E+00	1.02E-01	7.10E-02	1.24E+00	1.13E-01			
3.94E-01	1.07E+00	8.91E-02	1.75E-01	1.38E+00	1.01E-01	9.06E-02	1.24E+00	1.13E-01			
4.86E-01	1.07E+00	8.92E-02	2.14E-01	1.38E+00	1.00E-01	1.10E-01	1.24E+00	1.13E-01			
7.09E-01	1.07E+00	8.96E-02	3.10E-01	1.38E+00	9.89E-02	1.58E-01	1.25E+00	1.13E-01			
9.47E-01	1.06E+00	9.09E-02	4.12E-01	1.39E+00	9.80E-02	2.09E-01	1.25E+00	1.13E-01			
1.19E+00	1.06E+00	9.32E-02	5.18E-01	1.39E+00	9.76E-02	2.62E-01	1.25E+00	1.14E-01			
1.43E+00	1.06E+00	9.45E-02	6.19E-01	1.39E+00	9.71E-02	3.12E-01	1.25E+00	1.14E-01			

Tables A-3a and A-3b 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 10^{-4} and 10^{-5} mean annual frequency of exceedance. These factors are unverified and are provided for information only. The figures should be considered the governing information.

Table A-3a. Median AFs and sigmas for Model 1, Profile 1, for 2 PGA levels.

For Information Only

M1P1K1	Rock PGA=0.194			M1P1K1	PGA=0.741		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.161	0.828	0.081	100.0	0.516	0.697	0.100
87.1	0.162	0.814	0.082	87.1	0.520	0.679	0.101
75.9	0.164	0.788	0.083	75.9	0.525	0.648	0.103
66.1	0.168	0.740	0.086	66.1	0.535	0.592	0.107
57.5	0.176	0.662	0.092	57.5	0.554	0.509	0.114
50.1	0.190	0.596	0.105	50.1	0.591	0.445	0.129
43.7	0.209	0.554	0.118	43.7	0.641	0.408	0.144
38.0	0.232	0.559	0.134	38.0	0.703	0.413	0.162
33.1	0.254	0.578	0.148	33.1	0.771	0.435	0.176
28.8	0.280	0.638	0.150	28.8	0.847	0.485	0.186
25.1	0.299	0.675	0.142	25.1	0.920	0.530	0.177
21.9	0.313	0.741	0.149	21.9	0.969	0.596	0.176
19.1	0.326	0.783	0.145	19.1	1.012	0.641	0.175
16.6	0.339	0.846	0.139	16.6	1.060	0.708	0.169
14.5	0.350	0.914	0.154	14.5	1.105	0.782	0.170
12.6	0.358	0.959	0.161	12.6	1.145	0.842	0.177
11.0	0.350	0.963	0.136	11.0	1.130	0.860	0.163
9.5	0.344	0.989	0.112	9.5	1.106	0.890	0.134
8.3	0.342	1.065	0.110	8.3	1.099	0.968	0.126
7.2	0.336	1.117	0.105	7.2	1.097	1.040	0.125
6.3	0.328	1.161	0.091	6.3	1.070	1.087	0.101
5.5	0.314	1.164	0.113	5.5	1.027	1.100	0.118
4.8	0.302	1.144	0.101	4.8	0.989	1.091	0.115
4.2	0.284	1.109	0.108	4.2	0.929	1.063	0.120
3.6	0.276	1.107	0.089	3.6	0.904	1.069	0.097
3.2	0.261	1.110	0.103	3.2	0.866	1.093	0.106
2.8	0.246	1.102	0.090	2.8	0.827	1.106	0.100
2.4	0.225	1.093	0.083	2.4	0.760	1.106	0.090
2.1	0.208	1.110	0.070	2.1	0.703	1.131	0.069
1.8	0.191	1.142	0.092	1.8	0.642	1.161	0.086
1.6	0.184	1.270	0.102	1.6	0.614	1.287	0.098
1.4	0.166	1.328	0.076	1.4	0.550	1.347	0.077
1.2	0.152	1.377	0.078	1.2	0.498	1.392	0.077
1.0	0.141	1.415	0.070	1.0	0.458	1.428	0.068
0.91	0.121	1.334	0.078	0.91	0.390	1.344	0.076
0.79	0.105	1.288	0.077	0.79	0.338	1.296	0.075
0.69	0.095	1.299	0.084	0.69	0.300	1.305	0.082
0.60	0.082	1.287	0.067	0.60	0.257	1.291	0.065
0.52	0.069	1.266	0.066	0.52	0.214	1.270	0.065
0.46	0.058	1.284	0.087	0.46	0.179	1.286	0.086
0.10	0.002	1.205	0.033	0.10	0.007	1.195	0.035

Table A-3b. Median AFs and sigmas for Model 2, Profile 1, for 2 PGA levels.

For Information Only

M2P1K1		PGA=0.194		M2P1K1		PGA=0.741	
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.169	0.872	0.055	100.0	0.613	0.828	0.058
87.1	0.171	0.858	0.055	87.1	0.620	0.811	0.059
75.9	0.173	0.833	0.055	75.9	0.632	0.781	0.059
66.1	0.178	0.785	0.055	66.1	0.655	0.725	0.059
57.5	0.188	0.709	0.057	57.5	0.703	0.646	0.063
50.1	0.206	0.647	0.069	50.1	0.789	0.594	0.081
43.7	0.230	0.610	0.084	43.7	0.894	0.569	0.098
38.0	0.257	0.619	0.096	38.0	1.005	0.590	0.108
33.1	0.282	0.642	0.109	33.1	1.101	0.621	0.118
28.8	0.311	0.707	0.105	28.8	1.208	0.692	0.112
25.1	0.328	0.740	0.113	25.1	1.262	0.728	0.118
21.9	0.341	0.808	0.123	21.9	1.298	0.799	0.127
19.1	0.353	0.847	0.117	19.1	1.326	0.840	0.121
16.6	0.364	0.909	0.117	16.6	1.353	0.904	0.119
14.5	0.373	0.973	0.137	14.5	1.370	0.970	0.139
12.6	0.378	1.013	0.138	12.6	1.373	1.010	0.140
11.0	0.370	1.015	0.112	11.0	1.329	1.012	0.114
9.5	0.361	1.038	0.089	9.5	1.286	1.035	0.090
8.3	0.356	1.111	0.089	8.3	1.258	1.108	0.090
7.2	0.348	1.156	0.088	7.2	1.217	1.153	0.089
6.3	0.339	1.199	0.085	6.3	1.177	1.196	0.085
5.5	0.323	1.196	0.104	5.5	1.114	1.194	0.104
4.8	0.310	1.172	0.095	4.8	1.061	1.170	0.095
4.2	0.290	1.131	0.098	4.2	0.987	1.130	0.098
3.6	0.281	1.127	0.083	3.6	0.951	1.125	0.083
3.2	0.263	1.120	0.098	3.2	0.886	1.119	0.097
2.8	0.247	1.108	0.088	2.8	0.828	1.107	0.088
2.4	0.225	1.094	0.080	2.4	0.750	1.092	0.080
2.1	0.208	1.109	0.071	2.1	0.688	1.108	0.070
1.8	0.191	1.141	0.094	1.8	0.630	1.139	0.093
1.6	0.184	1.269	0.102	1.6	0.604	1.266	0.102
1.4	0.166	1.325	0.075	1.4	0.540	1.322	0.075
1.2	0.151	1.375	0.079	1.2	0.491	1.371	0.078
1.0	0.140	1.413	0.071	1.0	0.452	1.408	0.070
0.91	0.120	1.332	0.078	0.91	0.385	1.328	0.077
0.79	0.105	1.287	0.077	0.79	0.335	1.284	0.076
0.69	0.095	1.299	0.084	0.69	0.298	1.296	0.082
0.60	0.082	1.286	0.067	0.60	0.255	1.284	0.066
0.52	0.069	1.266	0.067	0.52	0.213	1.264	0.066
0.46	0.058	1.284	0.087	0.46	0.179	1.281	0.087
0.10	0.002	1.205	0.033	0.10	0.007	1.193	0.035

Appendix B

IPEEE Adequacy Review

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1.0 Background

The Nuclear Regulatory Commission (NRC) staff issued Generic Letter (GL) 88-20, Supplement 4 on June 28, 1991 (Reference 6.10), requesting that each licensee conduct an individual plant examination of external events (IPEEE) for severe accident vulnerabilities. Concurrently, NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities" (Reference 6.9) was issued to provide utilities with detailed guidance for performance of the IPEEE.

A seismic margin assessment (SMA) was performed for the seismic portion of the Arkansas Nuclear One (ANO) – Unit 1 IPEEE (Reference 6.1) using the Electric Power Research Institute (EPRI) SMA methodology, EPRI NP-6041 (Reference 6.3) with enhancements identified in NUREG-1407 (Reference 6.9). ANO-1 performed a 0.3g "modified" full scope SMA utilizing a NUREG/CR-0098 (Reference 6.4) spectral shape for a rock site. The "modified" full scope SMA involved developing a Safe Shutdown Equipment List (SSEL) and performing High-Confidence of Low-Probability of Failure (HCLPF) calculations only for components that potentially had a capacity less than the 0.3g review level earthquake (RLE). Capacities for reactor internals and soil-related failures were not included in the "modified" full scope SMA. The calculated plant-level HCLPF for ANO – Unit 1 resulting from performance of the IPEEE was greater than 0.3g. The results of the ANO – Unit 1 IPEEE (Reference 6.1) were provided to the NRC on May 31, 1996.

The NRC staff submitted a request for additional information (RAI) in two letters dated April 3, 1998 (Reference 6.11) and May 7, 1998 (Reference 6.12), relating to ANO – Unit 1 and ANO – Unit 2. ANO responded to the RAI letters with additional information by letter dated March 30, 1999 (Reference 6.13). The NRC staff later submitted a request for supplemental information concerning the RAI responses in a letter dated February 7, 2000 (Reference 6.14). ANO responded to the request for supplemental information by letter dated June 14, 2000 (Reference 6.15).

The NRC issued its Staff Evaluation Report (SER) on February 27, 2001 for the ANO – Unit 1 and ANO – Unit 2 IPEEEs (Reference 6.2). The SER concluded that the ANO-1 and ANO-2 IPEEE process was capable of identifying the most likely severe accidents and severe accident vulnerabilities, meeting the intent of GL 88-20 (Reference 6.10).

2.0 General Considerations

The plant safe shutdown earthquake (SSE) is a Housner type spectrum anchored to 0.2g peak horizontal ground acceleration and 0.133g peak vertical ground acceleration.

The ANO-1 IPEEE is a modified full scope EPRI seismic margin assessment. The EPRI SMA was selected as the method for the IPEEE evaluation because it was compatible with the Unresolved Safety Issue (USI) A-46 assessment being conducted in parallel with the IPEEE work. The Seismic Qualification Utility Group (SQUG) Generic Implementation Procedure (GIP)

(Reference 6.16) used for USI A-46 allowed for coordination of activities to support both projects. The Review Level Earthquake (RLE), based on the NUREG/CR-0098 (Reference 6.4) spectrum applicable to a rock site and anchored to a 0.3g peak ground acceleration, was used for the determination of component HCLPFs. The minimum component HCLPFs was found to be at least a 0.3g PGA value, after addressing any HCLPFs that fell below that level, resulting in a plant HCLPF of at least 0.3g. Therefore, the IPEEE HCLPF Spectrum (IHS) that can be used for comparison against the new GMRS is equal to the RLE spectrum anchored at a 0.3g PGA.

The IPEEE commitments and modifications that were required to achieve the plant level HCLPF have been completed. Verification of the completion of these commitments and modifications were provided in the ANO – Unit 1 Response (Reference 6.17) to 10 CFR Part 50.54(f) Request for Information Recommendation 2.3 Seismic (Reference 6.18) and are further discussed below in Section 3.0 Prerequisites. Confirmation that these modifications are still in place is described in the Prerequisites section of this report.

The following sections summarize the results of the IPEEE adequacy evaluation according to the guidance of the Screening, Prioritization and Implementation Details (SPID) (Reference 6.5).

2.1 Relay Chatter

The ANO – Unit 1 relay evaluation for IPEEE was consistent with the requirements of a full-scope evaluation, as described in NUREG-1407.

The following is included in the SER (Reference 6.2) for ANO-1: "*The relay review program at ANO-1 exceeded this [the IPEEE] requirement because full capacity versus demand screening, in accordance with the GIP (Reference 6.16), was performed on all relays associated with small break LOCA and containment performance. The evaluation was performed according to the GIP (Reference 6.16) using the Design Basis SSE Response Spectra as the basis. This also meets the RLE in the IPEEE SMA due to the conservative amplification factors used for USI A-46 and the more liberal response spectra peak clipping allowed for an SMA.*"

2.2 Soil Failure Evaluation

The safety-related structures at ANO – Unit 1 are founded on rock. As stated in NUREG-1407 (Reference 6.9), Section 3.2.1, a plant in the full-scope category that is located on a rock site is not required to perform a soil failure evaluation.

3.0 Prerequisites

The following items have been addressed in order to use the IPEEE analysis for screening purposes and to demonstrate that the IPEEE results can be used for comparison with the GMRS:

1) Confirmation that commitments made under the IPEEE have been met.

2) Confirmation that all of the modifications and other changes credited in the IPEEE analysis are in place.
3) Confirmation that any identified deficiencies or weaknesses to NUREG-1407 in the ANO – Unit 1 IPEEE NRC SER are properly justified to ensure that the IPEEE conclusions remain valid.
4) Confirmation that major plant modifications since the completion of the IPEEE have not degraded/impacted the conclusion reached in the IPEEE.

Response:

The IPEEE commitments and modifications have been completed. Verification of the completion of these commitments and modifications were provided in the ANO – Unit 1 Seismic Walkdown Report (Reference 6.17) Attachment A. Attachment A provides: a description of the action taken, whether the vulnerability continues to be addressed, and when the resolution actions were completed.

The ANO – Unit 1 NRC SER (Reference 6.2) on the seismic portion of the IPEEE states that the ANO – Unit 1 IPEEE appears to meet the objectives of Generic Letter 88-20; addresses all the USIs and Generic Safety Issues (GSIs) requested in NUREG-1407 (Reference 6.9); and contains suitable discussion of seismic/fire interaction, seismic/flood interaction, and containment performance.

The ANO – Unit 1 NRC SER (Reference 6.2) did note that details of operator actions credited when defining success paths were not included in the IPEEE submittal (Reference 6.1). However, the operator actions were discussed in detail in the responses to RAIs.

Major new or replacement equipment was identified, as described in the Walkdown Report (Reference 6.17) and placed on the list of equipment to be examined during the walkdowns. The IPEEE SSEL was used as the starting point for developing an equipment list for the walkdowns, so that all the equipment on the IPEEE SSEL was walked down again.

No conditions were identified that could adversely affect IPEEE conclusions and, therefore, risk insights in the IPEEE analysis remain valid.

4.0 Adequacy Demonstration

4.1 Structural Models and Structural Response Analysis

Methodology used:

Structural Models

Pertinent resources, including IPEEE (Reference 6.1), SAR (Reference 6.19), structural calculations, and drawings (References 6.20 through 6.46) were reviewed.

Major structures for the ANO – Unit 1 site considered in the SMA are the Reactor Building – Internal Structure, Reactor Building – Containment Shell, Auxiliary Building, Intake Structure, and Diesel Fuel Storage Vault. Structural models were developed in the '70s for the purposes of generating modal properties for dynamic analysis. The Review Level Earthquake for the IPEEE SMA is the median shaped NUREG/CR-0098 (Reference 6.4) spectrum, applicable to a rock site, anchored to a 0.3g peak ground acceleration.

The dynamic models were developed such that they can accurately predict the building response, including in-structure response spectra, in the frequency range of interest. The ANO – Unit 1 dynamic models of the structures are adequate to represent frequencies in excess of 20 Hz and, as such, are adequate for the assessments focused on the 1 Hz to 10 Hz range.

The structural models for these buildings consist of massless beam elements and lumped masses at major floor elevations. The massless beam elements represent the stiffness properties of concrete walls. The beam elements, in general, are rigidly linked to each other and to a lumped mass at each major floor elevation. Thus, each floor elevation acts as a rigid body. For structures where there are no major floors, such as the Containment Shell, the mass is modeled uniformly along the height of the structure. The Reactor Building – Containment Shell does not have any significant structural eccentricity between the center of mass and center of rigidity. Reactor Building – Internal Structure, Auxiliary Building and Intake Structure have some torsional irregularities. However, the structural models are detailed enough to capture the overall structural responses for both the horizontal and vertical components of ground motion.

The ANO – Unit 1 structures are founded on rock, which is typical of the area and consists primarily of shale and sandstone.

For the dynamic analyses, the bedrock on which the structure is founded was modeled using soil springs.

Compliance with NUREG-1407:

This methodology meets the guidance and requirements of EPRI NP-6041 and the enhancements specified in NUREG-1407.

Adequate for Screening:

The IPEEE methodology and structural modeling are in compliance with NUREG-1407 (Reference 6.9) and are adequate for screening purposes.

4.2 In-Structure Demand and ISRS

Methodology used:

The ANO-1 in-structure response spectra (ISRS) for the IPEEE SMA are presented in (Reference 6.1). The ISRS were generated using time history analyses. The IPEEE SMA ISRSs were compared against the original ISRSs (References 6.47 through 6.49). The comparison shows matching amplification frequencies and modal characteristics. The IPEEE SMA ISRSs are deemed reasonable.

Compliance with NUREG-1407:

In-structure response spectra were developed for the IPEEE SMA (Reference 6.1). The IPEEE SMA was done in accordance to the guidance and requirements of EPRI NP-6041 (Reference 6.3) and the enhancements specified in NUREG-1407 (Reference 6.9). The IPEEE ISRS are consistent with the design basis spectra and deemed acceptable for screening purposes.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE in-structure demands and ISRS results are adequate for screening purposes.

4.3 Selection of Seismic Equipment List (SEL)/Safe Shutdown Equipment List (SSEL)

Methodology used:

The selection of equipment in the IPEEE (Reference 6.1) is done to address USI A-46 and to support the IPEEE. Equipment selection to address USI A-46 issues is based on the GIP (Reference 6.16), Section 3 and Appendix A. Equipment selection to support the IPEEE is based on NUREG-1407 (Reference 6.9) and EPRI NP-6041-SL (Reference 6.3). The list of equipment provided in Appendix B of the IPEEE (Reference 6.1) addresses both USI A-46 and

IPEEE requirements and is the equipment that would be used for the safety functions required to establish and maintain a safe shutdown condition, including a primary and alternate success path.

The following safety functions were satisfied by the IPEEE success paths: reactivity control, reactor coolant pressure control, reactor coolant inventory control, and decay heat removal. In addition, equipment required to prevent early containment failure was included on the SSEL. Equipment was selected that provided redundancy for each of the safe shutdown functions (secondary success path). The list of components includes an indication of the component location and the equipment class defined in the GIP (Reference 6.16).

Support system requirements for the above functional success paths were identified. Equipment in support systems required for the operation of safe shutdown equipment or for indication of plant conditions showing safe shutdown were included in the SSEL.

The passive and active components included in the IPEEE scope are identified in Appendix B of the ANO – Unit 1 IPEEE submittal (Reference 6.1).

Compliance with NUREG-1407:

This methodology meets the guidance and requirements of EPRI NP-6041 (Reference 6.3) and the enhancements specified in NUREG-1407 (Reference 6.9). Section 3.2.5.1 of NUREG-1407 (Reference 6.9) requires a complete set of potential success paths be identified and the narrowing/elimination of paths to be documented in detail. Section 3.9 of the ANO – Unit 1 IPEEE (Reference 6.1) documents in detail the system analysis and the selection of equipment for the primary and backup success paths.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE seismic equipment selection results are adequate for screening purposes.

