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

October 4, 2017

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

SUBJECT: QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2 – FLOOD HAZARD MITIGATION STRATEGIES ASSESSMENT (CAC NOS. MF7966 AND MF7967)

Dear Mr. Hanson:

By letter dated March 12, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12053A340), the U.S. Nuclear Regulatory Commission (NRC) 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 Licenses" (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant, as documented in the NRC's Near-Term Task Force (NTTF) report (ADAMS Accession No. ML111861807).

Enclosure 2 to the 50.54(f) letter requested that licensees reevaluate flood hazards for their sites using present-day methods and regulatory guidance used by the NRC staff when reviewing applications for early site permits and combined licenses (ADAMS Accession No. ML12056A046). Concurrent with the reevaluation of flood hazards, licensees were required to develop and implement mitigating strategies in accordance with NRC Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (ADAMS Accession No. ML12054A735). In order to proceed with implementation of Order EA-12-049, licensees used the current licensing basis flood hazard or the most recent flood hazard information, which may not be based on present-day methodologies and guidance, in the development of their mitigating strategies.

By letter dated December 1, 2016 (ADAMS Accession No. ML16336A805), Exelon Generation Company, LLC (Exelon, the licensee) submitted the mitigation strategies assessment (MSA) for Quad Cities Nuclear Power Station, Units 1 and 2 (Quad Cities). The MSAs are intended to confirm that licensees have adequately addressed the reevaluated flooding hazards within their mitigating strategies for beyond-design-basis external events. The purpose of this letter is to provide the NRC's assessment of the Quad Cities MSA.

The NRC staff has concluded that the Quad Cities MSA was performed consistent with the guidance described in Appendix G of Nuclear Energy Institute 12-06, Revision 2, as endorsed by Japan Lessons-Learned Division (JLD) interim staff guidance (ISG) JLD-ISG-2012-01,

Revision 1, and that the licensee has demonstrated that the mitigation strategies are reasonably protected from reevaluated flood hazards conditions for beyond-design-basis external events. This closes out the NRC's efforts associated with CAC Nos. MF7966 and MF7967.

If you have any questions, please contact me at 301-415-1056 or at Lauren.Gibson@nrc.gov.

Sincerely,

Lauren Kate Gibson

Lauren K. Gibson, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Enclosure:
Staff Assessment Related to the
Mitigating Strategies for Quad Cities

Docket Nos. 50-254 and 50-265

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO MITIGATION STRATEGIES FOR

QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2

AS A RESULT OF THE REEVALUATED FLOODING HAZARD NEAR-TERM TASK FORCE

RECOMMENDATION 2.1- FLOODING CAC NOS. MF7966 AND MF7967

1.0 INTRODUCTION

By letter dated March 12, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12053A340), the U.S. Nuclear Regulatory Commission (NRC) 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 Licenses" (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant, as documented in the NRC's Near-Term Task Force (NTTF) report (ADAMS Accession No. ML111861807). Enclosure 2 to the 50.54(f) letter requested that licensees reevaluate flood hazards for their sites using present-day methods and regulatory guidance used by the NRC staff when reviewing applications for early site permits and combined licenses (ADAMS Accession No. ML12056A046). Concurrent with the reevaluation of flood hazards, licensees were required to develop and implement mitigating strategies in accordance with NRC Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (ADAMS Accession No. ML12054A735). That order requires holders of operating reactor licenses and construction permits issued under 10 CFR Part 50 to modify the plants to provide additional capabilities and defense-in-depth for responding to beyond-design-basis external events, and to submit to the NRC for review a final integrated plan (FIP) that describes how compliance with the requirements of Attachment 2 of the order was achieved. In order to proceed with implementation of Order EA-12-049, licensees used the current licensing basis flood hazard or the most recent flood hazard information, which may not be based on present-day methodologies and guidance, in the development of their mitigating strategies. Quad Cities Nuclear Power Station, Units 1 and 2 (Quad Cities) submitted its flood hazard reevaluation report (FHRR) by letter dated March 12, 2013 (ADAMS Accession No. ML130810038), and supplemented by letters July 3, 2014, January 13, 2015, and October 4, 2016 (ADAMS Accession Nos. ML14238A384, ML15021A179, and ML16278A530, respectively.)

The NRC staff and industry recognized the difficulty in developing and implementing mitigating strategies before completing the reevaluation of flood hazards. The NRC staff described this issue and provided recommendations to the Commission on integrating these related activities in COMSECY-14-0037, "Integration of Mitigating Strategies for Beyond-Design-Basis External Events and the Reevaluation of Flood Hazards," dated November 21, 2014 (ADAMS Accession No. ML14309A256). The Commission issued a staff requirements memorandum on March 30, 2015 (ADAMS Accession No. ML15089A236), affirming that the Commission expects licensees

for operating nuclear power plants to address the reevaluated flood hazards, which are considered beyond-design-basis external events, within their mitigating strategies.

