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

February 17, 2016

Mr. Bryan C. Hanson
President and Chief Nuclear Officer
Exelon Generation Company, LLC
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: OYSTER CREEK NUCLEAR GENERATING STATION - 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 NO. MF5257)

Dear Mr. Hanson:

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, Exelon Generation Company, LLC (Exelon, the licensee), responded to this request for Oyster Creek Nuclear Generating Station (Oyster Creek).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for Oyster Creek and, as documented in the enclosed staff assessment, determined that you provided sufficient information in response to Enclosure 1, Items (1) - (9) of the 50.54(f) letter.

The NRC staff concludes that the licensee responded appropriately and has completed its response to Enclosure 1, of the 50.54(f) letter. Furthermore, the NRC staff review concluded that the reevaluated seismic hazard is bounded by the plant licensing and design basis. As such, the NRC staff concludes that no further responses or regulatory actions associated with Phase 2 of Near-Term Task Force (NTTF) Recommendation 2.1 "Seismic" are required for Oyster Creek. This closes out the NRC's efforts associated with Phase 1 and 2 of NTTF Recommendation 2.1 "Seismic" (CAC No. MF5257).

If you have any questions, please contact me at (301) 415-1115.

Sincerely,

Nicholas J DiFrancesco, Senior Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No. 50-219

Enclosure:
Staff Assessment of Seismic
Hazard Evaluation 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

OYSTER CREEK NUCLEAR GENERATING STATION

DOCKET NO. 50-219

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).

Enclosure

(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 2004, 2006, 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 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 (Kaegi, 2013), Exelon Generation Company, LLC (Exelon, the licensee), submitted partial site response information for Oyster Creek Nuclear Generating Station (Oyster Creek). By letter dated March 31, 2014 (Barstow, 2014a), Exelon submitted its SHSR. By letter dated August 21, 2014 (Barstow, 2014b), the licensee supplemented its report in response to a discussion in the June 17, 2014, NRC public meeting (NRC, 2014b).

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 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 provides further guidance regarding the appropriate use of GMMs for 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 PSHA base rock hazard curves. Finally, Attachment 1 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 (Barstow, 2014a), Exelon provided the SHSR for the Oyster Creek site. The licensee's SHSR indicates that the site GMRS exceeds the 1995 Weston site specific response spectrum (SSRS) for Oyster Creek below the frequency of approximately 1.9 Hertz (Hz) and between approximately 18 – 70 Hz. The licensee stated that the 1995 Weston SSRS has been the design basis for the plant since 1995. Based on a comparison of the GMRS with the SSRS, the licensee stated that Oyster Creek screens out of performing a seismic risk evaluation as well as a SFP evaluation. However, due to the low frequency exceedance of the GMRS relative to the SSRS, Oyster Creek stated it would evaluate the safety significant of low-frequency susceptible SSCs, as required by SPID (Reference 5) Section 3.2.1.1 special screening considerations. Additionally, due to the exceedance of the GMRS relative to the SSRS above 10 Hz, Oyster Creek will perform a HF confirmation.

On May 9, 2014 (NRC, 2014a), the NRC staff issued a letter providing the outcome of its 30-day screening and prioritization evaluation. In the letter, the NRC staff characterized the Oyster Creek site as conditionally screened-in, because additional information was needed to support a screening and prioritization decision. On November 28, 2014 (NRC, 2014c), the staff issued a letter providing the outcome of its seismic screening and prioritization review for Oyster Creek. For its screening and prioritization decision, the NRC staff performed its intial screening evaluation for Oyster Creek based on a comparison of the GMRS with the licensee's Housner- shape design spectrum anchored at 0.22 g, which is the original SSE for the plant. The NRC staff concluded that a seismic risk evaluation, SFP evaluation, and a HF confirmation are merited for Oyster Creek.

As stated in the October 27, 2015, letter (NRC, 2015), the NRC revisted these initial screening determinations. After futher evaluating the GMRS exceedances to the SSE, information regarding the plant's seismic core damage frequency (SCDF) and insights related to the plant's conditional containment failure probability, the NRC concluded that a seismic risk evaluation was not merited Creek Creek. Subsequently, following additional review and refinement of the Housner- shape design spectrum anchored at 0.22 g, the NRC staff determined that the GMRS remains bounded by the Housner-shape design spectrum anchored at 0.22 g across the frequency range. As such the NRC staff concludes that a SFP evaluation and HF confirmation are no longer merited for Oyster Creek. The staff notes that letter (Barstow, 2015) dated December 4, 2015, Oyster Creek provided a HF assessmented based on the the 1995 Weston SSRS which remains under staff review.