4.4 Screening of Components

Methodology used:

The Seismic Review Team (SRT) screened from further margin review structures and components for which the SRT could document HCLPFs at or above the specified RLE of 0.3g based on their combined experience and judgment and use of earthquake experience data.

The screening guidance given in EPRI NP-6041 (Reference 6.3) was used. This is the same procedure used for the resolution of USI A-46.

Structures and equipment that could not be screened were further evaluated as documented in the IPEEE submittal (Reference 6.1) in section 3.5. The unscreened components were subjected to a Conservative Deterministic Failure Margin (CDFM) analysis as described in EPRI NP-6041 (Reference 6.3) to determine HCLPFs for the components and documented in Table 3.5-1 of the IPEEE (Reference 6.1). Plant walkdowns provided information about components, such as anchorage details, required for the HCLPF evaluation.

Compliance with NUREG-1407:

The above methodology meets the requirements of NUREG-1407 (Reference 6.9) Section 3.2.5.5 Screening Criteria which states that screening guidance given in the GIP (Reference 6.16) may be used provided review/screening is performed at the appropriate RLE, caveats included in the margins report are observed and use of the generic equipment ruggedness spectrum are observed. NUREG-1407 (Reference 6.9) also requires that spatial interaction evaluations such as assessing the effects of flooding, as noted in EPRI NP-6041 (Reference 6.3), be performed.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE screening of component results are adequate for screening purposes.

4.5 Walkdowns

Methodology used:

IPEEE Walkdowns

Seismic walkdowns for USI A-46 and for the IPEEE were performed concurrently. Components common to both programs were inspected only once. Two walkdowns were performed at ANO-1, the first walkdown was performed during an outage and included equipment inside the containment, the second walkdown was performed a few months later and included the equipment outside of containment. The IPEEE walkdown scope included passive components and structures, containment isolation and performance, and seismic interactions.

The IPEEE walkdowns are documented in the IPEEE report (Reference 6.1) and in the Seismic Evaluation Work Sheets (SEWS) in accordance with EPRI NP-6041 (Reference 6.3) and the SQUG (Reference 6.16).

Major structures and components were walked down. Components within the IPEEE scope but not within the A-46 evaluation scope were identified so that combined walkdowns could be performed to address both A-46 and IPEEE. With the exception of some anchorage or interaction issues, equipment walked down for A-46 and IPEEE was judged to screen at 0.3g. Seismic outliers were identified for resolution at a later date by modifications or further analysis.

Walkdowns were conducted by a combination of one S&A engineer and one ANO seismic engineer, with access to an ANO systems engineer and operations personnel. Seismic Review Team members were SQUG trained and certified.

The potential for spatial system interactions was considered during seismic walkdowns. System interaction issues were considered and noted on the SEWS for the IPEEE. The following provides examples of what was considered either previously as part of A-46 walkdowns or as part of the IPEEE:

- Proximity: The proximity of structures to components and components to components was considered during walkdowns. For example, the proximity of valve operators to structures and other components was considered. Masonry block walls were revisited during the IPEEE analysis and were screened for the SMA. To ensure that block walls have capacity above 0.3g, HCLPF calculation was performed for the worst case block wall that was not upgraded during the IE-80-11 program (Reference 6.50). This block wall was calculated to have a capacity of 0.39g.
- Seismic II over I: Interactions with overhead equipment or nearby equipment, including block walls, were evaluated during the walkdowns.
- Seismic Spray & Flooding: The possibility of water spray and flooding impact on systems was considered during the walkdown. No tanks were found in areas with SSEL equipment and fire water piping was judged to have supports with sufficient capacity.
- Seismic Fires: The potential for seismic induced fires impacting SSEL equipment was evaluated during the walkdowns. No cabinets (fire sources) were found in areas containing SSEL equipment.

The above spatial interactions were evaluated and found acceptable.

<u>Near-Term Task Force (NTTF) Recommendation 2.3 Walkdowns</u>

On March 12, 2012 NRC issued a generic letter (Reference 6.18) requesting, in part, information relating to seismic walkdowns. In response, Entergy performed the requested seismic walkdowns and area walk-bys over a three week period during September and October of 2012. Walkdown inspections focused on anchorages and seismic spatial interactions, but also included inspections for other potentially adverse seismic conditions. The NTTF Recommendation 2.3 walkdowns are documented in a walkdown report (Reference 6.17).

Verification of the resolution of commitments made to address seismic vulnerabilities identified in the IPEEE are provided in the ANO – Unit 1 Seismic Walkdown Report (Reference 6.17) Attachment A. Attachment A provides: a description of the action taken, whether the vulnerability continues to be addressed, and when the resolution actions were completed. The walkdown report (Reference 6.17) was submitted to the NRC on November 27, 2012.

Compliance with NUREG-1407:

Walkdowns were conducted and documented in accordance with EPRI NP-6041 (Reference 6.3) as required by Section 3.2.5.2 of NUREG-1407 (Reference 6.9).

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE walkdown results are adequate for screening purposes.

4.6 Fragility Evaluation

Methodology used:

ANO – Unit 1 developed and implemented a program to satisfy the requirements of the IPEEE seismic margins evaluation. The SMA program concentrated on verifying the seismic adequacy of structures, equipment, large tanks, cable tray conduit raceway systems and other distribution systems, and relays. The screening and verification walkdowns verified that the equipment, tanks, distribution systems, structures and relays are able to withstand the 0.3g Review Level Earthquake at the plant and still provide for its safe shutdown.

- Components were screened using the criteria contained in Tables 2-3 and 2-4 of EPRI NP-6041 (Reference 6.3).
- Components that are screened are judged to have a seismic capacity in excess of the RLE demand. HCLPF capacities are determined for those items that are not screened out.
- CFDM HCLPF capacity calculations were typically required for equipment anchorages, large tanks, and block walls.

All the Class I Structures were screened out based on the EPRI NP-6041 (Reference 6.3) screening criteria.

Compliance with NUREG-1407:

ANO – Unit 1 calculated HCLPFs for all outlier components in accordance with the guidance of EPRI NP-6041 (Reference 6.3) and NUREG-1407 (Reference 6.9) Section 3.2.5.7.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE fragility evaluation results are adequate for screening purposes.

4.7 System Modeling

Methodology used:

Functional success paths were developed for the four safety functions: reactivity control, Reactor Coolant System (RCS) pressure control, RCS inventory control, and decay heat removal. Primary and alternate success paths for each safety function were identified. Alternate success paths involve the same systems as the primary success paths by using the opposite train. Plant-specific Success Path Logic Diagrams (SPLDs) are provided in the RAI response (Reference 6.13) for both loss of off-site power (LOSP) and small Loss of Coolant Accident (LOCA) with both the primary and alternate success path. Dependency matrices are also provided in the RAI responses that identify the support systems required for operation of the front-line systems in the SPLD.

The evaluation of non-seismic failures and human actions was not addressed explicitly in the IPEEE (Reference 6.1) evaluation of seismic risk; however, both are discussed in the responses to RAIs (Reference 6.13). A fault tree was developed from the detailed plant fault tree, taking no credit for components on the IPEEE SSEL and quantified to determine the conditional core damage probability. The conditional core damage probability was combined with the frequency of a 0.3g earthquake at the ANO site from EPRI NP-6395-D (Reference 6.51) to estimate a Core Damage Frequency (CDF) below 1.0E-06. It was concluded that the risk from a 0.3g seismic event was therefore insignificant.

The identification of success paths and components was based on nominal credit for operator actions, given that sufficient manpower, time, and procedures were available. Specific operator actions necessary for safe shutdown are not discussed in the IPEEE submittal (Reference 6.1), but are discussed in the responses to RAIs.

Compliance with NUREG-1407:

NUREG-1407 (Reference 6.9), Section 3.2.5.1 states that for IPEEE purposes, it is desirable that to the maximum extent possible, that the alternate path involve operational sequences, systems, piping runs and components different from those used in the preferred path. As indicated above and documented in the IPEEE, different components and trains were selected, but from the same systems at ANO – Unit 1.

Taking into account the information supplied in RAI responses, the treatment of non-seismic failures and human actions in the ANO – Unit 1 IPEEE meets the requirements of Section 3.2.5.8 of NUREG-1407 (Reference 6.9).

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE system modeling results are adequate for screening purposes.

4.8 Containment Performance

Methodology used:

Containment performance was evaluated for gross containment failure, containment system failure, containment bypass, containment isolation failure, and interactions with containment. The containment structure was evaluated using the methodology and guidance of EPRI NP-6041 (Reference 6.3).

For containment isolation and bypass, containment penetrations were evaluated with respect to seal failure, valve failure, and failure of piping between penetrations and isolation valves.

The containment evaluation found that no significant vulnerabilities exist that would impact containment performance for the RLE.

Compliance with NUREG-1407:

The review of containment meets the requirements of Section 3.2.6 of NUREG-1407 (Reference 6.9) to evaluate the containment integrity, isolation, bypass and suppression functions to identify vulnerabilities that involve early failure of the containment functions.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE containment performance results are adequate for screening purposes.

4.9 Peer Review

Methodology used:

An independent peer review of the SMA was conducted by Mr. Harry Johnson of Programmatic Solutions. Mr. Johnson conducted two days of walkdowns as part of his review. Mr. Johnson's review report is included in the IPEEE submittal (Reference 6.1) in Appendix D. Mr. Johnson concluded that the methods used were appropriate, the methods have been correctly implemented, and the actions recommended in the IPEEE to address seismic vulnerabilities are reasonable.

In addition to the independent peer review by Mr. Johnson, a peer review of the SSEL was conducted by Dr. Robert Budnitz of Future Resources Associates, Inc. Dr. Budnitz's review report is also included in the IPEEE (Reference 6.1) in Appendix D. Comments consisted of editorial comments related to clarification of IPEEE text and were incorporated in the IPEEE report (Reference 6.1).

Two engineers from Enercon, Mr. Sean Smolarek and Mr. Eric Dilbone reviewed the IPEEE, as described in the Walkdown Report (Reference 6.17).

"In-house" review is evidenced by the reviewer sign-off on IPEEE cover sheets, but there is no discussion of in-house review in the IPEEE report body.

Compliance with NUREG-1407:

The above review process, using a combination of independent in-house review and two external consultants for seismic review, meets the requirements of Section 7 of NUREG-1407 (Reference 6.9) for peer review.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE peer review results are adequate for screening purposes.

5.0 Conclusion

The ANO – Unit 1 IPEEE was a modified full scope seismic margin submittal and requires the performance of a detailed review of relay chatter. The modified scope of the ANO – Unit 1 IPEEE excluded soil-related failures.

The following is included in the SER (Reference 6.2) for ANO-1: "*The relay review program at ANO-1 exceeded this [the IPEEE] requirement because full capacity versus demand screening, in accordance with the GIP (Reference 6.16), was performed on all relays associated with small break LOCA and containment performance. The evaluation was performed according to the GIP (Reference 6.16) using the Design Basis SSE Response Spectra as the basis. This also meets the RLE in the IPEEE SMA due to the conservative amplification factors used for USI A-46 and the more liberal response spectra peak clipping allowed for an SMA.*"

Based on the IPEEE adequacy review performed consistent with the guidance contained in EPRI 1025287 (SPID) (Reference 6.5) and documented herein, the ANO – Unit 1 IPEEE results are considered adequate for screening and the risk insights gained from the IPEEE remain valid under the current plant configuration.

6.0 References

6.1 Arkansas Nuclear One Document, 96-R-1006-02, Rev. 000, "IPEEE Seismic Margins Assessment (SMA) of Arkansas Nuclear One, Unit 1."

6.2 United States Nuclear Regulatory Commission, "Staff Evaluation Report of Individual Plant Examination of External Events (IPEEE) Submittal on Arkansas Nuclear One, Units 1 & 2," Enclosure 1 to Letter Dated February 27, 2001 [0CNA020113].

6.3 Electric Power Research Institute, "A Methodology for Assessment of Nuclear Power Plant Seismic Margin," EPRI NP-6041-SL, Revision 1, August 1991.

6.4 "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," NUREG/CR-0098, US NRC, May 1978.

6.5 Electric Power Research Institute, TR-1025287, "Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic," November 2012.

6.6 NEI Letter, Kimberly A. Keithline to David L. Skeen, NRC "Relay Chatter Reviews for Seismic Hazard Screening," dated October 3, 2013 [ML13281A308].

6.7 NEI Letter, A.R. Pietrangelo to D.L. Skeen, NRC "Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations," dated April 9, 2013 [ML13101A379].

6.8 NRC Letter, E. Leeds to J. Pollock, NEI "Acceptance Letter for NEI Submittal of Augmented Approach, Ground Motion Model Update Project, and 10CFR50.54(f) Schedule Modifications Related to the NTTF Recommendation 2.1, Seismic Reevaluations," dated May 7, 2013 [ML13106A331].

6.9 United States Nuclear Regulatory Commission, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," NUREG-1407, June 1991.

6.10 "Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities - 10CFR50.54(f)," Generic Letter No. 88-20, Supplement 4, US NRC, June 28, 1991

6.11 NRC Letter to Entergy, Request for Additional Information Pertaining to the Arkansas Nuclear One (ANO) Summary Reports for the Individual Plant Examination of External Events (IPEEE), dated April 3, 1998 [0CNA049807, 0CNA049808].

6.12 NRC Letter to Entergy, Request for Additional Information Pertaining to the Arkansas Nuclear One (ANO) Summary Reports for the Individual Plant Examination of External Events (IPEEE), dated May 7, 1998 [0CNA059806].

6.13 Entergy Letter to NRC "Arkansas Nuclear One – Units 1 and 2 Docket Nos. 50-313 and 50-368 License Nos. DPR-51 and NPF-6 Additional Information Pertaining to GL 87-02 and 88-20," dated March 30, 1999 [0CAN039901].
6.14 NRC Letter to Entergy, Request for Supplemental Information Concerning Entergy Operations Previous Responses Dated March 30, 1999, dated February 7, 2000 [0CNA020004].
6.15 Entergy Letter to NRC "Arkansas Nuclear One – Units 1 and 2 Docket Nos. 50-313 and 50-368 License Nos. DPR-51 and NPF-6 IPEEE Supplemental RAI Response," dated June 14, 2000 [0CAN060003].
6.16 Seismic Qualification Utility Group (SQUG), "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment," Revision 2, March, 1993.
6.17 Entergy Letter to NRC, "ANO-1 Seismic Walkdown Report," Attachment 1 to letter 1CAN111201, dated November 27, 2012.
6.18 NRC Generic 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 [ML12053A340].
6.19 Arkansas Nuclear One Unit 1, Safety Analysis Report, Amendment No. 26.
6.20 Arkansas Nuclear One Drawing, C-148, Rev. 13, "Reactor Building Reinforced Concrete Basement Floor Elevation 336'-6"."
6.21 Arkansas Nuclear One Drawing, C-149, Rev. 8, "Reactor Building Reinforced Concrete Ground Floor Elevation 357'-0"."
6.22 Arkansas Nuclear One Drawing, C-150, Rev. 7, "Reactor Building Reinforced Concrete Intermediate Floor Elevation 376'-6"."
6.23 Arkansas Nuclear One Drawing, C-151, Rev. 2, "Reactor Building Reinforced Concrete Plans Elevation 362'-0" to Elevation 376'-6"."
6.24 Arkansas Nuclear One Drawing, C-152, Rev. 7, "Reactor Building Reinforced Concrete Operating Floor Elevation 401'-6"."
6.25 Arkansas Nuclear One Drawing, C-153, Rev. 6, "Reactor Building Reinforced Concrete Shielding Floor Elevation 424'-6"."
6.26 Arkansas Nuclear One Drawing, C-201, Rev. 4, "Concrete Auxiliary Building Plan at Elevation 317'-0"."
6.27 Arkansas Nuclear One Drawing, C-202, Rev. 14, "Concrete Auxiliary Building Plan at Elevation 335'-0"."
6.28 Arkansas Nuclear One Drawing, C-203, Rev. 11, "Concrete Auxiliary Building Plan at Elevation 354'-0"."
6.29 Arkansas Nuclear One Drawing, C-204, Rev. 13, "Concrete Auxiliary Building Plan at Elevation 372'-0"."
6.30 Arkansas Nuclear One Drawing, C-205, Rev. 11, "Concrete Auxiliary Building Plan at Elevation 386'-0"."
6.31 Arkansas Nuclear One Drawing, C-206, Rev. 17, "Concrete Auxiliary Building Plan at Elevation 404'-0"."
6.32 Arkansas Nuclear One Drawing, C-213, Rev. 13, "Concrete Auxiliary Building Section – A."
6.33 Arkansas Nuclear One Drawing, C-214, Rev. 9, "Concrete Auxiliary Building Section – B and C."
6.34 Arkansas Nuclear One Drawing, C-215, Rev. 8, "Concrete Auxiliary Building Section – D."
6.35 Arkansas Nuclear One Drawing, C-216, Rev. 12, "Concrete Auxiliary Building Section – E."

6.36 Arkansas Nuclear One Drawing, C-217, Rev. 8, "Concrete Auxiliary Building Section – F."
6.37 Arkansas Nuclear One Drawing, C-223, Rev. 3, "Concrete Auxiliary Building Section – H."
6.38 Arkansas Nuclear One Drawing, C-224, Rev. 4, "Concrete Auxiliary Building Section – J."
6.39 Arkansas Nuclear One Drawing, C-225, Rev. 4, "Concrete Auxiliary Building Section – K."
6.40 Arkansas Nuclear One Drawing, C-226, Rev. 6, "Concrete Auxiliary Building Plan at Elevation 327'-0 & Elevation 355'-4."
6.41 Arkansas Nuclear One Drawing, C-229, Rev. 5, "Concrete Auxiliary Building Sections."
6.42 Arkansas Nuclear One Drawing, C-80, Rev. 5, "Intake Structure Foundation Plan Elevation 315'-0" & 322'-6"."
6.43 Arkansas Nuclear One Drawing, C-81, Rev. 18, "Intake Structure Plan at Elevation 354'-0"."
6.44 Arkansas Nuclear One Drawing, C-82, Rev. 22, "Intake Structure Plans & Sections."
6.45 Arkansas Nuclear One Drawing, C-83, Rev. 14, "Intake Structure Sections."
6.46 Arkansas Nuclear One Drawing, C-84, Rev. 10, "Intake Structure Sections & Details."
6.47 Arkansas Nuclear One Unit 1, 6600-C-101, Rev. 1 , "Specification for Earthquake Resistance Design of Equipment Located in the Reactor Building for Arkansas Power & Light Company Arkansas Nuclear One Little Rock, Arkansas 72203."
6.48 Arkansas Nuclear One Unit 1, APL-C-501, Rev. 2 , "Earthquake Resistance Design of Structures and/or Components Located in the Reactor Building for the Arkansas Nuclear One Unit 1 Power Plant."
6.49 Arkansas Nuclear One Unit 1, AP&L-C-502, Rev. 2, "Earthquake Resistance Design of Structures and/or Components Located in the Auxiliary Building for the Arkansas Nuclear One Unit 1 Power Plant."
6.50 "Masonry Wall Design," IE Bulletin No. 80-11, US NRC May 8, 1980.
6.51 Electric Power Research Institute, NP-6395-D, "Probabilistic Seismic Hazard Evaluation at Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Issue," April 1989.