Nuclear Energy Institute (NEI) 12-06, Revision 2, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide" (ADAMS Accession No. ML16005A625), has been endorsed by the NRC as an appropriate methodology for licensees to perform assessments of the mitigating strategies against the reevaluated flood hazards developed in response to the March 12, 2012, 50.54(f) letter. The guidance in NEI 12-06, Revision 2, and Appendix G in particular, supports the proposed Mitigation of Beyond-Design-Basis Events rulemaking. The NRC's endorsement of NEI 12-06, including exceptions, clarifications, and additions, is described in NRC Japan Lessons-Learned Division (JLD) interim staff guidance (ISG) JLD-ISG-2012-01, Revision 1, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (ADAMS Accession No. ML15357A163). Therefore, Appendix G of NEI 12-06, Revision 2, describes acceptable methods for demonstrating that the reevaluated flooding hazard is addressed within the Quad Cities mitigating strategies for beyond-design-basis external events.

2.0 BACKGROUND

By letter dated September 4, 2015 (ADAMS Accession No. ML15238B672), the NRC issued an interim staff response (ISR) letter for Quad Cities. The letter provided the reevaluated flood hazards that exceeded the current design basis (CDB) for Quad Cities and were suitable inputs for the mitigating strategies assessment (MSA) (i.e., defines the mitigating strategies flood hazard information described in NEI guidance document NEI 12-06). For Quad Cities, the mechanisms listed as not bounded by the CDB in the letter are local intense precipitation (LIP) and failure of dams/onsite water control/storage structures.

The letter also stated that NRC staff would evaluate, as applicable, the flood event duration (FED) parameters (including warning time and period of inundation) and flood-related associated effects (AEs) developed by the licensee during the NRC staff's review of the MSA. This is consistent with the guidance provided in Revision 2 of NEI 12-06. By letter dated December 1, 2016 (ADAMS Accession No. ML16336A805), Exelon Generation Company, LLC (Exelon, the licensee) submitted the MSA for Quad Cities. The MSA also included the relevant information regarding the FED parameters and AEs needed to complete the review. The licensee had also provided AEs and FED parameters by letter dated October 4, 2016 (ADAMS Accession No. ML16278A530).

3.0 TECHNICAL EVALUATION

3.1 Mitigating Strategies under Order EA-12-049

Quad Cities is not yet required to be in compliance with the Mitigating Strategies Order[1]. When the licensee submits its compliance letter and final integrated plan (FIP), the NRC staff will evaluate the strategies in the plan and will document the review in a safety evaluation. The intent of the safety evaluation is to inform the licensee whether or not its integrated plans, if

[1] By letter dated March 21, 2017 (ADAMS Accession No. ML17025A248), the NRC relaxed the requirement for full implementation of Order EA-12-049 until June 30, 2018.

implemented as described, appear to adequately address the requirements of Order EA-12-049. An inspection will confirm compliance with the order.

The licensee provided an Overall Integrated Plan (OIP) by letter dated February 28, 2013 (ADAMS Accession No. ML13060A420). The NRC provided its review of the plan by letter dated November 22, 2013 (ADAMS Accession No. ML13220A351). The FIP will be an updated and/or modified version of the OIP.

A brief summary of the Quad Cities FLEX strategies as described in the MSA are listed below:

- Phase 1: The RCIC [reactor core isolation cooling] system provides core cooling and reactor makeup. Electric power for the relief valves and instrumentation is provided by station batteries, whose life is extended by a deep load shed.

- Phase 2: FLEX portable equipment is transported to the pre-established deployment locations and connected. Reactor and spent fuel makeup capability is provided by an installed seismically qualified well (preferred) or directly from the plant circulating water discharge bay. FLEX diesels provide power to the station batteries and other AC loads.

- Phase 3: Offsite equipment is available, if needed.

3.2 Evaluation of Current FLEX strategies

In the MSA, Section 5 states that:

> The reevaluated (MSFHI [mitigating strategies flood hazard information]) flood parameters . . . were incorporated as a design input to all FLEX related plant modifications. Additionally, when established, the FLEX strategies were reviewed and modified to ensure that all FLEX related activities could be performed for the reevaluated flood hazard conditions . . .

The licensee is not yet required to be in compliance with the Mitigating Strategies Order. The licensee did note, however, that they have modified the FLEX strategies from the OIP to account for the reevaluated hazard levels for LIP and failure of dams / onsite water control/storage structures. The reevaluated flood elevations for LIP and failure of dams / onsite water control/storage structures are being used as inputs in developing the FLEX strategy, including aspects related to the storage and deployment of FLEX equipment, validation of FLEX actions, and viability of FLEX connection points.

