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

October 5, 2015

Mr. Joseph W. Shea
Vice President, Nuclear Licensing
Tennessee Valley Authority
1101 Market Street, LP 3D-C
Chattanooga, TN 37402-2801

SUBJECT: WATTS BAR NUCLEAR PLANT, UNIT 1 - STAFF ASSESSMENT OF INFORMATION PROVIDED PURSUANT TO TITLE 10 OF THE *CODE OF FEDERAL REGULATIONS*, SECTION 50.54(f), SEISMIC HAZARD REEVALUATIONS RELATING TO RECOMMENDATION 2.1 OF THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT (TAC NO. MF3769)

Dear Mr. Shea:

By letter dated 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*, 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 31, 2014, Tennessee Valley Authority (TVA) responded to this request for Watts Bar Nuclear Plant, Unit 1 (Watts Bar, Unit 1).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazards for Watts Bar, Unit 1 and, as documented in the enclosed staff assessment, determined that you provided sufficient information in 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 NRC staff concludes that TVA's reevaluated seismic hazard for Watts Bar, Unit 1 is suitable for other activities associated with the NRC Near-Term Task Force Recommendation 2.1, "Seismic."

The NRC's determinations with respect to TVA's expedited seismic evaluation process, and TVA's seismic risk evaluation including the high frequency evaluation and the spent fuel pool evaluation (i.e., Items (4), (6), (8), and (9)) for Watts Bar, Unit 1 are pending.

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

Sincerely,

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

Docket No. 50-390

Enclosure:
Staff Assessment of Seismic
Hazard and Screening Report

cc w/encl: Distribution via Listserv

STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO SEISMIC HAZARD AND SCREENING REPORT

WATTS BAR NUCLEAR PLANT, UNIT 1

DOCKET NO. 50-390

1.0 INTRODUCTION

By letter dated March 12, 2012 (NRC, 2012a), the U.S. Nuclear Regulatory Commission (NRC, the 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* (CFR), Section 50.54, "Conditions of licenses," paragraph (f) (hereafter referred to as the "50.54(f) letter"). The 50.54(f) letter was issued in connection with the NRC's implementing of lessons-learned from the 2011 accident at the Fukushima Dai-ichi nuclear facility, as documented in the "Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident" (NRC, 2011b).[1] In particular, the NRC Near-Term Task Force (NTTF) Recommendation 2.1, and subsequent Staff Requirements Memoranda (SRMs) 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 "Requested Information" section of Enclosure 1 requires each addressee to 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(s),

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

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

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

(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. NRC Regulatory Guide (RG) 1.208, "A Performance-based Approach to Define the Site-Specific Earthquake Ground Motion," 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 requested.

By letter dated November 27, 2012 (Keithline, 2012), the Nuclear Energy Institute (NEI) submitted Electric Power Research Institute (EPRI) report 1025287, "Seismic Evaluation Guidance: Screening, Prioritization, and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic" (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 the 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 NRC endorsed the SPID.

The "Required Response" section of Enclosure 1 to the 50.54(f) letter specifies that Central and Eastern United States (CEUS) addressees are requested to provide their Seismic Hazard and Screening Report (SHSR) by 1.5 years after issuance of the 50.54(f) letter. However, in order to allow for the completion of the 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 addressees 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 (ESEP) 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 ground motion model for use by CEUS plants in developing a plant-specific GMRS.

By letter dated April 9, 2013 (Pietrangelo, 2013), industry stated its intention to follow the SPID to develop the SHSR for existing nuclear power plants. By letter dated March 31, 2014 (Shea, 2014), the Tennessee Valley Authority (TVA) submitted partial site response information for Watts Bar Nuclear Plant, Unit 1 (Watts Bar, Unit 1). By letter dated March 31, 2014 (Shea, 2014), TVA submitted its SHSR.

