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

February 10, 2016

Mr. Bryan C. Hanson
Senior Vice President
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President and Chief Nuclear Officer
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4300 Winfield Road
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SUBJECT: QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2 - STAFF ASSESSMENT OF INFORMATION PROVIDED PURSUANT TO TITLE 10 OF THE *CODE OF FEDERAL REGULATIONS* PART 50, SECTION 50.54(f), SEISMIC HAZARD REEVALUATIONS FOR RECOMMENDATION 2.1 OF THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT (TAC NOS. MF3879 AND MF3880)

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 Quad Cities Nuclear Power Station, Units 1 and 2 (Quad Cities).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for Quad Cities and as documented in the enclosed staff assessment, determined that you provided sufficient information in response to Enclosure 1, Items (1) - (3), (5) - (9) and the comparison portion to 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".

The staff notes that by letter dated, October 27, 2015 (Agengywide Documents Access and Management System (ADAMS) Accession No. ML15194A015), the NRC staff inadvertently indicated that a spent fuel pool (SFP) evaluation (Item (9)) instead of a high frequency confirmation (Item (4) was expected for Quad Cities. As discussed in this staff assessment, a SFP evaluation is not merited and therefore, Exelon is not required to perform a SFP evaluation for Quad Cities. A high frequency confirmation is merited and expected for Quad Cities.

Contigent upon the NRC's review and acceptance of Exelon's high frequency confirmation (Item 4) for Quad Cities, 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 Vega, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos. 50-254 and 50-265

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

QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2

DOCKET NOS. 50-254 AND 265

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),

[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 NRC 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 (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 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 at least partial site response information for Quad Cities Nuclear Power Station Units 1 and 2 (Quad Cities). By letter dated March 31, 2014 (Kaegi, 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) ground motion models. 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 (Kaegi, 2014), the licensee provided the Quad Cities SHSR. The licensee's SHSR indicates that the site GMRS is bounded by at least one of two SSE design ground motion spectra in the frequency range of 1 to 10 Hertz (Hz). Therefore, the licensee screens out of performing a seismic risk evaluation. Furthermore, because the GMRS is bounded by at least one of the two SSE spectra between 1 and 10 Hz, Quad Cities also screens out of performing a SFP evaluation. Additionally, above 10 Hz, the GMRS is bounded by one SSE spectra, therefore a HF confirmation will not be performed.

On May 9, 2014 (NRC, 2014a), the NRC staff issued a letter providing the outcome of its 30- day, preliminary, screening and prioritization evaluation. In the letter, the NRC staff characterized the Quad Cities site as conditionally screened-in, because additional information was needed to support a screening and prioritization decision. On October 3, 2014 (NRC, 2014b), the NRC staff issued a letter providing the outcome of its final seismic screening and prioritization results. The licensee's GMRS, as well as the staff's confirmatory GMRS, are bounded by the SSE for Quad Cities in the frequency range of 1 to 10 Hz. Therefore, Quad Cities screens out of conducting a risk evaluation, as well as the SFP evaluation. Additionally, due to exceedences of the GMRS in relation to the two SSEs over the frequency range of approximately 15 to 35 Hz, a HF confirmation is merited for Quad Cities.

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 generally characterized by (1) a peak ground acceleration (PGA) value, which anchors the response spectra at high frequencies (typically at 20 to 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.

The Quad Cities UFSAR discusses the two primary design and licensing basis spectra that represent the SSE approved during original licensing. The first spectra is the Golden Gate Park spectra, which is based on the 1957 San Francisco earthquake that was initially used to qualify most system, structures, and components. The second spectra that was introduced in the design and licensing basis was the Housner shape design spectra. The Housner spectra is bounding for frequency lower than 3.77 Hz. The licensee completed reanalysis using the Housner spectra for structures which could control the design. Both SSE spectra were normalized to 0.24g (24 percent of the acceleration due to earth's gravity) peak ground acceleration, which is double the operating basis earthquake.

The staff notes that the licensee maintains a bounding plant spectrum (i.e., TDBD-DQ-1) used to evaluate some engineering design modifications including the extended power uprate project. This bounding engineering spectrum is not reviewed or approved design and licensing basis SSE spectra.

