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

March 1, 2016

Mr. William R. Gideon
Brunswick Steam Electric Plant
Site Vice President
Brunswick Steam Electric Plant
8470 River Rd. SE (M/C BNP001)
Southport, NC 28461

SUBJECT: BRUNSWICK STEAM ELECTRIC PLANT, 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 (CAC NOS. MF3824 AND MF3825)

Dear Mr. Gideon:

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 31, 2014, Duke Energy Progress, Inc. (Duke, the licensee), responded to this request for Brunswick Steam Electric Plant, Units 1 and 2 (Brunswick).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for Brunswick and, as documented in the enclosed staff assessment, determined that you provided sufficient information in response to Enclosure 1, Items (1) – (3), (5) - (7) and the comparison portion of Item (4) of the 50.54(f) letter. Further, the NRC staff concludes that the licensee's reevaluated seismic hazard is suitable for other actions associated with Near-Term Task Force Recommendation 2.1, "Seismic".

As indicated in the NRC letter dated October 27, 2015 (ADAMS Accession No. ML15194A015), Duke is requested to submit a spent fuel pool evaluation, a full-scope Individual Plant Examination of External Events (IPEEE) relay chatter review and a High Frequency (HF) equipment confirmation. Contingent upon the NRC staff's review and acceptance of Duke's high frequency confirmation (Item 4), the full-scope IPEEE relay chatter review and spent fuel pool evaluation (Item (9)) for Brunswick, 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. 50-325 and 50-324

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

BRUNSWICK STEAM ELECTRIC PLANT, UNITS 1 AND 2

DOCKET NOS. 50-325 AND 50-324

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] In particular, 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),

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[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 11, 2013 (Waldrep, 2013), Duke Energy Progress, Inc. (Duke, the licensee) submitted at least partial site response information for Brunswick Steam Electric Plant, Units 1 and 2 (Brunswick). By letter dated March 31, 2014 (Hamrick, 2014), 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 the 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 described 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 31, 2014 (Hamrick, 2014), the licensee provided the Brunswick SHSR. The licensee's SHSR indicates that the site GMRS exceeds the site SSE for a portion of the frequency range from 1 to 10 Hertz (Hz). However, the licensee indicated that over the frequency range of 1 to 9 Hz, the GMRS is bounded by either the site SSE or the site Individual Plant Examination of External Events (IPEEE) plant-level high confidence of low probability of failure (HCLPF) spectrum (IHS). For frequencies above 9 Hz, the IHS also bounds the majority, but not all of the licensee's site GMRS. Following the guidance in Section 3.3 of the SPID, the licensee provided an evaluation of its IPEEE program in order to use the IHS as the plant seismic capacity for the screening comparison with the GMRS. Between 9 and 10 Hz the licensee indicated that the GMRS exceeds the IHS by a slight amount; however, the exceedance falls within the narrow-band-exceedance criteria specified in the SPID and, as such, Brunswick screens out of performing a SPRA. With respect to the high-frequency exceedance, the full scope IPEEE detailed review of relay chatter required in SPID Section 3.3.1 has not been completed by the licensee. Therefore, the licensee stated that it will complete the relay chatter review consistent with NEI letter to NRC dated October 3, 2013 (Keithline, 2013) on the same schedule as the HF confirmation as proposed in the NEI letter dated April 9, 2013 (Pietrangelo, 2013), and accepted in NRC's letter dated May 7, 2013 (NRC, 2013a). Additionally, above 10 Hz, a portion of the GMRS exceeds both the IHS and SSE. Therefore the licensee stated that it will perform the HF confirmation per the SPID Section 3.4. Furthermore, because the GMRS exceeds the SSE between 1 and 10 Hz, Brunswick screens in to perform a SFP evaluation.

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 Brunswick site as conditionally screened-in, because additional information was needed to support a screening decision based on the licensee's use of the IPEEE screening criteria in the SPID. On September 17, 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 and the licensee's original IPEEE submittal, the NRC staff confirmed that the licensee met the IPEEE adequacy criteria in the SPID provided that the relay chatter review is completed. The staff confirmed that the licensee's GMRS, as well as the staff's confirmatory GMRS is bounded by the SSE or IHS over the frequency range of 1 to 10 Hz, with the exception of a minimal amount of exceedance between 9 to 10 Hz. Therefore, the NRC staff concludes that a plant seismic risk evaluation is not warranted for Brunswick. However, because the GMRS exceeds the SSE and IHS for a portion of the frequency range above 10 Hz, a HF confirmation is merited. Finally, the SFP evaluation is merited because the IPEEE program did not include the SFP and the GMRS exceeds the SSE over the frequency range of approximately 7 to 100 Hz.

