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

March 6, 2019

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: DRESDEN NUCLEAR POWER STATION, UNITS 2 AND 3 – STAFF ASSESSMENT OF FLOOD HAZARD INTEGRATED ASSESSMENT (CAC NOS. MG0221 AND MG0222; EPID L-2017-JLD-0050)

Dear Mr. Hanson:

The purpose of this letter is to document the staff's evaluation of the Dresden Nuclear Power Station, Units 2 and 3 (Dresden) flooding integrated assessment (IA) which was submitted in response to Near-Term Task Force (NTTF) Recommendation 2.1 "Flooding." The U.S. Nuclear Regulatory Commission (NRC) has concluded that that the results and risk insights provided by the Dresden flooding IA and the staff's independent assessment support the NRC's determination that no further response or regulatory actions are required.

By letter dated March 12, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12053A340), the NRC issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, under Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f), 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 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). By letter dated May 10, 2013 (ADAMS Accession No. ML131350111), Exelon Generation Company, LLC (Exelon, the licensee) submitted its flood hazard reevaluation report (FHRR) for Dresden. The licensee supplemented its FHRR by letter dated January 31, 2014 (ADAMS Accession No. ML14031A443). In response to an NRC Request for Additional Information dated April 9, 2014 (ADAMS Accession No. ML14070A589), the licensee further supplemented its FHRR by letter dated May 19, 2014 (ADAMS Accession No. ML15092A821).

After reviewing the licensee's response, the NRC staff issued a staff assessment of the FHRR by letter dated March 31, 2015 (ADAMS Accession No. ML15072A007), and supplemented the assessment by letter dated November 4, 2015 (ADAMS Accession No. ML15307A056). These letters affirmed that the local intense precipitation (LIP) and dam failure flood-causing mechanisms at Dresden are not bounded by the plant's current design basis, and, therefore, additional assessments of the flood hazard mechanisms are necessary.

By letter dated September 8, 2017 (ADAMS Accession No. ML17251A365), the licensee submitted its integrated assessment for Dresden. Integrated assessments are intended for the NRC to assess the site's capability to cope with the reevaluated hazard and to determine if additional regulatory actions are necessary under the backfit regulation. The purpose of this staff assessment is to provide the results of the NRC's evaluation of the Dresden integrated assessment.

As set forth in the attached staff assessment, the NRC staff has concluded that the Dresden integrated assessment was performed consistent with the guidance described in Nuclear Energy Institute (NEI) 16-05, Revision 1, "External Flooding Assessment Guidelines" (ADAMS Accession No. ML16165A178), and consistent with the NRC staff endorsement of that guidance. Guidance document NEI 16-05, Revision 1, has been endorsed by Japan Lessons-Learned Division (JLD) interim staff guidance (ISG) JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flood Hazard Reevaluation" (ADAMS Accession No. ML16162A301).

The NRC staff has further concluded that the licensee has demonstrated that effective flood protection, if appropriately implemented, exists for the LIP flooding mechanism. In addition, the NRC staff has concluded that for the combined effects riverine flooding mechanism the licensee has an effective mitigation strategy for floods to 520.2 ft. mean sea level (MSL), and a feasible mitigation strategy for higher, less frequent floods. The staff considered the following in reaching its conclusion for the combined effects riverine flooding mechanism:

1. the site flooding response does not substantially change with the additional foot of water from the reevaluated hazard,

2. opening the turbine bay to flood waters and using a barge-mounted pump for core cooling and SFP cooling is the current licensing basis for floods substantially above site grade,

3. the licensee has an effective strategy to respond to floods below site grade and to a level of 521 ft. (which is greater than the staff developed 1E-3 annual exceedance probability with margin flood level of 520.2 ft. MSL),

4. the licensee has a feasible strategy for less frequent floods above 521 ft. MSL,

5. the staff has inspected, audited, and reviewed, as appropriate, pertinent provision of the licensee's strategy and found it acceptable.

Based on the above, no additional regulatory actions are necessary.

If you have any questions, please contact Joseph Sebrosky at 301-415-1132, or by e-mail at Joseph.Sebrosky@nrc.gov.

Sincerely,

Louise Lund, Director
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket Nos: 50-237 and 50-249

Enclosure:
Staff Assessment Related to the
Flooding Integrated Assessment for Dresden

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO THE INTEGRATED ASSESSMENT

FOR DRESDEN NUCLEAR POWER STATION, UNITS 2 AND 3

AS A RESULT OF THE REEVALUATED FLOODING HAZARD

NEAR-TERM TASK FORCE RECOMMENDATION 2.1 - FLOODING

CAC NOS. MG0221 AND MG0222, EPID L-2017-JLD-0050

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), 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 of the 50.54(f) letter requested that licensees reevaluate flood hazards for their respective 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). If the reevaluated hazard for any flood-causing mechanism is not bounded by the plant's current design basis (CDB) flood hazard, an additional assessment of plant response would be necessary. Specifically, the 50.54(f) letter states that an integrated assessment should be submitted, and described the information that the integrated assessment should contain. By letter dated November 30, 2012 (ADAMS Accession No. ML12311A214), the NRC staff issued Japan Lessons-Learned Project Directorate (JLD) interim staff guidance (ISG) JLD-ISG-2012-05, "Guidance for Performing the Integrated Assessment for External Flooding."

On June 30, 2015 (ADAMS Accession No. ML15153A104), the NRC staff issued COMSECY-15-0019, describing the closure plan for the reevaluation of flooding hazards for operating nuclear power plants. The Commission approved the closure plan on July 28, 2015 (ADAMS Accession No. ML15209A682). COMSECY-15-0019 outlines a revised process for addressing cases in which the reevaluated flood hazard is not bounded by the plant's CDB. The revised process describes a graded approach in which licensees with hazards exceeding their CDB flood may not be required to complete an integrated assessment, but instead may perform a focused evaluation (FE). By letter dated September 1, 2015 (ADAMS Accession No. ML15174A257), the NRC informed all affected licensees of the plan to use a graded approach in addressing the reevaluated flood hazard.

Nuclear Energy Institute (NEI) 16-05, Revision 1, "External Flooding Assessment Guidelines" (ADAMS Accession No. ML16165A178), was issued by NEI to describe a method of applying a graded approach to address the reevaluated flood hazards. It has been endorsed by the NRC as an appropriate methodology for licensees to use in response to the 50.54(f) letter. The NRC's endorsement of NEI 16-05, including exceptions, clarifications, and additions, is described in NRC JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flood Hazard Reevaluation" (ADAMS Accession No. ML16162A301). Therefore, NEI 16-05, Revision 1, as endorsed, describes acceptable methods for Dresden to address their response to the reevaluated flood hazard mechanisms.

The NRC staff described how the licensee's assessment of the reevaluated hazard would be reviewed to determine if further regulatory action should be taken, such as backfitting additional safety enhancements, in an internal memorandum dated September 21, 2016 (ADAMS Accession No. ML16237A103). This memorandum describes the formation of a Senior Management Review Panel (SMRP) consisting of three division directors from the Office of Nuclear Reactor Regulation that are expected to reach a decision for each plant submitting an integrated assessment. The SMRP is supported by NRC technical staff who are responsible for consolidating relevant information and developing recommendations for the consideration of the panel. In presenting recommendations to the SMRP, the supporting technical staff is expected to recommend placement of each flooding IA plant into one of three groups:

1) **Group 1** will include plants for which available information clearly indicates that further regulatory action is not warranted. For flooding hazards, Group 1 will include plants that have demonstrated (1) effective protection for severe flood hazards, and (2) that consequential flooding is expected to occur only for hazards with a sufficiently small mean annual frequency of exceedance.

2) **Group 2** will include plants for which it is clear that further regulatory action should be considered under the NRC's backfit provisions. This group may include plants that are unable to protect against relatively frequent flood hazards such that the event frequency in combination with other factors result in a risk to public health and safety for which a regulatory action is expected to provide a substantial safety enhancement.

3) **Group 3** will include plants for which further regulatory action may be needed, but for which more thorough consideration of both qualitative and quantitative risk insights is needed before determining whether a formal backfit analysis is warranted.

The evaluation process that was performed to provide the basis for the staff's grouping recommendation to the SMRP for Dresden is described below.

2.0 BACKGROUND

This document provides the final NRC staff assessment associated with the information that the licensee provided in response to the reevaluated flooding hazard portion of the 50.54(f) letter. Therefore, this background section includes a summary description of the reevaluated flood information provided by the licensee and the associated assessments performed by the NRC staff. The reevaluated flood information includes: 1) the flood hazard reevaluation report (FHRR); 2) the mitigation strategies assessment (MSA); and 3) the integrated assessment (IA).

