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

August 16, 2016

Mr. Bryan C. Hanson
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President and Chief Nuclear Officer
Exelon Nuclear
4300 Winfield Road
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SUBJECT: BYRON STATION, UNITS 1 AND 2 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NOS. MF3893 AND MF3894)

Dear Mr. Hanson:

By letter dated March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information pursuant to Title 10 of the *Code of Federal Regulations*, Section 50.54(f) (hereafter referred to as the 50.54(f) letter). The request was issued as part of implementing lessons learned from the accident at the Fukushima Dai-ichi nuclear power plant. Enclosure 2 to the 50.54(f) letter requested licensees to reevaluate flood-causing mechanisms using present-day methodologies and guidance. By letter dated March 12, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14079A416), Exelon Generation Company, LLC (Exelon, the licensee) responded to this request for Byron Station, Units 1 and 2 (Byron).

By letter dated September 3, 2015 (ADAMS Accession No. ML15243A462), the NRC staff sent Exelon a summary of the staff's review of Byron's reevaluated flood-causing mechanisms. The enclosed staff assessment provides the documentation supporting the NRC staff's conclusions summarized in the letter. As stated in the letter, because the reevaluated flood hazard mechanisms at Byron are bounded by the current design-basis, it is unnecessary for the licensee to perform an integrated assessment or focused evaluation.

Therefore, the NRC staff confirms that the licensee responded appropriately to Enclosure 2 of the 50.54(f) letter. This closes out the NRC's efforts associated with CAC Nos. MF3893 and MF3894.

If you have any questions, please contact me at (301) 415-6197 or e-mail at Tekia.Govan@nrc.gov.

Sincerely,

Tekia V. Govan

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

Docket Nos. 50-454 and 50-455

Enclosure:
Staff Assessment of Flood Hazard
Reevaluation Report

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION
RELATED TO FLOODING HAZARD REEVALUATION REPORT
NEAR-TERM TASK FORCE RECOMMENDATION 2.1
BYRON STATION, UNITS. 1 AND 2
DOCKET NOS. 50-454 AND 50-455

1.0 INTRODUCTION

By letter dated March 12, 2012 (NRC, 2012a), 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 license" (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 (NRC, 2011a). Recommendation 2.1 in that document recommended that the staff issue orders to all licensees to reevaluate seismic and flooding hazards for their sites against current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY-11-0124 (NRC, 2011c) and SECY-11-0137 (NRC, 2011d) directed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f) to address this recommendation.

Enclosure 2 to the 50.54(f) letter (NRC, 2012a) 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 (ESPs) and combined licenses (COLs). The required response section of Enclosure 2 specified that NRC staff would provide a prioritization plan indicating Flooding Hazard Reevaluation Report (FHRR) deadlines for each plant. On May 11, 2012, the staff issued its prioritization of the FHRRs (NRC, 2012b).

If the reevaluated hazard for any flood-causing mechanisms is not "bounded" by the plant's current design basis (CDB) flood hazard, an additional assessment of plant response is necessary, as described in the 50.54(f) letter and COMSECY-15-0019, "Mitigating Strategies and Flooding Hazard Reevaluation Action Plan" (NRC, 2015b).

By letter dated March 12, 2014 (Exelon, 2014a), Exelon Generation Company, LLC (Exelon, the licensee) provided its FHRR for Byron Station, Units 1 and 2 (Byron). The NRC staff issued requests for additional information (RAIs) to the licensee (NRC, 2014a and NRC, 2015a). The licensee responded to the RAIs by letters dated July 14, 2014 (Kaegi, 2014), and May 26, 2015 (Kaegi, 2015).

By letter dated September 3, 2015, the NRC issued an Interim Staff Response (ISR) letter to the licensee (NRC, 2015c), which states that all the reevaluated flood hazard mechanisms (local intense precipitation (LIP) and flooding from streams and rivers) at Byron are bounded by the current design-basis. Therefore, the NRC staff does not anticipate that the licensee will perform any additional assessments of Byron's plant response.

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

As stated above, Enclosure 2 to 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 ESPs and COLs. This section describes present-day regulatory requirements that are applicable to the FHRR.

Sections 50.34(a)(1), (a)(3), (a)(4), (b)(1), (b)(2), and (b)(4) of 10 CFR describe the required content of the preliminary and final safety analysis report, including a discussion of the facility site with a particular emphasis on the site evaluation factors identified in 10 CFR Part 100. The licensee should provide any pertinent information identified or developed since the submittal of the preliminary safety analysis report in the final safety analysis report.

General Design Criterion 2 in Appendix A of Part 50 states that structures, systems, and components (SSCs) important to safety at nuclear power plants must be designed to withstand the effects of natural phenomena, such as earthquakes, tornados, hurricanes, floods, tsunamis, and seiches, without loss of capability to perform their intended safety functions. The design bases for these SSCs are to reflect appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area. The design bases are also to have sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

Section 50.2 of 10 CFR defines the design bases as the information which identifies the specific functions that an SSC of a facility must perform, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design which each licensee is required to develop and maintain. These values may be (a) restraints derived from generally accepted "state of the art" practices for achieving functional goals, or (b) requirements derived from analysis (based on calculation, experiments, or both) of the effects of a postulated accident for which a SSC must meet its functional goals.

Section 54.3 of 10 CFR defines the current licensing basis (CLB) as: "the set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect." This includes 10 CFR Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 52, 54, 55, 70, 72, 73, 100 and appendices thereto; orders; license conditions; exemptions; and technical specifications, as well as the plant-specific design-basis information as documented in the most recent final safety analysis report. The licensee's commitments made in docketed licensing correspondence, which remain in effect, are also considered part of the CLB.

Present-day regulations for reactor site criteria (Subpart B to 10 CFR Part 100 for applications on or after January 10, 1997) state, in part, that the physical characteristics of the site must be evaluated and site parameters established such that potential threats from such physical characteristics will pose no undue risk to the type of facility proposed to be located at the site. Factors to be considered when evaluating sites include the nature and proximity of dams and other man-related hazards (10 CFR 100.20(b)) and the physical characteristics of the site, including the hydrology (10 CFR 100.21(d)).

2.2 Enclosure 2 to the 50.54(f) Letter

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoked. The 50.54(f) letter (NRC, 2012a) requested licensees reevaluate the flood-causing mechanisms for their respective sites using present-day methodologies and regulatory guidance used by the NRC for the ESP and COL reviews.

2.2.1 Flood-Causing Mechanisms

Attachment 1 to Enclosure 2 of the 50.54(f) letter (NRC, 2012a) discusses flood-causing mechanisms for the licensee to address in its FHRR. Table 2.2-1 lists the flood-causing mechanisms that the licensee should consider. Table 2.2-1 also lists the corresponding Standard Review Plan (SRP) (NRC, 2007) section(s) and applicable interim staff guidance (ISG) documents containing acceptance criteria and review procedures. The licensee should incorporate and report associated effects per Japan Lessons-Learned Directorate (JLD) JLD-ISG-2012-05, "Guidance for Performing the Integrated Assessment for External Flooding" (NRC, 2012c), in addition to the maximum water level associated with each flood-causing mechanism.

2.2.2 Associated Effects

In reevaluating the flood-causing mechanisms, the "flood height and associated effects" should be considered. JLD-ISG-2012-05 (NRC, 2012c) defines "flood height and associated effects" as the maximum stillwater surface elevation plus:

- Wind waves and run-up effects
- Hydrodynamic loading, including debris
- Effects caused by sediment deposition and erosion
- Concurrent site conditions, including adverse weather conditions
- Groundwater ingress
- Other pertinent factors

2.2.3 Combined Effects Flood

The worst flooding at a site that may result from a reasonable combination of individual flooding mechanisms is sometimes referred to as a "Combined Effect Flood." Even if some or all of these individual flood-causing mechanisms are less severe than their worst-case occurrence, their combination may still exceed the most severe flooding effects from the worst-case occurrence of any single mechanism described in the 50.54(f) letter (see SRP Section 2.4.2, "Areas of Review" (NRC, 2007)). Attachment 1 of the 50.54(f) letter) describes the "Combined Effect Flood" as defined in American National Standards Institute/American Nuclear Society (ANSI/ANS) 2.8-1992 (ANSI/ANS, 1992) as follows:

> For flood hazard associated with combined events, American Nuclear Society (ANS) 2.8-1992 provides guidance for combination of flood causing mechanisms for flood hazard at nuclear power reactor sites. In addition to those listed in the ANS guidance, additional plausible combined events should be considered on a site specific basis and should be based on the impacts of other flood causing mechanisms and the location of the site.