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 its SHSR (Barstow, 2014a) and supplement dated August 21, 2014 (Barstow, 2014b), the licensee described its seismic licensing and design bases for Oyster Creek. The licensee stated that the original seismic design at Oyster Creek was based on a Housner-shaped ground response spectrum and a peak ground acceleration of 0.22g (22 percent of the acceleration due to earth's gravity) derived from the El Centro ground acceleration scaled to account for the regional seismic activity appropriate for New Jersey. The licensee stated that the Updated Final Safety Analysis Report (UFSAR) was updated to specify that starting in September 1995, "the Weston Geophysical SSRS and associated ISRS [in-Structure Response Spectra] would be used as the design and licensing bases SSE going forward." The licensee stated that the response spectrum anchored at 0.184g horizontal PGA (i.e., 1995 Weston SSRS) represents the lower bound capacity earthquake for plant safe shutdown and is therefore appropriate for use in the seismic screening. The 1995 Weston SSRS provides additional capacity over the Housner-shape design spectrum anchored at 0.22 g in the approximate range of 3 to 15 Hz. As such, the NRC staff requested clarification whether the safety-related SSCs built prior to 1995 were also evaluated to the Weston SSRS. In the August 21, 2014, response (Barstow, 2014b), the licensee described various SSCs that were analyzed to the 1995 Weston SSRS.

The staff reviewed the licensee's description of its Weston SSRS for Oyster Creek in its SHSR and supplement dated August 21, 2014 (Barstow, 2014b). To further confirm the Weston SSRS, the staff also reviewed the Oyster Creek UFSAR, Revision 18 (Exelon, 2013). The NRC staff could not confirm that all safety-related SSCs were evaluated to the 1995 Weston SSRS and therefore, would demonstrate that it is the equivalent of the original plant design basis SSE. Therefore, the staff performed its screening evaluation for Oyster Creek based on a comparison of the GMRS with the lower value of the licensee's Housner-shape design spectrum anchored at 0.22 g.

In its SHSR (Barstow, 2014a), the licensee stated that the control point elevation for the SSE is located at the ground surface at elevation 23 ft mean sea level (MSL). Based on its review of the SHSR and the UFSAR, the NRC staff confirmed that the licensee's control point elevation for Oyster Creek is consistent with the 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). For its PSHA, the licensee used a minimum moment magnitude (M_w) of 5.0 as specified in the 50.54(f) letter. The licensee further stated that it included CEUS-SSC background sources out to a distance of 400 miles [640 km] and included the Charlevoix and Charleston repeated large magnitude earthquake (RLME) sources, which lie within 620 miles [1,000 km] of the site. The RLME sources are those source areas or faults for which more than one large magnitude ($M_w >= 6.5$) 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 base rock seismic hazard curves because it performed a site response analysis to determine the control point seismic hazard curves. The licensee provided 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 its own PSHA calculations for base rock conditions at the Oyster Creek 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 Oyster Creek site. In addition, the NRC staff included all of the RLME sources falling within a 620 mi [1000 km] radius of the site, which includes the Charlevoix and Charleston RLME 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 the licensee's results.

Based on its review of the SHSR, the NRC staff concludes that the licensee appropriately 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 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

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 Oyster Creek UFSAR, Revision 18 (Exelon, 2013). The licensee stated that the site is underlain by approximately 4,000 ft. [1,219 m] of unconsolidated coastal plain sediment ranging in age from Cretaceous to present. Precambrian basement rock is estimated at a depth of about 4,000 ft. (1,219 m).

To develop its site base case shear wave velocity profile, the licensee used the results of the geophysical investigations in the UFSAR and independent spent fuel storage installation for Oyster Creek, including shear and compressional wave velocity, density and thickness, as provided in SHSR Table 2.3.1-1. Seismic shear wave velocities for the approximately 4,000 ft. (1,219 m) of sediments beneath the site range from 270 feet per second (fps) [82 meters per second] to 1,780 fps [542 meters per second].

To account for uncertainty in the subsurface shear wave velocities, the licensee developed three site base case profiles. The middle, or best estimate, profile was developed by matching the measured shear-wave velocity from standard penetration tests in the upper 300 ft. (91 m). To develop the shear wave velocities for the deeper layers of the profile, the licensee used the shear wave velocity templates provided in the SPID. As such, the resulting base-case profile consists of the measured velocities for the upper layers combined with the adjusted template extended to the profile to basement rock. To develop the upper and lower base case profiles, the licensee used a natural log standard deviation of 0.35, which reflects the rather large uncertainty in the shear wave velocity. 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 nonlinear dynamic material properties were determined during siting. Therefore, the licensee assumed that the non-linear behavior of the soil under the site could be modeled with either EPRI soil or Peninsular Range curves for shear modulus reduction and hysteretic damping curves. The licensee applied these shear modulus reduction and damping curves over the upper 500 ft. [152 m] of the underlying soils.