2.0 REGULATORY BACKGROUND

The 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 Criterion (GDC) 2, "Design Bases for Protection Against Natural Phenomena" and Appendix A to 10 CFR Part 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants." 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 the SSCs reflect appropriate consideration of the most severe of the natural phenomena that had been historically reported for the site and surrounding area, with sufficient margin for the 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. Pursuant to this regulation, on March 12, 2012, the NRC 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. It states that addressees of plants located in the CEUS 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 provides further guidance regarding the appropriate use of GMMs for plants located in the CEUS. Specifically, Section 2.3 of the SPID recommends 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 their PSHA base rock hazard curves. Finally, Attachment 1 to Enclosure 1 of the 50.54(f) letter requests 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 31, 2014 (Shea, 2014), TVA provided the SHSR for Watts Bar, Unit 1. The SHSR indicated that the site GMRS exceeds the SSE for Watts Bar, Unit 1 over the frequency range of 4 to 10 Hertz (Hz). Therefore, consistent with the 50.54(f) letter, TVA will perform a plant seismic risk evaluation. Further, TVA indicated that, since the GMRS also exceeds the SSE above 10 Hz, a high-frequency confirmation will be performed. A SFP evaluation will also be performed.

On May 9, 2014 (NRC, 2014), the NRC staff issued a letter providing the outcome of its 30-day screening and prioritization evaluation. As indicated in the letter, the NRC staff confirmed TVA's screening results. TVA's GMRS as well as the confirmatory GMRS developed by the NRC staff, exceed the SSE for Watts Bar, Unit 1 above 4 Hz. As such, a plant seismic risk evaluation, SFP evaluation, and high-frequency confirmation is requested for Watts Bar, Unit 1.

3.0 TECHNICAL EVALUATION

The NRC staff evaluated TVA'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 requested the addressees to provide the SSE ground motion values, as well as the specification of the control point elevation(s) for comparison to the GMRS. For an operating license applicant or holder whose construction permit was issued before 1997, the SSE is the design 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 the SHSR, TVA described its seismic design bases for Watts Bar, Unit 1. TVA stated that the SSE for Watts Bar, Unit 1 is based on evaluation of the maximum earthquake potential for the region surrounding the site. Considering the historic seismicity of the site region, the maximum potential earthquake was determined to be intensity VIII on the Modified Mercalli Intensity (MMI) scale. TVA stated that, although this earthquake is listed as intensity VIII, there is considerable evidence that it should be evaluated as intensity VII on the MMI scale (TVA, Amendment 11, Section 2.5.2.4 and Figure 2.5-236b[2]).

The SSE is defined in terms of a PGA and a design response spectrum. Assuming an intensity of VIII occurring adjacent to the site, a PGA of 0.14 g (14 percent of the acceleration due to Earth's gravity) was estimated. For additional conservatism, this peak ground acceleration was increased to 0.18 g as the anchor point for the SSE.

In Section 3.2 of the SHSR, TVA defined the SSE control point elevation at the "Deepest Structure Foundation Control Point" at 664 feet (ft) [202 meters (m)] mean sea level (MSL) (at a depth of 64 ft [20 m]). The NRC staff reviewed TVA's description of its updated SSE for Watts Bar, Unit 1 in the SHSR. The NRC staff performed its screening evaluation for Watts Bar, Unit 1 based on a comparison of the GMRS with TVA's SSE, which is a Housner shape design spectrum anchored at 0.18 g. With regard to the SSE for Watts Bar, Unit 1, based on its review of the SHSR and updated final safety analysis report (UFSAR) (TVA, Amendment 11, Section 2.5.2.4), the NRC staff was able to confirm that TVA's SSE is a RG 1.60, "Design Response Spectra for Seismic Design at Nuclear Power Plants," spectrum anchored at 0.18 g.

Based on its review of the SHSR and the UFSAR, the NRC staff confirmed that TVA's control point elevation for the Watts Bar, Unit 1 site is consistent with the guidance provided in the SPID.

3.2 Probabilistic Seismic Hazard Analysis

In Section 2.2 of the SHSR, TVA 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). For its PSHA, TVA used a minimum moment magnitude (M_w) of 5.0, as specified in the 50.54(f) letter. TVA further stated that it included CEUS-SSC background sources out to a distance of 400 miles (mi) [640 kilometers (km)] and included the Charleston, Commerce, Eastern Rift Margin Fault northern segment, Eastern Rift Margin Fault southern segment, Marianna, New Madrid Fault System, and Wabash Valley repeated large magnitude earthquake (RLME) sources, which lie within 620 miles [1,000 km] of the site. RLME sources are those source areas or faults for which more than one large magnitude ($M_w \geq 6.5$) earthquake has occurred in the historical or paleo-earthquake (geologic evidence for prehistoric seismicity) record. TVA used the mid-continent version of the updated EPRI GMM (EPRI, 2013) for each of the CEUS-SSC sources. Consistent with the SPID, TVA did not provide base rock seismic hazard curves because it performed a site response analysis to determine the control point seismic hazard curves. TVA provided its control point seismic hazard curves in Section 2.3.7 of its SHSR. The NRC staff's review of TVA's control point seismic hazard curves is provided in Section 3.3 of this assessment.