Enclosure 2 to

0CAN031404

Seismic Hazard and Screening Report for ANO-2

Seismic Hazard and Screening Report for Arkansas Nuclear One Unit 2

Table of Contents

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 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 (U.S. NRC, 2012) that requests information to assure that these recommendations are addressed by all U.S. nuclear power plants. The 50.54(f) letter (U.S. NRC, 2012) 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, 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 (U.S. NRC, 2012) pertaining to NTTF Recommendation 2.1 for the Arkansas Nuclear One (ANO) – Unit 2 plant, located in Pope County, Arkansas. In providing this information, Entergy 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, 2013c), 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 ANO – Unit 2 was 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 (U.S. NRC, 2012) and following the guidance provided in the SPID (EPRI, 2013a), 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, ANO – Unit 2 screens-in for a Spent Fuel Pool evaluation and a High Frequency Confirmation. Additionally, based on the results of the screening evaluation, ANO – Unit 2 screens-out of a risk evaluation.

2.0 Seismic Hazard Reevaluation

The Arkansas Nuclear One site is located approximately six miles west-northwest of Russellville, Arkansas, on a peninsula formed by the Dardanelle Reservoir which acts as the water source for each Unit. The Arkansas Nuclear One site is in the center of the Arkansas Valley section of the Ouachita province. The Arkansas Valley lies within the area of outcrop of Paleozoic rocks which occupy essentially the northwestern half of the state. The rocks of the Arkansas Valley are nearly all of sedimentary origin. They include only a few bodies of igneous rock. The beds in the valley consist chiefly of non-fossiliferous shale and sandstone, all of Carboniferous age, and most of them belonging to the lower part of the Pennsylvanian series. The rocks are generally highly carbonaceous and in some places are coal bearing. They contain little or no calcareous material. (Entergy, 2014a), (Entergy, 2014b)

The site is underlain by 8 to 30 ft of moderate to stiff, plastic, red and tan clay with occasional zones of silty clay, which overlies black, dense, horizontally bedded shale and sandstone of the McAlester formation. (Entergy, 2014a)

The nature of the structural features of the Arkansas Valley and their relation to the structure of the adjacent Ouachita and Boston Mountains show that the dominant force in the production of those features was horizontal pressure exerted from the south. It is believed that the folding and thrust faulting developed in post-Paleozoic pre-Cretaceous time due to the subsidence of a land mass to the south which supplied sediments in the place where this land mass once stood. The normal faults were also connected with this episode of deformation. These are believed to have formed either contemporaneously with folding, before folding, or as a result of tension developed after the period of folding. Some normal faults are also believed to have formed during deposition and subsidence of the Pennsylvanian sediments. In the Arkansas Valley, the southward-dipping faults terminate against northward-dipping normal faults. The precise dating of the folds and faults of the Arkansas Valley cannot be done with assurance, but it is known that they are very old geologic structures and probably were formed before Cretaceous time. (Entergy, 2014a) (Entergy, 2014b)

East-west trending folds are mapped in the area of the site. From about three miles north to three miles south of the site are two anticlines and one syncline. From north to south these structures are as follows: London anticline, Scranton syncline, and the Prairie View anticline. The plant site is located on the Scranton syncline in which the maximum dip rarely exceeds 10 degrees except locally where contorted beds may dip as steeply as 20 degrees. (Entergy, 2014a) (Entergy, 2014b)

The London anticline extends from about four and one-half miles northwest of the town of London, east to about three miles northwest of the site. This anticline may continue east to connect with the anticline which is mapped northeast of the site to a point three and one-half miles north of Russellville. The south limb of the London anticline is steeper than the north limb. (Entergy, 2014a) (Entergy, 2014b)

The Scranton syncline, also known as the Ouita syncline, extends from northeast of Russellville, west to a point where it probably dies out about five miles northwest of Scranton. Here it is presumably terminated by the Dublin fault, which is an east-west-trending fault over nine miles west of the site. On the western part of the Scranton syncline the south limb is steeper than the north limb. However, on the eastern portion of the syncline the north limb is steeper than the south limb. (Entergy, 2014a) (Entergy, 2014b)

The Prairie View anticline is mapped from a point three miles southwest of the town of Scranton, east to at least as far as Russellville. This nearly symmetrical anticline is broken by northward-dipping normal faults. (Entergy, 2014a) (Entergy, 2014b)

There are a number of old faults mapped in the vicinity of the Arkansas River, particularly to the northwest and west of the site. These are in the main, east-west-trending faults. Of these, the London and Prairie View faults are the closest to the site. The London fault and an accompanying unnamed small branch fault trend east-west about four miles north of the site. A small fault which branches from the unnamed fault lies about two and one-half miles northeast of the site. The London fault is a high-angle south-dipping normal fault. It is best exposed about eight miles northwest of the site at Big Piney Creek where the western part of the fault ends. At this locality, the fault plane dips 58° south and has an apparent displacement of about 20 ft. The fault is also exposed to the east along Flat Rock Creek and in a drainage ditch along a country road about eight miles from the site. The unnamed eastwest-trending fault lies about one mile south of the London fault. The trend of this unnamed fault changes toward the east to generally northwest-southeast and appears to intersect the London fault in the vicinity of the north fork of Mill Creek. This fault is at least pre-Cretaceous in age. (Entergy, 2014a) (Entergy, 2014b)

The Prairie View fault is concealed under alluvium about six miles west of the site. Another six miles to the west, the fault is exposed. It is an east-west-trending high-angle north-dipping normal fault. This fault extends to the west as far as three miles northwest of Subiaco. The maximum displacement along the fault is 350 ft two miles west of the town of Prairie View. Near the western end of the fault there is about 170 ft of maximum displacement and the fault plane dips about 65° northward. About three miles from the western end of the fault is a small branch fault which is downthrown on the southside and is assumed to be dipping south. The Prairie View anticline is faulted by the Prairie View fault and is similar to the faulted anticlines discussed by Hendricks and Parks. It is their opinion that the faulted anticlines in the Fort Smith district were either faulted then folded, or contemporaneously faulted and folded. Therefore, the Prairie View fault is at least as old as the folding in this area, which is pre-Cretaceous. (Entergy, 2014a) (Entergy, 2014b)

In summary, the only faults within five miles of the site are the Prairie View fault, and the London fault and its branch faults. The closest fault is only a small branch fault and approaches within about two and one-half miles of the site. The last movement of these faults is believed to have occurred prior to the Cretaceous. (Entergy, 2014a) (Entergy, 2014b)

Considering the historic seismicity of the site region, Entergy determined that because of the excellent formation conditions and the recent general quiescence of the area that a low earthquake intensity could be selected. However, considering the New Madrid earthquake, which is the only severe earthquake experienced in the central United States in historic time, an intensity of VII on the Modified Mercalli Intensity Scale of 1931 (Maximum Earthquake) has been assigned for the site. This is considered to be conservative and corresponds to a design spectrum of 0.20g for the SSE. (Entergy, 2014a) (Entergy, 2014b)

2.1 Regional and Local Geology

The Arkansas Valley is essentially a Paleozoic basin which had its most significant development during the Mississippian and Pennsylvanian. The greatest accumulations occurred during the Lower (Morrowan) and Lower Middle (Atokan) Pennsylvanian. Deformation of the Ouachitas occurred during Mid-Pennsylvanian time. During this time, the Ouachitas were strongly folded, with some thrust faulting, especially in Oklahoma. The Arkansas Valley section lies between the essentially flat-lying rocks of the Boston Mountains on the north and complexly folded strata of the Ouachita Mountains on the south. Its structure, therefore, has some of the characteristics of both its bounding regions, but is generally a region of broad, gentle folds which trend east-west and are only moderately faulted. Faulting is related to the folding and is pre-Cretaceous in age. (Entergy, 2014b)

Since Cretaceous (and probably late Paleozoic) time, erosion has been the primary agent in the development of land forms in the region. No sediments younger than Pennsylvanian are found in the region, except for Quaternary terrace and alluvial deposits along the stream valleys. In a few places, intrusive rocks, mapped by as mid-Cretaceous cut the Paleozoic sediments. In the Arkansas Valley, these rocks consist of scattered dikes and sills of varying composition. None occur at the plant site. (Entergy, 2014b)

The site is about six miles northwest from Russellville, and about two miles from the small town of London. The plant is situated on a peninsula formed by the Corps of Engineers' Dardanelle Reservoir. The plant is located on a broad, nearly flat bench adjacent to the floodplain of the Arkansas River. This bench is at about Elevation 353 ft, at the lower of the two Pleistocene terrace levels. Soil on the terrace consists of clay and silty clay, and is from eight to 30 ft thick at the site. The broad floodplain of the Arkansas River is now covered with the waters of the Dardanelle Reservoir in the vicinity of the site. The low hills adjacent to the site are formed by the gently upturned strata along the flanks of the Scranton-Ouita syncline. Relief within the limits of the site area is less than 10 ft. (Entergy, 2014b)

2.2 Probabilistic Seismic Hazard Analysis

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter (U.S. NRC, 2012) and following the guidance in the SPID (EPRI, 2013a), 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 (CEUS-SSC, 2012) together with the updated Electric Power Research Institute (EPRI) Ground-Motion Model (GMM) for the Central and Eastern United States (CEUS) (EPRI, 2013b). For the PSHA, a lower-bound moment magnitude of 5.0 was used, as specified in the 50.54(f) letter (U.S. NRC, 2012). (EPRI, 2013d)

For the PSHA, the CEUS-SSC background seismic sources out to a distance of 400 miles (640 km) around the ANO – Unit 2 site were included. This distance exceeds the 200 mile (320 km) recommendation contained in Reg. Guide 1.208 (U.S. NRC, 2007) and was chosen for completeness. Background sources included in this site analysis are the following (EPRI, 2013d):

1. Extended Continental Crust—Gulf Coast (ECC_GC)
2. Gulf Highly Extended Crust (GHEX)
3. Illinois Basin Extended Basement (IBEB)
4. Mesozoic and younger extended prior – narrow (MESE-N)
5. Mesozoic and younger extended prior – wide (MESE-W)
6. Midcontinent-Craton alternative A (MIDC_A)
7. Midcontinent-Craton alternative B (MIDC_B)
8. Midcontinent-Craton alternative C (MIDC_C)
9. Midcontinent-Craton alternative D (MIDC_D)
10. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
11. Non-Mesozoic and younger extended prior – wide (NMESE-W)
12. Oklahoma Aulacogen (OKA)
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 Repeated Large Magnitude Earthquake (RLME) sources), in NUREG-2115 (CEUS-SSC, 2012) modeled for the CEUS-SSC, the following sources lie within 1,000 km of the site and were included in the analysis (EPRI, 2013d):

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

For each of the above background and RLME sources, the mid-continent version of the updated CEUS EPRI GMM was used. (EPRI, 2013d)

2.2.2 Base Rock Seismic Hazard Curves

Consistent with the SPID (EPRI, 2013a), base rock seismic hazard curves are not provided as the site amplification approach referred to as Method 3 has been used. Seismic hazard curves are shown below in Section 2.3.7 at the SSE control point elevation. (EPRI, 2013d)

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the 50.54(f) Request for Information (U.S. NRC, 2012) and in the SPID (EPRI, 2013a) for nuclear power plant sites that are not founded on hard rock (defined as 2.83 km/sec), a site response analysis was performed for ANO – Unit 2. (EPRI, 2013d)

2.3.1 Description of Subsurface Material

Arkansas Nuclear One – Unit 2 is located on a peninsula formed by the Dardanelle Reservoir about 57 miles (92 km) northwest of Little Rock, Arkansas. The site is situated in the center of the Arkansas Valley in the Ouachita Physiographic Province. The site is founded on Pennsylvania McAlester formation which is hard, dense shale at the top of about 5,000 ft (1,524 m) of firm sedimentary rock. The SSE was specified at an elevation of 326 ft (99.4 m) within the Pennsylvanian shale (Entergy, 2014b).

2.3.2 Development of Base Case Profiles and Nonlinear Material Properties

The basic information used to create the site geologic profile at the ANO – Unit 2 site was taken from plant specific information in the Safety Analysis Report (SAR) with the following description (Entergy, 2014a) (Entergy, 2014b):

The reactor containment building is founded on shale of the McAlester Formation with embedment depth of around 26 ft. with tendon galleries of about 36 ft. below grade. Basement rock is estimated to be at a depth of 5,000 ft. The site shear-wave (S-wave) velocity of 5,350 fps (was) calculated using a Poisson's ratio of 0.30 and the range of values of the compressional-wave (P-wave) velocity from 10,000 to 14,500 fps for McAlester shale. The site seismic profiles are shown in Figure 2.5-21 of the SAR (Entergy, 2014b)

The location of the SSE at elevation 326 ft (99.4 m) is within the Pennsylvanian shale with firm sedimentary rocks extending to Precambrian basement at a depth of about 5,000 ft (1,524 m) (Entergy, 2014b).

Shear-wave velocities for the profile were unspecified with compressional-wave velocities listed between 10,000 and 14,500 ft/s (3,048 m/s and 4,419 m/s respectively), likely based on shallow refraction surveys (Entergy, 2014a) (Entergy 2014b). To develop a mean base-case shear-

wave velocity profile, a shallow velocity of 5,300 ft/s (1,616 m/s) was assumed. This value reflects an assumption of a reasonable Poisson ratio of about 0.30 and the lower value of the compressional-wave velocity for the top of the Pennsylvanian McAlester Formation. (EPRI, 2013d)

Provided the materials to basement depth reflect similar sedimentary rocks and age, the shear-wave velocity gradient for sedimentary rock of 0.5 m/m/s (EPRI, 2013a) was assumed to be appropriate for the site. The shallow shear-wave velocity of 5,300 ft/s (1,616 m/s) was taken at the surface of the profile with the velocity gradient applied at that point, resulting in a base-case shear-wave velocity of about 7,772 ft/s (2,369 m/s) at a depth of 5,000 ft (1,524 m). The mean or best estimate base-case profile is shown as profile P1 in Figure 2.3.2-1. (EPRI, 2013d)

Based on the uncertainty in shear-wave velocities due to the lack of measurements, a scale factor of 1.57 was adopted to reflect upper and lower range base-cases. The scale factor of 1.57 reflects a $\sigma_{\mu ln}$ of about 0.35 based on the SPID (EPRI, 2013a) 10th and 90th fractiles which implies a 1.28 scale factor on σ_{μ}. (EPRI, 2013d)

Using the best estimate or mean base-case profile (P1), the depth independent scale factor of 1.57 was applied to develop lower and upper range base-cases profiles P2 and P3 respectively with the stiffest profile (P3) reaching reference rock velocities at a depth of about 1,200 ft (366 m). Base-case profiles P1 and P2 have a mean depth below the SSE of 5,000 ft (1,524 m) to hard reference rock, randomized ±1,500 ft (±457 m). The base-case profiles (P1, P2, and P3) are shown in Figure 2.3.2-1 and listed in Table 2.3.2-1. The depth randomization reflects ±30% of the depth to provide a realistic broadening of the fundamental resonance rather than reflect actual random variations to basement shear-wave velocities across a footprint. (EPRI, 2013d)

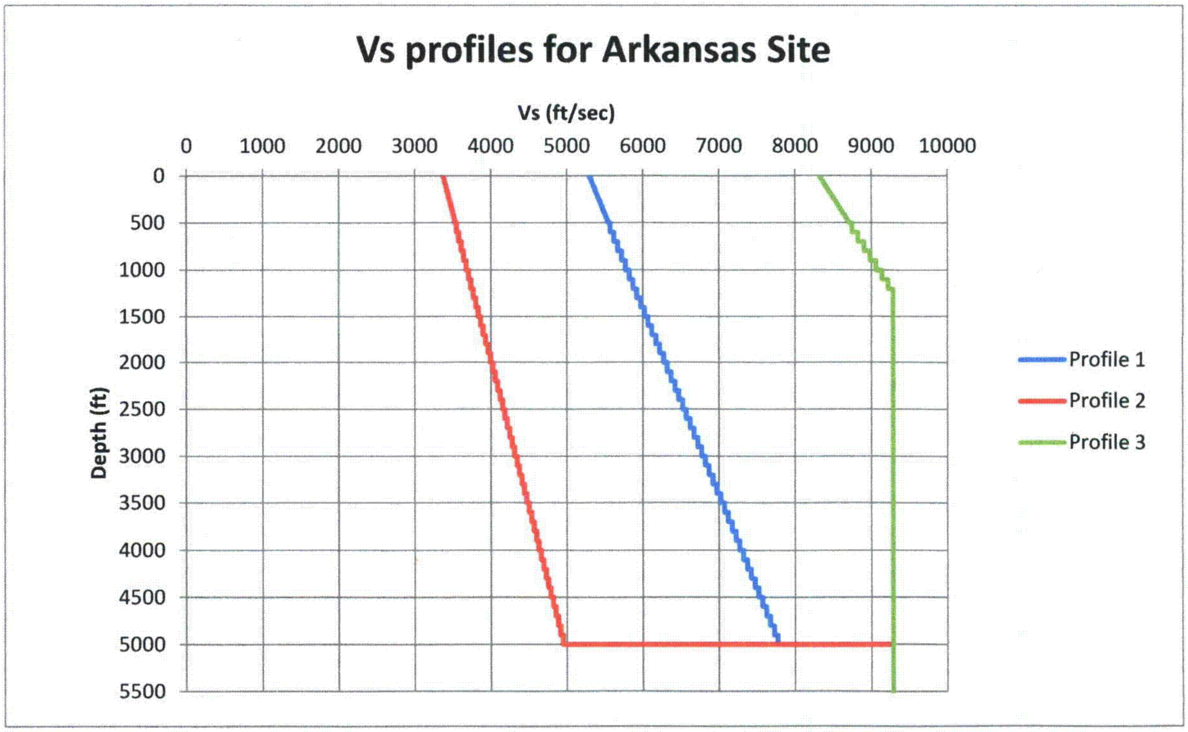

Figure 2.3.2-1. Shear-wave velocity profiles for ANO – Unit 2. (EPRI, 2013d)

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 3 profiles, ANO – Unit 2 site. (EPRI, 2013d)

Profile 1			Profile 2			Profile 3		
thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)
	0	5,302		0	3,378		0	8,325
10.0	10.0	5,302	10.0	10.0	3,378	10.0	10.0	8,325
10.0	20.0	5,307	10.0	20.0	3,381	10.0	20.0	8,332
10.0	30.0	5,312	10.0	30.0	3,384	10.0	30.0	8,340
10.0	40.0	5,317	10.0	40.0	3,387	10.0	40.0	8,348
10.0	50.0	5,322	10.0	50.0	3,390	10.0	50.0	8,356
10.0	60.0	5,327	10.0	60.0	3,393	10.0	60.0	8,364
10.0	70.0	5,332	10.0	70.0	3,397	10.0	70.0	8,372
10.0	80.0	5,337	10.0	80.0	3,400	10.0	80.0	8,379
10.0	90.0	5,342	10.0	90.0	3,403	10.0	90.0	8,387
10.0	100.0	5,347	10.0	100.0	3,406	10.0	100.0	8,395
10.0	110.0	5,352	10.0	110.0	3,409	10.0	110.0	8,403
10.0	120.0	5,357	10.0	120.0	3,413	10.0	120.0	8,411
10.0	130.0	5,362	10.0	130.0	3,416	10.0	130.0	8,419
10.0	140.0	5,367	10.0	140.0	3,419	10.0	140.0	8,427
10.0	150.0	5,372	10.0	150.0	3,422	10.0	150.0	8,434
10.0	160.0	5,377	10.0	160.0	3,425	10.0	160.0	8,442
10.0	170.0	5,382	10.0	170.0	3,428	10.0	170.0	8,450
10.0	180.0	5,387	10.0	180.0	3,432	10.0	180.0	8,458
10.0	190.0	5,392	10.0	190.0	3,435	10.0	190.0	8,466
10.0	200.0	5,397	10.0	200.0	3,438	10.0	200.0	8,474
10.0	210.0	5,402	10.0	210.0	3,441	10.0	210.0	8,481
10.0	220.0	5,407	10.0	220.0	3,444	10.0	220.0	8,489
10.0	230.0	5,412	10.0	230.0	3,448	10.0	230.0	8,497
10.0	240.0	5,417	10.0	240.0	3,451	10.0	240.0	8,505
10.0	250.0	5,422	10.0	250.0	3,454	10.0	250.0	8,513
10.0	260.0	5,427	10.0	260.0	3,457	10.0	260.0	8,521
10.0	270.0	5,432	10.0	270.0	3,460	10.0	270.0	8,529
10.0	280.0	5,437	10.0	280.0	3,464	10.0	280.0	8,536
10.0	290.0	5,442	10.0	290.0	3,467	10.0	290.0	8,544
10.0	300.0	5,447	10.0	300.0	3,470	10.0	300.0	8,552
10.0	310.0	5,452	10.0	310.0	3,473	10.0	310.0	8,560
10.0	320.0	5,457	10.0	320.0	3,476	10.0	320.0	8,568
10.0	330.0	5,462	10.0	330.0	3,479	10.0	330.0	8,576
10.0	340.0	5,467	10.0	340.0	3,483	10.0	340.0	8,584
10.0	350.0	5,472	10.0	350.0	3,486	10.0	350.0	8,591
10.0	360.0	5,477	10.0	360.0	3,489	10.0	360.0	8,599
10.0	370.0	5,482	10.0	370.0	3,492	10.0	370.0	8,607