Flood Hazard Reevaluation Report

By letter dated May 10, 2013 (ADAMS Accession No. ML131350111), Exelon Generation Company, LLC (Exelon, the licensee) submitted its FHRR for the Dresden Nuclear Power

Station, Units 2 and 3 (Dresden). The licensee supplemented its FHRR by letter dated January 31, 2014 (ADAMS Accession No. ML14031A443). In response to a request for additional information dated April 9, 2014 (ADAMS Accession No. ML14070A589), the licensee further supplemented its FHRR by letter dated May 19, 2014 (ADAMS Accession No. ML15092A821). After reviewing the licensee's responses, the NRC staff issued a staff assessment of the FHRR by letter dated March 31, 2015 (ADAMS Accession No. ML15072A007), and supplemented the assessment by letter dated November 4, 2015 (ADAMS Accession No. ML15307A056). These letters affirmed that the local intense precipitation (LIP) and dam failure flood-causing mechanisms at Dresden are not bounded by the plant's CDB, and, therefore, additional assessments of the flood hazard mechanisms are necessary.

Mitigation Strategies Assessment

By letter dated June 30, 2016 (ADAMS Accession No. ML16182A388), the licensee submitted the flooding MSA for Dresden for review by the NRC staff. The MSAs were intended to confirm that licensees had adequately addressed the reevaluated flooding hazards within their mitigating strategies for beyond-design-basis external events that were put in place to meet NRC Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events." Elevations given in this staff assessment are elevation above mean sea level (MSL). The NRC staff's safety evaluation for the licensee's compliance plans for Order EA-12-049 was issued on February 16, 2017 (ADAMS Accession No. ML17037C929), and accepted the licensee's mitigation strategy for coping with the current licensing basis flood of 528 feet (ft.) MSL.

By letter dated December 8, 2016 (ADAMS Accession No. ML16300A199), and corrected by letter dated March 29, 2017 (ADAMS Accession No. ML17076A198), the NRC staff issued its assessment of the Dresden MSA, in which the licensee stated that the mitigation strategies were based on the FHRR dam failure flooding mechanism and therefore could be successfully implemented under the reevaluated flood hazard conditions. For LIP, the licensee concluded that no modifications to their mitigation strategies were needed. The NRC staff concluded that the licensee demonstrated that the mitigation strategies could be successfully implemented for the reevaluated flood hazard conditions for beyond-design-basis external events.

Integrated Assessment

By letter dated September 8, 2017 (ADAMS Accession No. ML17251A365), the licensee submitted its IA for Dresden. The IAs are intended for the NRC to assess the site's capability to cope with the reevaluated flood hazard and to determine if additional regulatory actions are necessary. These regulatory actions would be taken in accordance with 10 CFR 50.109, "Backfitting." The purpose of this staff assessment is to provide the results of the NRC staff's evaluation of the Dresden IA.

3.0 TECHNICAL EVALUATION

Dresden, Units 2 and 3, are General Electric boiling-water reactors (BWRs), Model 3, with Mark I containments and isolation condensers. There is no reactor core isolation cooling system, but there is a high-pressure coolant injection (HPCI) system. The Dresden site is located on the south bank of the confluence of the Des Plaines and Kankakee Rivers that forms the Illinois River. The site is just upstream of the United States Army Corps of Engineers (USACE) Dresden Island Lock and Dam. As stated in the IA, the design plant grade is at elevation 517.0 ft. MSL and the finished floor elevation of both Units 2 and 3 is 517.5 ft. MSL.

Guidance document NEI 16-05, Revision 1, as endorsed, describes the different flood impact assessments paths. For LIP, the licensee is pursuing Path 2 in order to confirm that they have adequately demonstrated that effective flood protection is provided for the unbounded mechanism. For riverine flooding, including failure of upstream dams, the licensee is pursuing Path 5, a scenario-based approach. Because the assessment includes paths other than Paths 1-3 of NEI 16-05, an IA was required instead of a focused evaluation. The current licensing basis for Dresden was exceeded for two mechanisms, as described in the table below.

Table 3.0-1

Mechanism	Water Surface Elevation		NEI 16-05, Revision 1 Path
	Current Licensing Basis (MSL)	Reevaluated Hazard Water Level (MSL)	
Local Intense Precipitation (LIP)	517.5 ft.	517.6 ft. to 518.1 ft.	2 (Effective Flood Protection)
Combined Effects (Riverine Flooding + Dam Failure + wind wave run-up)	528.0 ft.	529.0 ft.	5 (Scenario Based Approach)

Since the site response to each of these mechanisms is different, the NRC evaluated them separately below.

3.1 Characterization of Flood Parameters

Associated effects (AE) and flood event duration (FED) parameters were assessed by Exelon and have already been reviewed by the NRC, as summarized by letters dated March 31, 2015 (ADAMS Accession No. ML15072A007), and November 4, 2015 (ADAMS Accession No. ML15307A056). Exelon used the AE and FED parameters as input to the Dresden IA.

3.2 Local Intense Precipitation

For LIP, the NRC staff evaluated the impact of the unbounded mechanism, the available physical margin, and the reliability of the site protection features. No assessment of the overall site response was necessary since no time-critical actions were identified. Although the licensee analyzed a 1-hour LIP event in its FHRR, the staff notes that LIP events could last for longer time periods.

3.2.1 Description of Impact of Unbounded Flood Mechanism

The expected water surface elevations throughout the site for the reevaluated LIP range from 517.6 ft. MSL to 518.1 ft. MSL, all of which exceed the ground level finished floor elevation of 517.5 ft. MSL. Some flood water is therefore expected to ingress into the reactor building through the secondary containment interlock door seals. However, the licensee determined that there was no impact on safety-related equipment or installed FLEX equipment.

3.2.2 Evaluation of Available Physical Margin and Reliability of Flood Protection Features

The licensee calculated the expected water ingress based on the allowable leakage area through the interlock seals and compared the depth of the water to the elevation of safety-related equipment and installed FLEX equipment. The licensee found that the minimum available physical margin was to the installed FLEX pumps in the torus basement. Without crediting the installed sump pumps, the margin is 2.2 inches. Therefore, no impact on key structures, systems, or components is expected as a result of LIP.

The licensee relies on permanently installed features, including the reactor building doors, to provide flood protection. The licensee therefore evaluated the combined impact and static loads that were described in Table 4, Enclosure 1 of the FHRR and compared them to the design-basis wind loads. In all cases, the design-basis wind loads bounded the impact and static loads from LIP. For personnel doors, the licensee determined a safety factor of 3.6. For rollup/bay doors, the licensee determined a safety factor of 9.4. Therefore, the NRC staff concludes that the doors meet the definition of being reliable to maintain key safety functions found in Appendix B of NEI 16-05, Revision 1, as endorsed.

Because increased focus has been placed on flood protection since the accident at Fukushima, licensees and NRC inspectors have identified deficiencies with equipment, procedures, and analyses relied on to either prevent or mitigate the effects of external flooding at a number of licensed facilities. Recent examples include those found in NRC Information Notice 2015-01, "Degraded Ability to Mitigate Flooding Events" (ADAMS Accession No. ML14279A268).

In addition, the NRC is cooperatively performing research with the Electric Power Research Institute to develop flood protection systems guidance that focuses on flood protection feature descriptions, design criteria, inspections, and available testing methods in accordance with a memorandum of understanding dated September 28, 2016 (ADAMS Accession No. ML16223A495). Therefore, the NRC staff expects that licensees will continue to maintain flood protection features in accordance with their current licensing basis. The NRC staff further expects that continued research involving flood protection systems will be performed and shared with licensees in accordance with the guidance provided in Management Directive 8.7, "Reactor Operating Experience Program," (ADAMS Accession No. ML122750292), as appropriate.

3.2.3 Conclusion

The NRC staff concludes that available physical margin and reliable flood protection features exist for the LIP flooding mechanism.

3.3 Combined Effects (Riverine Flooding and Wind Wave Run Up)

For this combined effects flood mechanism, the licensee is pursuing Path 5, whose purpose is to demonstrate an effective response to consequential flooding that has a relatively high likelihood of occurrence, and a feasible response to mitigate the effects of an extreme flood with a low likelihood of occurrence. Guidance document NEI 16-05, Revision 1, as endorsed, states that floods with an annual exceedance probability (AEP) of 1E-4 (or 1E-3 with margin) should be considered for the more frequent floods. The licensee selected an AEP of 1E-4 to use as the upper limit of the more frequent floods. The NRC staff reviewed the licensee's determination of the consequential flooding elevation corresponding to an AEP of 1E-4, which the licensee stated was 516.3 ft. MSL at the 95 percent confidence limit. The licensee's AEP of 1E-4 includes a 2-foot increase above the computed value to account for uncertainties. The NRC staff also reviewed the proposed site response to scenarios both above and below that elevation to determine if additional regulatory actions are necessary.