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 Oyster Creek, a site with about 4,000 ft. [1,219 m] of sediment over the assumed base rock material, the licensee-assumed a kappa value of 0.040s was appropriate. The licensee accounted for uncertainty in kappa at design loading levels by using two sets of shear modulus and hysteretic damping curves.

To account for randomness in material properties across the plant site, the licensee randomized its base case shear-wave velocity profiles using the guidance in the SPID. The licensee generated 30 random velocity profiles using a natural log standard deviation of 0.25 over the upper 50 ft. (15.24 m) and a standard deviation of 0.15 below that depth. In addition, to account for uncertainty in the depth to basement rock, the licensee randomized this depth by ±1,200 ft. [366 m], which is approximately 30 percent of the total profile thickness.

3.3.2 Site Response Method and Results

In Section 2.3.4 of its SHSR, the licensee states 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 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 the seven spectral frequencies for which ground motion equations are available.

3.3.3 Staff Confirmatory Analysis

To confirm the licensee's site response analysis, the NRC staff performed site response calculations for the Oyster Creek site. The NRC staff independently developed a shear-wave velocity profile, damping values, and modeled the potential nonlinear behavior of the subsurface using measurements and geologic information provided in the Oyster Creek UFSAR (Exelon, 2013), the Site Safety Analysis Report (SSAR) for the PSEG site in southwestern New Jersey (PSEG, 2014), information from local and regional well logs, 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 the guidance provided in the SPID for sites with less subsurface information, the NRC staff determined best-estimate and upper and lower base case shear-wave velocity profiles. Site investigations at the Oyster Creek site extended to a depth of approximately 120 ft. (37 m) (Exelon, 2013). The NRC staff used UFSAR thicknesses and velocities for the Cohansey sand and Lower Clay units that extend from the control point to 78 ft. (24 m). Below this depth, there is little subsurface information, so the NRC staff based its best-estimate velocity profile on information in the well logs associated with the International Ocean Drilling Project (IODP). Two onshore IODP sites are located within 20 mi (32 km) of the site (Browning, et al., 2011 and Miller, et al., 1998), which contain information about soil and rock material properties and unit thicknesses to a depth of approximately 1,500 ft. (457 m). Because geologic formations across the state are continuous and relatively uniform (Horace et al., 1983; Sugarman, et al., 2011), the NRC staff used the shear-wave velocities in the SSAR for the PSEG site (PSEG, 2014) for the soil and rock units identified from the onshore well logs. To account for the uncertainty in the shear wave velocities, the NRC staff used a natural log standard deviation of 0.35 to calculate the upper and lower base case profiles. Figure 3.3-1 of this assessment shows a comparison of the licensee's velocity profile with that developed by the NRC staff. The profiles developed by the licensee are similar to those developed by the NRC staff, but have less variability in seismic velocities due to the use of a template velocity profile. The NRC staff randomized the depth to reference rock by ±10 percent to allow for additional uncertainty.

Similar to the approach used by the licensee, the NRC staff used two different models to account for epistemic uncertainty in the nonlinear behavior of the soil and rock. The NRC staff used the EPRI soil curves and the Peninsular Range curves over the upper 500 ft. (152 m) of the profile to incorporate different degrees of non-linearity in the site profiles.

To determine kappa for its three profiles, the NRC staff used the low strain damping values, shear-wave velocities, and layer thicknesses for each geologic layer to arrive at values of 0.04, 0.04, and 0.03 sec, for the best-estimate, lower and upper base cases respectively. These values include the 0.006 sec contribution from the reference rock. To model the uncertainty in kappa, the NRC staff used a natural log standard deviation of 0.4 to calculate lower and upper values of kappa for each profile. The approach results in nine kappa values for the staff's site response analysis, which range from 0.018 to 0.048 sec.

Figure 3.3-2 of this assessment shows a comparison of the staff's and the licensee's median site amplification function and uncertainties (±1 standard deviation) for two of the eleven input loading levels. Amplification functions developed by both the licensee and the NRC staff are greatest at less than 1 Hz, decreasing in amplitude with increasing frequency until approximately 25 Hz. Minor differences in amplification functions developed by the NRC staff and the licensee are due to differences in depth to reference rock, the use of template velocities by the licensee, and the use of lower velocities near the surface by the licensee.

The licensee's approach to modeling the subsurface properties and their uncertainties results in similar amplification factors to those developed by the NRC staff. Figure 3.3-3 of this assessment shows a comparison of the licensee and NRC soil hazard curves. The licensee's curves are nearly identical to the staff's at 10 Hz and 100 Hz (PGA), but are slightly higher at 1 Hz. These differences in control point hazard curves have a minor impact on the resulting GMRS, discussed below. 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.