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[2] No changes were made in UFSAR Ammendment 11 Section 2.5.2-4 since the issuance of Amendment 10.

As part of its confirmatory analysis of TVA's GMRS, the NRC staff performed PSHA calculations for base rock site conditions at the Watts Bar, Unit 1 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, and TVA's approach, the NRC staff included all CEUS-SSC background seismic sources within a 310 mi [500 km] radius of the Watts Bar, Unit 1 site. In addition, the NRC staff included all of the RLME sources falling within a 620 mi [1000 km] radius of the site, which include Charleston, Commerce, Eastern Rift Margin Fault northern segment, Eastern Rift Margin Fault southern segment, Marianna, New Madrid Fault System, and Wabash Valley sources. 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). The NRC staff used the resulting base rock seismic hazard curves together with a confirmatory site response analysis, described in the next section, to develop control point seismic hazard curves and a GMRS for comparison with TVA's results.

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

3.3 Site Response Evaluation

After the completion of PSHA calculations for reference rock site conditions, Attachment 1 to Enclosure 1 of the 50.54(f) letter requests that addressees 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 base rock conditions as defined in the ground motion models 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 the older 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

TVA provided a detailed description of the site profile in sections 2.3.1 and 2.3.2 of its SHSR based on the information documented in the plant's UFSAR, AMEC (2013), and EPRI (2014).

The information used to create the site geologic profile at the site is shown in Tables 2.3.1-1 and 2.3.1-2 of the SHSR. According to Table 2.3.1-1, the SSE Control Point at a depth of 64 ft lies on interbedded shale and limestone. Tables 2.3.1-1 and 2.3.1-2 show the stratigraphic column, description, depth, best estimate shear-wave velocity, and velocity range. Depth to basement below the Rome Formation is at a depth of about 10,950 ft (EPRI, 2014). In Table 2.3.1-2 the shear-wave velocities range from about 5000-7000 ft/s [1524 – 2134 m/s] in the upper 1000 ft [305 m] (below the control point). These velocity measurements are based on the Spectral Analysis of Surface Waves to estimate shear-wave velocities at depths greater than 1000 ft [305 m] (AMEC, 2013).

TVA used the measured shear-wave velocities, the information on the regional geologic profile (summarized in SHSR Table 2.3.1-1), and the guidance in Appendix B of the SPID to develop shear-wave velocity profiles for the Watts Bar, Unit 1 site. Because of the depth variation of the top of the Rome Formation beneath the site due to the dip of the strata, TVA developed two sets of velocity profiles (six velocity profiles in total) with different depths to the reference rock. For the first set the depth to the reference rock is 592 ft [180 m] and for the second set the depth is 936 ft [285 m]. Tables 2.3.2-1 and 2.3.2-2 of the SHSR provide TVA's shear-wave velocity profiles for each set. To develop the best estimate for the base case shear-wave velocity profile, TVA set the initial shear-wave velocity at the SSE control point (at an elevation of 664 ft [202 m] MSL) to 5805 ft/s [1769 m/s]. Following the guidance in the SPID, TVA used a natural log standard deviation of 0.17 to develop upper and lower base case velocity profiles.

TVA stated that no site-specific dynamic material properties were determined in the initial siting of Watts Bar, Unit 1. Therefore, TVA stated that it followed the SPID guidance for firm rock sites and selected two alternative characterizations of nonlinear dynamic material behavior with equal weights. In the upper 500 ft [152 m], TVA used EPRI rock curves for one model and linear response with low-strain EPRI rock damping of about 3 percent for the other model. From 500 ft [152 m] to the reference rock, TVA used a damping value of 1.25-percent (Q=40).

TVA used the EPRI small strain damping in the upper 500 ft [152 m] and damping of 1.25 percent at greater depths to calculate kappa for all six velocity profiles. Because the range of these kappa values does not reflect the observed epistemic uncertainty for rock sites (Section B-5.1.3.2, SPID), TVA applied a scale factor of 1.68 (EPRI, 2013) to the kappa estimates for the median base case profiles to calculate the kappa for the lower and upper base case profiles. The total profile kappa values for the best estimate, upper, and lower base case velocity profiles with the depth to reference rock at 592 ft [180 m] are 0.012, 0.02, and 0.007 s, respectively. Total profile kappa values for the best estimate, upper, and lower base case velocity profiles with the depth to reference rock at 936 ft [285 m] are 0.013, 0.022, and 0.008 s, respectively.