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 3 profiles, ANO – Unit 2 site. (EPRI, 2013d)

Profile 1			Profile 2			Profile 3		
thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)
10.0	380.0	5,487	10.0	380.0	3,495	10.0	380.0	8,615
10.0	390.0	5,492	10.0	390.0	3,499	10.0	390.0	8,623
10.0	400.0	5,497	10.0	400.0	3,502	10.0	400.0	8,631
10.0	410.0	5,502	10.0	410.0	3,505	10.0	410.0	8,638
10.0	420.0	5,507	10.0	420.0	3,508	10.0	420.0	8,646
10.0	430.0	5,512	10.0	430.0	3,511	10.0	430.0	8,654
10.0	440.0	5,517	10.0	440.0	3,514	10.0	440.0	8,662
10.0	450.0	5,522	10.0	450.0	3,518	10.0	450.0	8,670
10.0	460.0	5,527	10.0	460.0	3,521	10.0	460.0	8,678
10.0	470.0	5,532	10.0	470.0	3,524	10.0	470.0	8,686
10.0	480.0	5,537	10.0	480.0	3,527	10.0	480.0	8,693
10.0	490.0	5,542	10.0	490.0	3,530	10.0	490.0	8,701
10.0	500.0	5,547	10.0	500.0	3,534	10.0	500.0	8,709
100.0	600.0	5,572	100.0	600.0	3,550	100.0	600.0	8,748
100.0	700.0	5,622	100.0	700.0	3,581	100.0	700.0	8,827
100.0	800.0	5,672	100.0	800.0	3,613	100.0	800.0	8,905
100.0	899.9	5,722	100.0	899.9	3,645	100.0	899.9	8,984
100.0	999.9	5,772	100.0	999.9	3,677	100.0	999.9	9,062
100.0	1,099.9	5,822	100.0	1,099.9	3,709	100.0	1,099.9	9,141
100.0	1,199.9	5,872	100.0	1,199.9	3,741	100.0	1,199.9	9,219
100.0	1,299.9	5,922	100.0	1,299.9	3,772	100.0	1,299.9	9,285
100.0	1,399.9	5,972	100.0	1,399.9	3,804	100.0	1,399.9	9,285
100.0	1,499.9	6,022	100.0	1,499.9	3,836	100.0	1,499.9	9,285
100.0	1,599.9	6,072	100.0	1,599.9	3,868	100.0	1,599.9	9,285
100.0	1,699.9	6,122	100.0	1,699.9	3,900	100.0	1,699.9	9,285
100.0	1,799.9	6,172	100.0	1,799.9	3,932	100.0	1,799.9	9,285
100.0	1,899.9	6,222	100.0	1,899.9	3,964	100.0	1,899.9	9,285
100.0	1,999.9	6,272	100.0	1,999.9	3,995	100.0	1,999.9	9,285
100.0	2,099.9	6,322	100.0	2,099.9	4,027	100.0	2,099.9	9,285
100.0	2,199.9	6,372	100.0	2,199.9	4,059	100.0	2,199.9	9,285
100.0	2,299.9	6,422	100.0	2,299.9	4,091	100.0	2,299.9	9,285
100.0	2,399.9	6,472	100.0	2,399.9	4,123	100.0	2,399.9	9,285
100.0	2,499.9	6,522	100.0	2,499.9	4,155	100.0	2,499.9	9,285
100.0	2,599.9	6,572	100.0	2,599.9	4,186	100.0	2,599.9	9,285
100.0	2,699.9	6,622	100.0	2,699.9	4,218	100.0	2,699.9	9,285
100.0	2,799.8	6,672	100.0	2,799.8	4,250	100.0	2,799.8	9,285
100.0	2,899.8	6,722	100.0	2,899.8	4,282	100.0	2,899.8	9,285
100.0	2,999.8	6,772	100.0	2,999.8	4,314	100.0	2,999.8	9,285

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 3 profiles, ANO – Unit 2 site. (EPRI, 2013d)

Profile 1			Profile 2			Profile 3		
thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)
100.0	3,099.8	6,822	100.0	3,099.8	4,346	100.0	3,099.8	9,285
100.0	3,199.8	6,872	100.0	3,199.8	4,378	100.0	3,199.8	9,285
100.0	3,299.8	6,922	100.0	3,299.8	4,409	100.0	3,299.8	9,285
100.0	3,399.8	6,972	100.0	3,399.8	4,441	100.0	3,399.8	9,285
100.0	3,499.8	7,022	100.0	3,499.8	4,473	100.0	3,499.8	9,285
100.0	3,599.8	7,072	100.0	3,599.8	4,505	100.0	3,599.8	9,285
100.0	3,699.8	7,122	100.0	3,699.8	4,537	100.0	3,699.8	9,285
100.0	3,799.8	7,172	100.0	3,799.8	4,569	100.0	3,799.8	9,285
100.0	3,899.8	7,222	100.0	3,899.8	4,600	100.0	3,899.8	9,285
100.0	3,999.8	7,272	100.0	3,999.8	4,632	100.0	3,999.8	9,285
100.0	4,099.8	7,322	100.0	4,099.8	4,664	100.0	4,099.8	9,285
100.0	4,199.8	7,372	100.0	4,199.8	4,696	100.0	4,199.8	9,285
100.0	4,299.8	7,422	100.0	4,299.8	4,728	100.0	4,299.8	9,285
100.0	4,399.8	7,472	100.0	4,399.8	4,760	100.0	4,399.8	9,285
100.0	4,499.8	7,522	100.0	4,499.8	4,792	100.0	4,499.8	9,285
100.0	4,599.8	7,572	100.0	4,599.8	4,823	100.0	4,599.8	9,285
100.0	4,699.8	7,622	100.0	4,699.8	4,855	100.0	4,699.8	9,285
100.0	4,799.7	7,672	100.0	4,799.7	4,887	100.0	4,799.7	9,285
100.0	4,899.7	7,722	100.0	4,899.7	4,919	100.0	4,899.7	9,285
100.0	4,999.7	7,772	100.0	4,999.7	4,951	100.0	4,999.7	9,285
3,280.8	8,280.6	9,285	3,280.8	8,280.6	9,285	3,280.8	8,280.6	9,285

2.3.2.1 Shear Modulus and Damping Curves

Nonlinear dynamic material properties were not available for ANO – Unit 2 for sedimentary rocks. The rock material over the upper 500 ft (150 m) was assumed to have behavior that could be modeled as either linear or non-linear. To represent this potential for either case in the upper 500 ft of sedimentary rock at the ANO – Unit 2 site, two sets of shear modulus reduction and hysteretic damping curves were used. Consistent with the SPID (EPRI, 2013a), 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 were used as the constant damping values in the upper 500 ft. (EPRI, 2013d)

2.3.2.2 Kappa

Base-case kappa estimates were determined using Section B-5.1.3.1 of the SPID (EPRI, 2013a) for a firm CEUS rock site. Kappa for a firm rock site with at least 3,000 ft (1 km) of sedimentary rock may be estimated from the average S-wave velocity over the upper 100 ft (V_{s100}) of the subsurface profile. For the ANO – Unit 2 site, with at least 3,000 ft (1 km) of firm rock, the corresponding average shear-wave velocities over the top 100 ft (31 m) were 5,325 ft/s (1,623 m/s) (P1), 3,391 ft/s (1,034 m/s) (P2), and 8,360 ft/s (2,548 m/s) (P3). The corresponding kappa estimates were 0.014 s, 0.023 s, and 0.009 s respectively. The range of kappa from 0.009 s to 0.023 s reflects a reasonable assessment of epistemic uncertainty. The suite of kappa estimates and associated weights are listed in Table 2.3.2-2. (EPRI, 2013d)

Table 2.3.2-2. Kappa Values and Weights Used for Site Response Analyses. (EPRI, 2013d)

Velocity Profile	Kappa(s)
P1	0.014
P2	0.023
P3	0.009
	Weights
P1	0.4
P2	0.3
P3	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 ANO – Unit 2 site, random shear wave velocity profiles were developed from the base case profiles shown in Figure 2.3.2-1. Consistent with the discussion in Appendix B of the SPID (EPRI, 2013a), the velocity randomization procedure made use of random field models which describe the statistical correlation between layering and shear wave velocity. The default randomization parameters developed in (Toro,1997) for United States Geological Survey "A" site conditions were used for this site. 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 0.15 below that depth. As specified in the SPID (EPRI, 2013a), 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. (EPRI, 2013d)

2.3.4 Input Spectra

Consistent with the guidance in Appendix B of the SPID (EPRI, 2013a), 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) were used in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed for the analysis of the ANO – Unit 2 site were the same as those identified in Tables B-4, B-5, B-6 and B-7 of the SPID (EPRI, 2013a) as appropriate for typical CEUS sites. (EPRI, 2013d)

2.3.5 Methodology

To perform the site response analyses for the ANO – Unit 2 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 (EPRI, 2013a). The guidance contained in Appendix B of the SPID (EPRI, 2013a) 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 the ANO – Unit 2 site. (EPRI, 2013d)

2.3.6 Amplification Functions

The results of the site response analysis consist of amplification factors (5% damped 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 (EPRI, 2013a) 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 (EPRI, 2013a) 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 the ANO – Unit 2 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 0.5g loading level and below. Above about the 0.5g loading level, the differences increase significantly but only above about 20 Hz. Tabular data for Figure 2.3.6-1 and Figure 2.3.6-2 is provided For Information Only in Appendix A. (EPRI, 2013d)

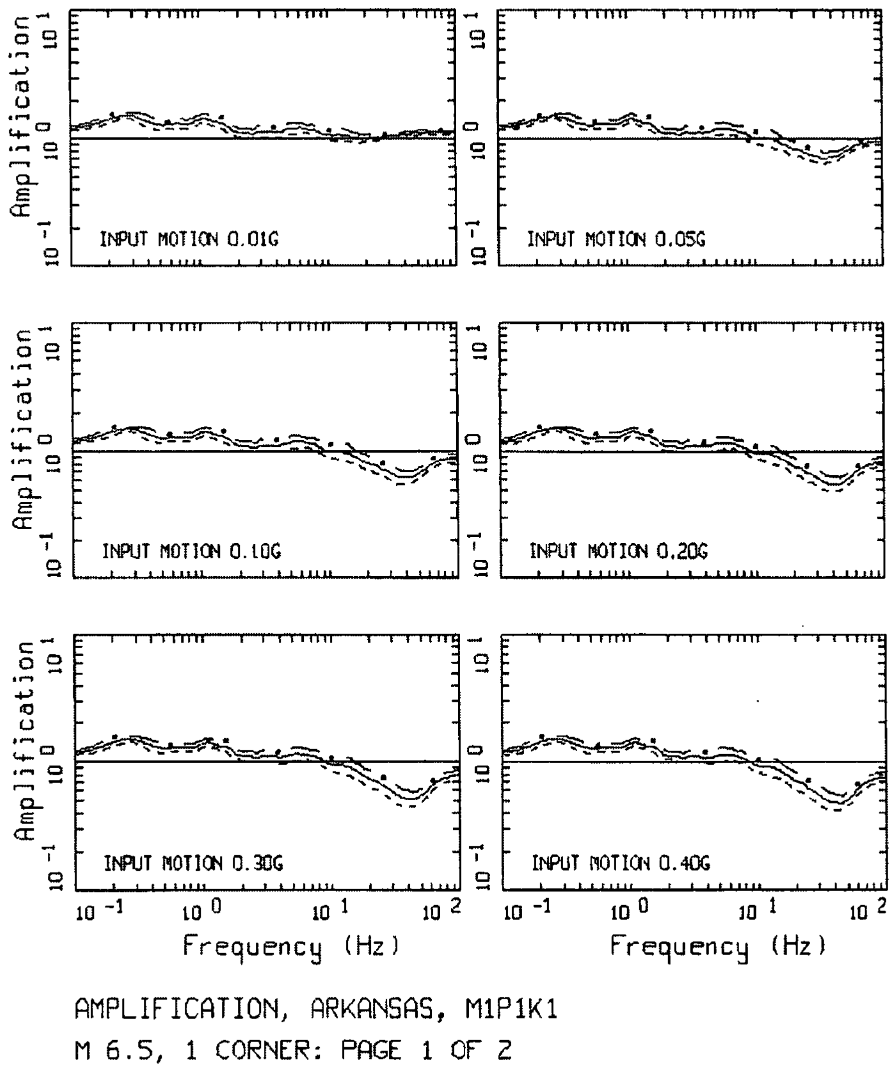

Figure 2.3.6-1. Example suite of amplification factors (5% damping pseudo-absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa (K1) at eleven loading levels of hard-rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (EPRI, 2013a). (EPRI, 2013d)

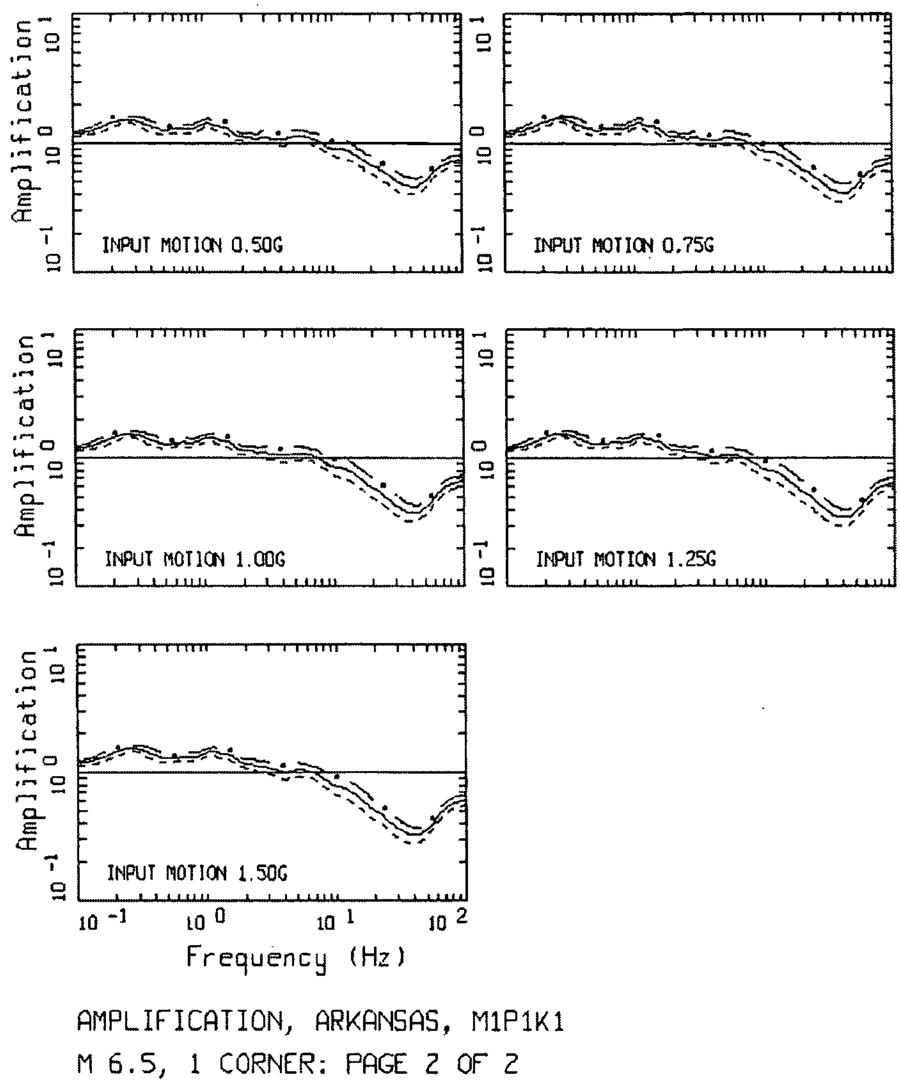

Figure 2.3.6-1.(cont.)