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 Oyster Creek 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 generally similar to that calculated by the NRC staff. The licensee's GMRS is higher than the staff's below approximately 5 Hz, and lower beyond. Minor differences in the shape and amplitude of the GMRS are due to differences in site response analyses as discussed 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 GMRS. As such, the NRC staff concludes that the GMRS determined by the licensee adequately characterizes the reevaluated hazard for the Oyster Creek 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 Oyster Creek 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. Based upon the preceding analysis, the NRC staff concludes that the licensee provided an acceptable response to Requested Information Items (1) – (9) identified in Enclosure 1 of the 50.54(f) letter. The NRC staff based its review on compared the GMRS to the Housner-shape design spectrum anchored at 0.22 g (i.e., original SSE) because the NRC staff could not confirm the that all safety-related SSCs built prior to 1995 were evaluated to the 1995 Weston SSRS.

In reaching this determination, the NRC staff confirmed that the licensee's GMRS for the Oyster Creek site is bounded by the Housner-shape design spectrum anchored at a PGA of 0.22 g in the 1 to 100 Hz range. As such, based on its screening criteria, the NRC staff concluded that a seismic risk evaluation, SFP evaluation, and a HF confirmation are not merited. Based upon the preceding analysis, the NRC staff concludes that the licensee responded appropriately and has completed its response to 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.

U.S. Nuclear Regulatory Commission Documents and Publications

NRC (U.S. Nuclear Regulatory Commission), 2007, A Performance-based Approach to Define the Site-Specific Earthquake Ground Motion, Regulatory Guide (RG) 1.208, March 2007.

NRC (U.S. Nuclear Regulatory Commission), 2011a, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," Commission Paper SECY-11-0093, July 12, 2011, ADAMS Accession No. ML11186A950.

NRC (U.S. Nuclear Regulatory Commission), 2011b, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," Enclosure to SECY-11-0093, July 12, 2011, ADAMS Accession No. ML11186A950.

NRC (U.S. Nuclear Regulatory Commission), 2011c, "Recommended Actions to be Taken without Delay from the Near-Term Task Force Report," Commission Paper SECY-11-0124, September 9, 2011, ADAMS Accession No. ML11245A158.

NRC (U.S. Nuclear Regulatory Commission), 2011d, "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned," Commission Paper SECY-11-0137, October 3, 2011, ADAMS Accession No. ML11272A111.

NRC (U.S. Nuclear Regulatory Commission), 2012a, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation and Michael R. Johnson, Director, Office of New Reactors, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, March 12, 2012, ADAMS Accession No. ML12053A340.

NRC (U.S. Nuclear Regulatory Commission), 2012b, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities", NUREG-2115, ADAMS stores the NUREG as multiple ADAMS documents, which are accessed through the web page http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2115/.

NRC (U.S. Nuclear Regulatory Commission), 2013a. Letter From Eric J. Leeds, to Joseph Pollock, Executive Director NEI, Acceptance Letter for NEI Submittal of Augmented Approach, Ground Motion Model Update Project, and 10 CFR 50.54(f) Schedule Modifications Related to the NTTF Recommendation 2.1, Seismic Reevaluations, May 7, 2013, ADAMS Accession No. ML13106A331.

NRC (U.S. Nuclear Regulatory Commission), 2013b, letter from David L. Skeen, Director, Japan Lessons-Learned Directorate, to Joseph E. Pollock, Executive Director, Nuclear Energy Institute, Endorsement of Electric Power Research Institute Draft Report 1025287, "Seismic Evaluation Guidance," February 15, 2013, ADAMS Accession No. ML12319A074.

NRC (U.S. Nuclear Regulatory Commission), 2013c. Letter from D. L. Skeen (NRC) to K. A. Keithline (NEI), Approval of Electric Power Research Institute Ground Motion Model Review Project Final Report for Use by Central and Eastern United States Nuclear Power Plants, August 28, 2013 ADAMS Accession No. ML13233A102.

NRC (U.S. Nuclear Regulatory Commission) 2014a. Letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation to All Power Reactor Licensees and holders of Construction Permits in Active or Deferred Status, Seismic Screening and Prioritization Results Regarding Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Seismic Hazard Reevaluations for Recommendations 2.1 of the Near-Term Task Force Review of Insights, May 9, 2014, ADAMS Accession No. ML14111A147.

NRC (U.S. Nuclear Regulatory Commission) 2014b. Summary of the June 17, 2014, Category 1 Public Meeting with Exelon and Omaha Public Power District to Discuss Seismic Hazard Reevaluations Associated with Implementation Of Japan Lessons-Learned Near-Term Task Force Recommendation 2.1, Seismic, August 11, 2014, ADAMS Accession No. ML14175A518.