To account for randomness in material properties across the plant site, TVA stated that it had randomized its base case shear-wave velocity profiles in accordance with Appendix B of the SPID. In addition, TVA randomized the depth to bedrock by 30 percent of the total profile thickness. TVA stated that this randomization was included to provide a realistic broadening of the spectral peaks and to reflect random variations in depth-to-basement shear velocities across the footprint.

3.3.2 Site Response Method and Results

In Section 2.3.4 of its SHSR, TVA stated that it had 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, TVA 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 two of 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, TVA used Method 3, described in Section B-6.0 of the SPID. TVA'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 NRC Staff Confirmatory Analysis

To confirm TVA's site response analysis, the NRC staff performed site response calculations for the Watts Bar, Unit 1 site. The NRC staff independently developed shear-wave velocity profiles, damping values, and modeled the potential nonlinear behavior of the rock using measurements and geologic information provided in the Watts Bar, Unit 1 UFSAR, and the guidance in 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.

The NRC staff developed three velocity profiles based on the measured shear-wave velocities for the depth interval between elevation 664 ft [202 m] (the control point) and elevation 560 ft [171 m], reported in the original FSAR. Original siting investigations included continuous compression wave velocities and shear wave velocities collected by TVA in seven boreholes at the reactor site. An investigation of the distribution of these measurements indicates a nearly log normal behavior with a median velocity of 5704 ft/s [1739 m/s], and a natural-log standard deviation of 0.134. The NRC staff used these values to develop a set of three velocity profiles from the control point to 100 ft [30 m] below the control point. The NRC staff assumed a linear increase in velocity with depth below elevation 560 ft and a larger epistemic uncertainty (natural log standard deviation of 0.26) to estimate the lower and upper base-case velocity profiles.

Figure 3.3-1 of this assessment shows the NRC staff velocity profiles compared to those developed by TVA. TVA developed two sets of three velocity profiles with varying depth-to-reference rock to account for the strata dip under the footprint of the plant, whereas the NRC staff used only one set of three profiles and placed the bedrock boundary at a depth of 1000 ft [305 m] below the control point. The near-surface (top 100 ft [31 m]) base-case velocity profiles are similar. However, below 100 ft [31 m] the spread in the NRC staff's velocity profiles is larger due to implementation of a larger epistemic uncertainty. In addition, the NRC staff's velocity profiles increase linearly with depth following the SPID guidance, whereas, TVA used a constant velocity with depth.

Similar to the approach used by TVA, the NRC staff used the SPID guidance to characterize the dynamic material behavior of the site response profile. Over the upper 500 ft [152m], the NRC staff used two alternative characterizations of nonlinear dynamic material behavior, EPRI rock curves and linear behavior for the Dedham granodiorite. The damping for the linear behavior was set equal to the small strain damping from the EPRI rock curves. The NRC staff used linear properties below 500 ft [152 m. To determine kappa, the NRC staff used guidance provided in the SPID for sites with less than 3000 ft [1000 m] of firm sedimentary rock. The NRC staff total kappa values for the best estimate, lower, and upper base case velocity profiles are 0.014, 0.023, 0.008 s, respectively.

To account for aleatory variability in material properties across the plant site in site response calculations, the NRC staff randomized its base case shear-wave velocity profiles following the SPID guidance provided in Appendix B of the SPID. Similar to TVA, the NRC staff randomized the depth to bedrock by 30 percent of the total profile thickness.

Figure 3.3-2 of this assessment shows a comparison of the NRC staff's and TVA's median site amplification functions and uncertainties for two of the eleven input loading levels. As shown in this figure, TVA's amplification functions are slightly lower below 4 Hz, and, on average, slightly higher above 4 Hz. The differences in the amplification function at lower frequencies (~ 1Hz) could be due to TVA using an additional set of three velocity profiles P1, P2, and P3, which has broadened the peak response. However, the NRC staff finds that these small differences are acceptable for this application because they are within the limits of the uncertainties.