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 ground motion and is characterized by (1) a peak ground acceleration (PGA) value which anchors the response spectra at high frequencies (typically between 20 to 30 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-basis for Brunswick. The licensee stated that for structures founded on dense sand it is appropriate to use both the Housner and El Centro response spectra with scaled amplitudes. The licensee determined that the smoothed 1940 North-South El Centro spectrum normalized by a factor of 0.08 g/0.33 g (8 /33 percent of the acceleration due to earth's gravity) or 0.24 for operating basis earthquake (OBE) would envelope the two recommended spectra. The licensee assumed the SSE to be a high intensity VII (Modified Mercalli Scale) event with horizontal ground motion of 0.16 g/0.08 g or twice the ordinates of the OBE spectrum. The licensee specified that the SSE control point is at the bottom of the Reactor Building basemat at elevation -28.33 ft (8.6 m).

The NRC staff reviewed the licensee's description of its SSE in the SHSR for the Brunswick site. Based on its review of the SHSR and the Updated Final Safety Analysis Report (UFSAR) (Progress Energy, 2012), the NRC staff confirmed that the licensee's SSE is defined in terms of PGA and a design response spectrum anchored at 0.16 g, as described by the licensee. Finally, based on its review of the SHSR and the UFSAR (Progress Energy, 2012), the NRC staff confirmed that the licensee's control point elevation for the Brunswick site SSE is defined at the bottom of the Reactor Building basemat, consistent with guidance provided in the SPID.

3.2 Probabilistic Seismic Hazard Analysis

In Section 2.2 of its 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 cutoff of **M**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 mi (640 km) around the site and included the Charleston and Wabash Valley Repeated Large Magnitude Earthquake (RLME) sources, which lie within 620 mi (1,000 km) of Brunswick. The 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 for each of the CEUS-SSC sources. Consistent with the SPID, the licensee did not provide its base rock seismic hazard curves since a site response analysis is necessary to determine the control point seismic hazard curves. The licensee provided its control point seismic hazard curves in Section 2.3.7 of the SHSR. The NRC 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 or reference rock site conditions at the Brunswick 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 Brunswick site. In addition, the NRC staff included the Charleston and Wabash Valley RLME sources, which lie within 620 km (1,000 mi) of the Brunswick 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, except for the Extended Continental Crust – Gulf Coast seismotectonic source for which the NRC staff used the Gulf version of the updated EPRI GMM.

Based on its review of the SHSR, the NRC staff concludes that the licensee followed the guidance provided in the SPID for selecting the 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 the licensee 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 would 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 these 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 Brunswick site rests on fill overlying sand of varying thickness from 5 to 20 ft (1.5 to 6 m) underlain by approximately 35 ft (11 m) of undifferentiated Pleistocene/Pliocene sedimentary deposits of predominantly clay materials. At a depth of about 50 ft (15 m) the Castle Hayne Formation of primarily sand is encountered with a thickness of about 30 ft (9 m) before the Peedee Confining Unit is reached at a depth of approximately 80 ft (24 m). The Peedee Confining Unit is about 35 ft (11 m) thick and consists of lenses of clay and sand with some limestone. At a depth of about 114 ft (35 m) is the Peedee Limestone, a 115 ft (35 m) thick limestone unit which changes to clay and sand at a depth of 230 ft (70 m) before terminating at the underlying Black Creek Formation at a depth of 530 ft (162 m). Crystalline basement rocks are encountered at a depth of approximately 1,500 ft (457 m).

The licensee developed a shear wave velocity profile from the surface to the top of the Peedee Limestone based on seismic refraction surveys and limited borehole measurements made at the Brunswick site. For the material underlying the Peedee Limestone, the licensee assumed a constant shear wave velocity of 3,000 ft/sec (915 m/sec) down to the basement rock at a depth of 1,500 ft (457 m). To capture the uncertainty in the shear wave velocities for the material beneath the site, the licensee developed lower and upper base case shear-wave velocities using a scale factor of 1.25 for the Yorktown Formation and Oligocene Sediments and 1.57 for deeper units, representing a natural log standard deviation of 0.17 and 0.35 respectively. 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 case profiles. Figure 3.3-1 of this assessment shows the licensee's three shear-wave velocity profiles.