All SSCs were evaluated considering either specific or a combination of these design spectra for any particular frequency of interest. Although the UFSAR does not define the SSE control point, consistent with the SPID, the licensee specified that the SSE control point is at the top of bedrock in the vicinity of the reactor building, roughly the surface of the Silurian dolomite at elevation 550 ft (168 m).

Based on the review of the licensee's submittal and the UFSAR (Exelon, 2013), the NRC staff confirms that the licensee's SSE design ground motion is defined by two design spectra and that the control point elevation determination is consistent with information provided in the Quad Citites UFSAR (Exelon, 2013), as well as guidance 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 Commerce, Eastern Rift Margin – North, Eastern Rift Margin – South, Marianna, New Madrid Fault System, and Wabash Valley Repeated Large Magnitude Earthquake (RLME) sources, which lie within 620 mi (1,000 km) of Quad Cities. 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 its SHSR. The staff's review of the licensee's control point seismic hazard curves is provided in Section 3.3 of this staff assessment.

As part of its confirmatory analysis of the licensee's GMRS, the NRC staff performed PSHA calculations for base rock site conditions at the Quad Cities site. As input, the NRC staff used the CEUS-SSC mode,l 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 Quad Cities site. In addition, the NRC staff included the Commerce, Eastern Rift Margin – North, Eastern Rift Margin – South, Marianna, New Madrid Fault System, and Wabash Valley

RLME sources, which lie within 620 km (1,000 mi) of the Quad Cities 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.

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 correct implementation of the CEUS-SSC model and the updated EPRI GMM.

3.3 Site Response Evaluation

After completing PSHA calculations for reference rock conditions, Attachment 1 to Enclosure 1 of the 50.54(f) letter requests that licensees 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 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. To develop site-specific hazard curves at the control point, the licensee performed a site response analysis.

3.3.1 Site Base Case Profiles

In its SHSR, the licensee indicated that it performed a site response analysis for Quad Cities. According to the licensee, the site rests on 30 to 80 feet of glacial materials overlying the weathered surface of the Niagaran and Alexandrian dolomites of Silurian age. This weathered surface showed some evidence of voids, which were grouted by the licensee. Beneath these dolomites are the Galena Dolomite and Platteville Formations, and the Prairie de Chien Group of Ordivician and Cambrian age sedimentary rocks. Precambrian igneous basement rock is encountered at a depth of about 3,250 ft (991 m).

The licensee provided site profile descriptions in Sections 2.3.1 and 2.3.2 of its SHSR based on information in the Quad Cities UFSAR (Exelon, 2013). The plant surface is at Elevation 595 ft (181 m) and is immediately underlain to Elevation 550 ft (168 m) by glacial deposits. The Silurian Niagaran Formation is encountered between Elevation 550 and 470 ft (168 and 143 m), while the SSE control point is found in the Niagaran at Elevation 550 ft (168 m). From elevation 470 to 300 ft (143 to 91 m) the Silurian Niagaran and Alexandrian Formations are present and older Ordovician and Cambrian sedimentary rocks are encountered from Elevation 300 to -2,700 ft (91 to -823 m), at which point Precambrian basement rock is reached. The licensee noted that its shear wave velocity estimates are based on measured compression wave velocities and an assumed Poisson ratio in the upper 250 ft (76 m). Due to the uncertainty in these shear wave velocity estimates, the licensee used a scale factor of 1.57 to accommodate the large amount of variability at the site.

For the best-estimate profile, the licensee assumed a shear wave velocity of 6,708 ft/s (2,045 m/s) at a depth of 250 ft (76 m) and applied a gradient of 0.5 ft/s/ft resulting in a shear wave velocity of 8,200 ft/s (2,500 m/s) at a depth of 3,250 ft (991 m). For the lower and upper range profiles, the licensee used scale factor of 1.57 consistent with the SPID. For the mean and lower profiles, the licensee extended hard rock to a depth of 3,250 ft (991 m), while the upper profile assumes hard rock at a depth of 80 ft (24 m).

The licensee stated that no site-specific dynamic material properties were determined during the initial investigations of the Quad Cities site. Therefore, the licensee assumed that the rock material in the upper 500 ft (150 m) could be modeled as either linear or non-linear using two sets of shear modulus reduction and hysteretic damping curves. Consistent with the SPID, the licensee determined that the EPRI rock curves (model M1) were appropriate to represent the more nonlinear response. To model the linear behavior of the rock (model M2), the licensee assumed a constant damping value of about 3 percent, which is consistent with the low strain damping from the EPRI rock curves.

