UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

December 15, 2015

Vice President, Operations
Arkansas Nuclear One
Entergy Operations, Inc.
1448 S.R. 333
Russellville, AR 72802

SUBJECT: ARKANSAS NUCLEAR ONE, UNITS 1 AND 2 - STAFF ASSESSMENT OF INFORMATION PROVIDED PURSUANT TO TITLE 10 OF THE *CODE OF FEDERAL REGULATIONS* PART 50, SECTION 50.54(f), SEISMIC HAZARD REEVALUATIONS FOR RECOMMENDATION 2.1 OF THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT (TAC NOS. MF3822 AND MF3823)

Dear Sir or Madam:

On March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information pursuant to Title 10 of the *Code of Federal Regulations*, Part 50, Section 50.54(f) (hereafter referred to as the 50.54(f) letter). The purpose of that request was to gather information concerning, in part, seismic hazards at each operating reactor site and to enable the NRC staff, using present-day NRC requirements and guidance, to determine whether licenses should be modified, suspended, or revoked.

By letter dated March 28, 2014, Entergy Operations, Inc. (Entergy, the licensee), responded to this request for Arkansas Nuclear One, Units 1 and 2 (ANO).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for ANO and, as documented in the enclosed staff assessment, determined that you provided sufficient information in response to Enclosure 1, Items (1) – (3), (5) - (8) and the comparison portion of Item (4) of the 50.54(f) letter. Further, the staff concludes that the licensee's reevaluated seismic hazard is suitable for other actions associated with Near-Term Task Force Recommendation 2.1, "Seismic".

Contingent upon the NRC staff's review and acceptance of Entergy's high frequency confirmation and spent fuel pool evaluation (i.e., Items (4) and (9)) for ANO, the Seismic Hazard Evaluation identified in Enclosure 1 of the 50.54(f) letter will be completed.

If you have any questions, please contact me at (301) 415-1617 or at Frankie.Vega@nrc.gov.

Sincerely,

Frankie G. Vega, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos. 50-313 and 50-368

Enclosure:
Staff Assessment of Seismic
Hazard Evaluation and Screening Report

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO SEISMIC HAZARD AND SCREENING REPORT

ARKANSAS NUCLEAR ONE, UNITS 1 AND 2

DOCKET NOS. 50-313 AND 50-368

1.0 INTRODUCTION

By letter dated March 12, 2012 (NRC, 2012a), the U.S. Nuclear Regulatory Commission (NRC or Commission) issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f) "Conditions of license" (hereafter referred to as the "50.54(f) letter"). The request and other regulatory actions were issued in connection with implementing lessons-learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant, as documented in the "Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident" (NRC, 2011b).[1] The NRC Near-Term Task Force (NTTF) Recommendation 2.1, and subsequent Staff Requirements Memoranda (SRM) associated with Commission Papers SECY-11-0124 (NRC, 2011c) and SECY-11-0137 (NRC, 2011d), instructed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

Enclosure 1 to the 50.54(f) letter requests that addressees perform a reevaluation of the seismic hazards at their sites using present-day NRC requirements and guidance to develop a ground motion response spectrum (GMRS).

The required response section of Enclosure 1 requests that each addressee provide the following information:

(1) Site-specific hazard curves (common fractiles and mean) over a range of spectral frequencies and annual exceedance frequencies,

(2) Site-specific, performance-based GMRS developed from the new site-specific seismic hazard curves at the control point elevation,

(3) Safe Shutdown Earthquake (SSE) ground motion values including specification of the control point elevation,

(4) Comparison of the GMRS and SSE. A high-frequency (HF) evaluation (if necessary),

[1] Issued as an enclosure to Commission Paper SECY-11-0093 (NRC, 2011a).

(5) Additional information such as insights from NTTF Recommendation 2.3 walkdown and estimates of plant seismic capacity developed from previous risk assessments to inform NRC screening and prioritization,

(6) Interim evaluation and actions taken or planned to address the higher seismic hazard relative to the design basis, as appropriate, prior to completion of the risk evaluation (if necessary),

(7) Statement if a seismic risk evaluation is necessary,

(8) Seismic risk evaluation (if necessary), and

(9) Spent fuel pool (SFP) evaluation (if necessary).

Present-day NRC requirements and guidance with respect to characterizing seismic hazards use a probabilistic approach in order to develop a risk-informed performance-based GMRS for the site. Regulatory Guide (RG) 1.208, A Performance-based Approach to Define the Site-Specific Earthquake Ground Motion (NRC, 2007), describes this approach. As described in the 50.54(f) letter, if the reevaluated seismic hazard, as characterized by the GMRS, is not bounded by the current plant design-basis SSE, further seismic risk evaluation of the plant is merited.

By letter dated November 27, 2012 (Keithline, 2012), the Nuclear Energy Institute (NEI) submitted Electric Power Research Institute (EPRI) report "Seismic Evaluation Guidance: Screening, Prioritization, and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1 Seismic" (EPRI, 2012), hereafter called the SPID. The SPID supplements the 50.54(f) letter with guidance necessary to perform seismic reevaluations and report the results to NRC in a manner that will address the Requested Information Items in Enclosure 1 of the 50.54(f) letter. By letter dated February 15, 2013 (NRC, 2013b), the staff endorsed the SPID.