The licensee stated that no site-specific dynamic material properties were determined during the initial investigations of the Brunswick site. Therefore, to accommodate the potential range in nonlinear dynamic properties in the upper 500 ft (152 m), the licensee used two sets of shear modulus reduction and hysteretic damping curves for both soil and firm rock. Consistent with the SPID, the licensee determined that the EPRI curves for soil and rock (model M1) were appropriate to represent the more nonlinear response. In contrast, to model the more linear response (model M2), the licensee used the Peninsular Range (PR) curves for soils combined with constant damping, derived from the low strain damping values of the EPRI rock curves, for the rock layers.

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. For the Brunswick site, with 50 ft (15 m) of soil overlying 1,417 ft (432 m) of firm rock, the licensee estimated kappa values for the best, lower and upper profiles of 0.024 sec, 0.033 sec, and 0.017 sec, respectively.

To account for aleatory variability in material properties across the plant site in its site response calculations, the licensee stated that it randomized its base case profiles following guidance in Appendix B of the SPID. The licensee stated that it also extended the depth of the profiles to 1,482 ft (452 m) randomized +/- 445 ft (136 m) reflecting 30 percent of the depth. The licensee stated that this randomization did not represent actual uncertainty in the depth to reference rock, but was used to broaden the spectral peak.

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, 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 11 input loading levels for the each base case profile. Consistent with the SPID, the licensee used a minimum median amplification value of 0.5 in the analysis.

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 reference rock hazard curves, determined from the initial PSHA (Section 3.2 of this assessment), and the amplification function 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 Brunswick site. The NRC staff independently developed a shear-wave velocity profiles, damping values, and modeled the potential behavior of the soil and rock using measurements and geologic information provided in the Brunswick, Units 1 and 2 UFSAR (Progress Energy, 2012) 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.

To capture the uncertainty in the site subsurface geology, the NRC staff developed three base case shear-wave velocity profiles. The best estimate base case shear-wave velocity profile is based on the information obtained from Figure 2-40 of the Brunswick, Units 1 and 2 UFSAR (Progress Energy, 2012) and the information obtained from other sources for the Castle Hayne, Peedee and Black Creek geologic formations (Odum et al., 2003; SCDOT Geotechnical Design Manual, 2008). The lower and the upper base case profiles were calculated using a scale factor of 1.21, consistent with a natural log standard deviation of 0.15. Figure 3.3-1 of this assessment shows a comparison of the shear-wave velocity profiles developed by the licensee with those developed by the NRC staff. The staff's best estimate base case profile generally demonstrates similar behavior as the licensee's profile except the staff's profile shear-wave velocity increases gradually below the depth of 180 ft [54.9 m] from 1,988 ft/sec (606 m/sec) to 2,709 ft/sec (826 m/sec) at the bedrock depth of 1,450 ft (442 m). The licensee assumed a slightly different depth to bedrock of 1482 ft (452 m). In addition to the differences in the best case profile, for its development of the lower and upper base case profiles, the licensee assumed higher uncertainties of 1.25 for the upper 65 ft (19.8 m) and 1.57 for the deeper part of the profile. As described below, these differences between the NRC staff's and licensee's profiles did not have a significant impact on the final hazard curves or GMRS for the site.

Consistent with the SPID and the approach used by the licensee, the NRC staff assumed a combination of EPRI and Peninsular Range shear modulus and damping material curves for the upper part of the profile, and linear behavior with no damping for the soft rock beneath 500 ft (152 m) for the Brunswick site in response to the range of input loading motions for all the three profiles.

To determine kappa for its three profiles, the NRC staff used the low strain damping values, shear wave velocities, Q-values, and layer thicknesses for each layer to arrive at kappa values for the best estimate, upper, and lower base case velocity profiles of 0.020, 0.018, 0.023 sec, respectively, which are, on average, slightly lower than the licensee's values (0.024, 0.017, 0.033). To model the uncertainty in kappa, the NRC staff used a natural log standard deviation of 0.15 to calculate lower and upper values of kappa for each profile. This approach results in nine kappa values for the staff's site response analysis, which range from 0.015 sec to 0.028 sec.