If two less severe mechanisms are plausibly combined (per ANSI/ANS-2.8-1992 (ANSI/ANS, 1992)), then the staff will document and report the result as part of one of the hazard sections. An example of a situation where this may occur is flooding at a riverine site located where the river enters the ocean. For this site, storm surge and river flooding should be plausibly combined.

2.2.4 Flood Event Duration

Flood event duration was defined in JLD-ISG-2012-05 (NRC, 2012c) as the length of time during which the flood event affects the site. It begins when conditions are met for entry into a flood procedure, or with notification of an impending flood (e.g., a flood forecast or notification of dam failure), and includes preparation for the flood. It continues during the period of inundation, and ends when water recedes from the site and the plant reaches a safe and stable state that can be maintained indefinitely. Figure 2.2-1 illustrates flood event duration.

2.2.5 Actions Following the FHRR

For the sites where the reevaluated flood hazard is not bounded by the CDB flood hazard for all flood-causing mechanisms, the 50.54(f) letter (NRC, 2012a) requests licensees and construction permit holders to:

- Submit an Interim Action Plan with the FHRR documenting actions planned or already taken to address the reevaluated hazard(s).

- Perform an integrated assessment subsequent to the FHRR to (a) evaluate the effectiveness of the CLB (i.e., flood protection and mitigation systems); (b) identify plant-specific vulnerabilities; and (c) assess the effectiveness of existing or planned systems and procedures for protecting against and mitigating consequences of flooding for the flood event duration.

If the reevaluated flood hazard is bounded by the CDB flood hazard for all flood-causing mechanisms at the site, licensees were not required to perform an integrated assessment. COMSECY-15-0019 (NRC, 2015b) 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 an approach in which licensees with LIP hazards exceeding their CDB flood will not be required to complete an integrated assessment, but instead would perform a focused evaluation. As part of the focused evaluation, licensees will assess the impact of the LIP hazard on their sites and then evaluate and implement any necessary programmatic, procedural or plant modifications to address the hazard exceedance. For other flood hazard mechanisms that exceed the CDB, licensees can assess the impact of these reevaluated hazards on their site by performing either a focused evaluation or an integrated assessment (NRC, 2015b).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of Byron. The licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews. The staff's review and evaluation is provided below.

To clarify and expand on portions of the Byron FHRR, the NRC staff issued RAIs to the licensee (NRC, 2015a). The licensee's responses to the RAIs were reviewed by NRC staff to confirm that the responses addressed the intent of the RAI and the needs of the NRC staff's review. The responses are included as part of the docketed information used for the NRC staff's review and is cited in this staff assessment to document the licensee's analyses of the flood hazards.

To provide additional information in support of the summaries and conclusions in the Byron FHRR (Exelon, 2014a), the licensee made several calculation packages available to the staff via an electronic reading room. These calculation packages were found only to expand upon and clarify the information provided on the docket, and so are not docketed or cited.

3.1 Site Information

The 50.54(f) letter (NRC, 2012a) included the SSCs important to safety and the ultimate heat sink (UHS) in the scope of the hazard reevaluation. Per the 50.54(f) letter, Enclosure 2, "Requested Information, Hazard Reevaluation Report," Item a, the licensee included pertinent data concerning these SSCs in the Byron FHRR (Exelon, 2014a). Enclosure 2 (Recommendation 2.1: Flooding), "Requested Information, Hazard Reevaluation Report," Item a, describes site information to be contained in the FHRR. The staff reviewed and summarized this information as follows in the sections below.

3.1.1 Detailed Site Information

The FHRR (Exelon, 2014a) states that Byron is located in Ogle County, Illinois approximately 3 mi (5 km) southwest of the town of Byron and approximately 2 mi (3 km) east of the Rock River (Exelon, 2014a) (Figure 3.1-1). The site's local drainage area is 2.03 mi^2 (3.27 km^2) (Exelon, 2014a). The River Screen House is located west of the site on the left-bank of Rock River (Figure 3.1-1) at river mile (RM) 114.2 (183.8 km) (Kaegi, 2014). The Rock River joins with the Mississippi River approximately 115 mi (185 km) downstream (Exelon, 2014a). One of the dams on the Rock River is the Oregon Dam, which is located at RM 109.75 (176.6 km), approximately 4.5 mi (7.2 km) downstream of the River Screen House in Oregon, IL (Kaegi, 2014). A small intermittent stream (Woodland Creek) drains the north side of the Byron site (Exelon, 2014a) and flows into the Rock River (Figure 3.1-1). The NRC staff's review of the topography around the plant site noted several other small unnamed streams that drain away from the plant site (Figure 3.1-1) indicating that overall drainage is away from the Byron site. Two on-site basins are located near the power block: the natural draft cooling towers (NDCT) flume and the essential service cooling tower/UHS basin (Figure 3.1-2) (Exelon, 2014a).

With respect to the vertical elevation datum, the elevations are referenced in the Byron FHRR (Exelon, 2014a) and in the Updated Final Safety Analysis Report (UFSAR) (Exelon, 2014b) as the U.S. Geological Survey (USGS) 1929 datum. However, as stated in the FHRR, the USGS does not have its own vertical datum. The National Geodetic Vertical Datum of 1929 (NVGD29) is often used for the elevation reference marked on benchmarks established by the USGS. In the FHRR, although the USGS 1929 datum is continuously used as a reference for all elevations throughout the document, the licensee states the assumption that the USGS 1929 datum is considered to be the same as the NGVD29 datum. The assumption was justified by the results from a site survey in 2013 as reported in the FHRR. The staff agreed with the licensee's justified assumption. Hence, all elevations referenced as USGS 1929 datum in the Byron FHRR are referenced as the NGVD29 datum in this staff assessment.

According to the Byron FHRR (Exelon, 2014a), the plant elevation grade is at an elevation of 869.0 ft (264.87 m) NGVD29 and the floor elevation of safety-related buildings is 870.0 ft (265.18 m) NGVD29. The topography, as seen in Figure 3.1-3, shows that the site is relatively flat and is generally lower than 870 ft (265.18 m) NGVD29. The safety-related elevation of equipment at the river screen house is 702.0 ft (213.97 m) NGVD29 (Exelon 2014).

Table 3.1-1 of this document provides the summary of controlling reevaluated flood-causing mechanisms, including associated effects, the licensee computed to be higher than the powerblock elevation.

3.1.2 Design-Basis Flood Hazards

The CDB[1] flood levels are summarized by flood-causing mechanism in Table 3.1-2. The CDB included flood hazards from LIP and the stillwater probable maximum flooding (PMF) from precipitation events (Exelon, 2014a). The LIP CDB is 870.9 ft (265.45 m) NGVD29 (Exelon, 2014a). For flooding from streams and rivers, the PMF CDB from the probable maximum precipitation (PMP) over the Rock River watershed is 708.3 ft (215.89 m) NGVD29 (Exelon, 2014a), which was based on a steady-state hydraulic analysis. Note that wind wave setup and wind wave runup were not considered in the CDB for the PMF (Exelon, 2014a). Dam failure on the Rock River was mentioned in the CDB, but no water surface elevation (WSE) was provided since flood waves would be dissipated before reaching the site (Exelon, 2014a). The NRC staff found that failure of onsite water storage structures was not provided in the FHRR discussion of the CDB. The CDBs for storm surge, seiche, tsunami, ice-induced flooding, and channel migration were not included because these flood mechanisms were not applicable to the Byron site (Exelon, 2014a).