Local Intense Precipitation

In the MSA, Table 2 provides a comparison of the FLEX design-basis flood hazard and the MSFHI for LIP. The licensee has made a few changes to account for the reevaluated hazard. These include the installation of barriers to protect critical plant equipment from water intrusion, increasing the height of vent piping for the emergency diesel underground fuel storage tanks, and modifying the roof parapets to reduce the structural load from excessive ponding. Furthermore, LIP was considered as a design input for the FLEX storage building and the deployment of the FLEX equipment.

The staff finds it reasonable that the LIP event will not negatively impact the implementation of the licensee's FLEX strategy because the strategy is being designed with the LIP event as a consideration.

Riverine Flooding Probable Maximum Flood, Dam Failure, and Wind-Wave Event Combination

Quad Cities is located on the east bank of the Mississippi River near Cordova, Illinois. In the MSA, Table 3 provides a comparison of the FLEX design-basis flood hazard and the MSFHI for the combined-effect flood (flood caused by precipitation plus hydrologic dam failure). The licensee states, "All flood preparation activities are completed prior to the flood level exceeding plant grade." Both units will be shut down and decay heat will be removed using normal procedures. As stated in the Updated Final Safety Analysis Report, the drywell head and reactor vessel head will be removed on both units, and the refueling cavity flooded. The licensee will use the flood mitigation timeline that was validated during the NRC On-site Flooding Walkdown Audit as described in the NRC Flooding Walkdown Audit Report dated February 21, 2014 (ADAMS Accession No. ML13326A263).

The NRC staff did not evaluate this strategy at this time because it does not employ the FLEX strategies. It is part of the current licensing basis, and, therefore, the NRC staff will consider whether any changes to it are warranted and justified after receiving the licensee's integrated assessment in response to the March 12, 2012, 50.54(f) letter.

However, the NRC notes that the licensee incorporated the river flood-causing mechanisms as an input into all FLEX-related design considerations.

3.3 Confirmation of the Flood Hazard Elevations in the MSA

The NRC staff reviewed the flood hazard elevations in the MSA, and confirmed the elevations match values in the site's ISR. For the LIP flood-causing mechanism, the MSA reports a maximum flood level of 597.7 feet (ft.) in vertical datum North American Vertical Datum of 1988 (NAVD88), which is equivalent to 598.4 ft. in vertical datum mean sea level (MSL) 1912 presented in the ISR letter. The MSA reports that plant grade level is at 595 ft. MSL1912.

3.4 Evaluation of Flood Event Duration

The staff reviewed information provided by the licensee in its MSA and in its letter dated October 4, 2016, regarding the FED parameters for flood hazards not bounded by the CDB. The FED parameters for the flood-causing mechanisms not bounded by the CDB are summarized in Table 3.3.2-1 below.

For the LIP flood-causing mechanism, the licensee stated that warning time procedures are consistent with NEI 15-05, "Warning Time for Local Intense Precipitation Events," Revision 6, dated April 8, 2015 (ADAMS Accession No. ML15104A158). They also reported that the periods of inundation and recession are 8 hours and 12 hours, respectively. For the LIP flood-causing mechanism, the maximum water elevations are listed in Table 1 of the MSA. The licensee used a 2-dimensional numerical modeling method to estimate the periods of inundation and recession. The staff confirmed that the licensee's reevaluation of the period of inundation and recession uses present-day methodologies and regulatory guidance.

For the dam failure combined with precipitation events flood-causing mechanism, the licensee states a warning time period of 76 hours from receiving the flood level forecast to the start of the 96 hour site preparation time prior to the flood waters exceeding site grade level. The licensee relied on a numerical modeling approach to simulate flood elevations and FED parameters for a postulated dam-failure event. The licensee determined a period of inundation of 240 hours and a period of recession of 24 hours. The staff noted that the licensee's warning time is conservatively small as it does not include the forecasting time for the PMP event. The staff confirmed in its review of the FHRR that the licensee's dam failure modeling used present-day methodologies and regulatory guidance (staff assessment dated November 18, 2016 (ADAMS Accession No. ML16323A343)).

In summary, the NRC staff agrees with the licensee's conclusion related to determining the FED parameters as the approach is consistent with the guidelines provided by Appendix G of NEI 12-06, Revision 2. Based on this review, the staff determined that the licensee's FED parameters are reasonable and acceptable for use in the MSA.