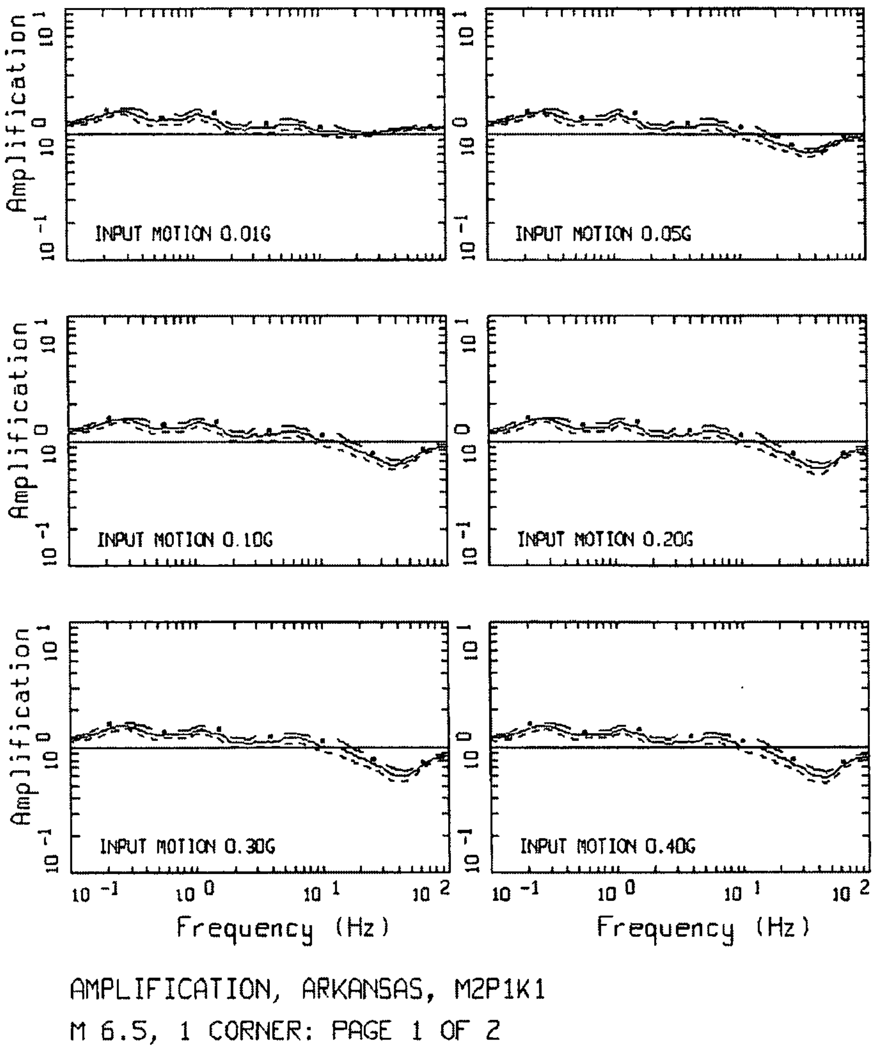

Figure 2.3.6-2. Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), linear site response (model M2), and base-case kappa (K1) at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (EPRI, 2013a). (EPRI, 2013d)

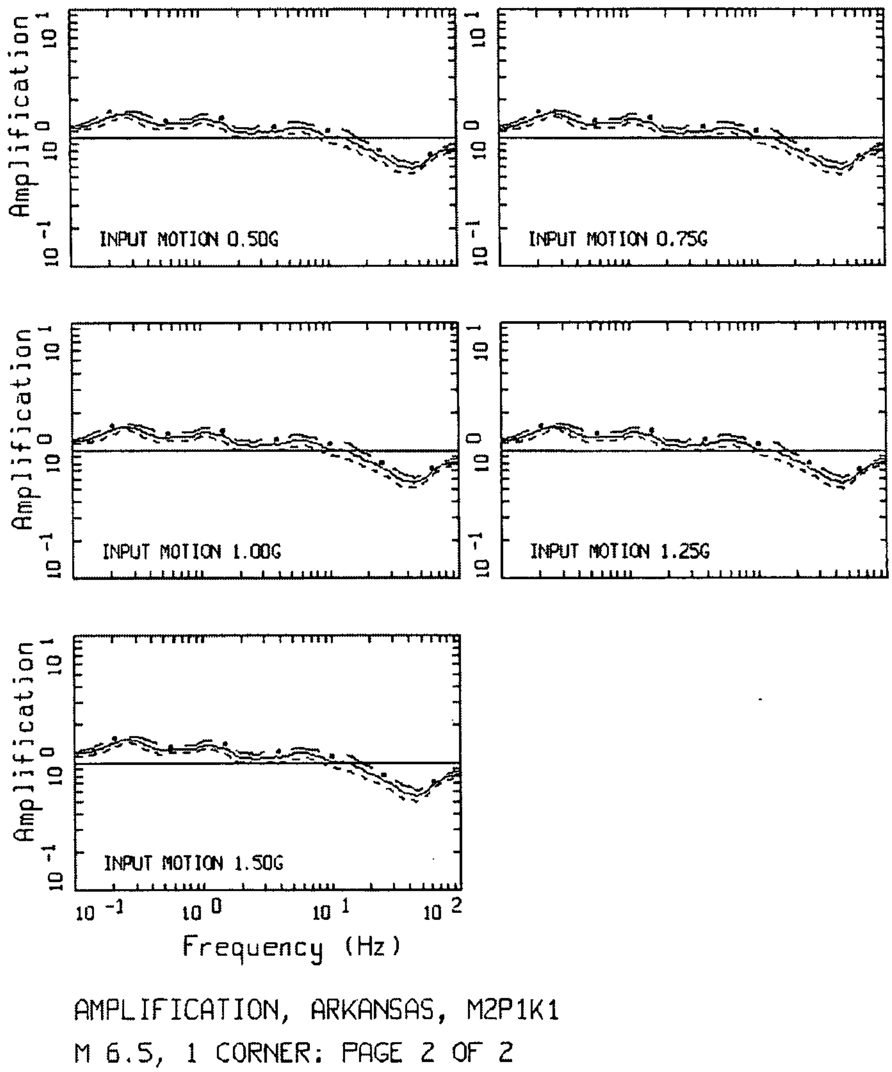

Figure 2.3.6-2.(cont.)

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 (EPRI, 2013a). 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 ANO – Unit 2 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. (EPRI, 2013d)

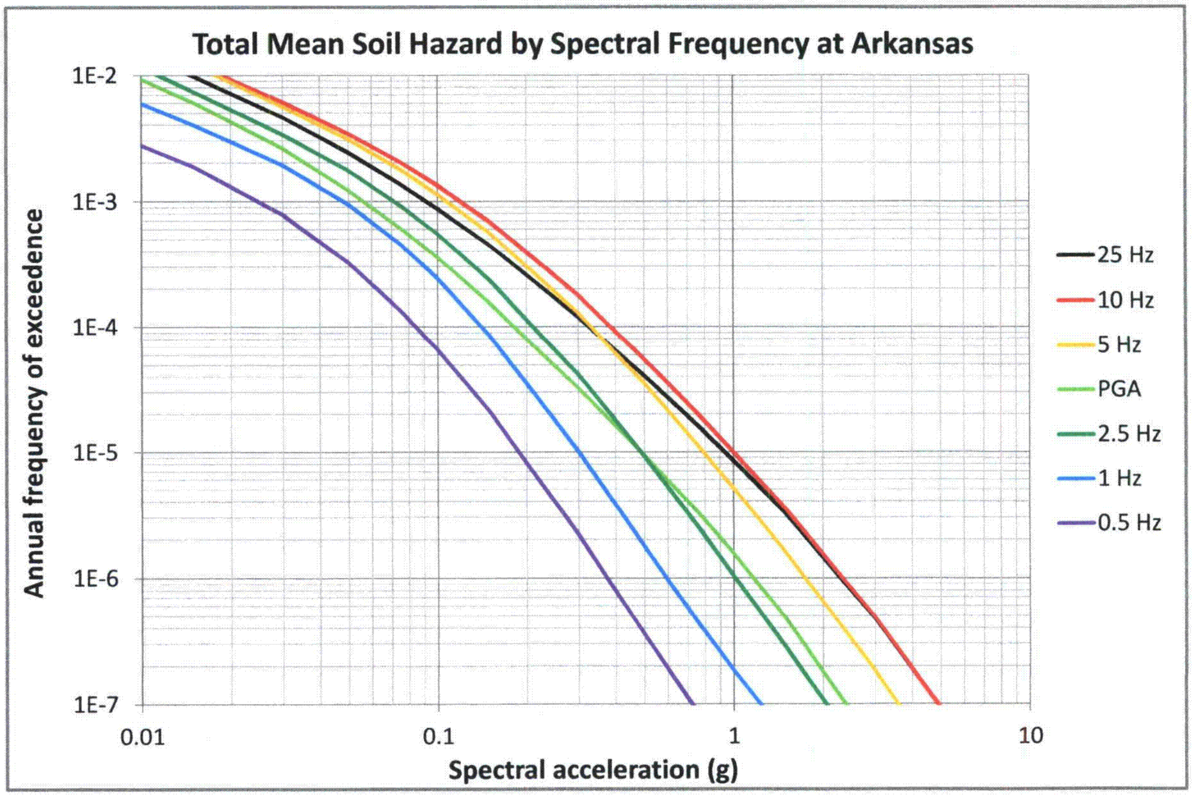

Figure 2.3.7-1. Control point mean hazard curves for spectral frequencies of 0.5, 1.0, 2.5, 5.0, 10, 25 and PGA (100 Hz) at ANO – Unit 2. (EPRI, 2013d)

2.4 Control Point Response Spectrum

The control point 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 10^{-4} and 10^{-5} per year hazard levels. Table 2.4-1 shows the UHRS and GMRS accelerations for a range of spectral frequencies. (EPRI, 2013d)

Table 2.4-1. UHRS and GMRS for ANO – Unit 2. (EPRI, 2013d)

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
100	1.82E-01	4.88E-01	2.40E-01
90	1.82E-01	4.91E-01	2.42E-01
80	1.83E-01	4.97E-01	2.44E-01
70	1.86E-01	5.09E-01	2.50E-01
60	1.96E-01	5.42E-01	2.65E-01
50	2.20E-01	6.22E-01	3.03E-01
40	2.59E-01	7.42E-01	3.61E-01
35	2.79E-01	8.02E-01	3.89E-01
30	3.02E-01	8.67E-01	4.21E-01
25	3.26E-01	9.32E-01	4.53E-01
20	3.54E-01	9.85E-01	4.82E-01
15	3.81E-01	1.03E+00	5.06E-01
12.5	3.90E-01	1.03E+00	5.10E-01
10	3.86E-01	1.00E+00	4.96E-01
9	3.80E-01	9.71E-01	4.83E-01
8	3.76E-01	9.46E-01	4.72E-01
7	3.64E-01	9.06E-01	4.53E-01
6	3.50E-01	8.54E-01	4.29E-01
5	3.32E-01	7.91E-01	3.99E-01
4	2.92E-01	6.90E-01	3.48E-01
3.5	2.71E-01	6.36E-01	3.22E-01
3	2.44E-01	5.67E-01	2.87E-01
2.5	2.11E-01	4.87E-01	2.47E-01
2	1.91E-01	4.35E-01	2.21E-01
1.5	1.73E-01	3.84E-01	1.96E-01
1.25	1.57E-01	3.43E-01	1.76E-01
1	1.41E-01	3.01E-01	1.55E-01
0.9	1.28E-01	2.76E-01	1.42E-01
0.8	1.20E-01	2.59E-01	1.33E-01
0.7	1.13E-01	2.47E-01	1.27E-01
0.6	1.00E-01	2.20E-01	1.13E-01
0.5	8.46E-02	1.88E-01	9.62E-02
0.4	6.77E-02	1.51E-01	7.70E-02
0.35	5.92E-02	1.32E-01	6.74E-02
0.3	5.08E-02	1.13E-01	5.77E-02
0.25	4.23E-02	9.41E-02	4.81E-02
0.2	3.38E-02	7.53E-02	3.85E-02
0.15	2.54E-02	5.65E-02	2.89E-02
0.125	2.12E-02	4.71E-02	2.41E-02
0.1	1.69E-02	3.76E-02	1.92E-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. (EPRI, 2013d)

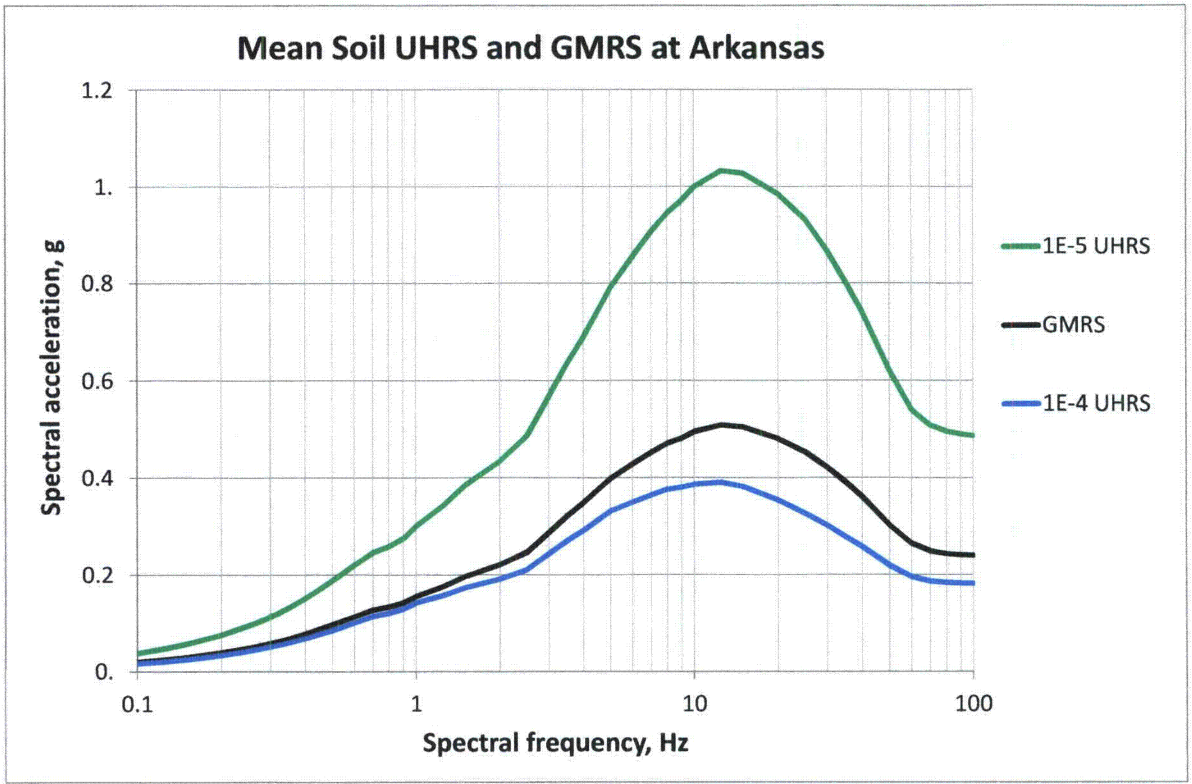

Figure 2.4-1. UHRS for 10^{-4} and 10^{-5} and GMRS at control point for ANO – Unit 2 (5%-damped response spectra). (EPRI, 2013d)

3.0 Plant Design Basis and Beyond Design Basis Evaluation Ground Motion

The design bases for ANO – Unit 2 are identified in the Updated Final Safety Analysis Report (Entergy, 2014b) and other pertinent documents.

An evaluation for beyond design basis (BDB) ground motions was performed in the Individual Plant Examination of External Events (IPEEE). The IPEEE capacity response spectrum is included below for screening purposes.

3.1 Safe Shutdown Earthquake Description of Spectral Shape

The SSEs for ANO – Unit 2 were developed in accordance with 10 CFR Part 100, Appendix A through an evaluation of the maximum earthquake potential for the region surrounding the site. Considering the historic seismicity of the site region, Entergy determined that because of the excellent formation conditions and the recent general quiescence of the area that a low earthquake intensity could be selected. However, considering the New Madrid earthquake, which is the only severe earthquake experienced in the central United States in historic time, an

intensity of VII on the Modified Mercalli Intensity Scale of 1931 has been assigned for the site. This is considered to be conservative and corresponds to a design spectrum of 0.20g for the SSE. (Entergy, 2014a)

The SSE is defined in terms of a PGA and a design response spectrum. Table 3.1-1 shows the spectral acceleration (SA) values as a function of frequency for the 5% damped horizontal SSE. (Entergy, 2014b)

Table 3.1-1. SSE for ANO – Unit 2 (Entergy, 2014b)

Freq. (Hz)	SA (g)
0.5	0.11
1.0	0.20
2.5	0.40
5.0	0.40
10	0.33
25	0.22
100	0.20

3.2 Control Point Elevation

The SSE control point elevation is at Elevation 326 ft. It is defined to be at the bottom of the foundation of the highest safety-related building, which is the Reactor Building. The bottom of the foundation for the Reactor Building is at 326 ft within the Pennsylvanian shale (Entergy, 2014b).

3.3 IPEEE Description and Capacity Response Spectrum

The IPEEE was performed as a focused scope SMA using the EPRI approach. The results of the IPEEE were submitted to the NRC (Entergy,1996). Results of the NRC review are documented in reference (U.S. NRC, 2001).

The ANO – Unit 2 Seismic IPEEE was performed using the Seismic Margins assessment option per the EPRI methodology of EPRI- 6041 (EPRI, 1991). With this method, a seismic margins earthquake (SME) was postulated and the items needed for safe shutdown were then evaluated for the SME demand. Components and structures that were determined to have sufficient capacity to survive the SME without loss of function were screened out. Items that did not screen were subjected to a more detailed evaluation, including calculation of a high-confidence of low-probability of failure (HCLPF) PGA for that item. A 0.30 PGA earthquake level and the NUREG/CR-0098 (U.S. NRC, 1978) median response spectra shape were used.

The IPEEE was reviewed for adequacy utilizing the guidance provided in Section 3.3 of the SPID (EPRI, 2013a). The IPEEE Adequacy Determination according to SPID (EPRI, 2013a) Section 3.3.1 is included in Appendix B.

The results of the review have shown, in accordance with the criteria established in SPID (EPRI, 2013a) Section 3.3, that the IPEEE is adequate to support screening of the updated seismic hazard for ANO – Unit 2. The review also concluded that the risk insights obtained from the IPEEE are still valid under the current plant configuration.

The safety-related structures at ANO – Unit 2 are founded on rock. As stated in NUREG 1407 Section 3.2.1, a plant in the full scope category that is located on a rock site is not required to perform a soil failure evaluation.

The 5% damped horizontal IPEEE HCLPF Spectrum (IHS) spectral acceleration for ANO – Unit 2 is provided in Table 3.3-1. The SSE and the IHS are shown in Figure 3.3-1.

Table 3.3-1. IHS for ANO – Unit 2 (Entergy, 1996).

Freq. (Hz)	IHS (g)
0.5	0.15
1.0	0.29
2.2	0.64
8.0	0.64
10	0.57
25	0.35
33	0.30
100	0.30

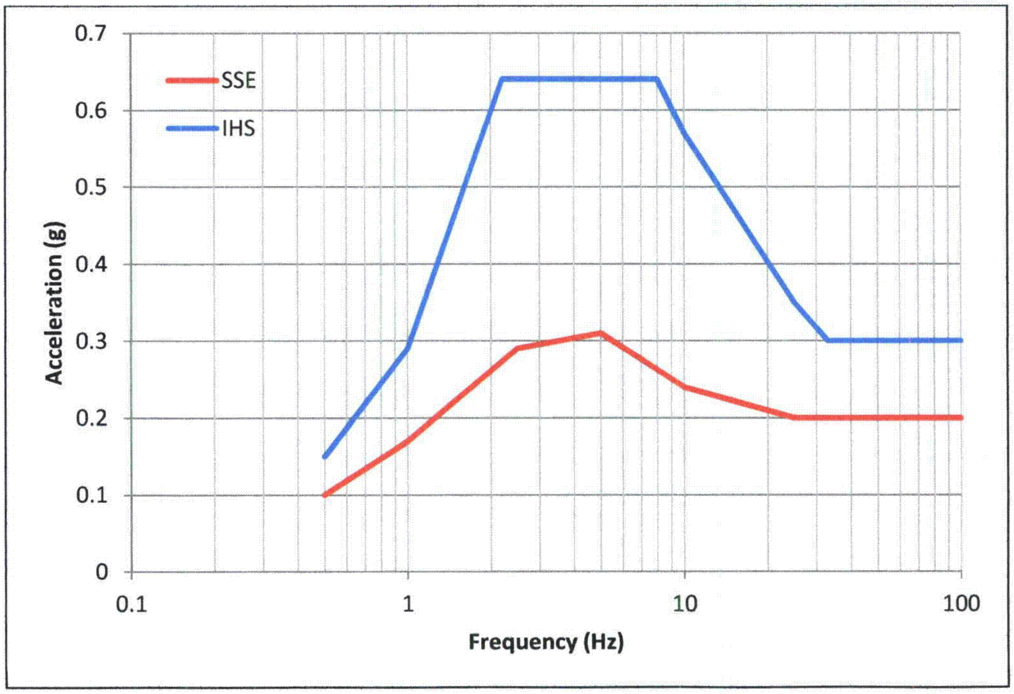

Figure 3.3-1. SSE and IHS Response Spectra for ANO – Unit 2.

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 IHS exceeds the GMRS for ANO – Unit 2. Based on this comparison, a risk evaluation will not be performed.

4.2 High Frequency Screening (> 10 Hz)

For a portion of the range above 10 Hz, the GMRS exceeds the SSE. Therefore, ANO – Unit 2 screens-in for a High Frequency Confirmation.