3.3.1 Current Licensing Basis Flooding Response

Dresden was initially considered a dry site. In 1982, a formal flood analysis as part of the NRC's Systematic Evaluation Program[1] indicated that flood waters would be above site grade. In response, the licensee developed a flood strategy. This strategy allowed the reactor building and turbine building to flood, which reduces the hydrostatic forces on the buildings. By letter dated December 16, 2016 (ADAMS Accession No. ML17353A045), the licensee informed the NRC that its flood strategy had been changed. The licensee informed the NRC of its plan to install a suppression pool vent system in the reactor building in accordance with NRC Order EA-13-109, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions." In order to ensure that the vent system would function correctly during flooding events, the licensee informed the NRC of its intention to install reactor building flood barriers when warning is received of the potential for a riverine flood event which will exceed the site grade level.

The reactor building flood barriers are designed to keep flood waters from entering the suppression pool. Without the reactor building flood barriers, flooding above the finished floor elevation (i.e., 517.5 ft. MSL) could enter the reactor building and be directed to the torus basement. Under such a scenario, the suppression pool within the torus would be susceptible to becoming water solid due to the flood water ingress through the torus to reactor building vacuum breakers installed on top of the torus at reference elevation 511 ft. MSL. In addition, and depending on the flood depth, the flood waters could also enter the drywell through the torus downcomers. If the wetwell and drywell are flooded, the wetwell ventilation path would be rendered unavailable as drywell pressurization would push flood water up the hardened containment vent path resulting in a vent path water seal.

In a letter dated January 12, 2018 (ADAMS Accession No. ML18012A111), the licensee stated that Dresden, Units 2 and 3 were in compliance with the Order EA-13-109. The staff evaluated the licensee's hardened containment vent system (including the plan to install reactor building flood barriers) in a safety evaluation dated April 27, 2018 (ADAMS Accession No. ML18079A382). The April 27, 2018, safety evaluation concluded that the licensee has developed guidance that includes the safe operation of the hardened containment vent system design and a water management strategy that, if implemented appropriately, should adequately address the requirements of Order EA-13-109. The staff evaluated implementation of the hardened containment vent system plans through inspection, using Temporary Instruction 2515 - 193, "Inspection of the Implementation of EA-13-109: Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions" (ADAMS Accession No. ML17249A105). In an inspection report dated July 30, 2018 (ADAMS Accession No. ML18211A542), the inspectors verified plans for complying with NRC Order EA–13–109 are in place and are being implemented by the licensee, and that no violation or findings were identified.

Consistent with the licensee's plans associated with Order EA-13-109, the licensee noted in its IA that the plate-type flood barriers are designed to cover all reactor building openings for the probable maximum flood (PMF) conditions. In engineering change (EC) 391644, the licensee evaluated water heights up to 529 ft. MSL on the exterior of the reactor building, and 525 ft. MSL internal to the building structures, where waves do not have an effect. The maximum expected flood level in the current licensing basis is 528 ft. MSL, which includes 3-foot waves.

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[1] In 1977, the NRC initiated the Systematic Evaluation Program (SEP) to review the designs of operating power plants that had been licensed before 1975 when the Standard Review Plan was issued. For more information regarding the SEP see NUREG-0933, "Resolution of Generic Safety Issues," Generic Issue 156: "Systematic Evaluation Program," available at: https://www.nrc.gov/sr0933/

This current licensing basis is described in the Updated Final Safety Analysis Report (UFSAR), Revision 12, Section 3.4.1.1 (ADAMS Accession No. ML17179A524).

As described in the IA, the current flood mitigation plan for floods above elevation 517 ft. MSL is as follows. The licensee will shut down and cool down both reactors and shift core cooling to the isolation condensers prior to the flood reaching elevation 513 ft. MSL. The isolation condensers are fed with cooling water using a diesel-powered isolation condenser makeup (ICMU) pump. Plant personnel will open doors to the turbine building and inside the turbine building will deploy two FLEX diesel-powered flood pumps placed on a floating platform (barge) that rises and falls with the flood level. One flood pump provides sufficient water for both units, the second pump is a backup.

When the flood level reaches elevation 518 ft. MSL, the barge mounted FLEX flood pump is aligned and started. The pump takes flood water suction from the test boiler pit in the turbine building and delivers this water to the fire header at elevation 538 ft. MSL. The flood pump provides make-up water to the isolation condensers, spent fuel pools and the reactor pressure vessel until flood waters recede and recovery and cleanup activities start. Starting the FLEX flood pump at a flood elevation of 518 ft. MSL provides sufficient time to transition from the ICMU pumps to the barge mounted FLEX flood pumps.

As described in the IA, after core cooling is shifted to the isolation condensers, the two diesel-ICMU pumps, which are permanent plant equipment, will initially be used to maintain core cooling by providing water to the shell side of the isolation condensers. This water comes from the clean demineralized water tank, which is next to the ICMU pump building. Because the flood waters have not yet flooded the turbine building, initially there is no water for the FLEX flood pump to pump. The NRC staff notes that the ICMU pump building and the clean demineralized water tank are surrounded by several large structures, which would provide shielding from floating debris. The staff notes that prior to the flood reaching elevation 517 ft. MSL offsite power is available to allow multiple sources of clean water to be used as a water supply for the ICMU pumps. When the flood levels reach elevation 517 ft. MSL, then power will be removed from transformers and MCCs on elevation 517 feet.

Also, a FLEX diesel generator is placed inside the turbine building above the flood height before flood waters arrive, and cables are connected to power vital plant equipment if other power sources are lost. The NRC staff issued a safety evaluation for NRC Order EA-12-049 by letter dated February 16, 2016 (ADAMS Accession No. ML17037C929), which found this strategy acceptable for compliance with the order. The FLEX flood pump takes suction from the water that has entered through the open roll-up door to the turbine bay and collected in the pit used for condenser tube removal. The pump will then provide makeup water to the isolation condensers, the reactor pressure vessel, and the spent fuel pools.

The licensee's current licensing basis for this flooding mechanism is 528 ft. MSL as described in Section 3.4.1.1 of the licensee's updated final safety analysis report (ADAMS Accession No. ML17179A528). As stated in the licensee's FHRR submittal in 2013, the flooding response plan includes the floating barge that would rise and fall with the flood level. Based on a site visit, the NRC staff did not identify any impediments to the existing barge being able to float as high as 529 ft. MSL.

3.3.2 Technical Evaluation of Hydrostatic, Hydrodynamic, and Floatation Forces on Buildings

As described in a letter dated July 18, 2017 (ADAMS Accession No. ML17192A452), the staff audited information related to the installation of reactor building flood barriers when warning is received of the potential for a riverine flood event which will exceed the site grade level. Specifically, the staff audited analyses that were performed to demonstrate that the reactor building and other structures important to safety can withstand hydrostatic, hydrodynamic, and buoyancy (flotation) loads generated by the reevaluated flood hazard. The staff also audited analyses that were performed to demonstrate that plate-type flood barriers can withstand loads generated by the reevaluated flood hazard. In addition, the NRC staff reviewed the work done to verify that no other penetrations could leak water into the reactor building.

The licensee initiated these calculations to support the implementation of NRC Order EA-13-109. As discussed in Section 3.3.1 of this assessment, the strategy for venting the containment, per NRC Order EA-13-109, includes keeping flood waters from entering the suppression pool, which could challenge the functionality of the vent system.

Although the installation of the reactor building flood barriers does not involve a license amendment and the staff's evaluation of the licensee's plans for compliance with vent Order EA-13-109 discusses these barriers, the staff performed a more detailed assessment of the ability of these flood barriers to withstand hydrostatic, hydrodynamic and flotation forces on key buildings. The basis for the staff's more detailed structural assessment is to support its review of the Dresden IA in accordance with NEI 16-05, Revision 1 guidance, as endorsed by the NRC. Specifically, the staff's assessment was done to support a determination of whether Dresden, Units 2 and 3 have effective flood protection for the more frequent flood scenarios and feasible flood protection for the less frequent flood scenarios.