NRC (U.S. Nuclear Regulatory Commission) 2014c. Letter from William Dean, Director, Office of Nuclear Reactor Regulation, to M. Pacilio, Oyster Creek Nuclear Generating Station - Seismic Screening and Prioritization Results Regarding Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Seismic Hazard Reevaluations for Recommendations 2.1 of the Near-Term Task Force Review of Insights, November 28, 2014, ADAMS Accession No. ML14307A638.

NRC (U.S. Nuclear Regulatory Commission) 2015. Letter from W. M. Dean (NRC) to Select Operating Power Reactor Licensees, Final Determination of Licensee Seismic Probabilistic Risk Assessments under the Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54 (f) Regarding Recommendation 2.1 "Seismic" of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, October 27, 2015, ADAMS Accession No. ML 15194A015.

Other References

Barstow, J., 2014a, Exelon Generation Company, LLC, Seismic Hazard and Screening Report (Central and Eastern United States (CEUS) Sites), Response to Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, March 31, 2014, ADAMS Accession No. ML14090A241.

Barstow, J., 2014b, Exelon Generation Company, LLC, Supplemental Information Regarding Seismic Hazard and Screening Report (Central and Eastern United States (CEUS) Sites) - Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, Attachment 3 (Oyster Creek), August 21, 2014, ADAMS Accession No. ML14234A124.

Barstow, J., 2015, Exelon Generation Company, LLC, High Frequency Supplement to Seismic Hazard Screening Report, Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, December 4, 2015, ADAMS Accession No. ML15338A005.

Browning, J.V., Sugarman, P. J., Miller, K. G., and others, 2011. Double Trouble Site, *in* Miller, Sugarman, Browning, et al., Proc. ODp, 174AX (Suppl.), College Station, TX (Ocean Drilling Program), 1-63.

Electric Power Research Institute (EPRI), 2004. EPRI Report 1009684, "CEUS Ground Motion Project Final Report." Palo Alto, CA, 2004.

Electric Power Research Institute (EPRI), 2006. EPRI Report 1014381, "Truncation of the Lognormal Distribution and Value of the Standard Deviation for Ground Motion Models in the Central and Eastern United States." Palo Alto, CA, 2006.

Electric Power Research Institute (EPRI), 2012. 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" November 27, 2012, ADAMS Accession No. ML12333A170.

Electric Power Research Institute (EPRI), 2013. EPRI Ground Motion Model Review Final Report, June 3, 2013, ADAMS Accession No. ML13155A553.

Exelon Generation Company (Exelon), 2013. Oyster Creek Nuclear Generating Station, Updated Final Safety Analysis Report (UFSAR), Revision 18, October 2013.

Kaegi, G.T., 2013, Exelon Generation Company, LLC, Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from Fukushima Dai-ichi Accident – 1.5 Year Response for CEUS Sites, September 12, 2013, ADAMS Accession No. ML13256A070.

Keithline, 2012, NEI Letter from Kimberly Keithline, Senior Project Manager, NEI, to David L. Skeen, Director, Japan Lessons-Learned Project Directorate, NRC, Final Draft of Industry Seismic Evaluation Guidance (EPRI 1025287), November 27, 2012, ADAMS Accession No. ML12333A168.

Miller, K. G., Sugarman, P. J., Browning, J. V., and others, 1998. Bass River Site. *In* Miller, K. G., Sugarman, P. J., Browning, J. V., et al., *Proc. ODB, INIT. Repts.*, 174AX: College Station, TX (Ocean Drilling Program), 5-43.

Pietrangelo, 2013, Letter from A. R. Pietrangelo (NEI) to D. L. Skeen (NRC), Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations, April 9, 2013, ADAMS Accession No. ML13101A379.

Richards, H. G., Olmstead, F. H., and Ruhle, J. L., 1983. *Generalized Structure Contour Maps of the New Jersey Coastal Plain*, Geological Report Series No. 4, New Jersey Geological Survey.

Sugarman, P. J., Monteverde, D. H., Pristas, R., and others, 2011. Characterization of the Carbon Dioxide Storage Potential Beneath the New Jersey Coastal Plain. *In* Final Report on Preliminary Characterization of CO2 Sequestration Potential in New Jersey and the Offshore Coastal Region, 1-44.