The required response section of Enclosure 1 to the 50.54(f) letter specifies that Central and Eastern United States (CEUS) licensees provide their Seismic Hazard and Screening Report (SHSR) by 1.5 years after issuance of the 50.54(f) letter. However, in order to complete its update of the EPRI seismic ground motion models (GMM) for the CEUS (EPRI, 2013), industry proposed a six-month extension to March 31, 2014, for submitting the SHSR. Industry also proposed that licensees perform an expedited assessment, referred to as the Augmented Approach, for addressing the requested interim evaluation (Item 6 above), which would use a simplified assessment to demonstrate that certain key pieces of plant equipment for core cooling and containment functions, given a loss of all alternating current power, would be able to withstand a seismic hazard up to two times the design-basis. Attachment 2 to the April 9, 2013, letter (Pietrangelo, 2013) provides a revised schedule for plants needing to perform (1) the Augmented Approach by implementing the Expedited Seismic Evaluation Process and (2) a seismic risk evaluation. By letter dated May 7, 2013 (NRC, 2013a), the NRC determined that the modified schedule was acceptable and by letter dated August 28, 2013 (NRC, 2013c), the

NRC determined that the updated GMM (EPRI, 2013) is an acceptable GMM for use by CEUS plants in developing a plant-specific GMRS

By letter dated April 9, 2013 (Pietrangelo, 2013), industry agreed to follow the SPID to develop the SHSR for existing nuclear power plants. By letter dated September 12, 2013 (Browning, 2013), Entergy Operations Inc. (Entergy, the licensee) submitted at least partial site response information for Arkansas Nuclear One, Units 1 and 2 (ANO). By letter dated March 28, 2014 (Browning, 2014a), the licensee submitted its SHSR.

2.0 REGULATORY BACKGROUND

The structures, systems, and components (SSCs) important to safety in operating nuclear power plants are designed either in accordance with, or meet the intent of Appendix A to 10 CFR Part 50, General Design Criteria (GDC) 2: "Design Bases for Protection Against Natural Phenomena;" and Appendix A to 10 CFR Part 100, "Reactor Site Criteria." The GDC 2 states that SSCs important to safety at nuclear power plants shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

For initial licensing, each licensee was required to develop and maintain design bases that, as defined by 10 CFR 50.2, identify the specific functions that an SSC of a facility must perform, and the specific values or ranges of values chosen for controlling parameters as reference bounds for the design. The design bases for SSCs reflect appropriate consideration of the most severe natural phenomena that had been historically reported for the site and surrounding area. The design bases also considered limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The seismic design bases for currently operating nuclear power plants were either developed in accordance with, or meet the intent of GDC 2 and 10 CFR Part 100, Appendix A. Although the regulatory requirements in Appendix A to 10 CFR Part 100 are fundamentally deterministic, the NRC process for determining the seismic design-basis ground motions for new reactor applications after January 10, 1997, as described in 10 CFR 100.23, requires that uncertainties be addressed through an appropriate analysis such as a probabilistic seismic hazard analysis (PSHA).

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoked. On March 12, 2012, the NRC staff issued requests for licensees to reevaluate the seismic hazards at their sites using present-day NRC requirements and guidance, and identify actions planned to address plant-specific vulnerabilities associated with the updated seismic hazards.

Attachment 1 to Enclosure 1 of the 50.54(f) letter describes an acceptable approach for performing the seismic hazard reevaluation for plants located in the CEUS. Licensees are expected to use the CEUS Seismic Source Characterization (CEUS-SSC) model in NUREG-2115 (NRC, 2012b) along with the appropriate EPRI (2004, 2006) GMMs. The SPID provided further guidance regarding the appropriate use of GMMs for the CEUS. Specifically, Section 2.3 of the SPID recommended the use of the updated GMM (EPRI, 2013) and, as such, licensees used the NRC-endorsed updated EPRI GMM instead of the older EPRI (2004, 2006) GMM to develop PSHA base rock hazard curves. Finally, Attachment 1 requested that licensees conduct an evaluation of the local site response in order to develop site-specific hazard curves and GMRS for comparison with the plant SSE.

2.1 Screening Evaluation Results

By letter dated March 28, 2014 (Browning, 2014a), the licensee provided the SHSR for the ANO site. The licensee's SHSR indicates that the site GMRS exceeds the SSEs for both ANO, Units 1 and 2 for a portion of the frequency range between 1 to 10 Hertz (Hz). However, the licensee indicated that over the frequency range of 1 to 10 Hz, the GMRS is bounded by the plant Individual Plant Examination of External Events (IPEEE) plant-level high confidence of low probability of failure (HCLPF) spectrum (IHS). In Appendix B of its SHSR, the licensee described its IPEEE program in order to use the IHS for its screening comparison with the GMRS. Because the IHS exceeds the GMRS over the 1 to 10 Hz range, the licensee indicated that ANO screens out of performing a plant risk evaluation. Above 10 Hz, the GMRS exceeds the IHS and therefore ANO screens in for a HF evaluation. With respect to the SFP evaluation, the licensee indicated that since the GMRS exceeds the SSEs for both Units 1 and 2, an evaluation will be performed.

On May 9, 2014 (NRC, 2014a), the NRC staff issued a letter providing the outcome of its 30-day, preliminary, screening and prioritization evaluation. In the letter, the NRC staff characterized the ANO site as conditionally screened-in, because additional information was needed to support the licensee's use of the IHS as the plant level capacity for its screening comparison. On August 21, 2014 (Browning, 2014b), the licensee provided its response to the staff's RAI (NRC, 2014c) clarifying the HCLPF for specific equipment and the contributions to non-seismic failures. On November 21, 2014 (NRC, 2014b), the NRC staff issued a letter providing the outcome of its final seismic screening and prioritization results. Based on its evaluation of the SHSR, the licensee's original IPEEE submittal, and the RAI response, the NRC staff confirmed that the licensee met the IPEEE adequacy criteria in the SPID. Also, the NRC staff confirmed that the licensee's GMRS, as well as the staff's confirmatory GMRS, are bounded by the IHS over the requency range between 1 to 10 Hz for ANO and, as such, a plant seismic risk evaluation is not warranted for ANO. Due to the exceedance of the GMRS over the IHS in the range of approximately 15 to 50 Hz, ANO screens in for a HF confirmation. In addition, a SFP evaluation is merited for both Units 1 and 2 because the IPEEE program did not include a SFP evaluation and the GMRS exceeds the SSEs for both units.