Overall, TVA's approach to modeling the subsurface rock properties and their uncertainty results in similar site amplification factors as those developed independently by the NRC staff. In addition, as shown in Figure 3.3-3 of this assessment, the soil hazard curves developed by TVA and the NRC staff at 1 Hz, 10 Hz, and PGA are very similar. 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, the NRC staff finds that alternative approaches in performing site response analyses, including the modeling of uncertainty, are acceptable for this application.

Based on its review of the SHSR, the NRC staff concludes that TVA'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 TVA's amplification factors and control point hazard curves adequately characterize the site response, including the uncertainty associated with the subsurface material properties, for the Watts Bar, Unit 1 site.

3.4 Ground Motion Response Spectra

In Section 2.4 of the SHSR, TVA stated that it had 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 assessment, respectively. Figure 3.4-1 of this assessment shows a comparison of the GMRS determined by TVA to that determined by the NRC staff.

As shown in Figure 3.4-1 of this assessment, TVA's GMRS shape is generally similar to that calculated by the NRC staff at frequencies less than 10 Hz. However, the NRC staff's confirmatory GMRS is somewhat lower than TVAs at 10-40 Hz, and slightly higher above 40 Hz. As described in Section 3.3 of this assessment, the NRC staff concludes that these minor differences over the higher frequency range are primarily due to the differences in the site response analyses performed by TVA and NRC staff. The NRC staff concludes that these differences are acceptable for the response to the 50.54(f) letter because TVA followed the guidance provided in the SPID with respect to both the PSHA and site response analysis for the Watts Bar, Unit 1 site.

The NRC staff confirmed that TVA 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 NRC staff performed both a PSHA and site response confirmatory analysis and achieved results consistent with TVA's horizontal GMRS. As such, the NRC staff concludes that the GMRS determined by TVA adequately characterizes the reevaluated hazard for the Watts Bar, Unit 1 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 TVA for the reevaluated seismic hazard for the Watts Bar, Unit 1 site. Based on its review, the NRC staff concludes that TVA conducted the hazard reevaluation using present-day methodologies and regulatory guidance, appropriately characterized the site given the information available, and met the intent of the guidance for determining the reevaluated seismic hazard. Based upon the preceding analysis, the NRC staff concludes that TVA has 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 NRC staff concludes that TVA's reevaluated seismic hazard for Watts Bar, Unit 1 is suitable for other activities associated with the NTTF Recommendation 2.1, "Seismic."

In reaching this determination, the NRC staff confirms TVA's conclusion that TVA's GMRS for the Watts Bar, Unit 1 site exceeds the facility's SSE in the 1 to 10 Hz range and also in the frequency range above 10 Hz. As such, pursuant to the 50.54(f) letter, a seismic risk evaluation, SFP evaluation and high-frequency confirmation are requested. The licensee indicated that the high frequency confirmation would be performed as part of its seismic risk evaluation. The NRC's determinations on the ESEP interim evaluation, and seismic risk evaluation including the high frequency confirmation and spent fuel pool evaluation (i.e., Items (4), (6), (8), and (9)) for Watts Bar, Unit 1 are pending.

REFERENCES

Note: "ADAMS Accession No." refers to documents available through the NRC's Agencywide Document Access and Management System (ADAMS). Publicly-available ADAMS documents may be accessed at http://www.nrc.gov/reading-rm/adams.html.