Figure 3.3-1 Plot of Staff's and Licensee's Base Case Shear-Wave Velocity Profiles at the Oyster Creek site

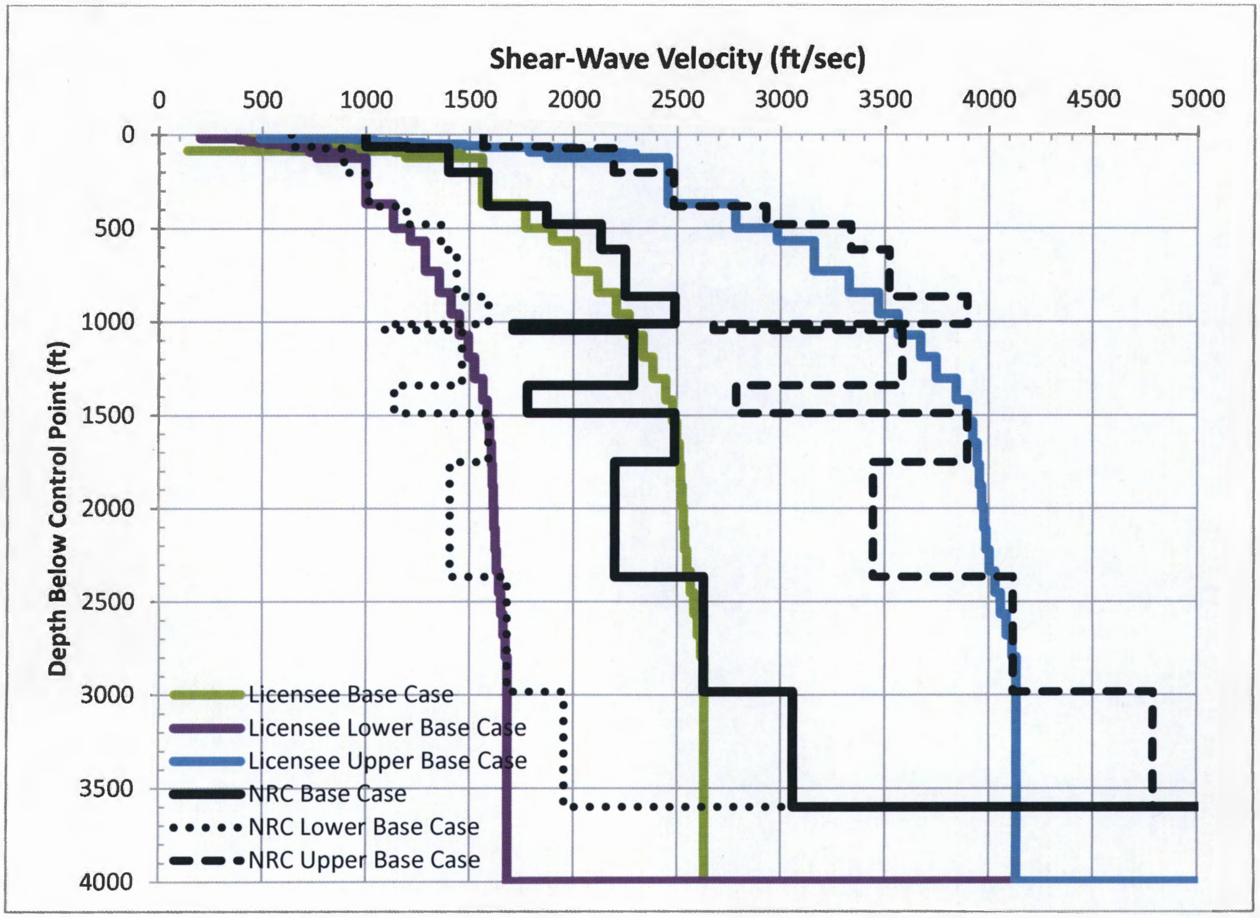


Figure 3.3- 2 Plot Comparing the Staff's and the License's Median Amplification Functions and Uncertainties for two input loading levels at the Oyster Creek site