3.1.3 Flood-Related Changes to the Licensing Basis

Changes to the licensing basis, as discussed in the Byron FHRR (Exelon, 2014a), are primarily for flooding from LIP due to site upgrades that changed the drainage pattern and produced the need for flood protection. The flood protection measures changes included concrete curbs or

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[1] The Byron FHRR primarily used the term CLB, with occasional use of CDB. The staff assessment uses the term CDB to be consistent with the 50.54(f) letter.

steel barriers to prevent flood waters from entering areas with essential equipment at four locations with external hatches, access doors, or personnel access doors (Exelon, 2014a).

3.1.4 Changes to the Watershed and Local Area,

The Byron FHRR (Exelon, 2014a) states that the watershed area is 8,174 mi^2 (21,171 km^2) and that changes to the watershed are small compared to the total area examined. Some changes at the Byron site included buildings, parking lots, and the upgrade of the security barrier (Exelon, 2014a).

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The Byron FHRR (Exelon, 2014a) states that the only safety-related equipment potentially affected by flooding is the essential service water (SX) makeup pumps (702.0 ft (213.97 m) NGVD29) housed in the river screen house. The FHRR notes that the SX equipment is protected by a 4 ft (1.22 m) high fire wall to an elevation of 706.0 ft (215.19 m) NGVD29. Sump pumps are also provided in the SX rooms for internal flooding, but the FHRR states they can be used for leakage from external flooding (Exelon, 2014a). The FHRR also states that if the SX pumps are inoperable, there are seismically-qualified wells at the Byron site to provide makeup water. All buildings on the site with walls below the site grade are designed to be watertight up the floor elevation of 870.0 ft (265.18 m) NGVD29, including the auxiliary, containment, turbine, and radwaste buildings (Exelon, 2014a). Reinforced concrete curbs or steel barriers are provided to prevent surface drainage from entering areas with critical equipment (Exelon, 2014a).

3.1.6 Results of Plant Walkdown Activities

The 50.54(f) letter requested that licensees plan and perform plant walkdown activities to verify that current flood protection systems are available, functional, and implementable. Other parts of the 50.54(f) letter asked the licensee to report any relevant information from the results of the plant walkdown activities.

By letter dated November 27, 2012, Exelon provided its flood walkdown report for Byron (Exelon, 2012), which was supplemented with information provided by letter dated May 21, 2013 (Exelon, 2013). The NRC staff prepared a staff assessment, dated June 30, 2014 (NRC, 2014b), to document its review of the walkdown report and supplemental information. The NRC staff concluded that the licensee's implementation of the flooding walkdown methodology met the intent of the walkdown guidance.

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported in the Byron FHRR (Exelon, 2014a) that the reevaluated flood hazard, including associated effects, for LIP and associated site drainage had a maximum stillwater-surface elevation of 870.8 ft (265.42 m) NGVD29. This flood-causing mechanism is discussed in the licensee's CDB (Exelon, 2014a). The CDB PMF elevation for LIP and associated site drainage is based on a stillwater-surface elevation of 870.9 ft (265.45 m) NGVD29 (Exelon, 2014a).

3.2.1 Site Drainage

The licensee used light distance and ranging (LiDAR) data of the power block and adjacent areas, supplemented by digital elevation model (DEM) from the USGS, to construct a combined DEM for use in the analysis of local site drainage (Exelon, 2014a). Site features such as the vehicle barrier system (VBS) (Figure 3.2-1) were included in the combined DEM following a field survey (Exelon, 2014a). The results from a field survey were used to examine the accuracy of the DEM data and were found to have a root mean square error of 0.125 ft (0.04 m) (Exelon, 2014a).

According to the Byron FHRR (Exelon, 2014a), the combined DEM was used to set up a FLO-2D model (FLO-2D, 2013) of the drainage area. FLO-2D is a distributed flow model that explicitly accounts for buildings, structures, and site surface drainage characteristics (slope and roughness) (FLO-2D, 2013).

3.2.2 Local Intense Precipitation

The licensee stated that the LIP event is defined by NUREG/CR-7046 (NRC, 2011e) as the 1-hour (h), 1-mi^2 PMP event (Exelon, 2014a). The licensee calculated the 1-h, 1-mi^2 PMP depth using a site-specific PMP (SSPMP) analysis method, which produced a rainfall depth of 13.6 inches (34.54 cm) (Exelon, 2014a). The SSPMP generally includes an analysis of a set of storms found to be appropriate to the site and involves the maximization and transposition of the storm set to the Byron site. Besides the storm set taken from Hydrometerological Report (HMR)-51 (National Oceanic and Atmospheric Administration ((NOAA), 1978), the SSPMP analysis for the Byron site analysis included additional storms not considered in HMR-51. To estimate the time distribution of the 1-h PMP, the licensee used the ratio analysis plots in HMR-52 (NOAA, 1982) for 5-, 15-, and 30-min time intervals. To evaluate the effect of the SSPMP on the maximum WSE, staff conducted a sensitivity test using a LIP depth derived from HMR-52 (NOAA, 1982), which is discussed in Section 3.2.4 of this staff assessment.

3.2.3 Hydraulic Model

The licensee's analysis used a FLO 2D (2013), with the following input data (Exelon, 2014a):

1. The 1-h probable maximum precipitation depth and time distribution of precipitation;
2. Site topography including grading, drainage divides, buildings, and other site drainage features; and,
3. Manning's roughness coefficients to characterize the land cover of the site.

The licensee submitted the FLO-2D model inputs and outputs (Kaegi, 2014) to the NRC. The FLO-2D model uses a grid input to represent the site topography and transforms the precipitation into runoff (FLO-2D, 2013). To produce surface runoff for the Byron site, the licensee assumed there were no precipitation losses (Exelon, 2014a). The licensee used a FLO-2D model grid spacing of 10-ft (3-m) by 10-ft (3-m) to discretize the topographic and structural features of the site (Kaegi, 2014). As stated in the Byron FHRR (Exelon, 2014a), the

Manning's roughness coefficient values were set to 0.035 for paved areas, 0.07 for open ground, and 0.30 for areas with shrubs and grass, which the licensee states are the midrange of values suggested by FLO-2D documentation (FLO-2D, 2013). The NRC staff noted that runoff from roofs were handled using area reduction factors with roof elevations the same as the site grade elevation, which are appropriate for FLO-2D.

The NRC staff reviewed publically-available aerial photography to verify that the licensee incorporated site features (e.g., buildings, observable drainage) appropriately. The NRC staff considers the parameters and grid size appropriate based on the licensee's sensitivity tests and staff's examinations.

3.2.4 Sensitivity Analyses

The licensee conducted a sensitivity test on Manning's roughness (Exelon, 2014a). For the sensitivity test, the licensee used the lower end of the suggested range for Manning's roughness coefficients with 0.02 for paved areas and 0.04 for open ground, but continued to use 0.30 for areas with shrubs and grass (Exelon, 2014a). The LIP analysis used Manning's roughness values in the mid-range of recommended range (Exelon, 2014a). The licensee found no change in the maximum WSE computed by FLO-2D and concluded that the model was insensitive to Manning's roughness (Exelon, 2014a). The NRC staff notes that a site with small topographic gradient (slope) would be expected to be insensitive to Manning's roughness coefficient because Manning's equation includes the slope in the calculation of velocity.

The NRC staff performed a separate sensitivity analysis of the SSPMP rainfall depths on resulting water-surface elevations and utilized HMR-51 (NOAA, 1978) and HMR-52 (NOAA, 1982) to calculate a maximum rainfall of 17.6 in (44.70 cm) at the Byron site, which is 4.0 in (10.16 cm) more than the maximum rainfall depth calculated by the licensee for the SSPMP. The NRC staff substituted the HMR computed rainfall depth for the SSPMP depth while using the same hyetograph distribution and FLO-2D model that the licensee used to analyze the LIP flooding (see Section 3.2.3 of this staff assessment). From this analysis, the NRC staff calculated a maximum water-surface elevation of 871.1 ft (265.51 m) NGVD29, which is 0.25 ft (0.08 m) greater than the maximum water surface elevation from the licensee's calculations. However, the NRC staff consider the difference between the maximum SSPMP flood elevation and the HMR flood elevation to be insignificant, and therefore the SSPMP maximum water-surface elevation is reasonable and acceptable.