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, ANO – Unit 2 screens-in for a Spent Fuel Pool evaluation.

5.0 Interim Actions

Based on the screening evaluation, the expedited seismic evaluation described in EPRI 3002000704 (EPRI, 2013c) will be performed as proposed in a letter to NRC (ML13101A379) dated April 9, 2013 (NEI, 2013a) and agreed to by NRC (ML13106A331) in a letter dated May 7, 2013 (U.S. NRC, 2013). The full evaluation of soil failures required in SPID (EPRI, 2013a) is not required as the supporting medium for safety related structures is rock with a Vs = 3500fps or more. Item 2.7 of Enclosure 3 to the NRC SER (US NRC, 2001) observes: "The principal structures at ANO-2 are founded on bedrock; therefore, a soil evaluation is not required."

Consistent with NRC letter (ML14030A046) dated February 20, 2014 (U.S. NRC, 2014), the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of ANO – Unit 2. 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," 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 (U.S. NRC, 2010):

> 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.

ANO – Unit 2 is included in the March 12, 2014 risk estimates (NEI, 2014). Using the methodology described in the NEI letter, all plants were shown to be below 10^{-4}/year; thus, the above conclusions apply.

In accordance with the Near-Term Task Force Recommendation 2.3, ANO – Unit 2 performed seismic walkdowns using the guidance in EPRI Report 1025286 (EPRI, 2012). The seismic walkdowns were completed and captured in Fukushima Seismic Walkdown Report (Entergy, 2013). The goal of the walkdowns was to verify current plant configuration with the existing licensing basis, to verify the current maintenance plans, and to identify any vulnerabilities. The walkdown also verified that any vulnerabilities identified in the IPEEE (Entergy, 1996) were

adequately addressed. The results of the walkdown, including any identified corrective actions, confirm that ANO – Unit 2 can adequately respond to a seismic event.

6.0 Conclusions

In accordance with the 50.54(f) request for information (U.S. NRC, 2012), a seismic hazard and screening evaluation was performed for Arkansas Nuclear One – Unit 2. 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, ANO – Unit 2 screens-in for a High Frequency Confirmation and a Spent Fuel Pool evaluation. Additionally, based on the results of the screening evaluation, ANO – Unit 2 screens-out of a risk evaluation.

7.0 References

10 CFR Part 50. Title 10, Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington DC.

10 CFR Part 50.72. Title 10, Code of Federal Regulations, Part 50.72, "Immediate Notification Requirements for Operating Nuclear Power Reactors," U.S. Nuclear Regulatory Commission, Washington DC.

10 CFR Part 50.73. Title 10, Code of Federal Regulations, Part 50.73, "Licensee Event Report System," U.S. Nuclear Regulatory Commission, Washington DC.

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NEI (2013b). NEI Letter, Kimberly A. Keithline to David L. Skeen, NRC "Relay Chatter Reviews for Seismic Hazard Screening," dated October 3, 2013.

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Appendix A

Tabulated Data

Table A-1a. Mean and Fractile Seismic Hazard Curves for 100 Hz (PGA) at ANO – Unit 2. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.02E-02	4.31E-02	6.64E-02	8.12E-02	9.51E-02	9.93E-02
0.001	6.09E-02	2.76E-02	4.77E-02	6.09E-02	7.66E-02	8.72E-02
0.005	1.83E-02	7.77E-03	1.16E-02	1.69E-02	2.29E-02	3.84E-02
0.01	9.30E-03	3.73E-03	5.35E-03	8.23E-03	1.20E-02	2.25E-02
0.015	6.06E-03	2.10E-03	3.05E-03	5.27E-03	8.23E-03	1.51E-02
0.03	2.60E-03	5.50E-04	8.60E-04	1.92E-03	4.25E-03	7.34E-03
0.05	1.22E-03	1.77E-04	2.92E-04	6.93E-04	2.16E-03	4.19E-03
0.075	6.12E-04	7.45E-05	1.27E-04	2.96E-04	9.93E-04	2.32E-03
0.1	3.57E-04	4.07E-05	7.34E-05	1.67E-04	5.20E-04	1.38E-03
0.15	1.55E-04	1.74E-05	3.42E-05	7.66E-05	2.04E-04	5.75E-04
0.3	3.21E-05	3.47E-06	7.77E-06	1.92E-05	4.50E-05	1.04E-04
0.5	9.43E-06	7.89E-07	2.01E-06	5.91E-06	1.51E-05	2.92E-05
0.75	3.38E-06	1.82E-07	5.42E-07	1.98E-06	5.66E-06	1.11E-05
1.	1.55E-06	5.35E-08	1.84E-07	8.23E-07	2.68E-06	5.42E-06
1.5	4.76E-07	7.03E-09	3.19E-08	1.98E-07	8.12E-07	1.82E-06
3.	4.66E-08	2.39E-10	9.11E-10	1.02E-08	7.23E-08	2.10E-07
5.	6.22E-09	1.42E-10	1.84E-10	8.35E-10	8.12E-09	3.01E-08
7.5	1.02E-09	1.32E-10	1.60E-10	2.13E-10	1.20E-09	5.12E-09
10.	2.51E-10	1.21E-10	1.32E-10	1.82E-10	3.57E-10	1.36E-09

Table A-1b. Mean and Fractile Seismic Hazard Curves for 25 Hz at ANO – Unit 2. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.59E-02	5.58E-02	7.34E-02	8.72E-02	9.93E-02	9.93E-02
0.001	6.98E-02	3.90E-02	5.83E-02	7.03E-02	8.23E-02	9.37E-02
0.005	2.62E-02	1.21E-02	1.84E-02	2.46E-02	3.19E-02	5.12E-02
0.01	1.45E-02	6.64E-03	9.24E-03	1.32E-02	1.79E-02	3.19E-02
0.015	9.81E-03	4.25E-03	5.91E-03	8.85E-03	1.27E-02	2.22E-02
0.03	4.61E-03	1.49E-03	2.16E-03	3.90E-03	6.73E-03	1.07E-02
0.05	2.41E-03	5.42E-04	8.35E-04	1.79E-03	4.01E-03	6.54E-03
0.075	1.36E-03	2.25E-04	3.68E-04	8.60E-04	2.39E-03	4.25E-03
0.1	8.75E-04	1.25E-04	2.10E-04	4.98E-04	1.51E-03	3.01E-03
0.15	4.45E-04	5.66E-05	1.01E-04	2.35E-04	6.93E-04	1.62E-03
0.3	1.19E-04	1.51E-05	2.96E-05	6.73E-05	1.64E-04	3.84E-04
0.5	4.05E-05	5.20E-06	1.10E-05	2.64E-05	6.00E-05	1.13E-04
0.75	1.65E-05	1.98E-06	4.50E-06	1.15E-05	2.60E-05	4.56E-05
1.	8.51E-06	9.37E-07	2.22E-06	5.91E-06	1.40E-05	2.39E-05
1.5	3.19E-06	2.80E-07	7.13E-07	2.13E-06	5.42E-06	9.51E-06
3.	4.77E-07	2.19E-08	6.54E-08	2.57E-07	8.60E-07	1.64E-06
5.	9.36E-08	2.25E-09	7.66E-09	3.90E-08	1.67E-07	3.57E-07
7.5	2.19E-08	3.95E-10	1.16E-09	6.83E-09	3.73E-08	9.11E-08
10.	7.14E-09	2.01E-10	3.57E-10	1.82E-09	1.15E-08	3.09E-08

Table A-1c. Mean and Fractile Seismic Hazard Curves for 10 Hz at ANO – Unit 2. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	9.37E-02	7.34E-02	8.00E-02	9.37E-02	9.93E-02	9.93E-02
0.001	8.10E-02	5.75E-02	6.83E-02	8.12E-02	9.37E-02	9.93E-02
0.005	3.41E-02	1.79E-02	2.46E-02	3.37E-02	4.31E-02	5.35E-02
0.01	1.86E-02	9.24E-03	1.25E-02	1.79E-02	2.35E-02	3.23E-02
0.015	1.25E-02	6.09E-03	8.23E-03	1.18E-02	1.62E-02	2.25E-02
0.03	6.11E-03	2.57E-03	3.57E-03	5.58E-03	8.47E-03	1.16E-02
0.05	3.41E-03	1.10E-03	1.62E-03	2.96E-03	5.20E-03	7.45E-03
0.075	2.02E-03	5.05E-04	7.77E-04	1.57E-03	3.33E-03	5.12E-03
0.1	1.34E-03	2.76E-04	4.37E-04	9.37E-04	2.29E-03	3.79E-03
0.15	6.90E-04	1.13E-04	1.87E-04	4.19E-04	1.16E-03	2.22E-03
0.3	1.78E-04	2.46E-05	4.50E-05	1.02E-04	2.57E-04	5.83E-04
0.5	5.54E-05	7.55E-06	1.51E-05	3.52E-05	7.89E-05	1.67E-04
0.75	2.06E-05	2.68E-06	5.75E-06	1.40E-05	3.14E-05	5.83E-05
1.	1.00E-05	1.16E-06	2.64E-06	7.03E-06	1.60E-05	2.84E-05
1.5	3.47E-06	3.01E-07	7.66E-07	2.35E-06	5.91E-06	1.05E-05
3.	4.83E-07	1.67E-08	5.58E-08	2.57E-07	8.72E-07	1.72E-06
5.	9.34E-08	1.21E-09	4.98E-09	3.57E-08	1.67E-07	3.79E-07
7.5	2.20E-08	2.32E-10	6.54E-10	6.09E-09	3.73E-08	9.65E-08
10.	7.22E-09	1.82E-10	2.39E-10	1.60E-09	1.16E-08	3.28E-08

Table A-1d. Mean and Fractile Seismic Hazard Curves for 5.0 Hz at ANO – Unit 2. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	9.55E-02	7.55E-02	8.23E-02	9.65E-02	9.93E-02	9.93E-02
0.001	8.43E-02	6.00E-02	6.93E-02	8.47E-02	9.93E-02	9.93E-02
0.005	3.61E-02	1.79E-02	2.49E-02	3.52E-02	4.77E-02	5.50E-02
0.01	1.89E-02	8.98E-03	1.25E-02	1.82E-02	2.57E-02	3.01E-02
0.015	1.23E-02	5.83E-03	8.00E-03	1.18E-02	1.67E-02	2.01E-02
0.03	5.64E-03	2.35E-03	3.33E-03	5.35E-03	8.00E-03	9.93E-03
0.05	3.08E-03	9.65E-04	1.49E-03	2.72E-03	4.70E-03	6.36E-03
0.075	1.78E-03	4.25E-04	6.73E-04	1.40E-03	2.92E-03	4.31E-03
0.1	1.14E-03	2.22E-04	3.63E-04	8.00E-04	1.92E-03	3.23E-03
0.15	5.60E-04	8.47E-05	1.44E-04	3.33E-04	8.98E-04	1.90E-03
0.3	1.29E-04	1.53E-05	2.80E-05	6.45E-05	1.69E-04	4.98E-04
0.5	3.54E-05	3.95E-06	8.00E-06	1.92E-05	4.70E-05	1.20E-04
0.75	1.16E-05	1.23E-06	2.68E-06	7.03E-06	1.72E-05	3.52E-05
1.	5.13E-06	4.90E-07	1.15E-06	3.28E-06	8.12E-06	1.53E-05
1.5	1.58E-06	1.15E-07	3.01E-07	1.01E-06	2.68E-06	4.98E-06
3.	1.85E-07	5.75E-09	1.95E-08	9.24E-08	3.23E-07	6.83E-07
5.	3.21E-08	5.20E-10	1.72E-09	1.10E-08	5.35E-08	1.34E-07
7.5	6.96E-09	1.92E-10	3.14E-10	1.67E-09	1.05E-08	3.14E-08
10.	2.17E-09	1.55E-10	1.87E-10	4.77E-10	3.01E-09	1.01E-08

Table A-1e. Mean and Fractile Seismic Hazard Curves for 2.5 Hz at ANO – Unit 2. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	9.00E-02	6.73E-02	7.55E-02	8.98E-02	9.93E-02	9.93E-02
0.001	7.37E-02	4.77E-02	5.75E-02	7.34E-02	9.11E-02	9.93E-02
0.005	2.44E-02	1.18E-02	1.57E-02	2.32E-02	3.33E-02	4.01E-02
0.01	1.17E-02	5.42E-03	7.34E-03	1.10E-02	1.60E-02	1.98E-02
0.015	7.39E-03	3.23E-03	4.50E-03	7.03E-03	1.02E-02	1.29E-02
0.03	3.35E-03	1.04E-03	1.62E-03	3.05E-03	5.05E-03	6.73E-03
0.05	1.74E-03	3.52E-04	6.09E-04	1.40E-03	2.92E-03	4.31E-03
0.075	9.27E-04	1.31E-04	2.35E-04	6.09E-04	1.62E-03	2.80E-03
0.1	5.49E-04	6.00E-05	1.11E-04	3.01E-04	9.37E-04	1.95E-03
0.15	2.35E-04	1.84E-05	3.57E-05	1.01E-04	3.57E-04	9.65E-04
0.3	4.12E-05	2.13E-06	4.70E-06	1.38E-05	5.05E-05	1.64E-04
0.5	9.27E-06	3.73E-07	9.65E-07	3.33E-06	1.16E-05	3.09E-05
0.75	2.61E-06	8.12E-08	2.46E-07	1.05E-06	3.63E-06	8.47E-06
1.	1.04E-06	2.53E-08	8.72E-08	4.31E-07	1.60E-06	3.57E-06
1.5	2.82E-07	4.19E-09	1.72E-08	1.10E-07	4.70E-07	1.08E-06
3.	2.84E-08	2.72E-10	7.89E-10	6.93E-09	4.50E-08	1.29E-07
5.	4.43E-09	1.82E-10	1.98E-10	7.45E-10	5.91E-09	2.07E-08
7.5	8.72E-10	1.32E-10	1.82E-10	2.19E-10	1.04E-09	4.07E-09
10.	2.52E-10	1.21E-10	1.32E-10	1.82E-10	3.52E-10	1.21E-09

Table A-1f. Mean and Fractile Seismic Hazard Curves for 1.0 Hz at ANO – Unit 2. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.70E-02	3.63E-02	4.77E-02	6.73E-02	8.47E-02	9.51E-02
0.001	4.59E-02	2.04E-02	2.96E-02	4.56E-02	6.09E-02	7.23E-02
0.005	1.18E-02	4.63E-03	6.83E-03	1.10E-02	1.64E-02	2.13E-02
0.01	5.95E-03	2.01E-03	3.19E-03	5.50E-03	8.60E-03	1.13E-02
0.015	4.00E-03	1.10E-03	1.87E-03	3.63E-03	6.09E-03	8.00E-03
0.03	1.92E-03	2.84E-04	5.75E-04	1.55E-03	3.28E-03	4.77E-03
0.05	9.45E-04	7.89E-05	1.79E-04	6.26E-04	1.74E-03	2.88E-03
0.075	4.54E-04	2.42E-05	5.91E-05	2.39E-04	8.35E-04	1.60E-03
0.1	2.42E-04	9.79E-06	2.46E-05	1.07E-04	4.31E-04	9.37E-04
0.15	8.57E-05	2.49E-06	6.54E-06	3.01E-05	1.40E-04	3.57E-04
0.3	1.01E-05	1.84E-07	5.75E-07	2.80E-06	1.42E-05	4.25E-05
0.5	1.77E-06	2.01E-08	7.77E-08	4.77E-07	2.49E-06	7.23E-06
0.75	4.57E-07	2.88E-09	1.36E-08	1.10E-07	6.73E-07	1.98E-06
1.	1.86E-07	7.45E-10	3.68E-09	3.79E-08	2.68E-07	8.47E-07
1.5	5.52E-08	2.16E-10	6.09E-10	7.77E-09	7.13E-08	2.64E-07
3.	6.63E-09	1.44E-10	1.82E-10	4.77E-10	5.91E-09	2.96E-08
5.	1.17E-09	1.32E-10	1.46E-10	1.82E-10	8.00E-10	4.50E-09
7.5	2.58E-10	1.21E-10	1.32E-10	1.82E-10	2.42E-10	9.51E-10
10.	8.12E-11	1.21E-10	1.32E-10	1.82E-10	1.82E-10	3.52E-10

Table A-1g. Mean and Fractile Seismic Hazard Curves for 0.5 Hz at ANO – Unit 2. (EPRI, 2013d)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	3.27E-02	1.62E-02	2.25E-02	3.19E-02	4.31E-02	5.20E-02
0.001	1.92E-02	8.72E-03	1.25E-02	1.82E-02	2.60E-02	3.28E-02
0.005	4.97E-03	1.51E-03	2.49E-03	4.56E-03	7.45E-03	9.79E-03
0.01	2.75E-03	4.83E-04	9.79E-04	2.39E-03	4.50E-03	6.26E-03
0.015	1.86E-03	2.07E-04	4.77E-04	1.49E-03	3.28E-03	4.77E-03
0.03	7.82E-04	3.42E-05	9.65E-05	4.43E-04	1.49E-03	2.64E-03
0.05	3.24E-04	7.03E-06	2.16E-05	1.27E-04	5.83E-04	1.32E-03
0.075	1.35E-04	1.77E-06	5.75E-06	3.79E-05	2.16E-04	6.00E-04
0.1	6.59E-05	6.26E-07	2.07E-06	1.44E-05	9.37E-05	3.01E-04
0.15	2.10E-05	1.27E-07	4.63E-07	3.33E-06	2.53E-05	9.51E-05
0.3	2.17E-06	5.58E-09	2.76E-08	2.35E-07	2.07E-06	9.11E-06
0.5	3.56E-07	5.05E-10	2.60E-09	3.05E-08	3.14E-07	1.55E-06
0.75	8.87E-08	1.92E-10	4.63E-10	5.35E-09	7.13E-08	4.07E-07
1.	3.54E-08	1.82E-10	2.16E-10	1.53E-09	2.42E-08	1.62E-07
1.5	1.04E-08	1.32E-10	1.82E-10	3.42E-10	5.12E-09	4.37E-08
3.	1.26E-09	1.21E-10	1.32E-10	1.82E-10	4.07E-10	3.79E-09
5.	2.27E-10	1.21E-10	1.32E-10	1.82E-10	1.82E-10	5.83E-10
7.5	5.06E-11	1.21E-10	1.32E-10	1.82E-10	1.82E-10	2.13E-10
10.	1.61E-11	1.21E-10	1.32E-10	1.82E-10	1.82E-10	1.82E-10

Table A-2. Amplification Functions for ANO – Unit 2. (EPRI, 2013d)