3.0 TECHNICAL EVALUATION

The NRC staff evaluated the licensee's submittal to determine if the provided information responded appropriately to Enclosure 1 of the 50.54(f) letter with respect to characterizing the reevaluated seismic hazard.

3.1 Plant Seismic Design-Basis

Enclosure 1 of the 50.54(f) letter requests the licensee provide the SSE ground motion values, as well as the specification of the control point elevation(s) for comparison to the GMRS. For operating reactors licensed before 1997, the SSE is the plant licensing basis earthquake and is characterized by (1) a peak ground acceleration (PGA) value which anchors the response spectra at high frequencies (typically at 33 Hz for the existing fleet of nuclear power plants; (2) a response spectrum shape which depicts the amplified response at all frequencies below the PGA; and (3) a control point where the SSE is defined.

In Section 3.1 of its SHSR, the licensee described its seismic design bases for the ANO site and stated that the SSE is defined in terms of a PGA and a design response spectrum. For ANO, Units 1 and 2, the licensee stated that the SSE is based on a postulated Intensity VII earthquake. Based on this earthquake, the response spectral shape was anchored at a PGA of 0.20 g (20 percent of the acceleration due to earth's gravity). Because the licensing of ANO, Unit 2 occurred after that of ANO, Unit 1, the response spectral shape is higher than that of ANO, Unit 1. In Section 3.2 of its SHSR, the licensee specifies that the SSE control point for both ANO, Units 1 and 2 is defined at the bottom of the Reactor Building foundation, the highest safety-related building, at elevation 326 ft. (99.4 m).

The NRC staff reviewed the licensee's description of its SSE in the SHSR for both ANO, Units 1 and 2. With regard to the SSEs, based on its review of the SHSR and Updated Final Safety Analysis Report (UFSAR; Entergy, 2014 and 2014b), the NRC staff confirmed that the licensee's SSEs are defined in terms of a PGA and a design response spectrum anchored at 0.2 g, as described by the licensee. Finally, based on review of the SHSR and the UFSAR (Entergy, 2014a and 2014b), the NRC staff confirmed that the licensee's control point elevation for both ANO, Units 1 and 2 SSEs is defined at elevation 326 ft. (99.4 m) at the bottom of the reactor building foundation and is consistent with the guidance provided in the SPID.

3.2 Probabilistic Seismic Hazard Analysis

In Section 2.2 of the SHSR, the licensee stated that, in accordance with the 50.54(f) letter and the SPID, it performed a PSHA using the CEUS-SSC model and the updated EPRI GMM for the CEUS (EPRI, 2013). The licensee used a minimum magnitude (**M**) of 5.0, as specified in the 50.54(f) letter. The licensee further stated that it included the CEUS-SSC background sources out to a distance of 400 miles (640 km) around the site and included the Cheraw, Commerce, Eastern Rift Margin – North, Eastern Rift Margin – South, Marianna, Meers, New Madrid Fault System, and Wabash Valley repeated large magnitude earthquake (RLME) sources, which lie within 621 mi (1,000 km) of the site. RLME sources are those source areas or faults for which more than one large magnitude (**M** ≥ 6.5) earthquake has occurred in the historical or paleo-earthquake (geologic evidence for prehistoric seismicity) record. The licensee used the mid-continent version of the updated EPRI GMM (EPRI, 2013) for each of the CEUS-SSC sources. Consistent with the SPID, the licensee did not provide its base rock seismic hazard curves in SHSR since a site response analysis is necessary to determine the control point seismic hazard curves. The licensee provides its control point seismic hazard curves in Section 2.3.7 of its SHSR. The staff's review of the licensee's control point seismic hazard curves is provided in Section 3.3 of this staff assessment.

As part of its confirmatory analysis of the licensee's GMRS, the NRC staff performed PSHA calculations for base rock site conditions for the ANO site. As input, the NRC staff used the CEUS-SSC model as documented in NUREG-2115 (NRC, 2012b) along with the updated EPRI GMM (EPRI, 2013). Consistent with the guidance provided in the SPID, the NRC staff included all CEUS-SSC background seismic sources within a 310 mi (500 km) radius of the ANO site. In addition, the NRC staff included RLME sources which lie within 621 mi (1,000 km) of the site. For each of the CEUS-SSC sources used in the PSHA, the NRC staff used the mid-continent version of the updated EPRI GMM (EPRI, 2013), except for the Extended Continental Crust – Gulf Coast (ECC-GC), and the Mesozoic and younger extended crust (narrow and wide) (MESE-N, MESE-W). For these sources, the NRC staff used the Gulf Coast version of the updated EPRI GMM (EPRI, 2013). The NRC staff used the resulting base rock seismic hazard curves together with a confirmatory site response analysis, described in the next section of this assessment, to develop control point seismic hazard curves and a GMRS for comparison with the licensee's results.

Based on its review of the SHSR, the NRC staff concludes that the licensee followed guidance provided in the SPID for selecting PSHA input models and parameters for the site. This includes the licensee's use and implementation of the CEUS-SSC model and the updated EPRI GMM.