The licensee also considered the impact of kappa, or small strain damping, on the 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 Quad Cities site, with at least 3,000 ft (914 m) of firm rock, the licensee estimated kappa values for the best, lower and upper profiles of 0.017 sec, 0.028 sec, and 0.007 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 in accordance with Appendix B of the SPID. The licensee stated that it also varied the depth of the best-estimate and lower profiles by +/- 975 ft (297 m), which is 30 percent of the total 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 eleven 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

The NRC staff performed independent calculations to confirm 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 Quad Cities site.

To perform its confirmatory analysis, the NRC staff utilized information from the Quad Cities Plant Design Analysis Report (PDAR) to estimate the near surface shear wave velocity of the dolomite from the Sulirian Niagaran Formation. Because the estimated near surface shear wave velocity is in the lower range for typical dolomites, NRC staff applied judgement in estimating the lower base case shear wave velocity. The upper base case velocity was estimated using a scale factor of 1.2, corresponding to a natural log standard deviation of 0.15. The NRC staff used the template velocity profiles from the SPID to estimate the shear wave velocities for the deeper layers. Figure 3.3-1 shows a comparison of the licensee's and staff's three base case velocity profiles. As shown in Figure 3.3-1, the staff's profiles are generally higher than the licensee's and do not include the licensee's low velocity zone between 50 and 75 ft (15 and 23 m). The reason for the difference is that the NRC staff relied primarily on the representative dolomitic bedrock properties in Table II-5-2 of the PDAR to characterize the near surface shear wave velocity. As such, the staff's three velocity profiles are generally higher than those estimated by the licensee. In contrast, the licensee appears to have assigned lower velocities to the soft solution-riddled zones between 50 and 75 ft (15 and 23 m). However, these dolomites beneath the plant were grouted prior to construction of the plant and likely now have somewhat higher shear wave velocities.

The NRC staff assumed the upper 500 ft (150 m) of rock material could demonstrate either linear or non-linear dynamic properties. To model the non-linear behavior of the rock, the NRC staff used EPRI Rock shear modulus degradation and damping curves while for the linear behavior, the NRC staff used a constant damping of 1 percent. The NRC staff used a kappa of 0.006 seconds for the base and upper case velocity profiles. For the lower base case velocity profile, the NRC staff used the empirical relationship from the SPID for CEUS rock sites with at least 3,000 ft (1,000 m) of firm sedimentary rock overlying hard rock, which resulted in a kappa value of 0.0144 seconds.

Figure 3.3-2 of this assessment shows a comparison of the staff's and licensee's median site amplification functions and uncertainties for the input loading level of 0.05 g. The licensee's and staff's amplification functions are similar with moderate differences in amplification at 25 Hz.

This difference is due to the differences between the staff's and licensee's near surface shear wave velocity profiles in the upper 50 to 75 ft (15 to 23 m). As shown in Figure 3.3-3, these differences do not substantially impact the lower frequency control point hazard curves, which are very similar. However, the staff's PGA control point hazard curve is moderately higher than the licensee's curve due to the differences in the best estimate base case and upper base case velocity profiles.

Overall, the licensee's approach to modeling the subsurface rock properties and uncertainty results in similar site amplification factors and standard deviation as well as the control point seismic hazard curves. Because the licensee followed the guidance in the SPID for characterizing the site response inputs, these minor differences are acceptable to the NRC staff. 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 to confirm 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 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 below, the licensee's GMRS shape is generally similar to that calculated by the NRC staff up to 10 Hz. At frequencies above 10 Hz, the GMRS determined by the licensee is lower from that determined by the NRC staff. As described above, these 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 concludes that these differences are acceptable for this application because the licensee followed the guidance provided in the SPID with respect to both the PSHA and site response analysis for the Quad Cities site.

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 Quad Cities 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 Quad Cities, Units 1 and 2. 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) – (3) and (5) - (7), and the comparison portion of Item (4), identified in Enclosure 1 of the 50.54(f) letter. Further, the licensee's reevaluated seismic hazard is acceptable to address other actions associated with NTTF Recommendation 2.1: "Seismic".