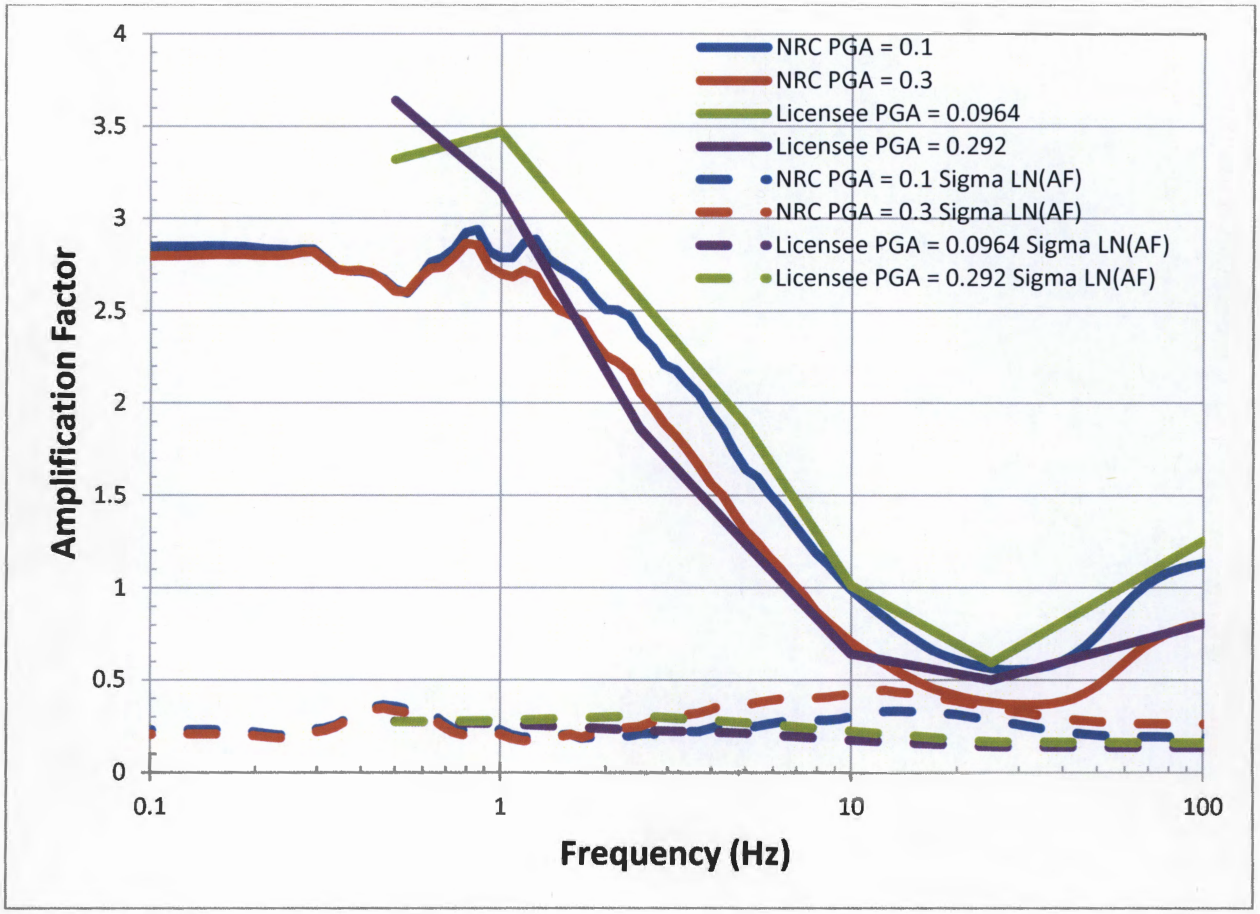


Figure 3.3-3 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies at the Oyster Creek site