3.5 Evaluation of Associated Effects

The staff reviewed the information provided by the licensee in its MSA and in its letter dated October 4, 2016, regarding reevaluated AE parameters for flood hazards not bounded by the CDB. The AE parameters related to water surface elevation (i.e., stillwater elevation with wind waves and runup effects) were previously reviewed by staff, and were transmitted to the licensee via the ISR. The AE parameters not directly associated with water surface elevation are discussed below and are summarized in Table 3.3.3-1.

For the LIP flood-causing mechanism, the licensee provided hydrostatic and hydrodynamic loads. This estimation is based on results from a 2-dimensional numerical modeling method. The licensee stated in its MSA, that sediment deposition and erosion is not expected as part of the LIP flood-causing mechanism because of the slow water velocities and shallow water depths. The licensee also stated in its MSA, that other AEs, including, debris, groundwater ingress, and other AEs, are minimal for the LIP event due to shallow flow depths and relatively slow flow velocities. The staff confirmed the AE parameters by reviewing the licensee-provided LIP model's input and output files. The staff confirmed that the inundation depths and flow velocities used to estimate hydrostatic and hydrodynamic loads are reasonable for use as part of the MSA. Correspondingly, the staff agrees with the licensee's assessment of the AE parameters for the LIP event.

For the dam failure combined with precipitation events flood-causing mechanism, the licensee analyzed the potential for debris loads using methods provided in Federal Emergency Management Agency (FEMA) P-259, "Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures," third edition. A debris weight estimate of 1,000 pounds (lbs.) (454 kg) was obtained from design load standard ASCE/SEI-7-10 (American Society of Civil Engineers (ASCE), 2012, "Minimum Design Loads for Buildings and Other Structures") as described in the 2015 supplement to the FHRR. Also in its January 13, 2015, FHRR supplement the licensee stated that an impact loading of 480 lbs. was estimated based on a maximum flood velocity at the site of 0.6 ft./s. The licensee also stated in its MSA, that all other AEs, including sediment deposition and erosion, debris, groundwater ingress, and other AEs, are either minimal or not applicable for the dam failure flood-causing mechanism. In the staff

assessment of the FHRR, the staff confirmed that the licensee-provided justifications and discussions related to these AE parameters are reasonable and acceptable as the licensee applied the FEMA and ASCE guidance correctly and appropriately. The staff reviewed the potential for a barge to impact critical plant structures during the dam failure event and concluded that direct impact by a barge is highly unlikely due to low overbank flow velocity at the site.

In summary, the staff concludes the licensee's methods were appropriate and the licensee-provided AE parameters are reasonable for use in the MSA.

3 CONCLUSION

The NRC staff has reviewed the information provided in the Quad Cities MSA related to the original FLEX strategies, as evaluated against the reevaluated hazard(s) described in Section 3 of this staff assessment, and found that:

- The FLEX design-basis incorporates the reevaluated hazards in the ISR.

Therefore, the NRC staff concludes that the licensee has followed the guidance in NEI 12-06, Revision 2, and, it appears reasonable that the licensee has the capability to deploy the FLEX strategies, as designed, against LIP.

Table 3.3.2-1. Flood Event Durations for Flood-Causing Mechanisms Not Bounded by the CDB

Flood-Causing Mechanism	Time Available for Preparation for Flood Event	Duration of Inundation of Site	Time for Water to Recede from Site
Local Intense Precipitation and Associated Drainage	Consistent with NEI 15-5 (NEI, 2015)	8 hours	12 hours
Failure of Dams and Onsite Water Control/Storage Structures [1]	96 hours for preparation or 76 hours for warning time	240 hours	24 hours

Source: the MSA and the letter dated October 4, 2016

TABLE 3.3.3-1. ASSOCIATED EFFECTS PARAMETERS NOT DIRECTLY ASSOCIATED WITH TOTAL WATER HEIGHT FOR FLOOD-CAUSING MECHANISMS NOT BOUNDED BY THE CDB

Associated Effects Parameter	Local Intense Precipitation and Associated Drainage	Failure of Dams and Onsite Water Control/Storage Structures [1]
Hydrodynamic loading at plant grade	280 lb./ft.	3.6 lb./ft. (equivalent hydrostatic)
Debris loading at plant grade	Minimal	480 lb.
Sediment loading at plant grade	Minimal	Minimal
Sediment deposition and erosion	Minimal	Minimal
Concurrent conditions, including adverse weather - Winds	Minimal	Not Applicable
Groundwater ingress	Minimal	Not Applicable
Other pertinent factors (e.g., waterborne projectiles)	Minimal	Not Applicable

Source: the MSA and the letter dated October 4, 2016

QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2 – FLOOD HAZARD MITIGATION STRATEGIES ASSESSMENT DATED October 4, 2017

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