In reaching this determination, the NRC staff confirms the licensee's conclusion that the licensee's GMRS for the Quad Cities site is bounded by the combination of design spectrum defining the SSE over the 1 to 10 Hz frequency range. As such, a seismic risk evaluation and SFP evaluation (i.e., Requested Information Items (8) and (9)) are not merited. Over the frequency range of approximately 15 to 35 Hz the NRC staff concludes that the GMRS exceeds the SSE and therefore, a HF confirmation (Item 4) is merited. The NRC review and acceptance of Exelon's HF confirmation will complete the Seismic Hazard Evaluation for Quad Cities 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.

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, Director, Office of Nuclear Reactor Regulation 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) 2014. 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. Letter from D. Dorman (NRC) to Operating Power Reactor Licensees on the Enclosed List, Screening and Prioritization Results Regarding Seismic Hazard Reevaluations for Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, October 3, 2014, ADAMS Accession No. ML14258A043.

Other References

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 Report 3002000717 "EPRI (2004, 2006) Ground-Motion Model Review Project Final Report," Palo Alto, CA, 2013.

Kaegi, G., 2013, Letter from G. Kaegi (Exelon Generation Company) to NRC, 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 the Fukushima Dai-ichi Accident – 1.5 Year Response for CEUS Sites, September 12, 2013, ADAMS Accession No. ML13256A070.

Kaegi, G., 2014, Letter from G. Kaegi (Exelon Generation Company) to NRC, 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, March 31, 2014, ADAMS Accession No. ML14090A526.

Keithline, 2012, 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.

Keithline, 2013, Submittal of EPRI (2004, 2006) Ground Motion Model Review Final Report, June 3, 2013, ADAMS Accession No. ML13170A378

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.

Exelon Generation Company (Exelon), Quad Cities Nuclear Generating Station, Updated Final Safety Analysis Report (UFSAR), Revision 12, October 2013.

Figure 3.3-1 Plot of Staff's and Licensee's Base Case Shear-Wave Velocity Profiles for the Quad Cities Site