3.2.5 Conclusion

The staff confirmed the licensee's conclusion that the reevaluated flood hazard for LIP and associated site drainage is bounded by the CDB flood hazard. Consequently, an additional assessment for LIP flood-causing mechanism is not required per the guidance discussed in COMSECY-15-0019 (NRC, 2015b).

3.3 Streams and Rivers

The licensee reported in the Byron FHRR (Exelon, 2014a) that the reevaluated flood hazard, including associated effects, for streams and rivers is based on a stillwater-surface elevation of 699.2 ft (213.12 m) NGVD29 (Exelon, 2014a), which does not include dam failure (See Section 3.4 of this staff assessment for dam failure results). Including the results from the wind-wave calculations for the dam failure scenario in Section 3.4.3 of this staff assessment, staff calculated the wind waves and runup resulted in an elevation of 703.4 ft (214.40 m) NGVD29.

This flood-causing mechanism is discussed in the licensee's CDB (Exelon, 2014a). The CDB PMF elevation for streams and rivers is based on a stillwater-surface elevation of 708.3 ft (215.89 m) NGVD29 from a steady-state hydraulic analysis and also does not include dam failure (Exelon, 2014a). No wind wave activity is included in the CDB of flooding from streams and rivers (Exelon, 2014a).

3.3.1 Precipitation and Snowpack/Snowmelt

The licensee considered precipitation scenarios for the following three alternatives (Exelon, 2014a) as derived from NUREG/CR-7046 (NRC, 2011e): (1) all-season PMP with antecedent rainfall at 40 percent of the PMP (Alternative 1); (2) snowmelt from the probable maximum snowpack with a 100-year, snow-season rainfall under rain-on-snow conditions (Alternative 2); and (3) snowmelt from a 100-year snowpack with a cool-season PMP under rain-on-snow conditions (Alternative 3).

The licensee estimated the all-season PMP by using HMR-51 and HMR-52 guidance (NOAA, 1978; NOAA, 1982) and HMR-52 software (BOSS, 1988) (Exelon, 2014a). The depth-area-duration values for 6-, 12-, 24-, and 72-h durations and 10-, 200-, 1,000-, 5,000-, 10,000-, and 20,000-mi^2 (25.9-, 518-, 2,590-, 12,950-, 25,900-, and 51,800-km^2) areas from HMR-51 were input to the HMR-52 software (Exelon, 2014a). The HMR-52 software determines the storm's size, center, and spatial orientation over the watersheds to maximize the precipitation and identify the controlling PMP. The staff reviewed the results provided in the Byron FHRR (Exelon, 2014a) and found the HMR-51 and HMR-52 methods appropriate and the results reasonable.

As stated in the Byron FHRR (Exelon, 2014a), the licensee calculated the two snowmelt values from a probable maximum snowpack and a 100-year snowpack using the *Runoff from Snowmelt* guidance provided by U.S. Army Corps of Engineers (USACE) (USACE, 1998). The licensee assumed the probable maximum snowpack was present prior to the rainfall event and covered the entire basin with unlimited depth (Exelon, 2014a). The license determined the 100-year snowpack based on historical snow depth records from the weather stations across the basin (Exelon, 2014a). According to the Byron FHRR, the rain-on-snow scenarios used the parameters of dew point temperature and hourly wind velocities that were derived from data collected from the representative weather stations to determine snowmelt. The NRC staff found the energy budget balance snowmelt equation used by the licensee for this calculation is acceptable. The NRC staff reviewed the analysis and verified that the methodology and procedure the license used were appropriate, the data collected were from acceptable sources, and the results are reasonable.

The licensee estimated the cool-season PMP by interpolating the 10-mi^2 (25.9 km^2) seasonal PMP from HMR-53 (NOAA, 1980) to the Byron site for each month of the snow season (November to April) (Exelon, 2014a). For the 100-year snow-season rainfall calculation, the licensee used the NOAA Atlas 14 precipitation frequency guidance (NOAA, 2006) to determine point precipitation depths at the Byron site (Exelon, 2014a). Based on the results, including snowmelt, the licensee identified Alternative 2 as the critical scenario (Exelon, 2014a). The NRC staff reviewed the licensee's analysis and concluded that it was consistent with present-day methodologies and reasonable for calculation of the PMF from streams and rivers.

3.3.2 Probable Maximum Flood

The licensee identified the source of potential stream and river flooding as the Rock River and its contributing watershed, which lies approximately 2 mi (5.2 km) west of the site (Exelon, 2014a). In the Byron FHRR (Exelon, 2014a), the licensee stated that the SX pumps at the river screen house on the Rock River are the only safety-related equipment that could be impacted by flooding hazards from streams and rivers. The locations of the Rock River, river screen house, and Byron site are shown in Figure 3.1-1.

The licensee constructed a hydrologic model of the Rock River watershed with USACE Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) software (Version 3.5) (USACE, 2010b) and selected the Snyder Unit Hydrograph Method to transform precipitation to surface runoff in the model (Exelon, 2014a). According to the Byron FHRR (Exelon, 2014a), the Snyder Unit hydrograph parameters (lag time and peak coefficient) and HEC-HMS loss parameters (initial loss and constant loss) were calibrated against the historical peak storm events at USGS gage stations. The NRC staff reviewed the calibrated model and concluded that the model input and parameters were reasonable based on common engineering practice.

To account for the effect of nonlinear basin response to the PMF (an extreme flood event), the licensee modified the calibrated model by increasing peak flow by 20 percent and reducing the time to peak by 33 percent (Exelon, 2014a), as recommended in NUREG/CR-7046 (NRC, 2011e). The licensee also included the baseflow in the HEC-HMS model (Exelon, 2014a).

3.3.3 Maximum Water Surface Elevation

To estimate the maximum flood elevation at the river screen house from the flows calculated by the HEC-HMS model (see Section 3.3.2 of this staff assessment), the licensee performed an analysis for dynamic channel routing of the inflow with a hydraulic model using the HEC-River Analysis System (RAS) software (Version 4.1 (USACE, 2010a)) (Exelon, 2014a). For reference, the river screen house is located at cross-section RM 115.0 (185 km) (Kaegi, 2014; Exelon, 2014a). The licensee developed the HEC-RAS hydraulic model for a reach of the Rock River from an upstream boundary at RM 125.07 (201.3 km), 10.1 mi (16.3 km) upstream from the river screen house at the Byron site, to the downstream boundary at RM 86.56 (139.3 km), 29 mi (46.7 km) downstream from the river screen house (Kaegi, 2014).

The licensee incorporated channel and floodplain geometries into the HEC-RAS model by developing a series of cross-sections based on the bathymetry data and cross section information in the Federal Emergency Management Agency (FEMA) HEC-2 model (USACE, 1985a; USACE, 1985b) (Exelon, 2014a). The licensee included seven bridges, and the Oregon and Dixon Dams were also included in the HEC-RAS model (Kaegi, 2014). Locations of upstream and downstream boundaries and cross sections in the HEC-RAS model, the river screen house, and USGS gage 05440700 are shown in Figure 3.3-1 (and in Figure 3.1-1). The downstream boundary was set as a normal depth condition in the HEC-RAS model, while the upstream boundary was an inflow hydrograph estimated from HEC-HMS analysis of the watershed (see Section 3.3.2 of this staff assessment) (Kaegi, 2014). The NRC staff reviewed the model components, geometry and spacing of cross sections, and structures and concluded that the HEC-RAS model construction is reasonable and the data sources used for developing the model are acceptable. The NRC staff also verified that the WSE at the river screen house was not sensitive to the normal depth condition at the downstream boundary or to dam operation at two downstream dam structures (Oregon and Dixon Dams).