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

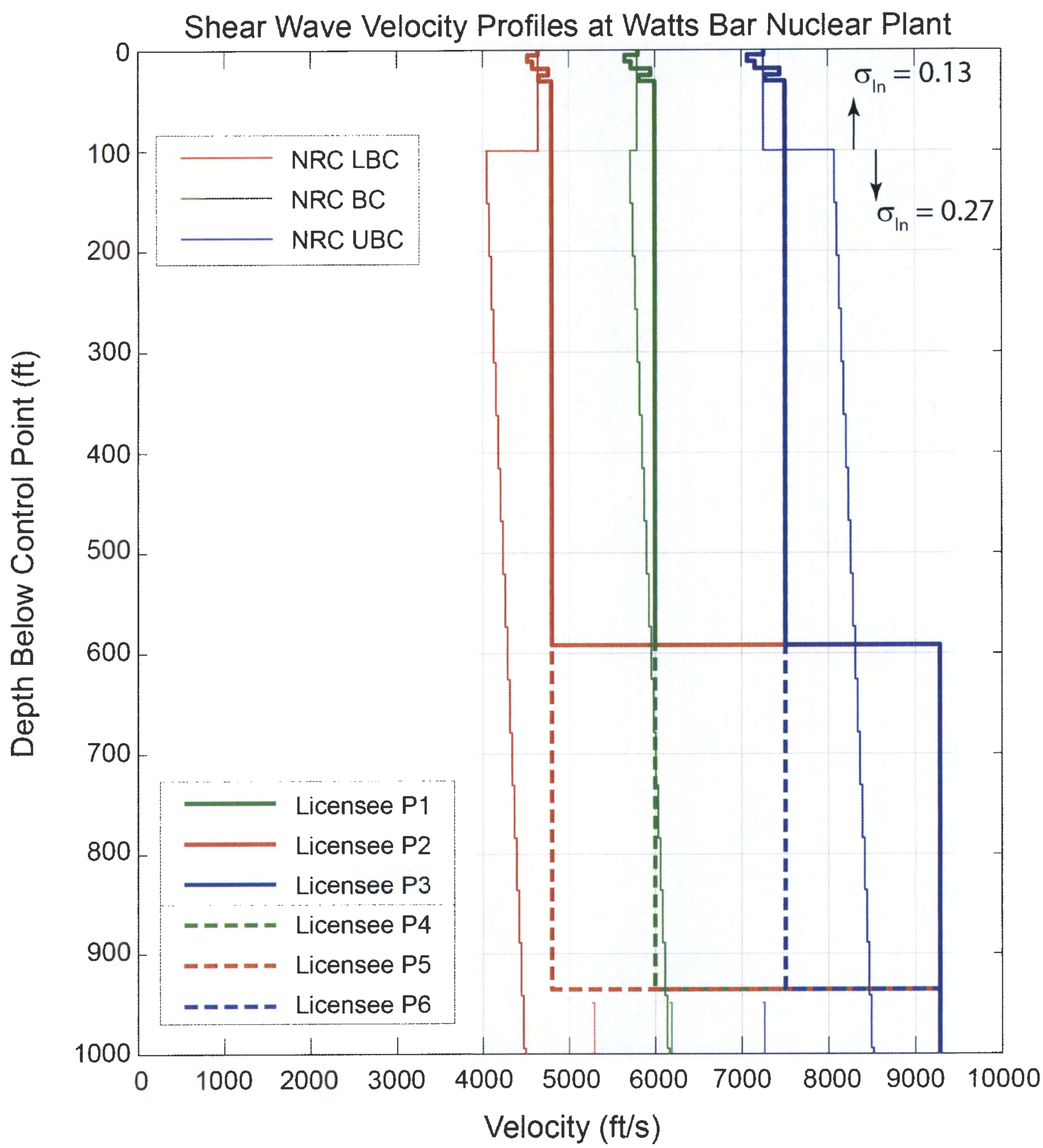


Figure 3.3-2 Plot Comparing the Staff's and TVA's Median Amplification Functions and Uncertainties for the Watts Bar, Unit 1 site