The NRC staff audited documents supporting the licensee's statements regarding the use of plate-type flood barriers and the structural capacity and stability of structures during the reevaluated flood. The staff audited the licensee's analysis No. DRE12-0079, Revision 2, "Evaluation of Plant Structures for Probable Maximum Flood Loads." In DRE12-0079, the licensee documented its assessment of the structural adequacy of the reactor building, reactor building trackway, HPCI Pump Building, HPCI access tunnel, the emergency diesel generator (EDG) Building, the Turbine Building, and the EDG room against loads associated with the reevaluated flood level. These buildings are reinforced concrete structures and the walls were credited as flood barriers. Document DRE12-0079 includes capacity calculations and finite element analyses of these flood-barrier walls under hydrostatic and hydrodynamic loads and the flotation analysis during the reevaluated flood event. The licensee concluded that the buildings have sufficient capacity to withstand the forces generated by the reevaluated flood and that none of the buildings will be adversely affected by buoyancy effects. The calculation also stated that the dominant load combinations were assessed per the American Concrete Institute (ACI) 349-97, "Code Requirements for Nuclear Safety Related Concrete Structures," which includes other design loads considered to determine the required strength for all structural elements.

The NRC staff referred to the guidance in Appendix B of NEI 16-05, Revision 1, as endorsed, to assess the information in DRE12-0079. This guidance states that concrete barriers are to be evaluated for static load, hydrodynamic loading from wave effects and debris, foundation design and treatment, removal of problem soils, stability, maintenance and surveillance. The NRC confirmed that DRE12-0079 verified the capacity of the structures mentioned above against the credible loads from the reevaluated flood event, as suggested in NEI 16-05, Revision 1. The NRC staff also compared the methodologies implemented in DRE12-0079 with accepted engineering standards found in Chapter 3.0 of NUREG-0800, "Design of Structure, Components, Equipment, and Systems." The NRC staff concludes that the calculation followed acceptable methodologies to demonstrate the structural capacity of the buildings during the flood. Regarding maintenance and surveillance, these buildings are considered important to safety and receive periodic inspections and maintenance. Therefore, the NRC staff concludes, based on the information provided by the licensee, that the reinforced concrete walls of these buildings (i.e., reactor building, reactor building trackway, HPCI Pump Building, HPCI access tunnel, the EDG Building, the Turbine Building, and the EDG room) meet the performance criteria in Appendix B of NEI 16-05, Revision 1, as endorsed by the NRC.

Another aspect of interest for the staff is the analysis performed to demonstrate that doors and flood barriers installed to prevent water intrusion are capable of performing their intended function. To support its conclusion regarding this aspect of the licensee's assessment, the staff audited Calculation DRE12-0078, Revision 1, "Barrier Design for Probable Maximum Flood Protection." In this document, the licensee evaluated the design and configuration of doors and identified locations where removable (plate-like) flood barriers would be installed. The document states that a walkdown of these doors was completed to assess the condition of door frames and adjacent walls where anchor attachments for the removable flood barrier would be installed. The removable barriers are described as made of aluminum or steel and are installed via anchors drilled into the reinforced concrete walls. Calculation DRE12-0078 assessed the capacity of these doors and removable barriers against pressure loads generated from the flood. As described in DRE12-0078, defects identified in doors and other vulnerabilities were identified and corrected to ensure flood protection.

To assess the information in Calculation DRE12-0078, the NRC staff referred to the guidance in Appendix B of NEI 16-05, Revision 1, as endorsed by the NRC. The guidance calls for consideration of hydrostatic force resistance, hydrodynamic force resistance, and debris impact force resistance. The NRC staff confirmed that the licensee considered the loading conditions identified in NEI 16-05, Revision 1, as endorsed by the NRC. The guidance also calls for consideration of accepted engineering practices for design, testing, installation, storage, and maintenance of these features. The NRC confirmed that information provided during the audit process covers design and testing of these barriers and that both design and testing were completed in accordance with standard engineering practices. Also, the NRC staff confirmed that guidance for installation of the removable barriers is provided in the Work Planning Instructions for EC 391644, in Document MA-DR-MM-6-00101, Revision 6, "Maintenance Activities for Site Flooding," in the Control Room Technical Requirements Manual, and other weather response related procedures for Dresden. Regarding storage, the licensee stated that these removable barriers are stored close to locations where they are to be installed in the event of a flood. The removable barriers are stored inside the buildings and protected from the environment. The NRC staff evaluated the information provided by the licensee and concludes that the doors and removable flood barriers to be used in the reactor building conform to the guidance in NEI 16-05, Revision 1, as endorsed by the NRC.

In addition, the licensee performed an analysis of other penetrations that may leak into the reactor building. The licensee assessed penetrations outside and inside the different buildings for water tightness under the assumed worst flooding condition (529 ft. MSL outside the buildings, and 525 ft. MSL inside the building). This information is covered by EC 391644, which was made available to the NRC staff for audit. The licensee stated that it performed walkdowns and identified penetrations that required further verifications, modifications, and/or repair. The corrective actions associated with this effort were reported as completed. The NRC staff referred to the guidance in Appendix B to NEI 16-05, Revision 1, as endorsed, to assess the work done for penetration seals and plugs. Section B.2.1.5 of NEI 16-05, Revision 1, refers to NEI 12-07, "Guidelines for Performing Verification Walkdowns of Plant Flood Protection Features" (ADAMS Accession No. ML12173A215), with consideration to NRC memorandum dated December 23, 2013 (ADAMS Accession No. ML13325A891). These two references are to be used with the reevaluated flood elevations to ensure that plugs and penetrations are adequately evaluated.

Both NEI 12-07 and the NRC memorandum dated December 23, 2013, state that available physical margin should be demonstrated when assessing flood protection features. In EC 391644, the licensee assessed the capacity of penetration seals against flood conditions and concluded that the seals can perform their intended function during the flood and that the seals have available physical margin. The NRC staff audited this calculation and found it to be sufficient to support the licensee's conclusions regarding the penetration seals and that these seals have available physical margin quantified as capacity against the flood pressures. The NRC staff concludes that the licensee followed the guidance in NEI 16-05, Revision 1, as endorsed, when addressing penetration seals.

Regarding the flood waters potentially entering the reactor building and affecting the hardened containment vent, Document EC 407086, Revision 000, "Reactor Building Flood Barrier In-Leakage," assesses the possibility of water intrusion into the suppression pool. As stated in EC 407086, in the event of water intrusion through narrow spaces between door frames and walls or doors, the amount of water entering the reactor building during the flood event will not affect the performance of the hardened containment vent. The NRC staff audited this EC to further understand the basis for the licensee's statements. In document EC 407086, the licensee estimated the flow rate of water that could leak through the flood barriers into the reactor building and the amount of time that it would take for the water to prevent the hardened vent functionality. The licensee concluded that the amount of time needed for the waters to affect the containment vent functionality exceeds the flood event duration with margin. The NRC staff assessed the licensee's analysis and concludes that the approach and assumptions documented in EC 407086 support the licensee's conclusion that leakage past the flood seals will not affect the containment vent functionality.

The licensee also evaluated the structural capacity and stability of the Isolation Condenser Pump House (ICPH) against the reevaluated flood. The ICPH is a small masonry and reinforced concrete structure categorized as Seismic Class II and located right next to the reactor building. The ICPH houses the ICMU pumps credited for core cooling. Flood protection for the ICPH is provided up to elevation 521 ft. MSL. To support its analysis of the ICPH, the staff audited multiple documents. Analysis document 01849.00-S(M)-005, Revision 1, "Isolation Condenser Pump House - Flotation of the Isolation Condenser Pump House," concludes that the ICPH can withstand the buoyancy forces from the flood if the ICPH basement is purposely flooded up to 6 ft. before the external flood reaches 517 ft. MSL. The licensee included guidance for intentionally flooding the ICPH basement in its site flooding procedure (Document MA-DR-MM-6-00101). DRE12-0080, Revision 3, "Isolation Condenser Pump House Flood Protection Details," stated that Exelon designed and evaluated flood barriers of the ICPH against a flood elevation of 521 ft. MSL. In DRE12-0079, the licensee stated that stability of the ICPH during floods higher than 521 ft. MSL relies on the skin friction between the ICPH concrete foundation walls and the surrounding soil. Also in DRE12-0079, the licensee stated that the ICPH is doweled into the reactor building at the interfaces of walls and concrete slabs and that this structural connection should provide stability during the flood.

As done with other structures at Dresden, the NRC staff referred to the guidance in NEI 16-05, Revision 1, as endorsed, to determine if the ICPH can perform as described by the licensee. The NRC staff assessed the information regarding the structural capacity of the ICPH in DRE12-0079 and found it to have followed acceptable engineering practices, consistent with the licensee's analysis for the other structures. The NRC staff reviewed the design information of the flood barriers in DRE12-0080 and found that it considers hydrostatic, hydrodynamic, and debris impact loads as stated in the NEI 16-05 guidance. The NRC staff confirmed that installation, storage and maintenance information for the ICPH flood barriers are documented in EC 391096, Revision 24, "Isolation Condenser Pump House Flood Protection," and that this information is consistent with its respective criteria in NEI 16-05, Revision 1, as endorsed. The NRC staff also assessed the stability of the ICPH structure during the flood event. The NRC audited flooding procedure for Dresden (Document MA-DR-MM-6-00101) and concludes that it provides guidance to flood the ICPH basement to a minimum of 6 ft. to stabilize the structure against buoyancy.