The licensee calibrated the HEC-RAS model to three historical events with high peak water surface elevations by adjusting the Manning's roughness coefficients for the river channel and the overbank until the simulated WSE was the same as or less than 1 ft (0.30 m) above the observed water surface elevation at the Byron USGS gage (RM 120.04; 193.2 km) (Figure 3.3-1) (Kaegi, 2015). The final Manning's roughness coefficients used in the calibrated HEC-RAS model were 0.03 for the river channel and 0.1 for the overbank. However, the staff noted that the historical peak flows used for model calibration were less than 20 percent of the controlling PMF flow rate. The licensee provided the following support information regarding the ability of the model calibration to address the uncertainty of Manning's roughness coefficient over greater flood depths and surface area during the PMF: (1) the Manning's roughness coefficient is conservative for the overbank land use and type along the Rock River reach included in the HEC-RAS model, and (2) greater depths in the river channel tend to reduce the flow resistance of roughness features (Kaegi, 2015). The staff performed an independent sensitivity analysis by increasing Manning's roughness coefficients up to 25 percent and confirmed that the licensee's resultant maximum WSE was reasonable.

The licensee evaluated the PMFs for the three precipitation and snowmelt alternatives using the surface runoff from the HEC-HMS model with nonlinear adjustment of the precipitation transformation function, the HEC-RAS model of the Rock River channel and overbanks, and determined that the controlling PMF is 193,800 cubic feet per second (cfs) (5487.8 m^3/s) for Alternative 2, which includes snowmelt from probable maximum snowpack with a 100-year, snow-season rainfall (Exelon, 2014a). As a result of the PMF analysis, the licensee determined from the HEC-RAS model that the maximum stillwater surface elevation is 699.2 ft (213.12 m) NGVD29, which is bounded by the licensee's CDB for the PMF on the Rock River (708.3 ft (215.89 m) NGVD 29) (Exelon, 2014a). The staff confirmed that Alternative 2 produced the highest PMF in the Rock River near Byron's river screen house. Additionally, the NRC staff confirmed that the licensee's methodology and application of regulatory guidance was appropriate.

3.3.4 Coincident Wind and Wave Activity

According to the Byron FHRR, the licensee examined wind-wave effects at the Byron site only as part of their dam failure analysis, which is discussed in Section 3.4 of this staff assessment. In that analysis, the licensee estimated wave runup to be 4.2 ft (1.28 m) induced by 2-year wind speed (Exelon, 2014a). Assuming the same wind wave runup from the licensee's wave wind effects analysis, the staff estimated the maximum WSE at the river screen house, including maximum stillwater surface elevation (699.2 ft (213.12 m) NGVD29) and wave runup (4.2 ft (1.28 m)), would be 703.4 ft (214.40 m) NGVD29. This estimated maximum WSE is 4.9 ft (1.49 m) below the CDB (708.3 ft (215.89 m) NGVD29). The NRC staff notes that the PMF plus wind wave effects is not the controlling scenario for the reevaluated flood hazard because it does not include hydrologic dam failure (see Section 3.4.3 of this staff assessment).

3.3.5 Conclusion

Based on the available information in the Byron FHRR (Exelon, 2014a) and the licensee's response to RAIs (Kaegi, 2014 and 2015), the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from streams and rivers at Byron is bounded by the CDB. Therefore an additional assessment for streams and rivers flood-causing mechanism is not required per the guidance discussed in COMSECY-15-0019 (NRC, 2015b).

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in the Byron FHRR (Exelon, 2014a) that the reevaluated flood hazard, including associated effects, is based on a maximum stillwater-surface elevation of 703.2 ft (214.34 m) NGVD29 at river screen house (Exelon, 2014a), 2 mi (3.2 km) west of the Byron site and includes the failure of upstream dams in the Rock River watershed under the PMF event analyzed in Section 3.3 of this staff assessment. Including wind waves and runup resulted in a maximum elevation of 707.4 ft (215.62 m) NGVD29 (Exelon, 2014a). While dam failure is mentioned in the CDB, no WSE is provided because the licensee states that the flood wave would be dissipated and only produce minor effects on maximum WSE at the site (Exelon, 2014a).

The licensee also reported in the Byron FHRR (Exelon, 2014a) that the reevaluated flooding hazard from failure of onsite water storage structures is based on a maximum stillwater-surface elevation of 869.9 ft (265.15 m) NGVD29 at the site (Exelon, 2014a). The NRC staff notes that this flood-causing mechanism was not discussed in the licensee's CDB, and no probable maximum flood elevation was reported.

As reported in the Byron FHRR (Exelon, 2014a), the licensee performed two separate dam failure analysis cases: one for upstream hydrologic dam failures in the Rock River watershed and another for onsite hydrologic, seismic, and sunny-day basin failures at the site. According to the FHRR, hydrologic dam failure bounds both the seismically-induced and sunny-day failures in the Rock River watershed, so that the latter two are not considered to be controlling flooding mechanisms. As stated by the licensee, for the first case, the SX makeup pumps at the River Screen House are the only safety-related equipment that could be impacted by flooding hazard from upstream dam failures (Exelon, 2014a). The SX pumps are protected to an elevation of 706.0 ft (215.19 m) NGVD29 by the presence of a 4-ft (1.22-m) high fire walls (Exelon, 2014). The locations of the Rock River, the river screen house, and the Byron site are shown in Figures 3.1-1 and 3.3-1. For the second case, the safety-related equipment in the power block could potentially be impacted by onsite basin failures (Exelon, 2014a). The safety-related equipment on the site is protected to an elevation up to 870.9 ft (265.45 m) NGVD29 (Exelon, 2014a). The locations of the onsite storage basins are shown in Figure 3.1-2.

3.4.1 Upstream Dam Failures

The licensee evaluated upstream dam failures in the Rock River watershed for the hydrologic, seismically-induced, and sunny-day dam failure mechanisms (Exelon, 2014a). The licensee used the PMF for the hydrologic dam failure analysis and the ½ PMF for the seismically-induced dam failure analysis (Exelon, 2014a). The licensee also determined that the sunny-day dam failure would be bounded by the hydrologic and seismic dam failures because of its smaller associated streamflow (Exelon, 2014a).

3.4.1.1 *Dam Assessment and Peak Dam Breach Outflow*

The licensee identified dams upstream from the Byron site within the Rock River watershed by using the USACE National Inventory of Dams (NID) database (Exelon, 2014a) (Figure 3.4-1). The licensee evaluated the effects of hydrologic dam failures with a simplified approach that used one hypothetical dam representing the total storage of the identified dams (Exelon, 2014a). The hypothetical dam was placed it at the nearest NID dam location (dam no. 133 in Figure 3.4-1), approximately 12 mi (19 km) upstream from the Byron's River Screen House. The licensee stated that most of the dams in the Rock River watershed are low-head dams because of the relatively low topographic relief of the area (Kaegi, 2015). The storage volume of a single hypothetical dam was estimated as the sum of maximum storage volumes for the 138 individual dams identified in the NID database (Kaegi, 2015). The height of the hypothetical dam was assumed as an average storage-weighted height for all the dams identified from the NID database (Kaegi, 2015). Figure 3.4-1 shows the locations of the dams from the NID database. The licensee evaluated the following methods to compute the peak flows from the hypothetical dam breach (Kaegi, 2015): the US Bureau of Reclamation method (USBR, 1982), the Natural Resources Conservation Service method (NRCS, 1985), and the method of Froehlich (1995). The licensee calculated the largest peak breach outflow from hydrologic dam failure using Froehlich's (1995) equation (Kaegi, 2015).