3.3 Site Response Evaluation

After completing PSHA calculations for reference rock site conditions, Attachment 1 to Enclosure 1 of the 50.54(f) letter requests that the licensee provide a GMRS developed from the site-specific seismic hazard curves at the control point elevation. In addition, the 50.54(f) letter specifies that the subsurface site response model, for both soil and rock sites, should extend to sufficient depth to reach the generic or reference rock conditions as defined in the GMMs used in the PSHA. To develop site-specific hazard curves at the control point elevation, Attachment 1 requests that licensees perform a site response analysis.

Detailed site response analyses were not typically performed for many of older the operating plants; therefore, Appendix B of the SPID provides detailed guidance on the development of site-specific amplification factors (including the treatment of uncertainty) for sites that do not have detailed, measured soil and rock parameters to extensive depths.

The purpose of the site response analysis is to determine the site amplification that will occur as a result of bedrock ground motions propagating upwards through the soil/rock column to the surface. The critical parameters that determine what frequencies of ground motion are affected by the upward propagation of bedrock motions are the layering of soil and/or soft rock, the thicknesses of these layers, the shear-wave velocities and low-strain damping of the layers, and the degree to which the shear modulus and damping change with increasing input bedrock amplitude.

3.3.1 Site Base Case Profiles

The licensee provided detailed site profile descriptions in Sections 2.3.1 and 2.3.2 of its SHSR based on information provided in the UFSAR and the guidance in Appendix B of the SPID. According to the licensee, the ANO site is located in the center of the Arkansas Valley section of the Ouachita physiographic province. The ANO site is underlain by 8 to 30 ft. of clay overlying the shale and sandstone of the 5,000 ft. thick McAlester formation.

The licensee developed the shear-wave velocities for the base case profile from the compressional wave velocities measured during the original licensing of the plant. The licensee assumed a shallow shear wave velocity of 5,300 ft/s (1,616 m/s) based on assuming a Poisson's ratio of 0.30. Because there are no on-site measurements of shear wave velocities for the deeper layers, the licensee used a velocity gradient of 0.5 m/m/s to develop the shear wave velocities for the lower portion of the base case profile, resulting in a base-case shear wave velocity of 7,772 ft/s (2,369 m/s) at a depth of 5,000 ft. (1,524 m). To capture the uncertainty in the shear wave velocities beneath the site, the licensee developed three base case shear-wave velocity profiles for the ANO site. To calculate the lower and upper base case shear-wave velocity profiles, the licensee used a scale factor of 1.57, reflecting a natural log standard deviation of 0.35. Table 2.3.2-1 and Figure 2.3.2-1 of the SHSR provide the licensee's shear-wave velocity profile for each of the three base cases. Figure 3.3-1 of this assessment shows the licensee's three shear-wave velocity base case profiles.

In Section 2.3.2.1 of its SHSR, the licensee stated that no site-specific dynamic material properties were determined for the ANO site sedimentary rocks. Therefore, the licensee followed the SPID guidance and assumed the rock material over the upper 500 ft. (15.24 m) could be modeled as either linear or non-linear. To characterize the potential nonlinear behavior of the rock, the licensee used the EPRI rock curves (model M1) over the upper 500 ft. (152.4 m) of the profile. To model the linear response (model M2), the licensee assumed a constant low-strain damping value of about 3 percent over the upper 500 ft. (152.4 m).

The licensee also considered the impact of kappa, or small strain damping, on site response. Kappa is measured in units of seconds (sec), and is the damping contributed by both intrinsic hysteretic damping as well as scattering due to wave propagation in heterogeneous material. As specified in Appendix B of the SPID for sites with at least 3,000 ft. (1,000 m) of firm rock, the licensee used the shear wave velocities over the upper 100 ft. (31 m) of each profile to estimate kappa values of 0.014s, 0.023s, and 0.009s for the base, lower and upper profiles, respectively.

To account for randomness in material properties across the plant site, the licensee stated in Section 2.3.3 of its SHSR that it randomized its base case shear-wave velocity profiles following the guidance in Appendix B of the SPID. In addition, as stated in Section 2.3.2.1 of its SHSR, the licensee randomized the depth to bedrock by ±1,500 ft. (±457 m), which corresponds to 30-percent of the total profile thickness. The licensee stated that this randomization did not represent the actual uncertainty in the depth to bedrock, but was used to broaden the spectral peaks.

3.3.2 Site Response Method and Results

In Section 2.3.4 of its SHSR, the licensee stated that it followed the guidance in Appendix B of the SPID to develop input ground motions for the site response analysis and in Section 2.3.5 of its SHSR, the licensee described its implementation of the random vibration theory (RVT) approach to perform its site response calculations. Finally, Section 2.3.6 of the SHSR shows the resulting amplification functions and associated uncertainties for the eleven input loading levels for the base case profile and EPRI rock shear modulus and damping curves.

In order to develop probabilistic site-specific control point hazard curves, as requested in Requested Information Item 1 of the 50.54(f) letter, the licensee used Method 3, described in Appendix B-6.0 of the SPID. The licensee's use of Method 3 involved computing the site-specific control point elevation hazard curves for a broad range of spectral accelerations by combining the site-specific bedrock hazard curves, determined from the initial PSHA (Section 3.2 of this assessment), and the amplification functions and their associated uncertainties, determined from the site response analysis.

3.3.3 Staff Confirmatory Analysis

To confirm the licensee's site response analysis, the NRC staff performed site response calculations for the ANO site. The NRC staff independently developed a shear-wave velocity profile, damping values, and modeled the potential nonlinear behavior of the rock using measurements and geologic information provided in the ANO1 UFSAR, the ANO2 UFSAR, well log information available from the Arkansas Geologic Survey (AGS, 1976, 2010), and Appendix B of the SPID. For its site response calculations, the NRC staff employed the RVT approach and developed input ground motions in accordance with Appendix B of the SPID.