The NRC staff performed a confirmatory calculation of the counteracting forces (opposing buoyancy) needed to maintain the ICPH building in place during the 521 ft. MSL flood elevation, as done by the licensee. This approach was considered conservative given that the 521 ft. MSL elevation is above the elevation where the ICMU pumps are credited because the FLEX makeup pumps would be aligned and put in service to take over the ICMU function when water elevation reaches 518 ft.

The resulting forces needed for stability of the ICPH were compared against the estimated skin friction (inherent) force between the concrete foundation vertical walls and the surrounding rock/soil layer, as stated in DRE12-0079. After comparing these forces, the NRC staff concludes that skin friction should be sufficient to stabilize the ICPH against buoyancy during the 521 ft. MSL flood event. The NRC staff did not review the structural connection between the ICPH and the reactor building, but it is reasonable to expect this connection will provide additional margin over the skin friction forces acting to stabilize the ICPH.

Based on the information provided by the licensee, and the NRC staff analysis described above, the staff concludes that the ICPH should not be affected by buoyancy forces during the period of operation for the ICMU pumps to support the proposed strategy.

3.3.3 Mitigating Strategies Assessment for Flooding

The licensee did not identify the need to make any changes to its mitigating strategies to account for the reevaluated combined effects PMF hazard of 529 ft. MSL. In its MSA, the licensee stated that the reevaluated hazard information was used as a design basis for their mitigating strategies. The NRC staff concluded in its staff assessment of the MSA that the licensee had demonstrated the capability to implement the original FLEX strategies, developed in response to Order EA-12-049, under the conditions associated with the combined effects PMF flood.

3.3.4 Feasible Response for Floods with a Low Frequency of Occurrence

Based on the licensee's flood hazard assessment, the licensee chose a site grade of 517 ft. MSL as a dividing point between consequential and non-consequential floods. For floods above 517 ft. MSL, the licensee will implement the FLEX strategy for flooding, which is the same strategy that is used for their current licensing basis flooding. The difference between the current licensing basis flood hazard elevation (528 ft. MSL) and the reevaluated flood hazard elevation (529 ft. MSL) is one foot. The NRC staff concludes that the successful implementation of the FLEX strategy for flooding would not be adversely affected by the addition of one foot of water.

3.3.5 Assessment of Consequential Flood Scenario Likelihood

As described in Section 1.0 of this staff assessment, NEI 16-05 presents methods which may be used to address flood scenarios and was endorsed by NRC with limited clarifications in JLD-ISG-16-01. In the Closure Plan for Reevaluation of Flooding Hazards for Operating Nuclear Power Plants (COMSECY-15-0019), the staff clarified that, "...if a flooding hazard associated with a frequency of 10^{-4} per year cannot be defined in a timely and/or a technically defensible manner for a site...a surrogate (e.g., 10^{-3} plus a factor [(margin)]) consistent with the current state of practice may be developed to provide quantitative risk insights to augment the available qualitative risk insights". In the resulting staff requirements memorandum (SRM), the Commission directed staff to, "...continue to look for additional opportunities to address any conservatism in the flood hazard evaluations and streamline the process..." (SRM-COMSECY-15-0019).

The licensee's IA details its analysis of the likelihood of the consequential riverine flood scenario at the Dresden site. The licensee used a gage-frequency analysis based on the flood-frequency approach described in the United States Geological Survey's 2017 draft "Guidelines for Determining Flood Flow Frequency, Bulletin 17C."[2] The staff reviewed the information provided by the licensee in its September 8, 2017, IA submittal with respect to determining the likelihood of a consequential riverine flood scenario (i.e., likelihood of river flood stage greater than 517 ft. above MSL). A series of pre-submittal and audit meetings were held with the licensee on August 2, 2017, September 15, 2017, and November 14, 2017, to discuss methods the licensee used to estimate the likelihood of the consequential flood scenario.

The NRC staff performed a preliminary evaluation of the licensee's data, models, and methods, as presented by the licensee in the IA submittal. The NRC staff also reviewed supporting information in references provided in an electronic reading room portal and conducted audits in which details were discussed with the licensee and contractors.

Based on the staff's preliminary reviews and evaluations, the staff identified a range of information needs for the licensee to address. The information needs were provided to the licensee on November 2, 2017, and supplemental information needs were provided to the licensee on January 3, 2018. The licensee provided draft responses to the information needs on January 29, 2018. The information needs and the licensee draft responses to these information needs are documented in a September 19, 2018, note to file (ADAMS Accession No. ML18260A104). After reviewing the licensee's draft responses, the NRC staff concluded that rather than continuing to perform a detailed review of the licensee's methods, it would be more efficient to conduct an independent confirmatory screening analysis to provide quantitative insights into flooding that may be expected at a frequency of 1E-3 AEP plus a factor.

The screening analysis developed by the staff used an estimate of the 1E-3 AEP precipitation event to determine an estimate for the 1E-3 AEP flood elevation. The staff's screening analysis concluded that a 516 ft. MSL flood elevation represents an adequate estimate for the 1E-3 AEP stillwater flood elevation, a 519 ft. MSL flood elevation represents the 1E-3 AEP plus a factor and a flood elevation of 520.2 ft. MSL flood elevation represents an adequate estimate for the 1E-3 AEP plus a factor including wind wave (shown in Table 3.3.5-1 as Scenario 4 and 5, respectively). For comparison, the plant grade elevation is 517 ft. MSL. Because the staff's screening assessment determined that the range of flood elevations are below a flood elevation of 521 ft. MSL at the ICMU pump building, the staff concludes that further review of the licensee's approach and methods is unnecessary (see Section 3.3.6 of this assessment for additional discussion). Therefore, the staff is not making a determination regarding the acceptability of the licensee's probabilistic flood hazard analysis (PFHA) and the staff's information needs and the licensee's responses related to said PFHA are not discussed any further in this staff assessment. The staff's screening analyses (including stillwater and wind wave analyses) are described in the following sections.

3.3.5.1 Stillwater Screening Analysis

For its initial flood hazard reevaluation report dated May 10, 2013, the licensee used the USACE Hydrologic Engineering Center's (HEC) Hydrologic Modeling System (HEC-HMS) and the River Analysis System (HEC-RAS) software to construct models to estimate the PMF water surface elevation. These hydrologic and hydraulic models developed by the licensee were previously reviewed by the NRC staff and were found to be acceptable for the PMF analysis at the Dresden site as documented in the staff's March 31, 2015, staff assessment. Therefore, the

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[2] England, J.F., Jr., Cohn, T.A., Faber, B.A., Stedinger, J.R., Thomas, W.O., Jr., Veilleux, A.G., Kiang, J.E., and Mason, R.R., Jr., 2017 Draft, Guidelines for determining flood flow frequency—Bulletin 17C: U.S. Geological Survey Techniques and Methods, book 4, chap. B5, page 148.

staff used these two models, with modifications described below, as part of its independent screening analysis.

The staff modified the licensee's HEC-HMS hydrologic model by using an independently developed 1E-3 AEP precipitation estimate from National Oceanic and Atmospheric Administration (NOAA) Atlas 14 as input and by reducing conservatisms inherent in the FHRR analysis before using it to estimate flow rates. The staff used the licensee's HEC-RAS hydraulic model without modification to estimate the rating curve (stage-flow relationship) for the expected flows of interest at the site.

The staff's screening analyses included an empirical sensitivity study to help identify the effect of conservatisms on the resulting flood elevations and provide quantitative insights into the factor that should be considered along with the 1E-3 AEP flood elevation, which is used as a surrogate for the 1E-4 AEP flood. The sensitivity study consisted of five screening scenarios that reduced the conservatisms of the FHRR PMF model in a sequence (starting with precipitation inputs and ending with runoff inputs) to determine a range of potential flood elevations for the Dresden site. For each scenario, flows computed using the modified HEC-HMS model were used in conjunction with the rating curve developed from the HEC-RAS model to estimate the corresponding stillwater flood elevations at the Dresden site.

For each of the five scenarios, the staff modified the licensee's FHRR PMF HEC-HMS hydrologic model as follows:

- Precipitation input

  For each of the five modeling scenarios, the staff developed precipitation inputs using an estimate of the 1E-3 AEP precipitation event with the assumption that it will produce a flood elevation with a frequency of 1E-3 AEP (i.e., an AEP-neutral approach). For this purpose, the NRC staff obtained point precipitation estimates for the 1E-3 AEP event and corresponding temporal precipitation distributions from the NOAA's Precipitation-Frequency Atlas of the United States (NOAA Atlas 14) web portal[3].