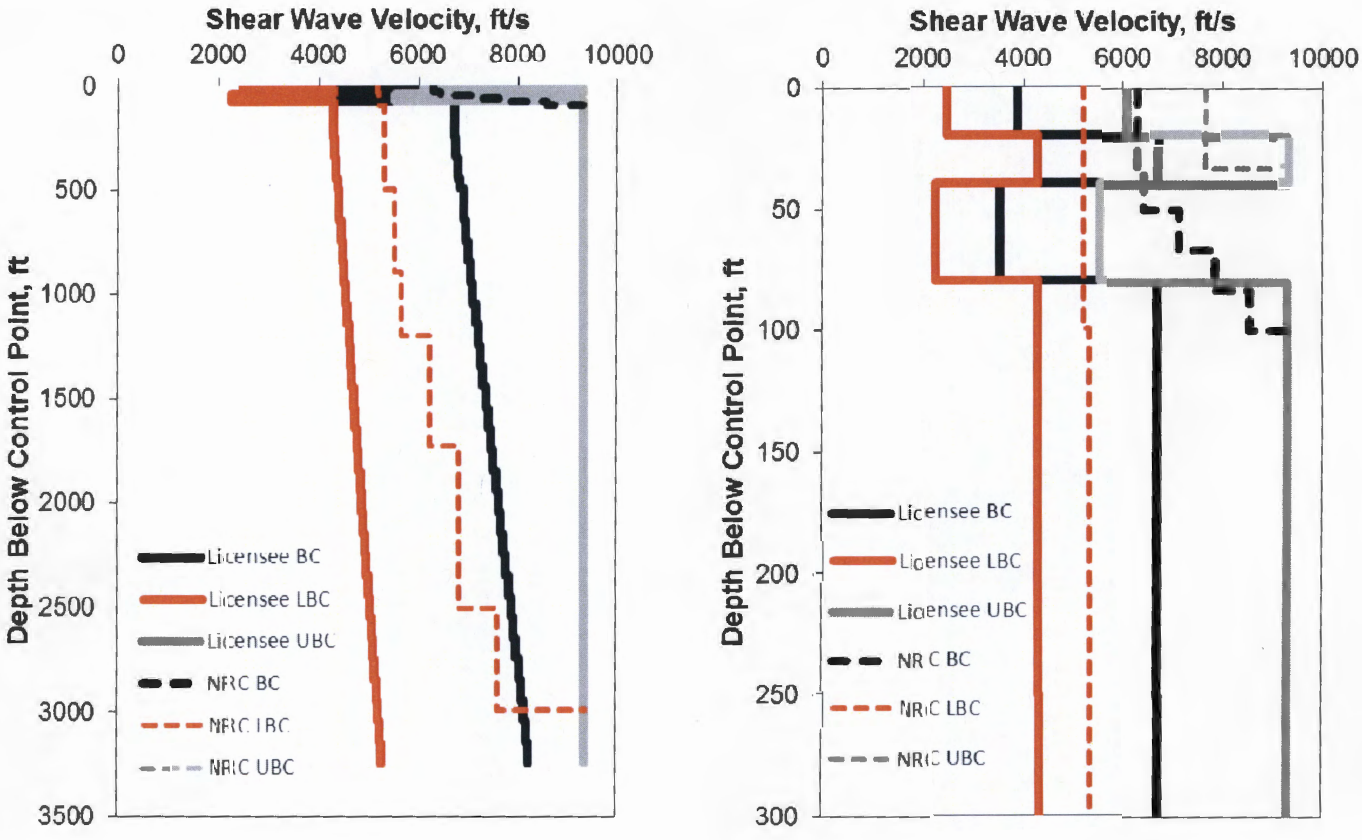


Figure 3.3- 1 Plot Comparing the Staff's and the Licensee's Median Amplification Functions and Uncertainties for the Quad Cities site.