Following guidance provided in the SPID for sites with little at-site information, the NRC staff independently determined a best-estimate and upper and lower base case profiles using guidance provided in the SPID and information provided in the ANO, Units 1 and 2 UFSARs. In addition to this information, the NRC staff used geologic and geophysical information from a number of well logs in the area surrounding the site to develop a site profile. The NRC staff used geologic information from logs of water wells drilled on the site (AGS, 2010) to develop a profile for the upper 152 ft. (46 m). The NRC staff modeled this portion of the profile as alternating sandstones and shales with velocities of 6,300 ft/s (1,920 m/s) and 5,100 ft/s (1,554 m/s) respectively. Below 152 ft. (46 m), the NRC staff used sonic log information from a well drilled approximately five miles (8 km) southeast of the plant (AGS, 1976). The sonic log contains P-wave velocity information to a depth of greater than 10,000 ft. (3,048 m), and NRC staff used this information to develop its base case velocity profile. The NRC staff assumed a Poisson's ratio of 0.28 to convert the P-wave velocity information to shear-wave velocities and smoothed the velocity log by taking the average velocity in each 250 ft. (76 m) interval. To capture the uncertainty in the rock shear wave velocities, the NRC staff used a natural log standard deviation of 0.15 to calculate upper and lower base case profiles. In addition, the NRC staff randomized the depth to reference rock by ±10 percent to account for additional uncertainty. Figure 3.3-1 of this assessment shows the staff's three base case velocity profiles compared to the base case profiles developed by the licensee. Overall, the profiles developed by the NRC staff show considerably more variability due to the staff's use of the sonic log data from nearby wells. In addition, the staff's lower base case profile is significantly higher than that of the licensee. However, as discussed below, these differences have a limited impact on the site amplification functions and resulting control point seismic hazard curves.

Similar to the approach used by the licensee, the NRC staff assumed both linear and non-linear behavior for the rock beneath ANO in response to the range of input loading motions. The NRC staff developed two damping profiles that incorporate different degrees of non-linearity. The NRC staff used the same damping curves as the licensee over the upper 500 ft (152 m). However, for the linear case, the NRC staff assumed that the rock would have a damping value of 1 percent compared to the approximately 3 percent considered by the licensee. The NRC staff weighted each of these alternatives equally in the site response analysis.

To determine kappa for its three profiles, the NRC staff followed guidance in the SPID for sites with greater than 3,000 ft. (914 m) of soft rock material overlying reference rock to arrive at a value of 0.014, 0.017, and 0.011 sec for the best-estimate, lower, and upper base case profiles, respectively. These values include the 0.006 sec contribution from the reference rock. To model the uncertainty in the kappa values determined in the staff's analysis, the staff used a natural log standard deviation of 0.35 to calculate lower and upper values of kappa for each profile. This approach resulted in nine kappa values for use in the site response analysis, which range from 0.007 to 0.027 sec.

Figure 3.3-2 of this assessment shows a comparison of the staff's and licensee's median site amplification functions and associated uncertainties (±1 standard deviation) for 2 of the 11 input loading levels. The primary peak in amplification occurs at approximately 1 Hz, with a smaller peak occurring at approximately 5 Hz. Amplification functions determined by the NRC staff are similar to those developed by the licensee. Minor differences are due to differences in seismic velocities and the greater depth to reference rock in the staff's profiles.

As shown in Figure 3.3-3 of this assessment, these differences in site response analysis have a minor impact on the control point seismic hazard curves and the resulting GMRS, as discussed below. Specifically, at 1 Hz and 10 Hz, the control point seismic hazard curves developed by the licensee are nearly identical to those developed by the NRC staff. Minor differences at PGA are attributed to differences in site response inputs. Appendix B of the SPID provides guidance for performing site response analyses, including capturing the uncertainty for sites with less subsurface data; however, the guidance is neither entirely prescriptive nor comprehensive. As such, various approaches in performing site response analyses, including the modeling of uncertainty, are acceptable for the 50.54(f) response.

In summary, the NRC staff concludes that the licensee's site response was conducted using present-day guidance and methodology, including the NRC-endorsed SPID. The NRC staff performed independent calculations which confirmed that the licensee's amplification factors and control point hazard curves adequately characterize the site response, including the uncertainty associated with the subsurface material properties, for the ANO site.

3.4 Ground Motion Response Spectra

In Section 2.4 of its SHSR, the licensee states that it used the control point hazard curves, described in SHSR Section 2.3.7, to develop the 10^{-4} and 10^{-5} (mean annual frequency of exceedance) uniform hazard response spectra (UHRS) and then computed the GMRS using the criteria in RG 1.208.

The NRC staff independently calculated the 10^{-4} and 10^{-5} UHRS using the results of its confirmatory PSHA and site response analyses, as described in Sections 3.2 and 3.3 of this staff assessment, respectively. Figure 3.4-1 of this assessment shows a comparison of the GMRS determined by the licensee to that determined by the NRC staff.

As shown in Figure 3.4-1, the licensee's GMRS shape is similar to that calculated by the NRC staff across all frequencies. At frequencies above approximately 15 Hz, the GMRS developed by the NRC staff moderately exceeds that developed by the licensee. As described above in Section 3.3, the staff concludes that these differences over the higher frequency range are minor and primarily due to the differences in the site response analyses performed by the licensee and staff.

The staff confirms that the licensee used the present-day guidance and methodology outlined in RG 1.208 and the SPID to calculate the horizontal GMRS, as requested in the 50.54(f) letter. The staff performed both a PSHA and site response confirmatory analysis and achieved results consistent with the licensee's horizontal GMRS. As such, the staff concludes that the GMRS determined by the licensee adequately characterizes the reevaluated hazard for the ANO site. Therefore, this GMRS is suitable for use in subsequent evaluations and confirmations, as needed, for the response to the 50.54(f) letter.