  The staff used the median value (50 percent) for precipitation depths obtained from the NOAA Atlas 14 web portal. The staff determined that a storm duration of 72 hours is appropriate for the Dresden watershed. The NOAA Atlas 14 provides temporal distributions of precipitation for 24-hour and 96-hour durations, therefore the NRC staff calculated the 72-hour precipitation values by linear interpolation.

- Areal reduction factors (ARF)

  The NOAA Atlas 14 precipitation depths are point precipitation estimates valid for small areas (generally 10 square miles or less). To estimate the average areal values for the large sub-basin areas in which the Dresden site is located, the staff adjusted the precipitation values obtained from NOAA Atlas 14 using an areal reduction factor (ARF). Typical values for ARF range from 0.4 to 1.0 and depend on factors such as basin area and storm duration, where an ARF of 1.0 is equal to no reduction in the point precipitation value. Based on its review of existing literature on the subject and a sensitivity analysis, the staff confirmed that the ARF parameter has a substantial impact on flood elevations at the Dresden site. Based on the literature review and engineering judgement, the staff's final consensus for the ARF for the watershed in which the Dresden site is located was a value of 0.8, which was used for Scenarios 2 through 5.

[3] NOAA Atlas 14 Web Portal (Accessed: April 3, 2018, and April 5, 2018.
https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html

- Peak and timing of the Unit Hydrograph (UH)

  For PMF analyses, it is common to adjust the unit hydrograph (UH) peak and time-to-peak to account for the fact that UHs are developed from observed events far smaller than large floods and may therefore underrepresent the watershed response under PMF conditions. Therefore, the licensee's FHRR PMF HEC-HMS hydrologic model increased peaks on the unit hydrograph (UH). The licensee also reduced the UH time-to-peak to account for faster flooding under PMF conditions. The NRC staff's independent screening analysis added realism in the hydrologic model by removing both of these assumptions.

- Infiltration rates

  The FHRR PMF HEC-HMS hydrologic model used zero or very low infiltration rates, which can result in greater runoff than would occur using more representative values. In the independent screening analysis, the staff added realism to the hydrologic model by increasing the infiltration rates to typical values based on the range of soil types in the subject watershed.

The staff generated a rating curve using the licensee's HEC-RAS model and compared this curve to the rating curve from flood frequency studies performed by the USACE for the region[4]. The NRC staff found the curve generated from the licensee's HEC-RAS model to be appropriate for use in the staff's independent analysis. The NRC staff used flow rates from the modified HEC-HMS models along with this rating curve to estimate the flood elevations for each scenario (Figure 3.3.5-1).

Scenarios 1 through 5 of the staff's independent screening analysis are described in more technical detail below and are summarized in Table 3.3.5-1.

Scenario 1: The purpose of this scenario was to examine the response to switching from PMF precipitation inputs to using precipitation with a 1,000-yr return period and an adjustment to point precipitation depths. Thus, staff used NOAA Atlas 14 in Scenario 1 for estimating the 1E-3 AEP point precipitation depth with a duration of 72 hours and assumed a median temporal distribution from the "All Cases" temporal distribution as shown in Figure A.1.1 of NOAA Atlas 14 Volume 2[5]. For this scenario, an ARF of 0.9 was used. The staff made no changes to the HEC-HMS model and retained the conservative assumptions of UH peaking and zero to very low infiltration rates.

Scenario 2: The purpose of this scenario was to examine the response to switching to a late-peaking temporal distribution and to a further adjustment to point precipitation depths. Therefore scenario 2 is identical to Scenario 1 except that the NRC staff assumed the 3rd quartile temporal precipitation pattern as shown in Figures A.1.4 (24-hour duration) and A.1.5 (96-hour duration) of NOAA Atlas 14 Volume 2. For this scenario, the NRC staff incorporated more realism by using a lower ARF of 0.8 to account for the spatial distribution of the point precipitation data.

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[4] USACE, Upper Mississippi River System Flow Frequency Study, Hydrology & Hydraulics, Appendix C, Illinois River, Rock Island District, August 2003

[5] Bonnin, Geoffrey M., Deborah Martin, Bingzhang Lin, Tye Parzybok, Michael Yekta, and David Riley: NOAA Atlas 14 Precipitation-Frequency Atlas of the United States, Volume 2 Version 3. U.S Department of Commerce, NOAA, National Weather Service, Silver Spring, MD 2004, Revised 2006

Scenario 3: Scenario 3 was identical to Scenario 2 except that the NRC staff incorporated additional realism to the model by removing UH peaking and timing adjustments. The purpose of this scenario is to provide a more representative watershed response to the precipitation.

Scenario 4: Scenario 4 was identical to Scenario 3 except that the NRC staff increased infiltration values in the HEC-HMS model from zero to the average rates based on the specified soil types. The purpose of this scenario was to provide a more representative watershed response to the precipitation. This scenario represents the model configuration expected to provide the best estimate of the flood elevations for the 72-hour duration precipitation-based 1E-3 AEP flood at the Dresden site.

Scenario 5: Scenario 5 is identical to Scenario 4 except that the NRC staff used precipitation depths from NOAA Atlas 14 that correspond to the upper 90 percent confidence interval. This scenario represents the model configuration expected to provide the estimated flood elevations for the 72-hour duration precipitation-based 1E-3 AEP plus margin (or factor) flood at the Dresden site (i.e., the 1E-4 AEP surrogate).

Scenario 4 is derived from a more realistic set of input parameter values and, as such, provides a better estimate of the 1E-3 annual exceedance probability (AEP) flood elevation. The staff used Scenario 5 to estimate the 1E-3 annual exceedance probability (AEP) flood elevation plus a factor, which is a surrogate for the 1E-4 AEP flood. Based on the results of Scenarios 4 and 5, the range expected for the stillwater flood elevation is between 516 ft. to 519 ft. MSL.

3.3.5.2 Wind Wave Analysis

The NRC staff performed an independent analysis to estimate the total water surface elevation (i.e., stillwater flood elevation plus contribution of wind wave runup). The NRC staff performed wind wave calculations using the maximum stillwater flood elevation (i.e., Scenario 5 water surface elevation estimate). Wind wave calculations were not applied to Scenario 4 since water surface elevations in that scenario are below the site grade of 517 ft. MSL.

The staff used the USACE Coastal Engineering Manual[6] to estimate the wind wave heights to be superimposed on the stillwater flood elevation for Scenario 5 only. Per the CEM, the NRC staff first estimated the wind wave heights assuming deep water conditions, followed by a check for shallow water conditions. Based on this check, the NRC staff determined that the shallow water conditions were applicable for the location of interest, which is the ICMU pump building. The CEM specifies that for shallow water conditions, wind wave heights should be estimated by multiplying the stillwater depth by a factor of 0.6.

The NRC staff used the stillwater flood elevation of 519 ft. MSL (Scenario 5), and the site grade of 517 ft. MSL to estimate a depth of 2 ft. at the ICMU pump building. Using this depth, the staff estimated a wind wave height of 1.2 ft. (2 ft. multiplied by a factor of 0.6) resulting in a maximum total water depth, including wind wave, of 520.2 ft. MSL.

3.3.5.3 Conclusion

Rather than performing a detailed review of the licensee's methods, the NRC staff concluded that it would be more efficient to first conduct a screening analysis. As such, the NRC staff performed an independent screening analysis to provide quantitative insights into flooding that may be expected at a frequency of 1E-3 AEP plus a factor. Based on its screening analysis, the NRC staff estimated that the range of flood elevations for the 72-hour duration

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[6] USACE, (2015), Coastal Engineering Manual (CEM), Engineer Manual 1110-2-1100, Change 4, U.S. Army Corps of Engineers, Washington, D.C. (Volume 2).

precipitation-based 1E-3 AEP flood varies from 516 to 519 ft. MSL for the stillwater flood elevation at the Dresden site. Additionally, the NRC staff estimated a wind wave height of 1.2 ft., for the 519 ft. MSL stillwater elevation for a total flood elevation of 520.2 ft. MSL. The staff's screening analyses had the following conclusions with respect to flood elevations at the Dresden site;

- the elevation of 516 ft. MSL represents an adequate estimate for the 1E-3 AEP stillwater flood elevation at the Dresden site,
- the elevation of 519 ft. MSL represents an adequate estimate for the 1E-3 AEP plus a factor stillwater flood elevation at the Dresden site and,
- the elevation of 520.2 ft. MSL represents an adequate estimate for the 1E-3 AEP plus a factor for the total flood water elevation including wind wave at the ICMU pump building at the Dresden site.