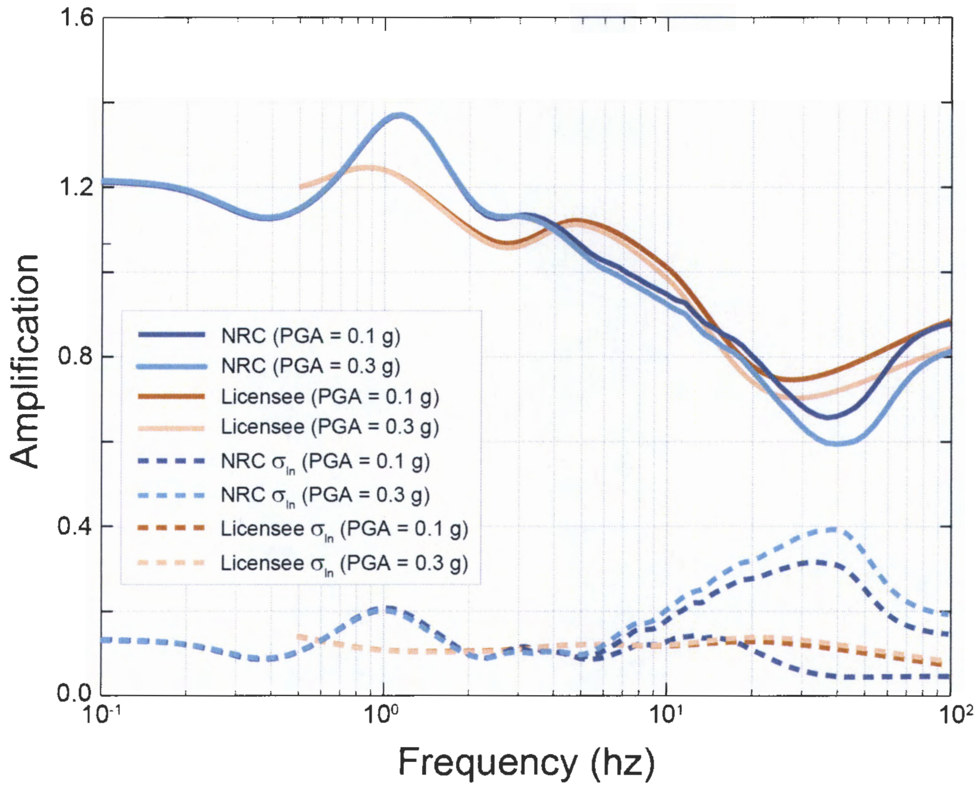


Figure 3.3-3 Plot Comparing the Staff's and TVA's Mean Control Point Hazard Curves at a Variety of Frequencies for the Watts Bar, Unit 1 site