4.0 CONCLUSION

The NRC staff reviewed the information provided by the licensee for the reevaluated seismic hazard for the ANO site. Based on its review, the NRC staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance, it appropriately characterized the site given the information available, and met the intent of the guidance for determining the reevaluated seismic hazard. The NRC staff concluded that the licensee demonstrated meeting the IPEEE screening criteria in SPID, and therefore the IHS could be used for comparison with the GMRS for the screening determination. Based upon the preceding analysis the NRC staff concludes that the licensee provided an acceptable response to Requested Information Items (1) – (3), (5) - (7), and the comparison portion of Item (4) identified in Enclosure 1 of the 50.54(f) letter. Further, the licensee's reevaluated seismic hazard is acceptable to address other actions associated with NTTF Recommendation 2.1: "Seismic".

In reaching this determination, NRC staff confirms the licensee's conclusion that the licensee's GMRS is bounded by the IHS over the frequency range between 1 to 10 Hz for ANO and, as such, a plant seismic risk evaluation (Item 8) is not warranted for ANO. The NRC staff also confirms that the GMRS exceeds the IHS over the frequency range of approximately 15 to 50 Hz and therefore, a HF confirmation (Item 4) is merited. In addition, a SFP evaluation (Item 9) is merited because the IPEEE program did not include a SFP evaluation and the GMRS exceeds the SSEs for both units. The NRC review and acceptance of licensee's SFP evaluation and HF confirmation will complete the Seismic Hazard Evaluation for ANO, Units 1and 2 identified in Enclosure 1 of the 50.54(f) letter.

REFERENCES

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Figure 3.3-1 Plot of the Staff's and Licensee's Base Case Shear-Wave Velocity Profiles for the ANO site

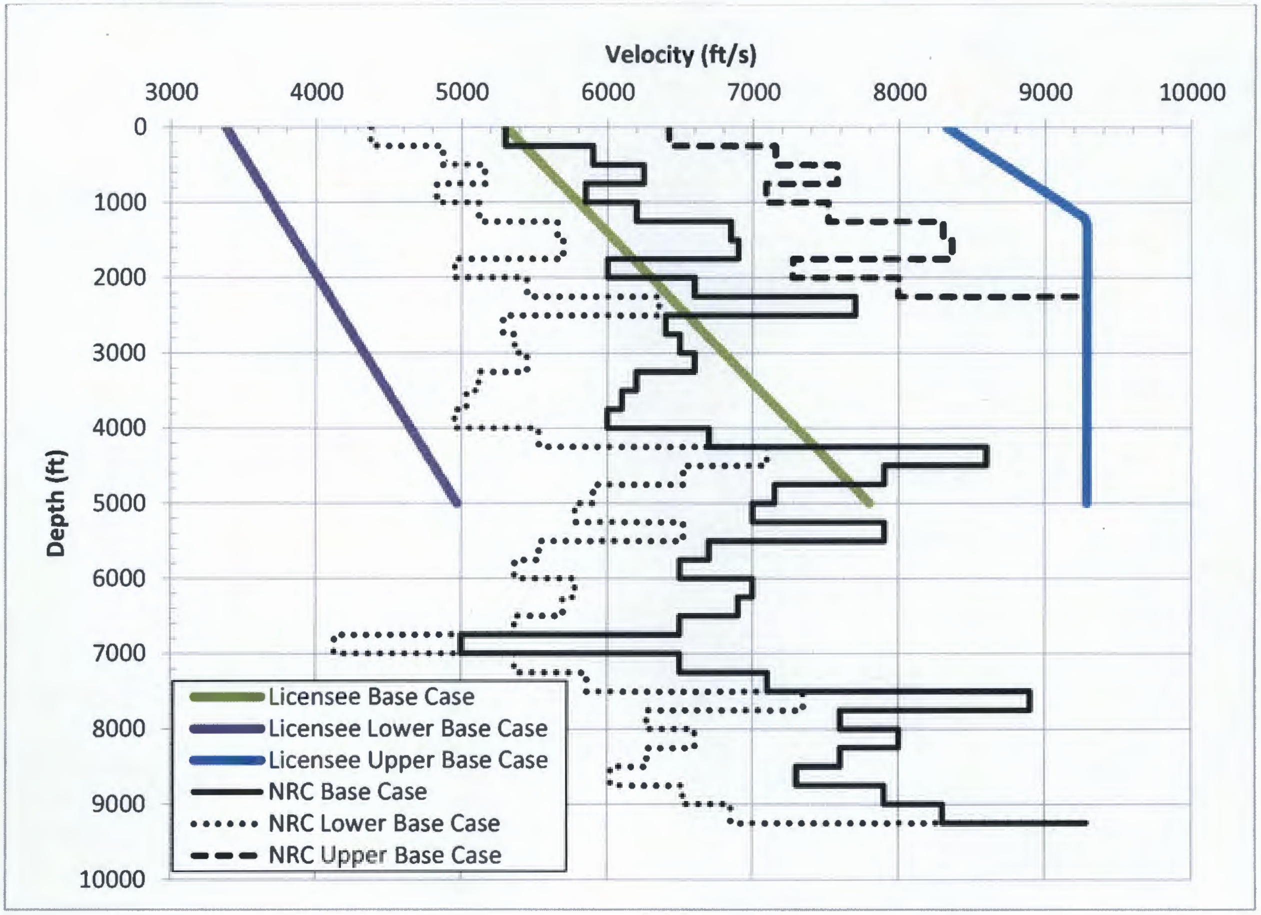


Figure 3.3- 2 Plot Comparing the Staff's and the License's Median Amplification Functions and Uncertainties for two input loading levels for the ANO site