As a result, the NRC staff concludes that the flood elevation of 520.2 ft. MSL should be used at the Dresden site when evaluating effective flood protection in accordance with NEI 16-05, Revision 1, as endorsed.

3.3.6 Effective Flooding Response for Consequential Floods with Relatively Higher Frequency of Occurrence

3.3.6.1 Effective Flood Response for Floods to 517 ft. MSL

Based on the licensee's probabilistic flood hazard assessment, the licensee chose a site grade of 517 ft. MSL as a dividing point between consequential and non-consequential floods. The licensee provides supporting information that demonstrates, in their opinion that the 1E-4 AEP is below this elevation. Flooding below 517 ft. MSL is handled by the existing procedurally-specified flood response, which relies on permanent plant equipment. If the flood level is predicted to exceed 509 ft. in the next 72 hours, the licensee will shut down both reactors within 12 hours and cool down to less than 212 °F within 36 hours. These actions are required by the Technical Requirements Manual. Under procedural direction, if the flood level reaches 513 ft., the operators transfer core decay heat removal to the isolation condensers. The isolation condensers can receive makeup water from several sources, with the preferred source being the two diesel-powered ICMU pumps, which take a suction from the clean demineralized water tank. The NRC staff concludes that this is an effective flooding response for floods less than 517 ft. MSL.

As described in Section 3.3.5 of this staff assessment the staff noted the concerns associated with the licensee's assessment of relatively higher frequency floods in the range of an annual exceedance probability of 1E-3 per year to 1E-4 per year. As described in Section 3.3.5 of this staff assessment, the staff developed 1E-3 AEP with margin of 519 ft. MSL and 520.2 ft. MSL with wind wave runup. The staff notes that the staff's calculated value of 1E-3 AEP flood elevation is below the site grade of 517 ft. MSL. The staff also notes that if the USACE rating curve was used instead of the licensee's rating curve (see Figure 3.3.5-1) the 1E-3 AEP with margin value would be lower than the site grade of 517 ft. MSL. (For flood levels below site grade there is no wind wave runup). Therefore, the staff's conclusions for the staff's 1E-3 AEP value or the 1E-3 AEP using the USACE HEC-RAS hydraulic rating curve is not changed from the evaluation found above for floods less than 517 ft. MSL.

3.3.6.2 Effective Flood Response for Floods to 520.2 ft. MSL

The staff evaluated floods in the 517 ft. MSL range to 520.2 ft. MSL to determine whether the licensee has effective flood protection (without relying on FLEX equipment) in the event such a flood were to occur. As discussed above, the licensee's current licensing basis is to remove decay heat via the isolation condensers once Unit 2 and Unit 3 service water pumps are secured at 513 ft. MSL. The permanently installed ICMU pumps located in the ICPH are protected from floods above site grade via procedural control to install plate type flood barriers. The ICPH has been analyzed and found acceptable to withstand flood levels to 521 ft. MSL as described in Section 3.3.2 of this staff assessment.

The ICMU pump diesels have an adequate fuel supply via their day tanks for eight hours[7]. The demineralized water storage tanks (which is the preferred method for refilling the isolation condensers) can supply water to the Unit 2 and Unit 3 isolation condensers for approximately the same amount of time[8]. The staff's assessment of hydrodynamic, and hydrostatic loads, and buoyancy forces above 517 ft. MSL can be found in Section 3.3.2 of this assessment. The staff considers this assessment bounding for flood levels to 521 ft. MSL, which is above the wind wave runup value of 520.2 ft. MSL described in Section 3.3.5 of this document. The staff notes that the ICPH and the demineralized water storage tanks are protected by various buildings such that wind wave runup at the ICPH and the demineralized water storage tanks should be minimized.

Therefore, the staff concludes that the licensee has effective flood protection to 521 ft. MSL (above the flood elevation of 1E-3 AEP with margin of 520.2 ft. MSL) including reactor decay heat removal via the isolation condensers which are replenished by the installed diesel driven ICMU pumps that use the demineralized water storage tanks as a water supply. The staff notes that the ICMU pumps can also replenish the reactor pressure vessel, and spent fuel pools through a cross tie.

3.3.7 Consideration of Additional Regulatory Actions

Lower Frequency Flood Events

As discussed in Section 2 of this staff assessment, by letter dated June 30, 2016 (ADAMS Accession No. ML16182A388), the licensee submitted the Dresden flooding MSA. As documented in a letter dated March 29, 2017 (ADAMS Accession No. ML17076A198), the NRC staff concluded that the licensee demonstrated that the mitigation strategies could be successfully implemented for the reevaluated flood hazard for beyond-design-basis external events. As described in Section 3.3.4 of this assessment the staff concludes that the successful implementation of the FLEX strategy for the combined effects flood of 529 ft. MSL would not be adversely affected by the addition of one foot of water when compared to the current licensing

[7] The amount of time that the fuel oil supply for the ICMU pump diesels and the water supply to the ICMU pumps can be used before supplies are replenished is highly dependent on the decay heat loads associated with the reactor. Eight hours represents an assessment of these supplies based on the licensee actions to shutdown the units well in advance of the water levels going above site grade.

[8] Although procedurally the licensee shifts to the FLEX barge mounted pumps at flood elevations of 518 ft. MSL, the staff believes that the licensee will consider current and projected river level conditions and will maintain a clean source of water to the ICMU pumps for as long as possible before transitioning to river water as the supply for the isolation condensers, reactor pressure vessel and spent fuel pools. The staff expects under certain conditions the licensee may not make the transition to the FLEX barge mounted pumps from the ICMU pumps until after a flood elevation of 518 ft. MSL is reached.

basis flood hazard elevation of 528 ft. MSL. Therefore, additional regulatory action associated with this lower frequency flood event is not warranted.

Higher Frequency Flood Events

In accordance with COMSECY 15-0019 the staff considered a surrogate to the 1E-4 AEP flood (e.g., 1E-3 AEP plus margin) to determine whether additional regulatory action to protect the plant from such events was necessary. As described in Section 3.3.6 of this document the staff concluded that the licensee has effective flood protection to 521 ft. MSL, which bounds both the licensee's 1E-4 AEP and the staff's 1E-3 AEP plus margin flood levels. Based on the staff's qualitative and quantitative assessment, which includes the licensee's ability to have effective flood protection to 521 ft. MSL with installed plant equipment, further modifications to the licensee's flood protection strategies could not be justified as a substantial safety enhancement nor are further modifications needed to provide reasonable assurance of adequate protection of public health and safety for the more frequent flood events. As discussed in Section 6 of this document, the staff's analysis credits a licensee regulatory commitment associated with the flood protection capabilities for the ICMU pump house. Therefore, the NRC staff finds no benefit in imposing a formal backfit in accordance with 10 CFR 50.109 based on the reevaluated flood hazard for the more frequent flood events, and is not recommending or pursuing this option for these events.

3.3.8 Conclusion

Given that:

1. the site flooding response does not substantially change with the additional foot of water from the reevaluated hazard,

2. opening the turbine bay to flood waters and using a barge-mounted pump for core cooling and SFP cooling is the current licensing basis for floods substantially above site grade, and

3. the licensee has an effective strategy to respond to floods below site grade and to a level of 521 ft. MSL (which is greater than the staff developed 1E-3 AEP with margin of 520.2 ft. MSL)

4. the licensee has a feasible strategy to respond to floods above 521 ft. MSL

5. the staff has inspected, audited, and reviewed, as appropriate, pertinent provision of the licensee's strategy and found it acceptable.

The NRC staff concludes that no additional regulatory actions are warranted for addressing the reevaluated flood hazard elevation for the combined effects hazard of PMF with dam failure and wind wave run-up.

4.0 SENIOR MANAGEMENT REVIEW PANEL

In accordance with the September 21, 2016, memo, described above the technical team met with the SMRP and presented the results of the review including the recommendation that the Dresden combined effects flood be treated as a Group 1 hazard. The staff noted, and the SMRP agreed, that the LIP flood hazard was outside the scope of the SMRP decision because in accordance with NEI 16-05, Revision 1, as endorsed, only Path 4 and 5 hazards are subject to an SMRP review. Because LIP was evaluated using the Path 2 process an SMRP decision for the treatment of this hazard was not necessary. The SMRP members asked questions and provided input to the technical team related to the Path 5 combined events flood hazard. The SMRP approved the staff's recommendation that the Dresden combined events flood hazard should be classified as a Group 1 hazard, meaning that no further response or regulatory action is required.

5.0 AUDIT REPORT

The NRC staff previously issued a generic audit plan dated July 18, 2017 (ADAMS Accession No. ML17192A452), that described the NRC staff's intention to conduct audits related to IAs and issue an audit report that summarizes and documents the NRC's regulatory audit of the licensee's IA. The NRC staff activities have been limited to performing the reviews described above. Because this staff assessment appropriately summarizes the results of those reviews, the NRC staff concludes that a separate audit report is not necessary, and that this document serves as the final audit report described in the July 18, 2017, letter.