Figure 3.3-2 of this assessment shows a comparison of the staff's and licensee's median site amplification functions and uncertainties (±1 standard deviation) for 2 of the 11 input loading levels. Due to the differences in shear-wave velocity profiles and kappa, the staff's amplification functions are slightly higher than those of the licensee. However, overall the licensee's approach to modeling the subsurface rock properties and their uncertainty results in amplification factors that are very similar to those developed by the NRC staff. In addition, as shown in Figure 3.3-3 of this assessment, the minor differences in the licensee's and staff's site response analyses lead to control point seismic hazard curves that 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, 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 Brunswick site.

3.4 Ground Motion Response Spectra

In Section 2.4 of its SHSR, the licensee stated 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 analysis, 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 generally similar to that calculated by the NRC staff. These minor differences in GMRS are the result of differences in the site response analyses performed by the licensee and NRC staff as discussed in Section 3.3 above.

The NRC 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 NRC staff performed both a PSHA and site response confirmatory analysis and achieved results consistent with the licensee's horizontal GMRS. As such, the NRC staff concludes that the GMRS determined by the licensee adequately characterizes the reevaluated hazard for the Brunswick site. Therefore, this GMRS is suitable for use in subsequent evaluations and confirmations, as needed, for the licensee's 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 Brunswick site. Based on its review, the NRC staff concludes that the licensee conducted the seismic 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. The NRC staff concluded that the licensee demonstrated that the IHS could be used for comparison with the GMRS for the screening decision. Based on the preceding analysis and with the completion of the IPEEE relay review, the NRC staff concludes that the licensee provided an acceptable response to Requested Information Items (1) – (3), (5), and (7) and a partial response to 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, the NRC staff confirms the licensee's conclusion that the licensee's GMRS for the Brunswick site is bounded by the IHS or SSE over the frequency range of 1 to 9 Hz. Between 9 and 10 Hz the NRC staff verified that the licensee's GMRS exceeds the IHS by a slight amount; however, the exceedance falls within the narrow-band-exceedance criteria specified in the SPID. Therefore, as stated in the October 27, 2015, letter, a seismic risk evaluation (Item 8) is not requested. The NRC staff confirmed the licensee's conclusion that it will perform an IPEEE relay chatter review to complete the criteria for using its IPEEE program for screening purposes. Because the GMRS exceeds both the IHS and SSE for a portion in the frequency range above 10 Hz, a HF confirmation is merited. Finally, because the IPEEE program did not include the SFP and the GMRS exceeds the SSE between 1 to 10 Hz, a SFP evaluation is merited.

The NRC review and acceptance of Duke's SFP evaluation (Item (9)), HF confirmation (Item (4)), and IPEEE relay chatter review for Brunswick will complete the Seismic Hazard Evaluation identified in Enclosure 1 of the 50.54(f) letter.

REFERENCES

Note: ADAMS Accession Nos. refers to documents available through NRC's Agencywide Documents Access and Management System (ADAMS). Publicly-available ADAMS documents may be accessed through 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 Brunswick Site