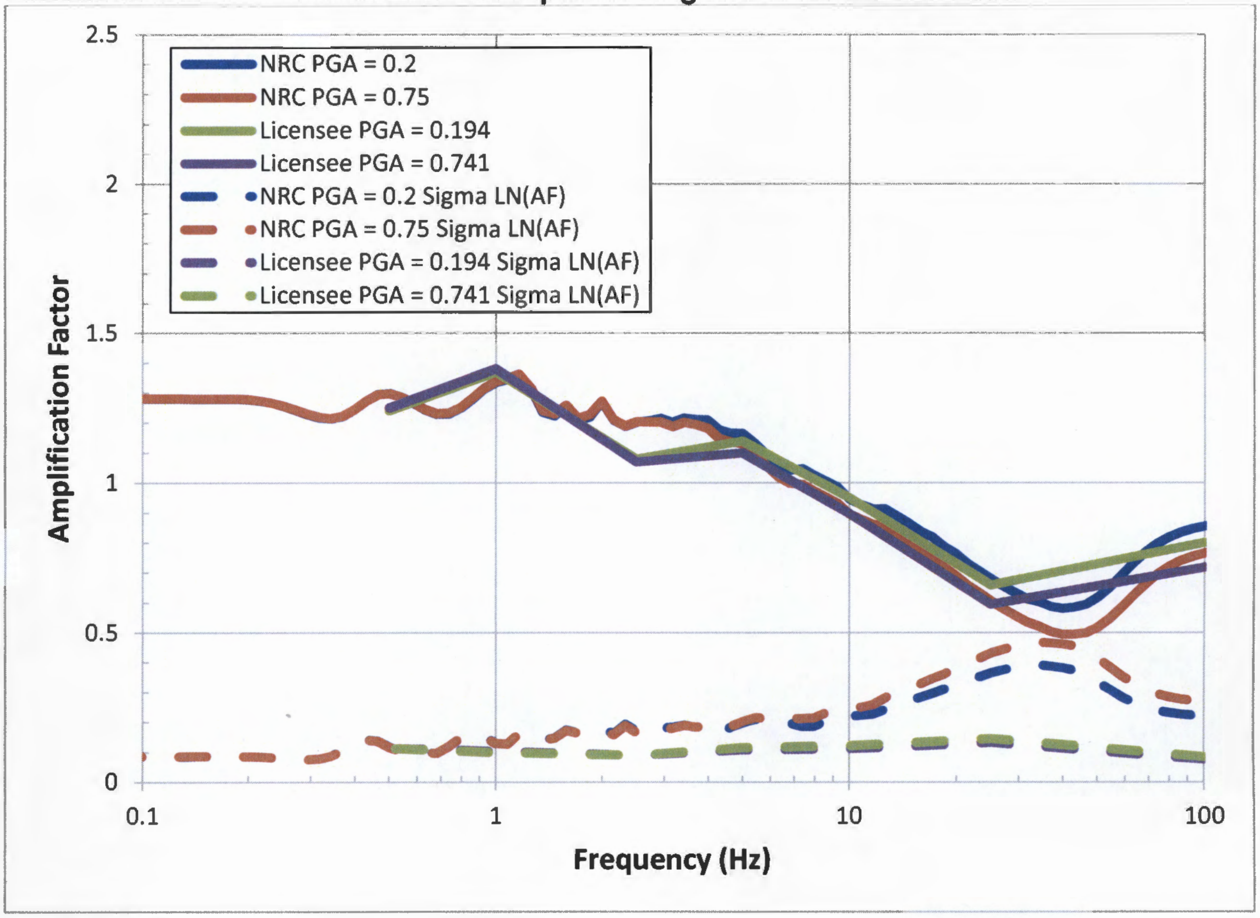


Figure 3.3-3 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the ANO site

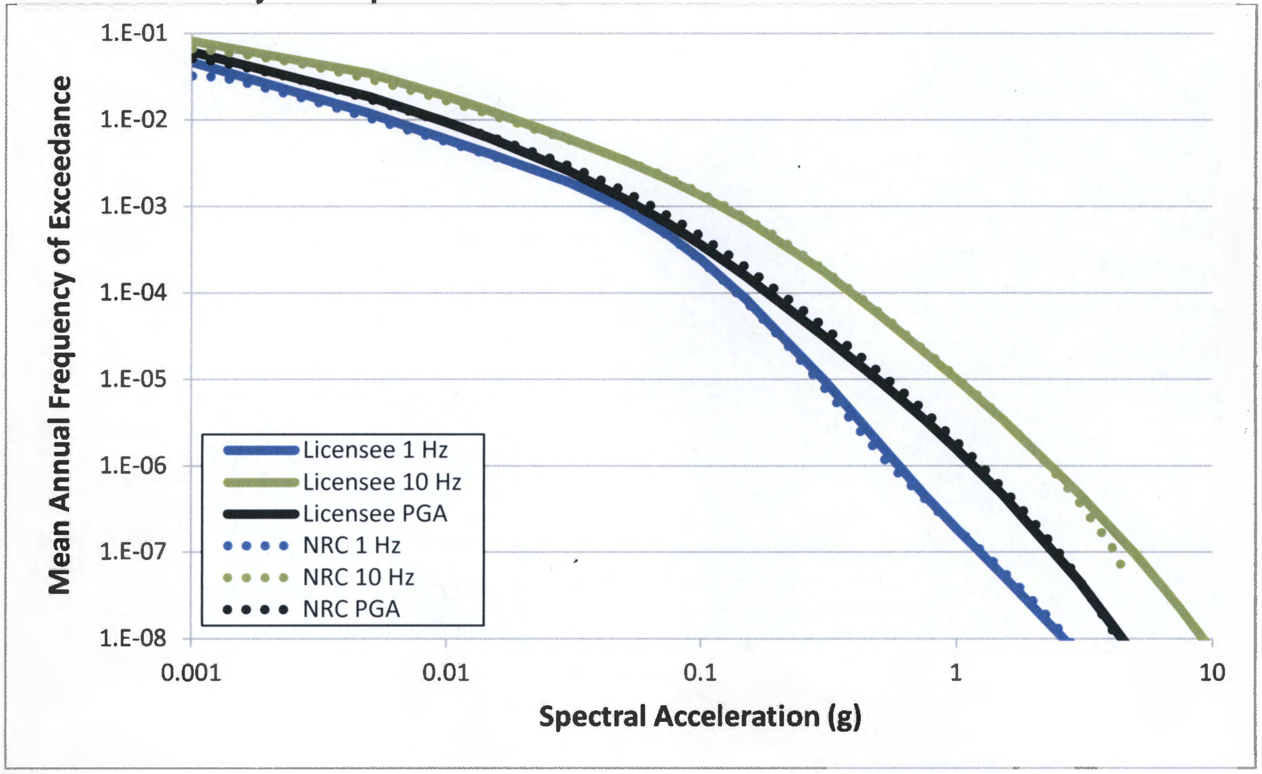
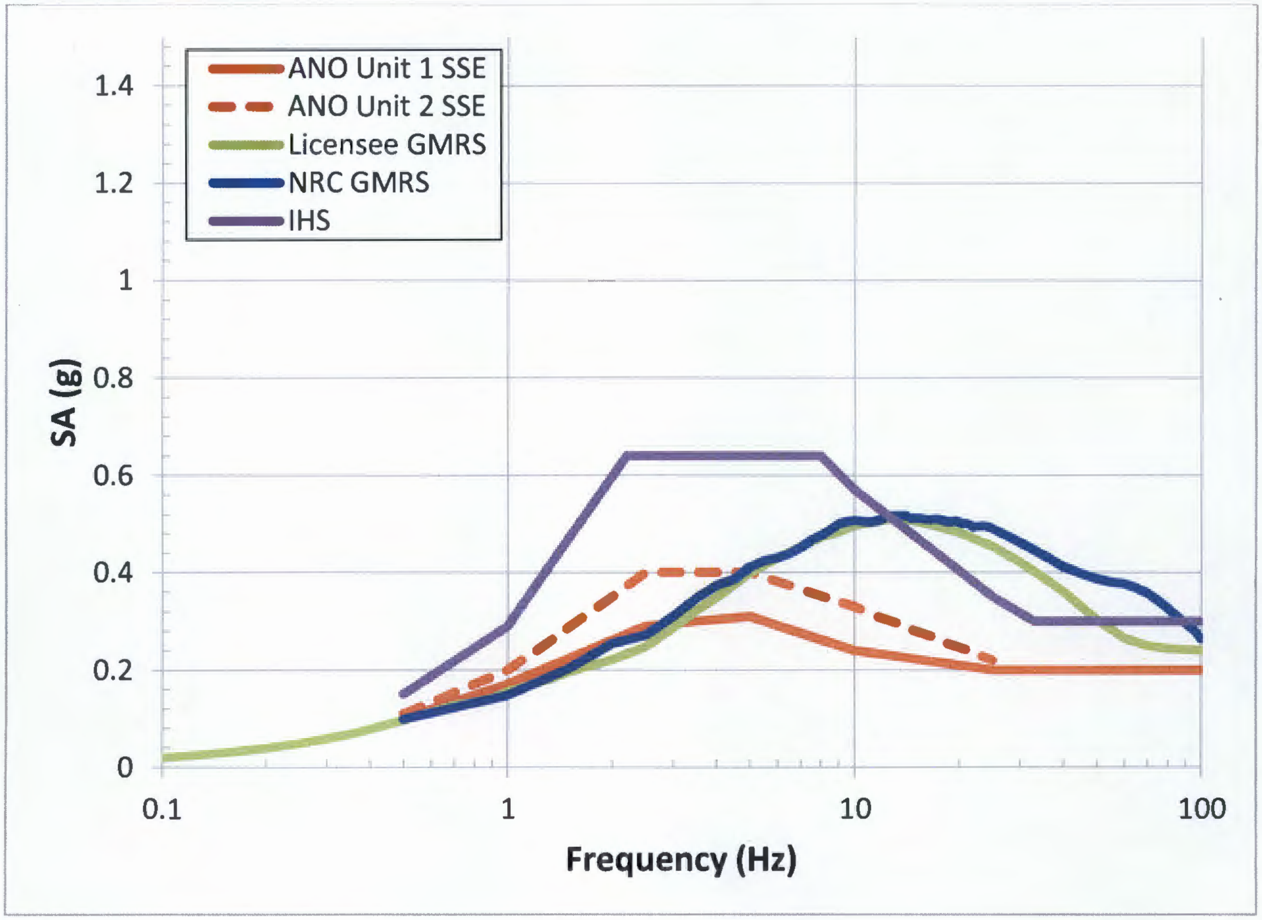


Figure 3.4-1 Comparison of the Staff's GMRS, Licensee's GMRS, SSE, and the IHS for the ANO site.



If you have any questions, please contact me at (301) 415-1617 or at Frankie.Vega@nrc.gov.

Sincerely,

/RA/

Frankie G. Vega, Project Manager
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Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos. 50-313 and 50-368

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