The licensee completed a sensitivity analysis of the hydraulic dam failure using a HEC-HMS model with a reach routing network (Kaegi, 2015) for comparison with the simplified approach reported in the FHRR. The sensitivity analysis included all 138 dams (Figure 3.4-1) and simulated the accumulated flow from the progressive dam failures routed through the reach network by the HEC-HMS model (Kaegi, 2015). The dam characteristics for each dam were estimated from those identified in the NID database (Kaegi, 2015). The estimated dam failure flow hydrograph from the HEC-HMS model was added on to the PMF hydrograph in the HEC-RAS model (Kaegi, 2015). The licensee found that this approach produced a lower WSE at Byron's river screen house than the simplified dam failure analysis using one hypothetical dam with a storage-weighted height and total storage based on all 138 reservoirs (Kaegi, 2015). The staff reviewed the sensitivity analysis and found that although it provided an accurate simulation of the accumulated effect of failures of all dams in series along Rock River within the watershed, it was less conservative than the simplified hypothetical dam failure analysis. The staff concluded that the results from the simplified hypothetical dam failure analysis were reasonable.

The NRC staff also examined the statement in the Byron FHRR (Exelon, 2014a) that seismic dam failure is bounded by hydrologic dam failure during the PMF. Because of the lower background flows used in the seismic dam failure analyses of either a 25-yr flood or ½ PMF (or

500-yr flood), as based on NUREG/CR-7046 (NRC, 2011e) in comparison with the PMF flows, staff agree with the licensee's statement that hydrologic dam failure is the bounding scenario.

3.4.1.2 Maximum Water Surface Elevation

The licensee calculated the maximum WSE for the single hypothetical dam failure case using the HEC-RAS model developed for the PMF analysis (see Section 3.3 of this staff assessment). On the basis of the peak breach flow from the hypothetical dam failure analysis, the licensee also estimated flow attenuation from the location of the hypothetical dam to Byron's river screen house using the U.S. Bureau of Reclamation (USBR) empirical attenuation equation (USBR, 1982) (Exelon, 2014a). The licensee incorporated the attenuated peak breach flow of 48,350 cfs (1,369 m^3/s) as a constant inflow to the HEC-RAS model (Kaegi, 2014).

The licensee provided an additional analysis of flood routing performed with the HEC-RAS and the HEC-HMS models to compare with using the empirical attenuation equation determination of peak breach flow from the hypothetical dam to the river screen house (Kaegi, 2015) (see Section 3.4.1.1 of this staff assessment). In this analysis, the licensee used the HEC-HMS model to route the dam failure flows from 138 dams using the Muskingum method and then added the dam failure hydrograph to the controlling PMF hydrograph at the upstream boundary of the HEC-RAS model (Kaegi, 2015). From this additional analysis (Kaegi, 2014), the licensee's resulting WSE at Byron's river screen house from the HEC-RAS model was lower than the WSE estimated with simplified analysis (one hypothetical dam failure and simplified flow attenuation) as reported in the Byron FHRR (Exelon, 2014a). The staff notes that while the licensee's additional analysis accurately simulated the dam failure processes in the Rock River watershed and is consistent with common engineering practice, the method was less conservative than the simplified analysis. Therefore, the NRC staff concluded that the maximum WSE derived using the simplified analysis with flow attenuation based on USBR (1982) methods was reasonable and appropriate.

The licensee also evaluated seismically-induced dam failures and stated in the Byron FHRR (Exelon, 2014a) that the effect of the peak breach outflow due to seismically-induced dam failures coincident with a ½ PMF was bounded by the hydrologic dam failure produced during the PMF. Because the background flows for the ½ PMF is smaller than for the full PMF, the staff agrees with the licensee's conclusion.

3.4.2 Onsite Basin Failures

The licensee identified the water-storage structures on the site and evaluated the impact of their failures on the WSE surrounding the power block on the site (Exelon, 2014a). The evaluation was performed by simulating the breach outflow from the onsite water storage structures with the HEC-HMS model and then computing WSE with the FLO-2D model developed in the LIP analysis (see Section 3.2 of this staff assessment) using the breach outflow as inflow to the FLO-2D model (Exelon, 2014a). The licensee evaluated the onsite basin failures under scenarios of hydrologic failure for PMF conditions (that is, coincident with the 72-hour PMP), seismically-induced failure for ½ PMF conditions (that is, coincident with ½ 72-hour PMP), and sunny-day dam failure due to piping failure of the embankment (Exelon, 2014a).

3.4.2.1 Dam Assessment and Peak Breach Outflow

The licensee identified two onsite water-storage structures that could potentially contribute to the flood hazard at the site (Exelon, 2014a): the NDCT flume (basin) and the UHS basin. The locations of the two onsite water basins are shown in Figure 3.1-2. The NDCT basin has 2-ft tall concrete walls that extend above the surrounding grade, and the UHS basin has 4-ft tall concrete walls that extend above the grade (Exelon, 2014a).

The failure outflow for each basin was estimated using the HEC-HMS model with estimated parameters (Exelon, 2014a). The parameter included the maximum reservoir water surface elevation that defines the breach trigger elevation, the basin length that defines the breach width, and a breach development time of 0.1 hours (Exelon, 2014a). For the NDCT basin, which is not a seismically-qualified structure, the licensee used HEC-HMS to compute the outflows from basin failures and determined that the largest breach flow would occur under the hydrologic dam failure scenario, which had the largest storage elevation and volume of the three scenarios (Exelon, 2014a). The UHS basin is a Category I seismically-qualified structure, and the maximum reservoir water elevation under the 72-hr PMP was below the top of wall (Exelon, 2014a). Consequently, the licensee assumed that no seismically induced or hydrologic dam failures will occur at the UHS basin, and that the only breach outflow is for sunny-day failure (Exelon, 2014a). The sunny-day failure of the UHS was computed using the HEC-HMS model for a normal operation water surface elevation (Exelon, 2014a). The hydrologic dam failure scenario flows from the NDCT and UHS basin failures were used as inflows for further dam failure analyses using FLO-2D (Exelon, 2014a), which is discussed further in Section 3.4.2.2 of this staff assessment.

The licensee indicated that LIP was used to produce the maximum depth in the basin and not to induce surface runoff over the whole of the Byron site and the NDCT has no drainage area and the LIP event does not cause the NDCT pool elevation to exceed the surrounding grade, which could lead to hydrologic dam failure (Kaegi, 2015). Additionally, the licensee stated that while LIP as a meteorological event would not occur coincidently with seismically-induced dam failure, the LIP produced depth was used as the starting condition for the seismic failure analysis of the NDCT basin (Kaegi, 2015). The NRC staff agrees that the driving head produced by the LIP over only the NDCT basin is reasonable and appropriately used for dam failure analysis of the NDCT basin.

3.4.2.2 Maximum Water Surface Elevation

The licensee estimated the maximum WSE from onsite basin failures using the FLO-2D model that was developed for the LIP analysis (see Section 3.2 of this staff assessment). The peak breach outflows from the HEC-HMS model of the NDCT and UHS basin failures (see Section 3.4.2.1 of this staff assessment) were evenly assigned as an inflow to the grid cells along the breach width in the FLO-2D model (Exelon, 2014a). Based on the FLO-2D modeling analysis, the computed maximum WSE near the power block was 869.9 ft (265.15 m) NGVD29 for the worst-case (hydrologic) dam failure at the NDCT basin (Exelon, 2014a). For the UHS basin, the results from simulating sunny-day structure failure indicated that the breach outflow would not inundate the power block. The staff reviewed the licensee's information and concluded that the maximum WSE in the Byron FHRR that was estimated for onsite basin failures was reasonable and appropriate.

3.4.3 Effects of Wind Waves

Based on the hydrologic dam failure analysis during the PMF on the Rock River, the licensee evaluated the associated effect of waves induced by a 2-year wind speed applied along the critical direction (Exelon, 2014a) using an approach consistent with NUREG/CR-7046 (NRC, 2011e). The wind speed of 46 mph with a 2-year return period was calculated using the Gumbel Distribution based on data recorded at the Rockford Airport station near the Byron site (Exelon, 2014a). Adjustments to the wind speed over water were made by the licensee based on guidance in the USACE Coastal Engineering Manual (USACE, 2008). The wave height and wave runup were calculated with the Automated Coastal Engineering System software (USACE, 1992) based on an empirical equation by Ahrens and Titus (1985). The resultant wave runup was 4.2 ft (1.28 m). The reevaluated maximum WSE (707.4 ft (215.62 m) NGVD29) due to the flood hazard from upstream hydrologic dam failure and the associated effect of wind waves is bounded by the CDB (708.3 ft (215.89 m) NGVD29) for the stream and river flood mechanism. Staff notes that the CDB was for a steady-state analysis of the PMF, but does not include dam failure. The NRC staff reviewed the analysis for the effect of wind wave and concluded that the licensee's evaluation is consistent with the regulatory guidance and common engineering practice.