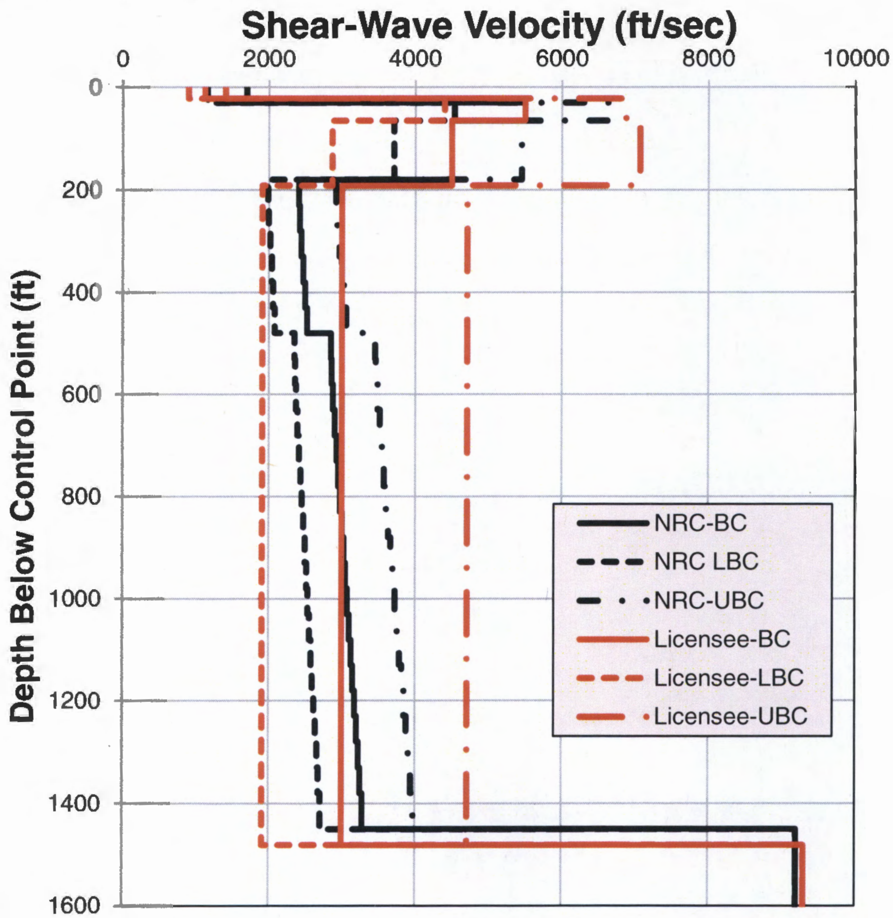


Figure 3.3-2 Plot Comparing the Staff's and the Licensee's Median Amplification Functions and Uncertainties for the Brunswick site.