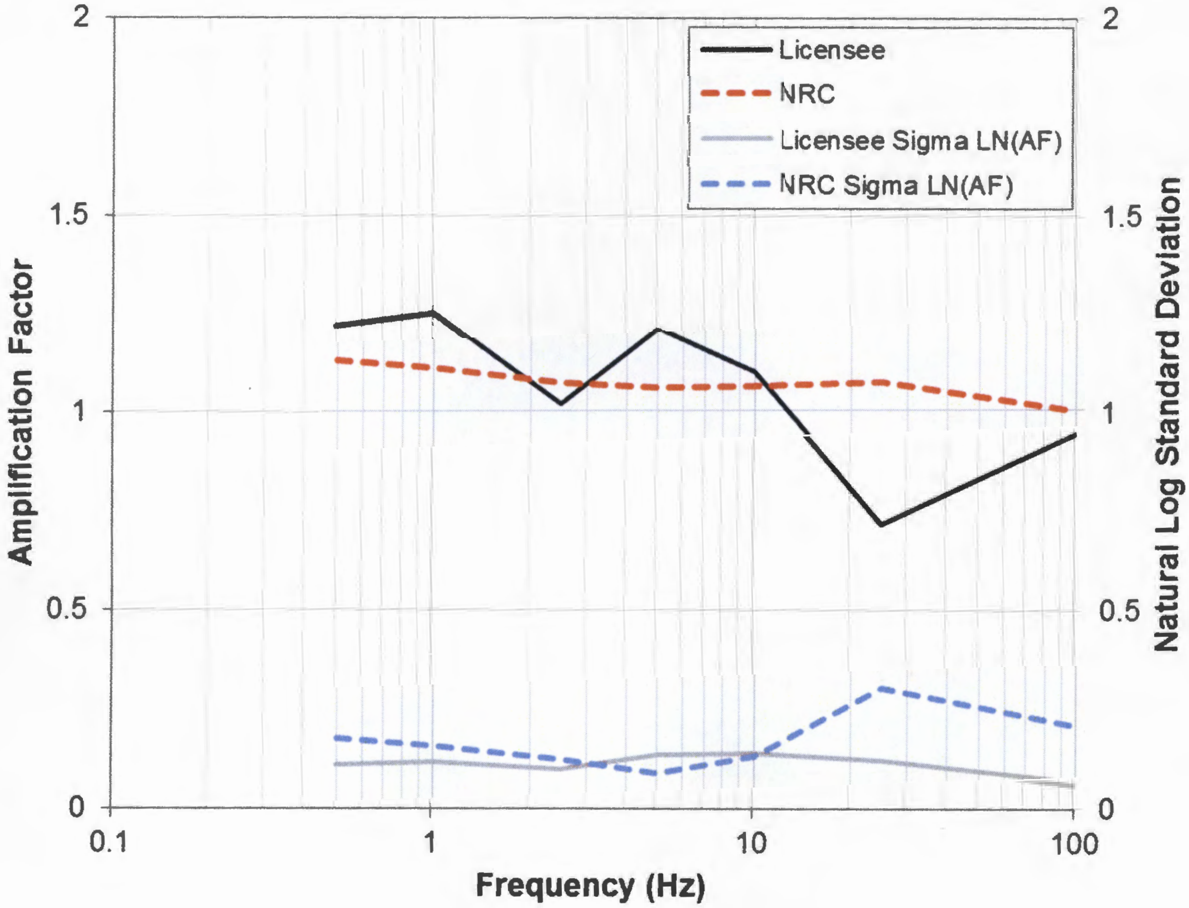


Figure 3.3-2 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the Quad Cities site