The effect of wind waves coincident with the onsite basin storage failures was not evaluated by the licensee. Because of the small size of the onsite water storage structures (NDCT and UHS), the effect of wind wave is minimal. The staff agrees with the licensee's determination. The maximum WSE from failure of onsite storage structures is discussed in Section 3.4.2.2 of this staff assessment.

3.4.4 Conclusion

The NRC staff confirmed the licensee's conclusion that the reevaluated flood hazard for dam failures and onsite water control or storage structures at Byron is bounded by the CDB. Therefore an additional assessment for dam failures and onsite water control or storage structures flood-causing mechanisms is not required per the guidance discussed in COMSECY-15-0019 (NRC, 2015b).

3.5 Storm Surge

In the Byron FHRR (Exelon, 2014a), the licensee reported that the reevaluated hazard, including associated effects, for storm surge does not inundate the plant site or the River Screen House. As such, the licensee did not report a maximum flood elevation for storm surge alone. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee stated in its FHRR (Exelon, 2014a) that the Byron site is not located on a large or open body of water and is far from the ocean. Also, the plant grade elevation of approximately 869 ft (264.9 m) NGVD29 is approximately 197 ft (60.1 m) above the Rock River, which is at an elevation of approximately 672 ft (204.8 m) NGVD29, so that no storm surge could inundate the site (Exelon, 2014a). The SX pumps are protected to an elevation of 707.3 ft (215.59 m) NGVD29, which is more than 30 ft (9.1 m) above the normal elevation of the Rock River

(Exelon, 2014a). The licensee also states in its FHRR (Exelon, 2014a) that the onsite NDCT and UHS basins have a restricted fetch length and would not produce a storm surge.

The NRC staff reviewed the licensee's FHRR and agrees that flooding as a result of storm surge would not be a mechanism of concern for Byron. The staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from storm surge is bounded by the CDB.

3.6 Seiche

In the Byron FHRR (Exelon, 2014a), the licensee reported that the reevaluated hazard, including associated effects, for seiche does not inundate the plant site or the river screen house. As such, the licensee did not report a maximum flood elevation for seiche alone. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee stated in its FHRR (Exelon, 2014a) that the Byron site is not located on a large or open water body and is far from the ocean. Also, the plant grade elevation of approximately 869 ft (264.9 m) NGVD29 is approximately 197 ft (60.1 m) above the Rock River, which is at an elevation of approximately 672 ft (204.8 m) NGVD29, so that no storm or seismic seiche could inundate the site (Exelon, 2014a). The SX pumps are protected to an elevation of 707.3 ft (215.59 m) NGVD29, which is more than 30 ft (9.1 m) above the Rock River (Exelon, 2014a). The licensee also conducted an analysis on the onsite NDCT and UHS basins and found that the basin's calculated seiche periods would result in only small accelerations and so would not produce a seismic seiche risk (Exelon, 2014a).

The NRC staff reviewed the Byron FHRR and agrees that flooding as a result of seiche would not be a mechanism of concern for the site. The staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from seiche is bounded by the CDB.

3.7 Tsunami

In the Byron FHRR (Exelon, 2014a), the licensee reported that the reevaluated hazard, including associated effects, for tsunami does not inundate the plant site or the river screen house. As such, the licensee did not report a maximum flood elevation for tsunami alone. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee reported in the Byron FHRR (Exelon, 2014a) that tsunami effects from large waterbodies are not a concern due to the site's inland location. The Byron site is approximately 800 mi (1,288 km) inland from the Atlantic coast, 82 mi (132 km) inland from the Lake Michigan, and 820 river mi (1,320 km) inland from the Gulf of Mexico (Exelon, 2014a). The licensee examined seismically-induced hill-slope failure as a source of tsunami-like wave (Exelon, 2014a). The licensee suggests in the Byron FHRR (Exelon, 2014a) that a USGS compilation of locations with landslide incidence and susceptibility in the United States shows the area to be at low risk for tsunamic generating landslides.

For comparison with the water levels of the Rock River, it is noted in the Byron FHRR (Exelon, 2014a) that the plant grade elevation of 869 ft (264.9 m) NGVD29 is approximately 197 ft (60.1 m) above the Rock River, which has an elevation of approximately 672 ft (204.8 m) NGVD29 during mean annual flow, so that no tsunami could plausibly inundate the Byron site.

The FHRR (Exelon, 2014a) also states that the SX pumps are protected to an elevation of 707.3 ft (215.59 m) NGVD29, which is more than 30 ft (9.1 m) above the Rock River.

The NRC staff reviewed the location of the site in relation to the Atlantic Coast, Great Lakes, and the Gulf of Mexico, as well as the licensee's findings in the Byron FHRR. The staff also examined the topography of the Rock River valley available from the USGS (2015a) near the river screen house. The staff found that while there was a hill slope across the river from the river screen house, any potential failure would likely be contained on the flood plain on the landward side of the highway that runs along the Rock River. The staff also examined the USGS Landslide Overview Map (USGS, 2015c) and found the area around the Byron site and the Rock River to have a low level of landslide incidence. Therefore the NRC staff agrees that flooding as a result of tsunami would not be a mechanism of concern for the site because the site and safety-related structures are well above any plausible tsunami height. The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from tsunami is bounded by the CDB.

3.8 Ice-Induced Flooding

In the Byron FHRR (Exelon, 2014a), the licensee reported that the reevaluated hazard, including associated effects, for ice-induced flooding does not inundate the plant site or the river screen house. As such, the licensee did not report a probable maximum flood elevation. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee examined the historical record from the ice-jam database (USACE, 2015) and conducted hydraulic modeling effects of hypothetical scenarios with an ice-jam break and an ice-jam backwater. According to the licensee (Exelon, 2014a), the largest ice-jam of record occurred on January 14, 2009, near the town of Joslin, IL, upstream of the Byron site. The greatest river stage at Joslin was 30 ft (9.1 m) with a calculated ice thickness of 20.4 ft (6.2 m) (Exelon, 2014a). This served as the basis for the ice-jam break scenario (Exelon, 2014a). The licensee also examined a scenario of an ice-jam backwater downstream of the Byron site at Oregon Dam with an assumed thickness being the same as the largest ice jam of record (2009 at Joslin, IL). Using the HEC-RAS model developed for the PMF analyses (see Section 3.3.3 of this staff assessment), the licensee calculated the maximum WSE from an upstream ice jam to be 696.1 ft (212.17 m) NGVD29 and the maximum WSE from a downstream ice jam to be 692.2 ft (210.98 m) NGVD29 (Exelon, 2014a). Both of the scenarios produce maximum water surface elevations at the river screen house that are bounded by the PMF.

The NRC staff independently searched the USACE Cold Regions Research and Engineering Laboratory Ice Jam Database (USACE, 2015) for current and historical ice jams near the Byron site and confirmed the information used by the licensee for the ice-induced flooding analysis. The NRC staff reviewed the licensee's findings in the Bryon FHRR and confirmed the licensee's conclusion that the reevaluated hazard for ice-induced flooding of the site is bounded by the CDB flood hazard.

3.9 Channel Migrations or Diversions

In the Byron FHRR (Exelon, 2014a), the licensee reported that the reevaluated hazard, including associated effects, for channel migrations or diversions does not inundate the plant site. As such, the licensee did not report a probable maximum flood elevation. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee examined the historical records including aerial photographs and topographic maps (Exelon, 2014a). Based on the examination, the licensee found that the Rock River channel in the vicinity of Byron has been stable for many years and there are no indications of the potential for channel migration or diversion (Exelon, 2014a).