6.0 REGULATORY COMMITMENT

In a letter dated August 28, 2013, the licensee stated that the installation of flood barriers, in lieu of sandbagging, to protect the ICMU pump building was a regulatory commitment. With regards to regulatory commitments, the NRC staff notes that NEI 99-04 "Guidelines for Managing NRC Commitments" (ADAMS Accession No. ML003680088), as endorsed by the NRC in SECY-00-0045 "Acceptance of NEI 99-04, "Guidelines for Managing NRC Commitments"" (ADAMS Accession No. ML003679799), provides an acceptable method to manage commitments. If the licensee were to change this regulatory commitment such that the ICMU pump building was not flood protected to 521 ft. MSL, the staff would expect to be informed in accordance with the process outlined in NEI 99-04, as endorsed by the NRC. If the commitment were to be changed the staff may revisit its conclusion that no additional regulatory action is warranted.

7.0 CONCLUSION

The NRC staff concludes that the Dresden IA was performed consistent with the guidance described in Nuclear Energy Institute (NEI) 16-05, Revision 1, "External Flooding Assessment Guidelines" (ADAMS Accession No. ML16165A178), with the clarifications provided in the NRC's endorsement document, JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flood Hazard Reevaluation" (ADAMS Accession No. ML16162A301). Although the NRC staff could not fully validate the flood hazard levels calculated by the licensee for the relatively more frequent river floods, the NRC staff has concluded that the licensee has demonstrated that effective flood protection, if appropriately implemented, exists for the LIP. For the combined effects probable maximum flood and dam failure flooding mechanism, the licensee has an effective mitigation strategy for floods to 521 ft. MSL level (which is greater than the staff developed 1E-3 AEP with margin of 520.2 ft. MSL), and a feasible mitigation strategy for higher, less frequent floods. As such, in accordance with Phase 2 of the process outlined in the 50.54(f) letter, additional regulatory actions associated with the reevaluated flood hazard, are not warranted.

Table 3.3.5-1 Results for Different Scenarios

Scenario Number	Scenario Description	Watershed Average Point Precipitation (inch)	Peak Discharge (cubic feet per second (cfs))	Max Stillwater Water Surface Elevation (ft) (MSL)	Wind Wave Height (ft)	Total Water Surface Elevation (ft) (MSL)
1	Basecase: median 1E-3 AEP point precipitation depth for 72 hr, 1000 yr storm, ARF=0.9, retain UH peaking and low infiltration	11.52	262,000	522	[redacted]	[redacted]
2	Vary precipitation pattern and reduce ARF to 0.8	11.52	227,000	520	[redacted]	[redacted]
3	Remove UH peaking	11.52	208,000	519	1.2	520.2
4	Increase infiltration to average rate for soil type	11.52	165,000	516	NA	516
5	Increase precipitation magnitude to 90th percentile	13.03	210,750	519	1.2	520.2

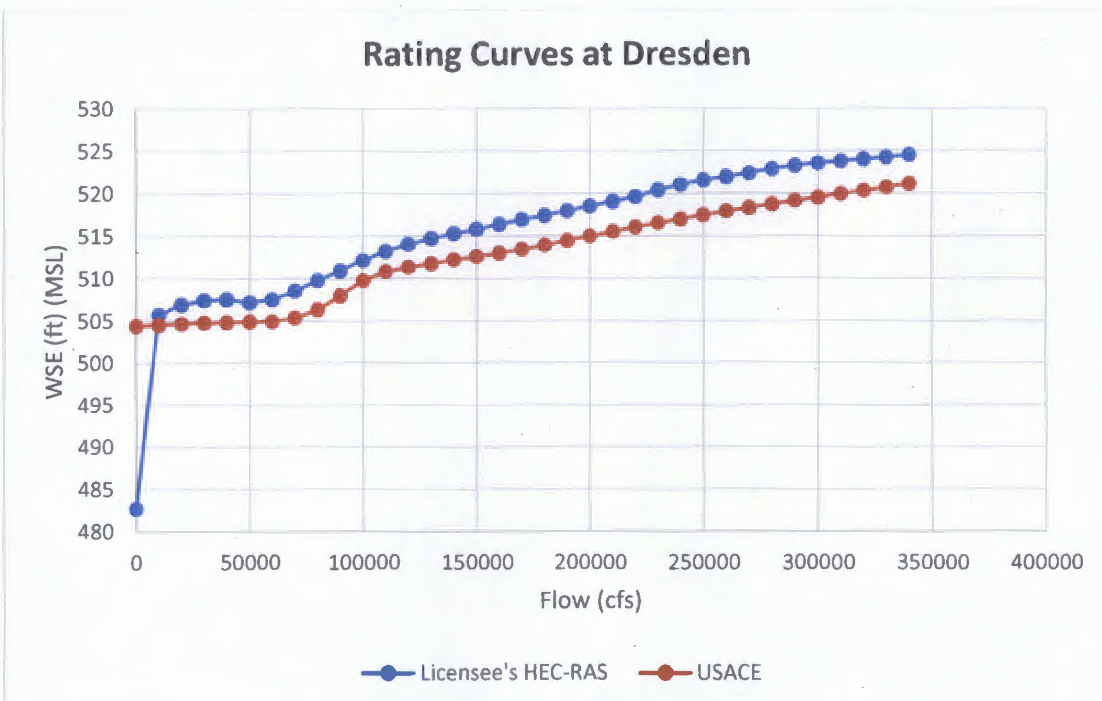

Figure 3.3.5-1 Rating Curves at the Dresden Site.

Table 3.3.5-1 Results for Different Scenarios

Scenario Number	Scenario Description	Watershed Average Point Precipitation (inch)	Peak Discharge (cubic feet per second (cfs))	Max Stillwater Water Surface Elevation (ft) (MSL)	Wind Wave Height (ft)	Total Water Surface Elevation (ft) (MSL)
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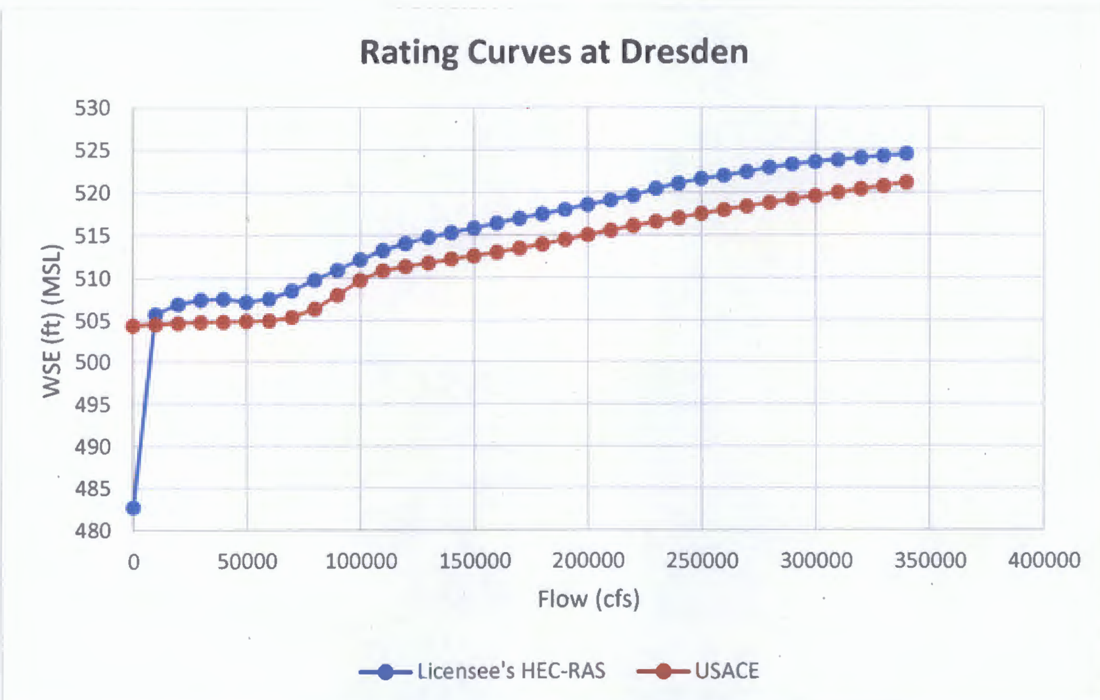

Figure 3.3.5-1 Rating Curves at the Dresden Site.

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DATE: March 6, 2019

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DATE	8/27/2018	9/10/2018	10/29/18	10/2/2018
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