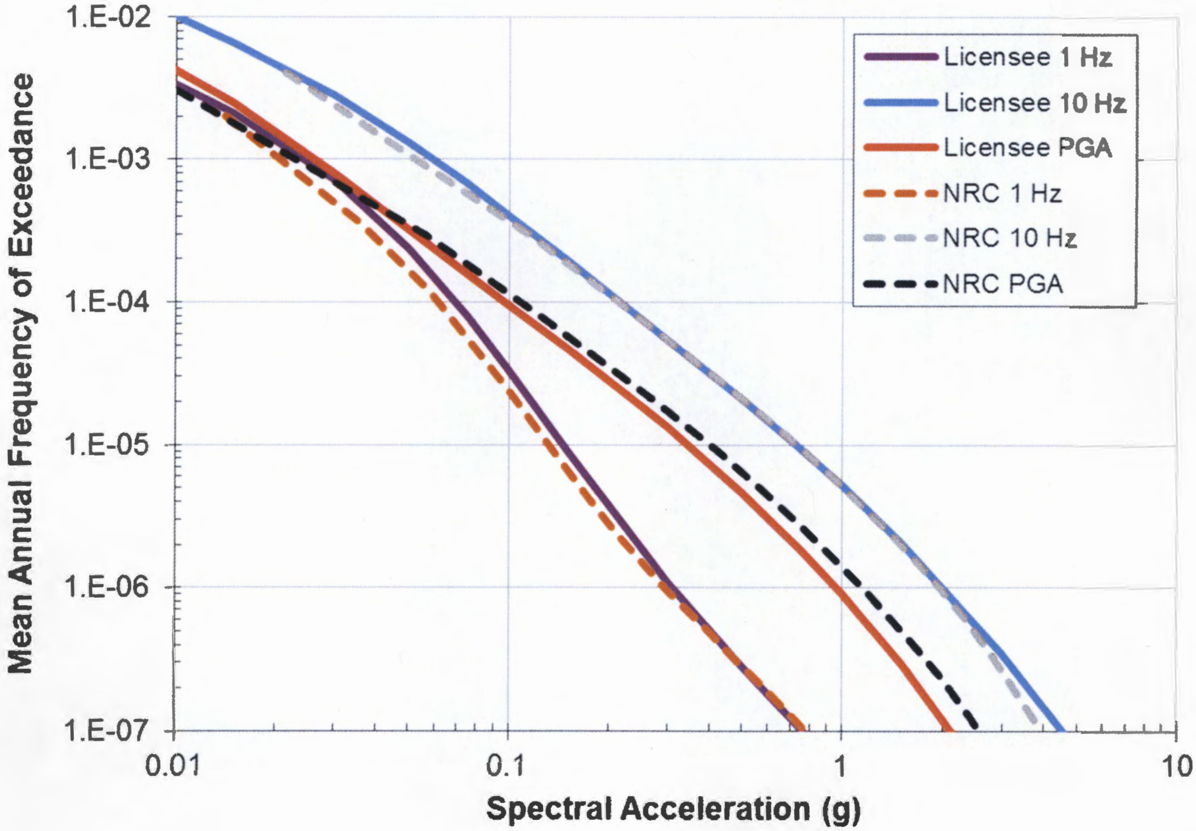
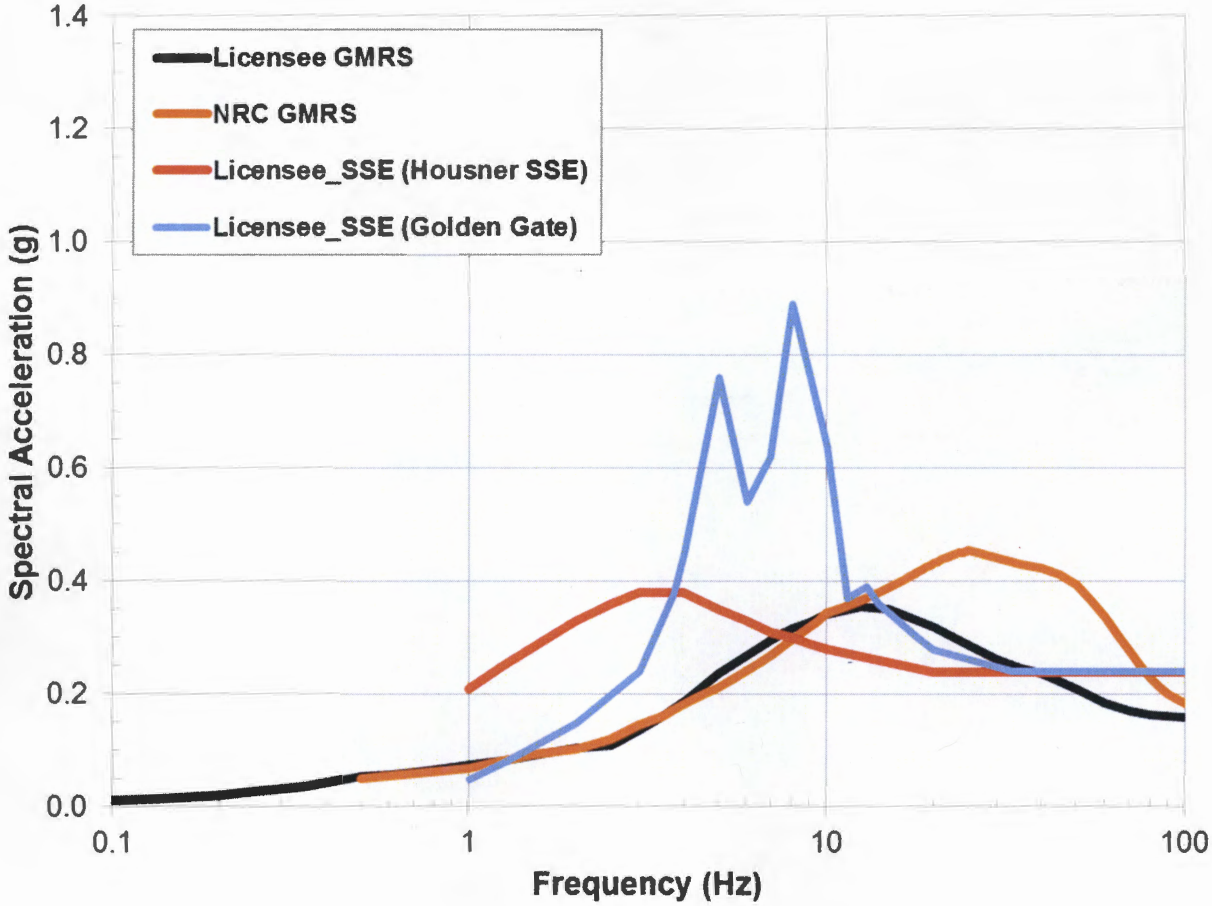


Figure 3.4-1 Comparison of the Staff's GMRS with Licensee's GMRS and the SSE for the Quad Cities site



Contigent upon the NRC's review and acceptance of Exelon's high frequency confirmation (Item 4) for Quad Cities, 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,

/RA/

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

Docket Nos. 50-254 and 50-265

Enclosure:
Staff Assessment of Seismic
Hazard Evaluation and Screening Report

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