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	1.08E+00	4.75E-02	1.30E-02	9.47E-01	5.76E-02	1.90E-02	1.02E+00	9.03E-02	2.09E-02	1.17E+00	9.85E-02
4.95E-02	9.08E-01	6.43E-02	1.02E-01	7.27E-01	1.11E-01	9.99E-02	9.80E-01	1.06E-01	8.24E-02	1.16E+00	1.04E-01
9.64E-02	8.49E-01	7.06E-02	2.13E-01	6.89E-01	1.24E-01	1.85E-01	9.67E-01	1.09E-01	1.44E-01	1.15E+00	1.05E-01
1.94E-01	8.00E-01	7.61E-02	4.43E-01	6.59E-01	1.32E-01	3.56E-01	9.50E-01	1.12E-01	2.65E-01	1.14E+00	1.08E-01
2.92E-01	7.74E-01	7.92E-02	6.76E-01	6.41E-01	1.35E-01	5.23E-01	9.37E-01	1.14E-01	3.84E-01	1.13E+00	1.09E-01
3.91E-01	7.56E-01	8.13E-02	9.09E-01	6.27E-01	1.38E-01	6.90E-01	9.26E-01	1.17E-01	5.02E-01	1.12E+00	1.11E-01
4.93E-01	7.42E-01	8.27E-02	1.15E+00	6.16E-01	1.41E-01	8.61E-01	9.16E-01	1.18E-01	6.22E-01	1.11E+00	1.12E-01
7.41E-01	7.18E-01	8.48E-02	1.73E+00	5.94E-01	1.45E-01	1.27E+00	8.96E-01	1.21E-01	9.13E-01	1.10E+00	1.15E-01
1.01E+00	7.00E-01	8.61E-02	2.36E+00	5.77E-01	1.47E-01	1.72E+00	8.79E-01	1.24E-01	1.22E+00	1.08E+00	1.17E-01
1.28E+00	6.85E-01	8.65E-02	3.01E+00	5.61E-01	1.50E-01	2.17E+00	8.64E-01	1.26E-01	1.54E+00	1.07E+00	1.18E-01
1.55E+00	6.74E-01	8.65E-02	3.63E+00	5.49E-01	1.51E-01	2.61E+00	8.51E-01	1.26E-01	1.85E+00	1.06E+00	1.19E-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	1.09E+00	8.96E-02	1.27E-02	1.39E+00	1.12E-01	8.25E-03	1.25E+00	1.19E-01			
7.05E-02	1.08E+00	8.90E-02	3.43E-02	1.38E+00	1.07E-01	1.96E-02	1.24E+00	1.15E-01			
1.18E-01	1.08E+00	8.87E-02	5.51E-02	1.37E+00	1.05E-01	3.02E-02	1.24E+00	1.14E-01			
2.12E-01	1.08E+00	8.88E-02	9.63E-02	1.37E+00	1.03E-01	5.11E-02	1.24E+00	1.13E-01			
3.04E-01	1.07E+00	8.89E-02	1.36E-01	1.37E+00	1.02E-01	7.10E-02	1.24E+00	1.13E-01			
3.94E-01	1.07E+00	8.91E-02	1.75E-01	1.38E+00	1.01E-01	9.06E-02	1.24E+00	1.13E-01			
4.86E-01	1.07E+00	8.92E-02	2.14E-01	1.38E+00	1.00E-01	1.10E-01	1.24E+00	1.13E-01			
7.09E-01	1.07E+00	8.96E-02	3.10E-01	1.38E+00	9.89E-02	1.58E-01	1.25E+00	1.13E-01			
9.47E-01	1.06E+00	9.09E-02	4.12E-01	1.39E+00	9.80E-02	2.09E-01	1.25E+00	1.13E-01			
1.19E+00	1.06E+00	9.32E-02	5.18E-01	1.39E+00	9.76E-02	2.62E-01	1.25E+00	1.14E-01			
1.43E+00	1.06E+00	9.45E-02	6.19E-01	1.39E+00	9.71E-02	3.12E-01	1.25E+00	1.14E-01			

Tables A-3a and A-3b 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 10^{-4} and 10^{-5} mean annual frequency of exceedance. These factors are unverified and are provided for information only. The figures should be considered the governing information.

Table A-3a. Median AFs and sigmas for Model 1, Profile 1, for 2 PGA levels.

For Information Only

M1P1K1	Rock PGA=0.194			M1P1K1	PGA=0.741		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.161	0.828	0.081	100.0	0.516	0.697	0.100
87.1	0.162	0.814	0.082	87.1	0.520	0.679	0.101
75.9	0.164	0.788	0.083	75.9	0.525	0.648	0.103
66.1	0.168	0.740	0.086	66.1	0.535	0.592	0.107
57.5	0.176	0.662	0.092	57.5	0.554	0.509	0.114
50.1	0.190	0.596	0.105	50.1	0.591	0.445	0.129
43.7	0.209	0.554	0.118	43.7	0.641	0.408	0.144
38.0	0.232	0.559	0.134	38.0	0.703	0.413	0.162
33.1	0.254	0.578	0.148	33.1	0.771	0.435	0.176
28.8	0.280	0.638	0.150	28.8	0.847	0.485	0.186
25.1	0.299	0.675	0.142	25.1	0.920	0.530	0.177
21.9	0.313	0.741	0.149	21.9	0.969	0.596	0.176
19.1	0.326	0.783	0.145	19.1	1.012	0.641	0.175
16.6	0.339	0.846	0.139	16.6	1.060	0.708	0.169
14.5	0.350	0.914	0.154	14.5	1.105	0.782	0.170
12.6	0.358	0.959	0.161	12.6	1.145	0.842	0.177
11.0	0.350	0.963	0.136	11.0	1.130	0.860	0.163
9.5	0.344	0.989	0.112	9.5	1.106	0.890	0.134
8.3	0.342	1.065	0.110	8.3	1.099	0.968	0.126
7.2	0.336	1.117	0.105	7.2	1.097	1.040	0.125
6.3	0.328	1.161	0.091	6.3	1.070	1.087	0.101
5.5	0.314	1.164	0.113	5.5	1.027	1.100	0.118
4.8	0.302	1.144	0.101	4.8	0.989	1.091	0.115
4.2	0.284	1.109	0.108	4.2	0.929	1.063	0.120
3.6	0.276	1.107	0.089	3.6	0.904	1.069	0.097
3.2	0.261	1.110	0.103	3.2	0.866	1.093	0.106
2.8	0.246	1.102	0.090	2.8	0.827	1.106	0.100
2.4	0.225	1.093	0.083	2.4	0.760	1.106	0.090
2.1	0.208	1.110	0.070	2.1	0.703	1.131	0.069
1.8	0.191	1.142	0.092	1.8	0.642	1.161	0.086
1.6	0.184	1.270	0.102	1.6	0.614	1.287	0.098
1.4	0.166	1.328	0.076	1.4	0.550	1.347	0.077
1.2	0.152	1.377	0.078	1.2	0.498	1.392	0.077
1.0	0.141	1.415	0.070	1.0	0.458	1.428	0.068
0.91	0.121	1.334	0.078	0.91	0.390	1.344	0.076
0.79	0.105	1.288	0.077	0.79	0.338	1.296	0.075
0.69	0.095	1.299	0.084	0.69	0.300	1.305	0.082
0.60	0.082	1.287	0.067	0.60	0.257	1.291	0.065
0.52	0.069	1.266	0.066	0.52	0.214	1.270	0.065
0.46	0.058	1.284	0.087	0.46	0.179	1.286	0.086
0.10	0.002	1.205	0.033	0.10	0.007	1.195	0.035

Table A-3b. Median AFs and sigmas for Model 2, Profile 1, for 2 PGA levels.

For Information Only

M2P1K1		PGA=0.194		M2P1K1		PGA=0.741	
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.169	0.872	0.055	100.0	0.613	0.828	0.058
87.1	0.171	0.858	0.055	87.1	0.620	0.811	0.059
75.9	0.173	0.833	0.055	75.9	0.632	0.781	0.059
66.1	0.178	0.785	0.055	66.1	0.655	0.725	0.059
57.5	0.188	0.709	0.057	57.5	0.703	0.646	0.063
50.1	0.206	0.647	0.069	50.1	0.789	0.594	0.081
43.7	0.230	0.610	0.084	43.7	0.894	0.569	0.098
38.0	0.257	0.619	0.096	38.0	1.005	0.590	0.108
33.1	0.282	0.642	0.109	33.1	1.101	0.621	0.118
28.8	0.311	0.707	0.105	28.8	1.208	0.692	0.112
25.1	0.328	0.740	0.113	25.1	1.262	0.728	0.118
21.9	0.341	0.808	0.123	21.9	1.298	0.799	0.127
19.1	0.353	0.847	0.117	19.1	1.326	0.840	0.121
16.6	0.364	0.909	0.117	16.6	1.353	0.904	0.119
14.5	0.373	0.973	0.137	14.5	1.370	0.970	0.139
12.6	0.378	1.013	0.138	12.6	1.373	1.010	0.140
11.0	0.370	1.015	0.112	11.0	1.329	1.012	0.114
9.5	0.361	1.038	0.089	9.5	1.286	1.035	0.090
8.3	0.356	1.111	0.089	8.3	1.258	1.108	0.090
7.2	0.348	1.156	0.088	7.2	1.217	1.153	0.089
6.3	0.339	1.199	0.085	6.3	1.177	1.196	0.085
5.5	0.323	1.196	0.104	5.5	1.114	1.194	0.104
4.8	0.310	1.172	0.095	4.8	1.061	1.170	0.095
4.2	0.290	1.131	0.098	4.2	0.987	1.130	0.098
3.6	0.281	1.127	0.083	3.6	0.951	1.125	0.083
3.2	0.263	1.120	0.098	3.2	0.886	1.119	0.097
2.8	0.247	1.108	0.088	2.8	0.828	1.107	0.088
2.4	0.225	1.094	0.080	2.4	0.750	1.092	0.080
2.1	0.208	1.109	0.071	2.1	0.688	1.108	0.070
1.8	0.191	1.141	0.094	1.8	0.630	1.139	0.093
1.6	0.184	1.269	0.102	1.6	0.604	1.266	0.102
1.4	0.166	1.325	0.075	1.4	0.540	1.322	0.075
1.2	0.151	1.375	0.079	1.2	0.491	1.371	0.078
1.0	0.140	1.413	0.071	1.0	0.452	1.408	0.070
0.91	0.120	1.332	0.078	0.91	0.385	1.328	0.077
0.79	0.105	1.287	0.077	0.79	0.335	1.284	0.076
0.69	0.095	1.299	0.084	0.69	0.298	1.296	0.082
0.60	0.082	1.286	0.067	0.60	0.255	1.284	0.066
0.52	0.069	1.266	0.067	0.52	0.213	1.264	0.066
0.46	0.058	1.284	0.087	0.46	0.179	1.281	0.087
0.10	0.002	1.205	0.033	0.10	0.007	1.193	0.035

Appendix B

IPEEE Adequacy Review[PDW1]

Table of Contents

1.0 Background

The Nuclear Regulatory Commission (NRC) staff issued Generic Letter (GL) 88-20, Supplement 4 on June 28, 1991 (Reference 6.10), requesting that each licensee conduct an individual plant examination of external events (IPEEE) for severe accident vulnerabilities. Concurrently, NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities" (Reference 6.9) was issued to provide utilities with detailed guidance for performance of the IPEEE.

A seismic margin assessment (SMA) was performed for the seismic portion of the Arkansas Nuclear One (ANO) - Unit 2 IPEEE using the Electric Power Research Institute (EPRI) SMA methodology, EPRI NP-6041 (Reference 6.3) with enhancements identified in NUREG-1407 (Reference 6.9). ANO - Unit 2 performed a 0.3g "modified" focused scope SMA utilizing a NUREG/CR0098 (Reference 6.4) spectral shape for a rock site. The "modified" focused scope SMA involved developing a Safe Shutdown Equipment List (SSEL) and performing High-Confidence of Low-Probability of Failure (HCLPF) calculations only for components that potentially had a capacity less than the 0.3g review level earthquake (RLE). Capacities for reactor internals and soil-related failures were not included in the "modified" focused-scope SMA. The calculated plant-level HCLPF for ANO - Unit 2 resulting from performance of the IPEEE was greater than 0.3g. The results of the ANO - Unit 2 IPEEE were provided to NRC in a letter dated May 31, 1996.

The NRC staff submitted a request for additional information (RAI) in two letters dated April 3, 1998 (Reference 6.11) and May 7, 1998 (Reference 6.12), relating to ANO Unit 1 and ANO - Unit 2. ANO responded to the RAI letters with additional information by letter dated March 30, 1999 (Reference 6.13). The NRC staff later submitted a request for supplemental information concerning the RAI responses in a letter dated February 7, 2000 (Reference 6.14). ANO responded to the request for supplemental information by letter dated June 14, 2000 (Reference 6.15).

The NRC issued its staff Staff Evaluation Report (SER) (Reference 6.2) on February 27, 2001 for the ANO - Unit 1 and ANO - Unit 2 IPEEEs. The SER concluded that the ANO-1 and ANO - UNIT 2 IPEEE process was capable of identifying the most likely severe accidents and severe accident vulnerabilities, meeting the intent of GL 88-20 (Reference 6.10).

2.0 General Considerations

The plant safe shutdown earthquake (SSE) is a Housner type spectrum anchored to 0.2g peak horizontal ground acceleration and 0.133g peak vertical ground acceleration.

The ANO-2 IPEEE is a modified focused scope EPRI seismic margin assessment. The EPRI SMA was selected as the method for the IPEEE evaluation because it was compatible with the Unresolved Safety Issue (USI) A-46 assessment being conducted in parallel with

the IPEEE work. The Seismic Qualification Utility Group (SQUG) Generic Implementation Procedure (GIP) (Reference 6.16) used for USI A-46 allowed for coordination of activities to support both projects. The Review Level Earthquake (RLE), based on the NUREG/CR-0098 (Reference 6.4) spectrum applicable to a rock site and anchored to a 0.3g peak ground acceleration, was used for the determination of component HCLPFs. The minimum component HCLPFs was found to be at least a 0.3g PGA value, after addressing any HCLPFs that fell below that level, resulting in a plant HCLPF of at least 0.3g. Therefore, the IPEEE HCLPF Spectrum (IHS) that can be used for comparison against the new GMRS is equal to the RLE spectrum anchored at a 0.3g PGA

The IPEEE commitments and modifications that were required to achieve the plant level HCLPF have been completed. Verification of the completion of these commitments and modifications were provided in the ANO - Unit 2 Response to 10CFR 50.54(f) Request for Information Recommendation 2.3 Seismic (Reference 6.17) and are further discussed below in Section 3.0 Prerequisites. Confirmation that these modifications are still in place is described in the Prerequisites section of this report.

The following sections summarize the results of the IPEEE adequacy evaluation according to the guidance of the Screening, Prioritization and Implementation Details (SPID) (Reference 6.5).

2.1 Relay Chatter

The ANO - Unit 2 relay evaluation for IPEEE used the same methodology as the ANO – Unit 1 relay evaluation and meets the requirements of a full-scope evaluation, as described in NUREG-1407 (Reference 6.9), even though ANO – Unit 2 is a focused-scope plant. In terms of relays identified, ANO-2 identified 2956 relays of which 2255 were classified "non-essential" and 273 were placed on the Essential Relay List. ANO- Unit 1 was a full scope plant and 2314 relays were identified of which 2002 were classified as "non-essential" and 223 were placed on the Essential Relay List.

The following is included in the SER (Reference 6.2) for ANO-2: "*The relay review program at ANO-2 exceeded this [the IPEEE] requirement because full capacity versus demand screening, in accordance with the GIP (Reference 6.16), was performed on all relays associated with small break LOCA and containment performance. The evaluation was performed according to the GIP (Reference 6.16) using the Design Basis SSE Response Spectra as the basis. This also meets the RLE in the IPEEE SMA due to the conservative amplification factors used for USI A-46 and the more liberal response spectra peak clipping allowed for an SMA.*"

2.2 Soil Failure Evaluation

The safety-related structures at ANO - Unit 2 are founded on rock. The full evaluation of soil failures required in SPID (EPRI, 2013a) is not required as the supporting medium for safety related structures is rock with a Vs = 3500fps or more. Item 2.7 of Enclosure 3 to the NRC SER (US NRC, 2001) observes: "The principal structures at ANO-2 are founded on bedrock; therefore, a soil evaluation is not required."

3.0 Prerequisites

The following items have been addressed in order to use the IPEEE analysis for screening purposes and to demonstrate that the IPEEE results can be used for comparison with the GMRS:

1. Confirmation that commitments made under the IPEEE have been met.
2. Confirmation that all of the modifications and other changes credited in the IPEEE analysis are in place.
3. Confirmation that any identified deficiencies or weaknesses to NUREG-1407 in the ANO - Unit 2 IPEEE NRC SER are properly justified to ensure that the IPEEE conclusions remain valid.
4. Confirmation that major plant modifications since the completion of the IPEEE have not degraded/impacted the conclusion reached in the IPEEE.

Response:

The IPEEE commitments and modifications have been completed. Verification of the completion of these commitments and modifications were provided in the ANO - Unit 2 Seismic Walkdown Report (Reference 6.17) Attachment A. Attachment A provides: a description of the action taken, whether the vulnerability continues to be addressed, and when the resolution actions were completed.

The ANO - Unit 2 NRC SER (Reference 6.2) on the seismic portion of the IPEEE states that the ANO - Unit 2 IPEEE appears to meet the objectives of Generic Letter 88-20 (Reference 6.10); addresses all the USIs and Generic Safety Issues (GSIs) requested in NUREG-1407 (Reference 6.9); and contains suitable discussion of seismic/fire interaction, seismic/flood interaction, and containment performance.

The ANO - Unit 2 NRC SER (Reference 6.2) did note that details of operator actions credited when defining success paths were not included in the IPEEE submittal (Reference 6.1). However, the operator actions were discussed in detail in the responses to RAIs.

Major new or replacement equipment was identified, as described in the Walkdown Report (Reference 6.17) and placed on the list of equipment to be examined during the walkdowns. The IPEEE SSEL was used as the starting point for developing an equipment list for the walkdowns, so that all the equipment on the IPEEE SSEL was walked down again.

No conditions were identified that could adversely affect IPEEE conclusions and, therefore, risk insights in the IPEEE analysis remain valid.

4.0 Adequacy Demonstration

4.1 Structural Models and Structural Response Analysis

Methodology used:

Structural Models

Pertinent resources, including IPEEE (Reference 6.1), Safety Analysis Report (SAR) (Reference 6.18), structural calculations (Reference 6.19 and 6.20) and drawings (Reference 6.21-6.26) are reviewed.

Major structures for the ANO - Unit 2 site considered in the SMA are the Reactor Building – Internal Structure, Reactor Building – Containment Shell, Auxiliary Building, Intake Structure, and Diesel Fuel Storage Vault. Structural models were developed in the '70s for the purposes of generating modal properties for dynamic analysis. The Review Level Earthquake for the IPEEE SMA is the median-shaped NUREG/CR-0098 (Reference 6.4) spectrum, applicable to a rock site, anchored to a 0.3g peak ground acceleration.

The dynamic models were developed such that they can accurately predict the building response, including in-structure response spectra, in the frequency range of interest. The ANO – Unit 2 dynamic models of the structures are adequate to represent frequencies in excess of 20 Hz and, as such, are adequate for the assessments focused on the 1 Hz to 10 Hz range

The structural models for these buildings consist of massless beam elements and lumped masses at major floor elevations. The massless beam elements represent the stiffness properties of concrete walls. The beam elements, in general, are rigidly linked to each other and to a lumped mass at each major floor elevation. Thus, each floor elevation acts as a rigid body. For structures where there are no major floors, such as the Containment Shell, the mass is modeled uniformly along the height of the structure. The Reactor Building – Containment Shell does not have any significant structural eccentricity between the center of mass and center of rigidity. Reactor Building – Internal Structure, Auxiliary Building and Intake Structure have some torsional irregularities. However, the structural models are detailed enough to capture the overall structural responses for both the horizontal and vertical components of ground motion.

The ANO structures are founded on rock, which is typical of the area and consists primarily of shale and sandstone.

The seismic analysis of the structures was performed using a fixed base.

Compliance with NUREG-1407:

This methodology meets the guidance and requirements of EPRI NP-6041 (Reference 6.3) and the enhancements specified in NUREG-1407 (Reference 6.9).

Adequate for Screening:

The IPEEE methodology and structural modeling are in compliance with NUREG-1407 (Reference 6.9) and are adequate for screening purposes.