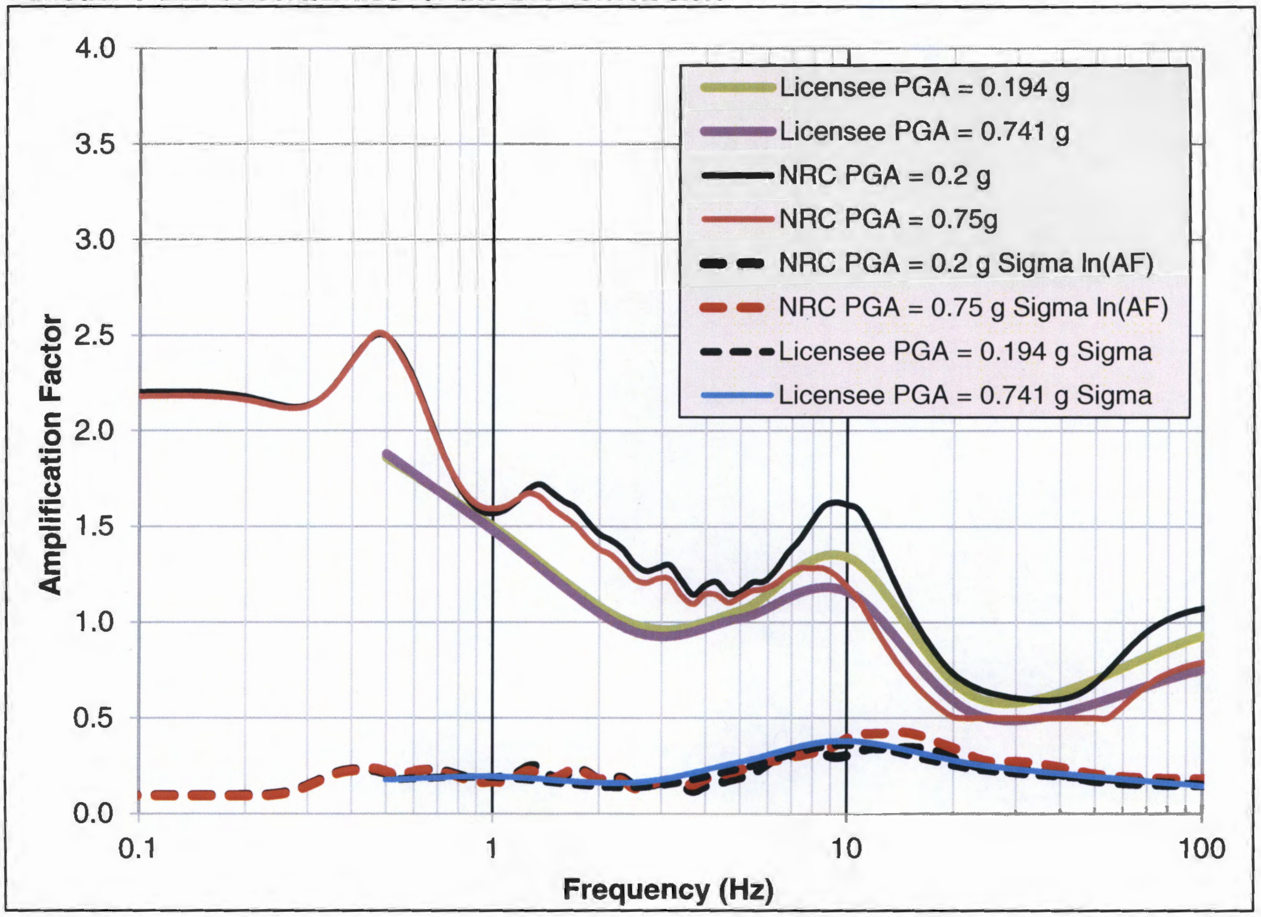


Figure 3.3-3 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the Brunswick site