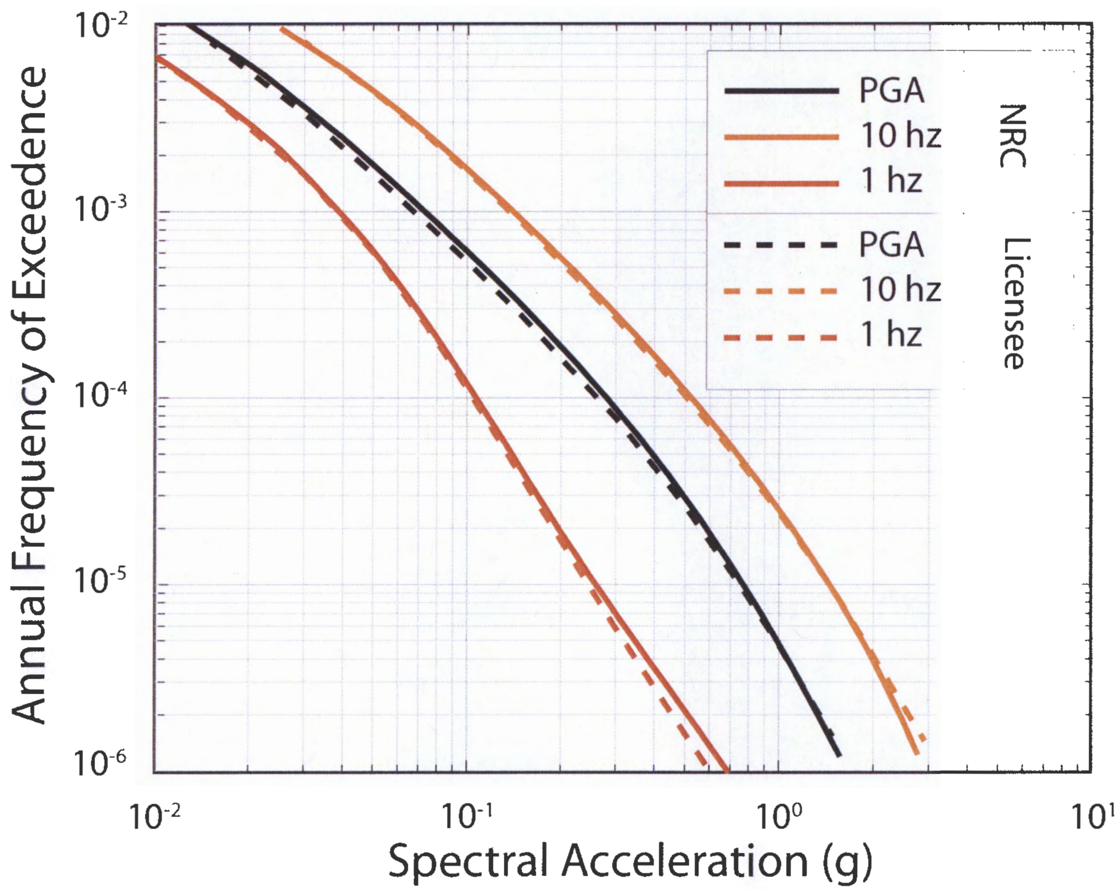
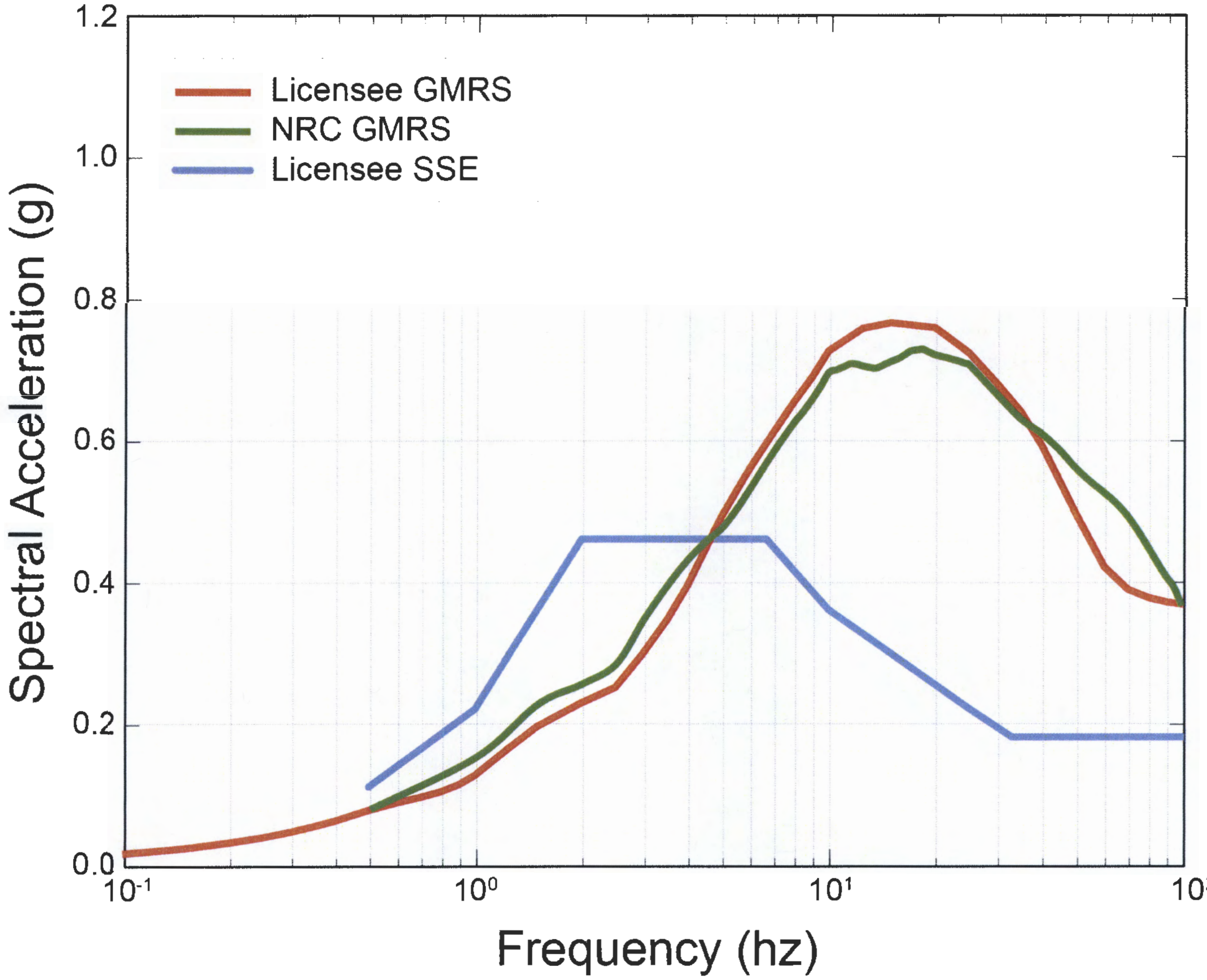


Figure 3.4-1 Comparison of the Staff's GMRS, Licensee's GMRS, and the SSE for the Watts Bar, Unit 1 site



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

Sincerely,

/RA/

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

Docket No. 50-390

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