4.2 In-Structure Demands and In-Structure Response Spectra

Methodology used:

The ANO - Unit 2 in-structure response spectra (ISRS) for the IPEEE SMA are presented in (Reference 6.1). The ISRS were generated using time history analyses. The IPEEE SMA ISRS were compared against the original ISRS (Reference 6.19) and (Reference 6.20). The comparison shows matching amplification frequencies and modal characteristics. The IPEEE SMA ISRS are deemed reasonable.

Compliance with NUREG-1407:

In-structure response spectra were developed for the IPEEE SMA (Reference 6.1). The IPEEE SMA was done in accordance to the guidance and requirements of EPRI NP-6041 (Reference 6.3) and the enhancements specified in NUREG-1407 (Reference 6.9). The IPEEE ISRS are consistent with the design basis spectra and deemed acceptable for screening purposes..

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE in-structure demands and ISRS results are adequate for screening purposes.

4.3 Selection of Seismic Equipment List (SEL)/Safe Shutdown Equipment List (SSEL)

The selection of equipment in the IPEEE (Reference 6.1) is done to address USI A-46 and to support the IPEEE. Equipment selection to address USI A-46 issues is based on the GIP (Reference 6.16), Section 3 and Appendix A. Equipment selection to support the IPEEE is based on NUREG-1407 (Reference 6.9) and EPRI NP-6041-SL (Reference 6.3). The list of equipment provided in Appendix B of the IPEEE (Reference 6.1) addresses both USI A-46 and IPEEE requirements and is the equipment that would be used for the safety functions

required to establish and maintain a safe shutdown condition, including a primary and alternate success path.

The following safety functions were satisfied by the IPEEE success paths: reactivity control, reactor coolant pressure control, reactor coolant inventory control, and decay heat removal. In addition, equipment required to prevent early containment failure was included on the SSEL. Equipment was selected that provided redundancy for each of the safe shutdown functions (secondary success path). The list of components includes an indication of the component location and the equipment class defined in the GIP (Reference 6.16).

Support system requirements for the above functional success paths were identified. Equipment in support systems required for the operation of safe shutdown equipment or for indication of plant conditions showing safe shutdown were included in the SSEL.

The passive and active components included in the IPEEE scope are identified in Appendix B of the ANO - Unit 2 IPEEE submittal (Reference 6.1).

Compliance with NUREG-1407:

This methodology meets the guidance and requirements of EPRI NP-6041 (Reference 6.3) and the enhancements specified in NUREG-1407 (Reference 6.9). Section 3.2.5.1 of NUREG-1407 (Reference 6.9) requires a complete set of potential success paths be identified and the narrowing/elimination of paths to be documented in detail. Section 3.9 of the ANO - Unit 2 IPEEE (Reference 6.1) documents in detail the system analysis and the selection of equipment for the primary and backup success paths. It is noted in the SER (Reference 6.2) that only one success path exists for small break Loss of Coolant Accidents (LOCAs), however, the responses to RAIs (Reference 6.13) state that only one success path is required for small break LOCAs.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE seismic equipment selection results are adequate for screening purposes.

4.4 Screening of Components

Methodology used:

The Seismic Review Team (SRT) screened from further margin review structures and components for which the SRT could document HCLPFs at or above the specified RLE of 0.3g based on their combined experience and judgment and use of earthquake experience data.

The screening guidance given in the GIP for Seismic Verification of Nuclear Power Plant Equipment (Reference 6.16) was used. This is the same procedure used for the resolution of USI A-46.

Structures and equipment that could not be screened were further evaluated as documented in the IPEEE submittal (Reference 6.1) in section 3.5. The unscreened components were subjected to a Conservative Deterministic Failure Margin (CDFM) analysis as described in EPRI NP-6041 (Reference 6.3) to determine HCLPFs for the components and documented in Table 3.5-1 of the IPEEE (Reference 6.1). Plant walkdowns provided information about components, such as anchorage details, required for the HCLPF evaluation.

Compliance with NUREG-1407:

The above methodology meets the requirements of NUREG-1407 (Reference 6.9) Section 3.2.5.5 Screening Criteria which states that screening guidance given in the GIP (Reference 6.16) may be used provided review/screening is performed at the appropriate RLE, caveats included in the margins report are observed and use of the generic equipment ruggedness spectrum are observed. NUREG-1407 (Reference 6.9) also requires that spatial interaction evaluations such as assessing the effects of flooding, as noted in EPRI NP-6041 (Reference 6.3), be performed.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE screening of component results are adequate for screening purposes.

4.5 Walkdowns

Methodology used:

IPEEE Walkdowns

Seismic walkdowns for USI A-46 and for the IPEEE were performed concurrently. Components common to both programs were inspected only once. Two walkdowns were performed at ANO - Unit 2, the first walkdown was performed during an outage and included equipment inside the containment,and the second walkdown was performed a few months later and included the equipment outside of containment. The IPEEE walkdown scope included passive components and structures, containment isolation and performance, and seismic interactions.

The IPEEE walkdowns are documented in the IPEEE report (Reference 6.1) and in the Seismic Evaluation Work Sheets (SEWS) in accordance with EPRI NP-6041 (Reference 6.3) and the SQUG (Reference 6.16).

Major structures and components were walked down. Components within the IPEEE scope but not within the A-46 evaluation scope were identified so that combined walkdowns could be performed to address both A-46 and IPEEE. With the exception of some anchorage or interaction issues, equipment walked down for A-46 and IPEEE was judged to screen at 0.3g. Seismic outliers were identified for resolution at a later date by modifications or further analysis.

Walkdowns were conducted by a combination of one S&A engineer and one ANO seismic engineer, with access to an ANO systems engineer and operations personnel. Seismic Review Team members were SQUG trained and certified.

The potential for spatial system interactions was considered during seismic walkdowns. System interaction issues were considered and noted on the SEWS for the IPEEE. The following provides examples of what was considered either previously as part of A-46 walkdowns or as part of the IPEEE:

- Proximity: The proximity of structures to components and components to components was considered during walkdowns. For example, the proximity of valve operators to structures and other components was considered. Masonry block walls were revisited during the IPEEE analysis and were screened for the SMA. To ensure that block walls have capacity above 0.3g, HCLPF calculation was performed for the worst case block wall that was not upgraded during the IE-80-11 program. This block wall was calculated to have a capacity of 0.35g.
- Seismic II over I: Interactions with overhead equipment or nearby equipment, including block walls, were evaluated during the walkdowns.
- Seismic Spray & Flooding: The possibility of water spray and flooding impact on systems was considered during the walkdown. No tanks were found in areas with SSEL equipment and fire water piping was judged to have supports with sufficient capacity.
- Seismic Fires: The potential for seismic induced fires impacting SSEL equipment was evaluated during the walkdowns. No cabinets (fire sources) were found in areas containing SSEL equipment.

The above spatial interactions were evaluated and found acceptable.

Near-Term Task Force (NTTF) Recommendation 2.3 Walkdowns

On March 12, 2012 NRC issued a generic letter (Reference 6.27) requesting, in part, information relating to seismic walkdowns. In response, Entergy performed the requested seismic walkdowns and area walk-bys over a three week period during September and October of 2012. Walkdown inspections focused on anchorages and seismic spatial

interactions, but also included inspections for other potentially adverse seismic conditions. The NTTF Recommendation 2.3 walkdowns are documented in a walkdown report (Reference 6.17).

Verification of the resolution of commitments made to address seismic vulnerabilities identified in the IPEEE are provided in the ANO - Unit 2 Seismic Walkdown Report (Reference 6.17) Attachment A. Attachment A provides: a description of the action taken, whether the vulnerability continues to be addressed, and when the resolution actions were completed. The walkdown report (Reference 6.17) was submitted to the NRC on November 27, 2012.

Compliance with NUREG-1407:

Walkdowns were conducted and documented in accordance with EPRI NP-6041 (Reference 6.3) as required by Section 3.2.5.2 of NUREG-1407 (Reference 6.9).

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE walkdown results are adequate for screening purposes.

4.6 Fragility Evaluation

Methodology used:

ANO - Unit 2 developed and implemented a program to satisfy the requirements of the IPEEE seismic margins evaluation. The SMA program concentrated on verifying the seismic adequacy of structures, equipment, large tanks, cable tray conduit raceway systems and other distribution systems, and relays. The screening and verification walkdowns verified that the equipment, tanks, distribution systems, structures and relays are able to withstand the 0.3g RLE at the plant and still provide for its safe shutdown.

- Components were screened using the criteria contained in Tables 2-3 and 2-4 of EPRI NP-6041 (Reference 6.3).
- Components that are screened are judged to have a seismic capacity in excess of the RLE demand. HCLPF capacities are determined for those items that are not screened out.
- CFDM HCLPF capacity calculations were performed for equipment anchorages, large tanks, and a worst-case block wall.

All the Class I Structures were screened out based on the EPRI NP-6041 (Reference 6.3) screening criteria.

Compliance with NUREG-1407:

ANO - Unit 2 calculated HCLPFs for all outlier components in accordance with the guidance of EPRI NP-6041 (Reference 6.3) and NUREG-1407 (Reference 6.9) Section 3.2.5.7.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE fragility evaluation results are adequate for screening purposes.

4.7 System Modeling

Methodology used:

Functional success paths were developed for the four safety functions: reactivity control, Reactor Coolant System (RCS) pressure control, RCS inventory control, and decay heat removal. Primary and alternate success paths for each safety function were identified. Alternate success paths involve the same systems as the primary success paths by using the opposite train. Plant-specific Success Path Logic Diagrams (SPLDs) are provided in the RAI response (Reference 6.13) for both loss of off-site power (LOSP) and small LOCA with both the primary and alternate success path. Dependency matrices are also provided in the RAI responses that identify the support systems required for operation of the front-line systems in the SPLD.

The evaluation of non-seismic failures and human actions was not addressed explicitly in the IPEEE evaluation of seismic risk; however, both are discussed in the responses to RAIs (Reference 6.13). A fault tree was developed from the detailed plant fault tree, taking no credit for components on the IPEEE SSEL and quantified to determine the conditional core damage probability. The conditional core damage probability was combined with the frequency of a 0.3g earthquake at the ANO site from EPRI NP-6395-D (Reference 6.28) to estimate a Core Damage Frequency (CDF) below 1.0E-06. It was concluded that the risk from a 0.3g seismic event was therefore insignificant.

The identification of success paths and components was based on nominal credit for operator actions, given that sufficient manpower, time, and procedures were available. Specific operator actions necessary for safe shutdown are not discussed in the IPEEE submittal (Reference 6.1), but are discussed in the responses to RAIs.

Compliance with NUREG-1407:

NUREG-1407 (Reference 6.9), Section 3.2.5.1 states that for IPEEE purposes, it is desirable that to the maximum extent possible, that the alternate path involves operational sequences, systems, piping runs and components different from those used in the preferred path. As indicated above and documented in the IPEEE, different components and trains were selected, but from the same systems at ANO - Unit 2.

Taking into account the information supplied in RAI responses, the treatment of non-seismic failures and human actions in the ANO - Unit 2 IPEEE meets the requirements of Section 3.2.5.8 of NUREG-1407 (Reference 6.9).

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE system modeling results are adequate for screening purposes.

4.8 Containment Performance

Methodology used:

Containment performance was evaluated for gross containment failure, containment system failure, containment bypass, containment isolation failure, and interactions with containment. The containment structure was evaluated using the methodology and guidance of EPRI NP-6041 (Reference 6.3).

For containment isolation and bypass, containment penetrations were evaluated with respect to seal failure, valve failure, and failure of piping between penetrations and isolation valves.

The containment evaluation found that no significant vulnerabilities exist that would impact containment performance for the RLE.

Compliance with NUREG-1407:

The review of containment meets the requirements of Section 3.2.6 of NUREG-1407 (Reference 6.9) to evaluate the containment integrity, isolation, bypass and suppression functions to identify vulnerabilities that involve early failure of the containment functions.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE containment performance results are adequate for screening purposes.

4.9 Peer Review

Methodology used:

An independent peer review of the SMA was conducted by Mr. Harry Johnson of Programmatic Solutions. Mr. Johnson conducted two days of walkdowns as part of his review. Mr. Johnson's review report is included in the IPEEE submittal (Reference 6.1) in Appendix D. Mr. Johnson concluded that the methods used are appropriate, the methods have been correctly implemented, and the actions recommended in the IPEEE to address seismic vulnerabilities are reasonable.

In addition to the independent peer review by Mr. Johnson, a peer review of the SSEL was conducted by Dr. Robert Budnitz of Future Resources Associates, Inc. Dr. Budnitz's review report is also included in the IPEEE (Reference 6.1) in Appendix D. One minor comment was provided that did not impact Dr. Budnitz's conclusion that the SSEL development was satisfactory.

Two engineers from Enercon, Mr. Sean Smolarek and Mr. Eric Dilbone reviewed the IPEEE, as described in the Walkdown Report (Reference 6.17).

"In-house" review is evidenced by the reviewer sign-off on IPEEE cover sheets, but there is no discussion of in-house review in the IPEEE (Reference 6.1) report body.

Compliance with NUREG-1407:

The above review process, using a combination of independent in-house review and two external consultants for seismic review, meets the requirements of Section 7 of NUREG-1407 (Reference 6.9) for peer review.

Adequate for Screening:

The methodology used is in compliance with NUREG-1407 (Reference 6.9) and the IPEEE peer review results are adequate for screening purposes.

5.0 Conclusions

The ANO - Unit 2 IPEEE was a modified focused scope seismic margin submittal and requires the performance of a detailed review of relay chatter. The ANO - Unit 2 relay evaluation for IPEEE used the same methodology as the ANO – Unit 1 relay evaluation and meets the requirements of a full-scope evaluation, as described in NUREG-1407 (Reference 6.9), even though ANO – Unit 2 is a focused-scope plant.

The following is included in the SER (Reference 6.2) for ANO-2: "*The relay review program at ANO-2 exceeded this [the IPEEE] requirement because full capacity versus demand screening, in accordance with the GIP (Reference 6.16), was performed on all relays associated with small break LOCA and containment performance. The evaluation was performed according to the GIP (Reference 6.16) using the Design Basis SSE Response Spectra as the basis. This also meets the RLE in the IPEEE SMA due to the conservative amplification factors used for USI A-46 and the more liberal response spectra peak clipping allowed for an SMA.*"

The modified scope of the ANO IPEEE excluded soil-related failures. The safety-related structures at ANO - Unit 2 are founded on rock. As stated in NUREG-1407 (Reference 6.9), Section 3.2.1, even a plant in the full-scope category that is located on a rock site is not required to perform a soil failure evaluation.

Based on the IPEEE adequacy review performed consistent with the guidance contained in EPRI 1025287 (SPID) (Reference 6.5) and documented herein, with the exception of the completion of the detailed relay chatter review, the ANO - Unit 2 IPEEE results are considered adequate for screening and the risk insights gained from the IPEEE remain valid under the current plant configuration.

6.0 References

6.1 Engineering Report for Arkansas Nuclear One, 96-R-2016-02, Rev. 0, "Individual Plant Examination of External Events (IPEEE) for Seismic SMA at ANO - UNIT 2."

6.2 United States Nuclear Regulatory Commission, "Staff Evaluation Report of Individual Plant Examination of External Events (IPEEE) Submittal on Arkansas Nuclear One, Units 1 & 2," Enclosure 1 to Letter Dated February 27, 2001 [0CNA020113].

6.3 Electric Power Research Institute, "A Methodology for Assessment of Nuclear Power Plant Seismic Margin," EPRI NP-6041-SL, Revision 1, August 1991.

6.4 "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," NUREG/CR- 0098, US NRC, May 1978.

6.5 Electric Power Research Institute, TR-1025287, "Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic," November 2012.

6.6 NEI Letter, Kimberly A. Keithline to David L. Skeen, NRC "Relay Chatter Reviews for Seismic Hazard Screening," dated October 3, 2013.

6.7 NEI Letter, A.R. Pietrangelo to D.L. Skeen, NRC "Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations," dated April 9, 2013 [ML13101A379].

6.8 NRC Letter, E. Leeds to J. Pollock, NEI "Acceptance Letter for NEI Submittal of Augmented Approach, Ground Motion Model Update Project, and 10CFR50.54(f) Schedule Modifications Related to the NTTF Recommendation 2.1, Seismic Reevaluations," dated May 7, 2013 [ML13106A331].

6.9 "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," NUREG-1407, US NRC, June 1991 [0CNA20113].

6.10 "Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities - 10CFR 50.54(f)," Generic Letter No. 88-20, Supplement 4, US NRC, June 28, 1991.

6.11 NRC Letter to Entergy, "Request for Additional Information Pertaining to the Arkansas Nuclear One (ANO) Summary Reports for the Individual Plant Examination of External Events (IPEEE)," dated April 3, 1998 [0CNA049807, 0CNA049808].

6.12 NRC Letter to Entergy, "Request for Additional Information Pertaining to the Arkansas Nuclear One (ANO) Summary Reports for the Individual Plant Examination of External Events (IPEEE)," dated May 7, 1998 [0CNA059806].

6.13 Entergy Letter to NRC "Arkansas Nuclear One – Units 1 and 2 Docket Nos. 50-313 and 50-368 License Nos. DPR-51 and NPF-6 Additional Information Pertaining to GL 87-02 and 88-20," dated March 30, 1999 [0CAN039901].

6.14 NRC Letter to Entergy, "Request for Supplemental Information Concerning Entergy Operations' Previous Responses," dated March 30, 1999, dated February 7, 2000 [0CNA020004].

6.15 Entergy Letter to NRC "Arkansas Nuclear One – Units 1 and 2 Docket Nos. 50-313 and 50-368 License Nos. DPR-51 and NPF-6 IPEEE Supplemental RAI Response," dated June 14, 2000 [0CAN060003].

6.16 Seismic Qualification Utility Group (SQUG), "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment," Revision 2, March, 1993.

6.17 Entergy, "ANO - UNIT 2 Seismic Walkdown Report," Attachment 1 to letter 2CAN111201, dated November 27, 2012.

6.18 Arkansas Nuclear One Unit 2, Safety Analysis Report, Amendment No. 25.

6.19 Arkansas Nuclear One Unit 2, APL-C-2501, Rev. 3 , "Earthquake Resistance Design of Structures and/or Components Located in the Reactor Building for the Arkansas Nuclear One Unit 2 Power Plant."

6.20 Arkansas Nuclear One Unit 2, AP&L-C-2502, Rev. 2, "Earthquake Resistance Design of Structures and/or Components Located in the Auxiliary Building for the Arkansas Nuclear One Unit 2 Power Plant."

6.21 Arkansas Nuclear One (Unit 2) Drawing, A-2100, Rev. 19, "Architectural Floor Plan @ Elevation 317'-0" & Category I Key Plans for Conc. Unit Masonry."

6.22 Arkansas Nuclear One (Unit 2) Drawing, A-2101, Rev. 41, "Architectural Floor Plan at Elevation 335'-0"."

6.23 Arkansas Nuclear One (Unit 2) Drawing, A-2102, Rev. 31, "Architectural Floor Plan at Elevation 354'-0"."

6.24 Arkansas Nuclear One Drawing, A-2103, Rev. 34, "Architectural Floor Plan at Elevations 368'- 0" 372'-0" & 374'-6"."
6.25 Arkansas Nuclear One Drawing, A-2105, Rev. 31, "Architectural Floor Plan at Elevations 404'- 0" & 422'-0"."
6.26 Arkansas Nuclear One Drawing, A-2106, Rev. 24, "Architectural Roof Plan."
6.27 NRC Generic 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 [ML12053A340].
6.28 Electric Power Research Institute, NP-6395-D, "Probabilistic Seismic Hazard Evaluation at Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Issue," April 1989.