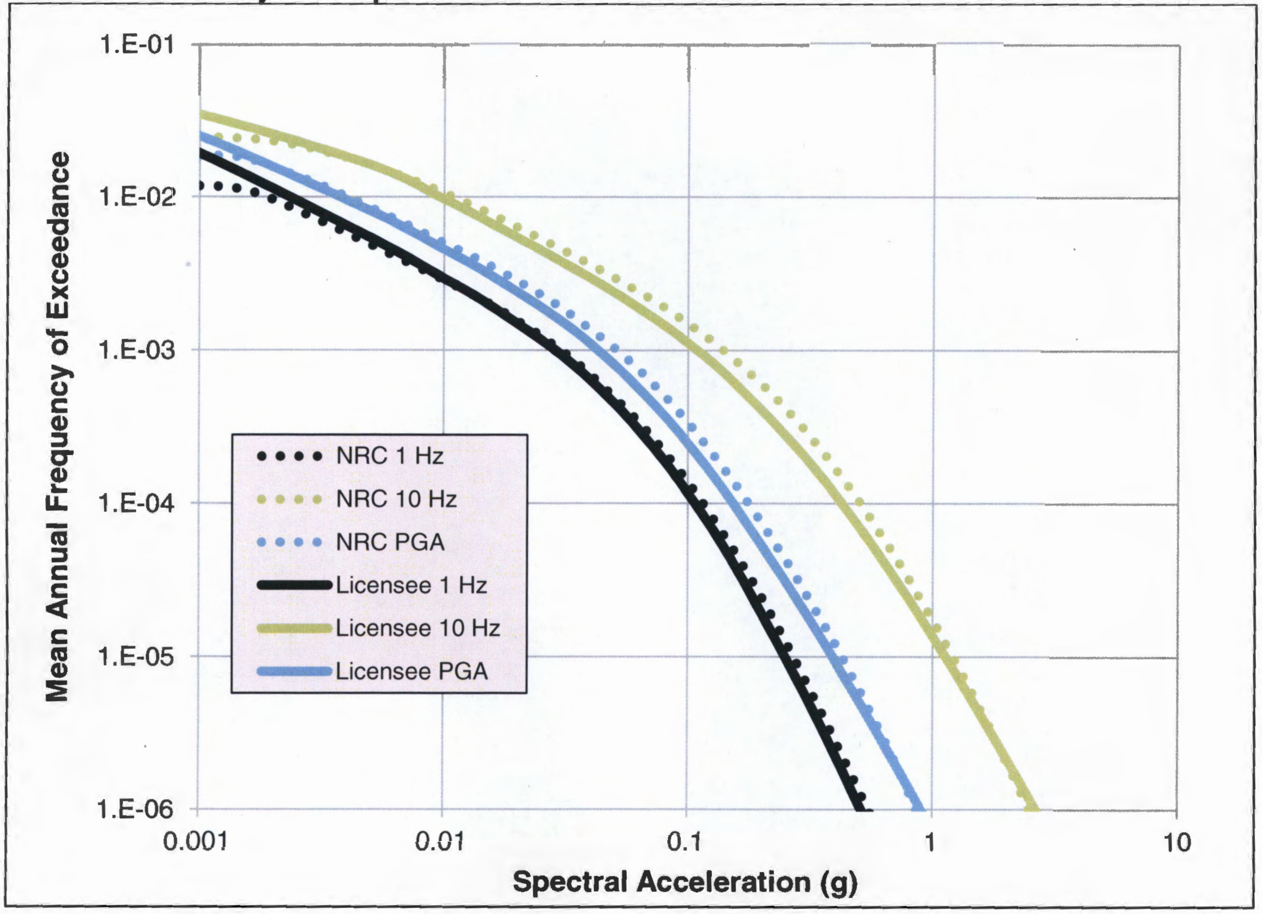
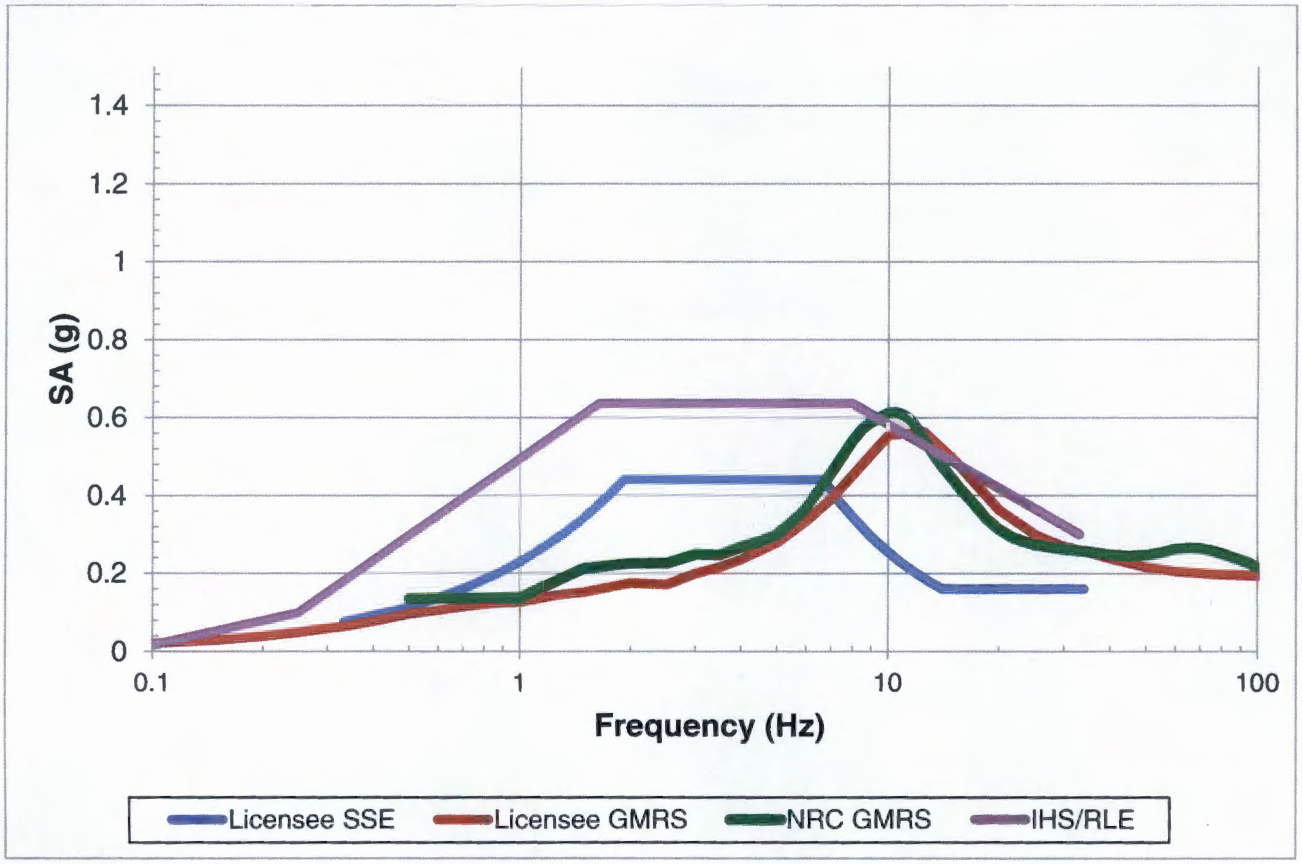


Figure 3.4-1 Comparison of the Staff's GMRS with Licensee's GMRS and the SSE for the Brunswick site



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

Sincerely,

/RA/

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Office of Nuclear Reactor Regulation

Docket Nos. 50-325 and 50-324

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