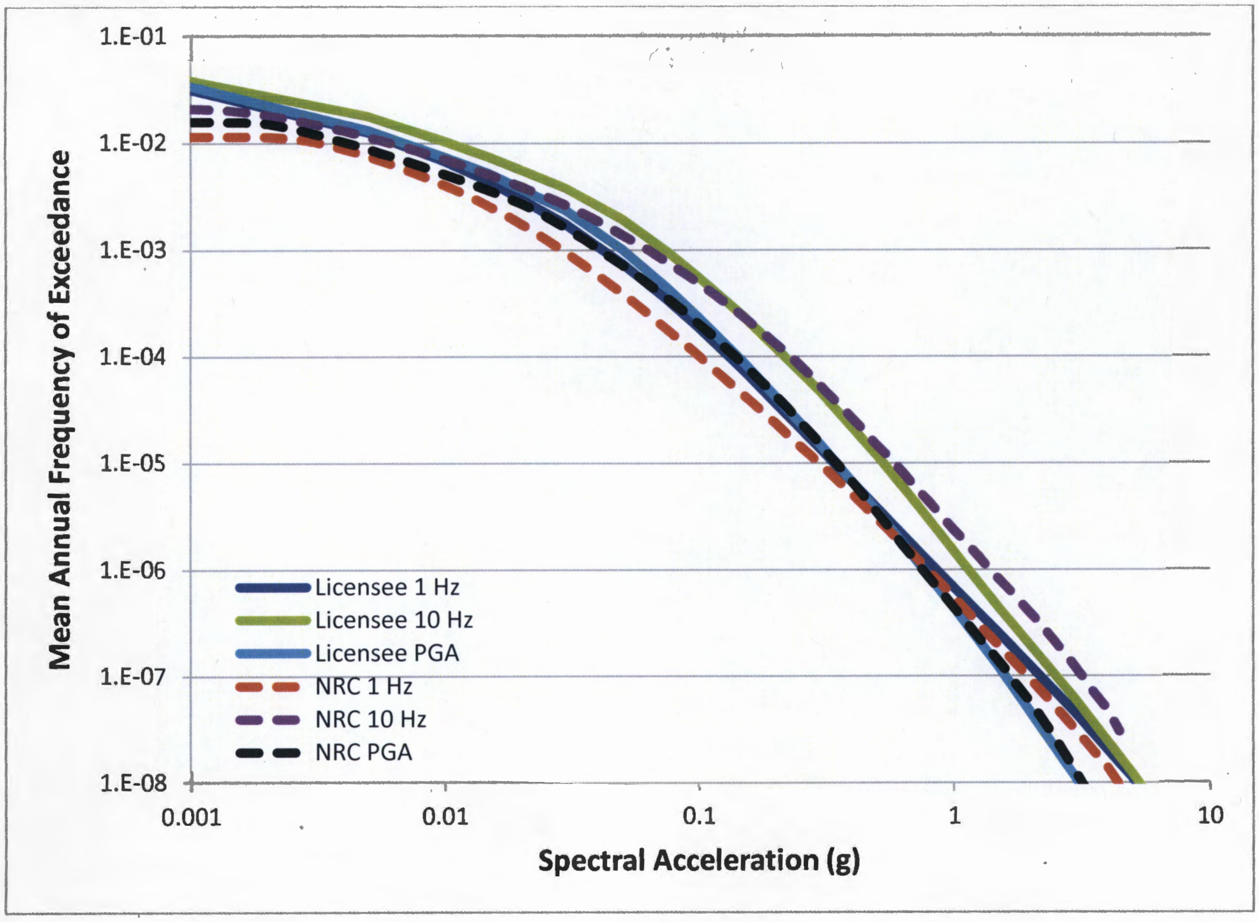
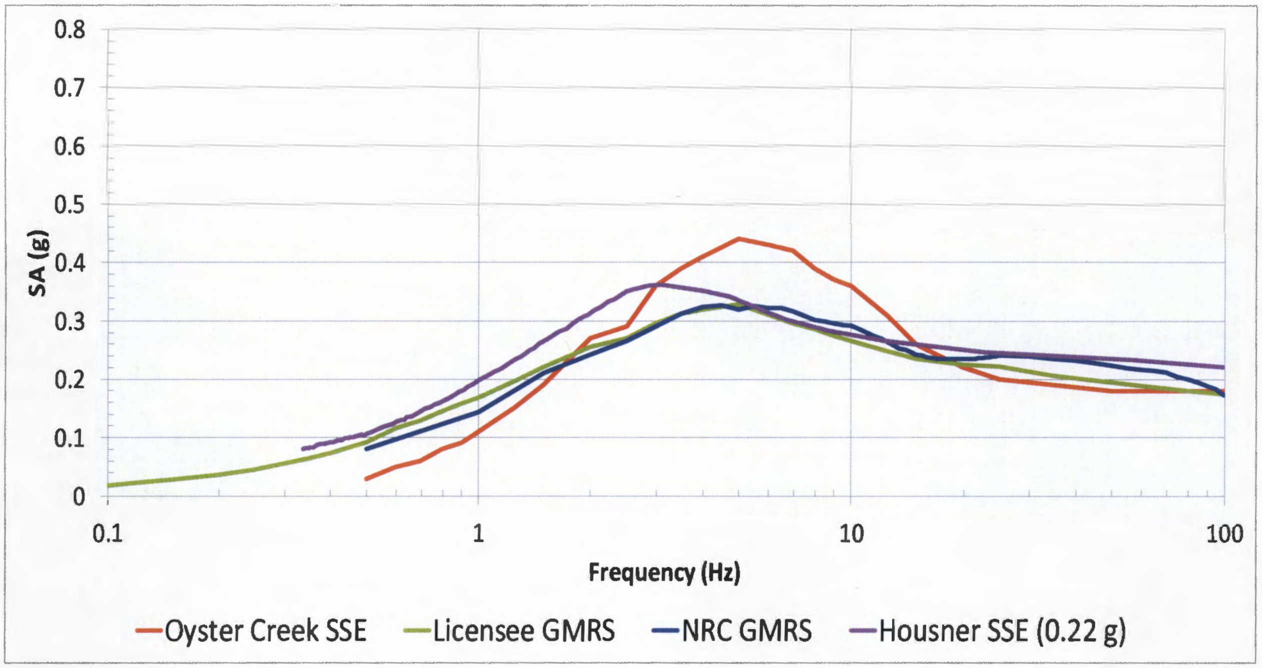


Figure 3.4-1 Comparison of the Staff's GMRS with Licensee's GMRS and the SSE for Oyster Creek.



If you have any questions, please contact me at (301) 415-1115.

Sincerely,

/RA/

Nicholas J DiFrancesco, Senior Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No. 50-219

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