The NRC staff reviewed basin topography and topology (USGS, 2015a; USGS, 2015b) and noted there was no evidence of channel migration or diversion along nearby streams or tributaries that could threaten the site. Accordingly, the staff agrees that channel diversions or migrations is not a flood-causing mechanism of concern for the Byron site or the river screen house. The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from channel migrations or diversions is bounded by the CBD flood hazard.

4.0 REEVALUATED FLOOD HEIGHT, EVENT DURATION, AND ASSOCIATED EFFECTS FOR HAZARDS NOT BOUNDED BY THE CDB

4.1 Reevaluated Flood Height for Hazards Not Bounded by the CDB

Section 3 of this staff assessment documents NRC staff review of the licensee's flood hazard water height results. The NRC staff agrees with the licensee's conclusion that all flood hazard mechanisms evaluated in the Byron FHRR (Exelon, 2014a) are bounded by the CDB. No further evaluation is warranted.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed the Byron FHRR (Exelon, 2014a) and agrees with the licensee that all flood causing mechanisms are bounded by the CDB. An evaluation of flood event duration parameters is not warranted.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed the Byron FHRR (Exelon, 2014a) and agrees with the licensee that all flood causing mechanisms are bounded by the CDB. An evaluation of associated effects not directly related with total water height is not warranted.

4.4 Conclusion

The NRC staff confirmed that the reevaluated flood hazard results are bounded by the Byron CDB hazard. Therefore, no additional assessments of plant response, as described in the 50.54(f) letter and COMSECY-15-0019, "Mitigating Strategies and Flooding Hazard Reevaluation Action Plan" (NRC, 2015b), at the Byron site is necessary.

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms of Byron. Based on its review of the above available information provided in

Exelon's 50.54(f) response (Exelon, 2014a; Kaegi 2014; and Kaegi 2015), the NRC staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

Based on the preceding analysis, the NRC staff confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter, dated March 12, 2012. In reaching this determination, the NRC staff confirmed the licensee's conclusions that (a) the reevaluated flood hazard results for all flood causing mechanisms are bounded by CDB flood hazard, and (b) no additional assessments of plant response are needed.

6.0 REFERENCES

Notes: ADAMS Accession Nos. refers to documents available through NRC's Agencywide Documents Access and Management System (ADAMS). Publicly-available ADAMS documents may be accessed through http://www.nrc.gov/reading-rm/adams.html.

U.S. Nuclear Regulatory Commission Documents and Publications

NRC (U.S. Nuclear Regulatory Commission), 2007, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," NUREG-0800, 2007. ADAMS stores the Standard Review Plan as multiple ADAMS documents, which are most easily accessed through NRC's public web site at http://www.nrc.gov/reading-rm/basic-ref/srp-review-standards.html.

NRC, 2009, "Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America, Final Report, "NUREG/CR-6966, PNNL-17397, March 2009, ADAMS Accession No. ML091590193.

NRC, 2011a, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," SECY-11-0093, July 12, 2011, ADAMS Accession No. ML11186A950.

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

NRC, 2011c, "Recommended Actions to be Taken Without Delay from the Near-Term Task Force Report," SECY-11-0124, September 9, 2011, ADAMS Accession No. ML11245A158.

NRC, 2011d, "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned," SECY-11-0137, October 3, 2011, ADAMS Accession No. ML11272A111.

NRC, 2011e, "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United State of America," NUREG/CR-7046, PNNL-20091, November 2011, ADAMS Accession No. ML11321A195.

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

NRC, 2012b, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, May 11, 2012, ADAMS Accession No. ML12097A510.

NRC, 2012c, "Guidance for Performing the Integrated Assessment for External Flooding," Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2012-05, Revision 0, November 30, 2012, ADAMS Accession No. ML12311A214.

NRC, 2013a, “Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment,” Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2012-06, Revision 0, January 4, 2013, ADAMS Accession No. ML12314A412.

NRC, 2013b, “Guidance For Assessment of Flooding Hazards Due to Dam Failure,” Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2013-01, Revision 0, July 29, 2013, ADAMS Accession No. ML13151A153.

NRC, 2014a, “2014/06/18 NRR E-mail Capture - RAIs for Braidwood, Byron, Clinton and LaSalle Flood Hazard Reevaluation,” June 18, 2014, ADAMS Accession No. ML14169A545.

NRC, 2014b, “Byron Station, Units 1 and 2, Staff Assessment of the Flooding Walkdown Report Supporting Implementation of Near-Term Task Force Recommendation 2.3 Related to the Fukushima Daiichi Nuclear Power Plant Accident (TAC Nos. MF0205 and MF0206),” June 30, 2014, ADAMS Accession No. ML14128A556.

NRC, 2015a, “2012/04/03 NRR E-mail Capture-RESEND: Braidwood, Byron, Clinton and LaSalle and 2 – Flooding Requests for Additional Information (TAC Nos. MF3893 and MF3894),” April 3, 2015, ADAMS Accession No. ML15093A313.

NRC, 2015b, “Mitigating Strategies and Flood Hazard Reevaluation Action Plan,” COMSECY-15-0019, June 30, 2015, ADAMS Accession No. ML15153A104.

NRC, 2015c, “Byron Station, Units 1 and 2 - Interim Staff Response to Reevaluated Flood Hazard Submitted in Response to 10 CFR 50.54(f) Information Request – Flood Causing Mechanism Reevaluation,” September 3, 2015, ADAMS Accession No. ML15229A148.

Codes and Standards

ANSI/ANS (American National Standards Institute/American Nuclear Society), 1992, ANSI/ANS-2.8-1992, “Determining Design Basis Flooding at Power Reactor Sites,” American Nuclear Society, LaGrange Park, IL, July 1992.

Other References

Ahrens, J. P., and Titus, M. F., 1985, "Wave Runup Formulas for Smooth Slopes," Journal of Waterway, Port, Coastal and Ocean Engineering, American Society of Civil Engineers, Vol. 111, No. 1, pp. 128-133.

BOSS (Boss International), 1988, BOSS HMR-52 Version 1.10.

Exelon (Exelon Generation Company, LLC), 2012, Letter from G. T. Kaegi, to the NRC regarding “Exelon Generation Company, LLC’s 180-Day Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Re: Flooding Aspects of Recommendation 2.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident,” November 27, 2012, ADAMS Package No. ML12332A380.

Exelon, 2013, Letter from G. T. Kaegi, to the NRC regarding "Byron Station, Units 1 and 2 - Supplemental Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Flooding Aspects of Recommendation 2.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," May 21, 2013, ADAMS Accession No. ML13141A594.

Exelon, 2014a, Letter from R.W. Gaston, to the NRC regarding "Exelon Generation Company, LLC Response to March 12, 2012, Request for Information Enclosure 2, Recommendation 2.1, Flooding, Required Response 2, Flood Hazard Reevaluation Report," March 12, 2014, ADAMS Accession Nos. ML14079A421 and ML14079A423, respectively.

Exelon, 2014b, "Byron/Braidwood Nuclear Stations, Updated Final Safety Analysis Report (UFSAR), Revision 15, Chapter 2.0 Site Characteristics – Byron," December 15, 2014, ADAMS Accession No. ML14363A407.

FEMA (Federal Emergency Management Agency), 2010a, "Flood Insurance Study – Lee County, Illinois," April 2010.

FEMA, 2010b, "Flood Insurance Study – Ogle County, Illinois," December 2010.

FLO-2D (FLO-2D Software Inc.), 2013, FLO -2D® Reference Manual, FLO -2D Software, Inc., Nutrioso, Arizona FLO-2D, 2013, Build Number 13-07-05, FLO -2D Software, Inc.

Froehlich, D.C., 1995, "Peak Outflow from Breached Embankment Dam," Journal of Water Resources Planning and Management, 121(1): 90-97.

Kaegi, G.T., 2014, "Response to Request for Additional Information Regarding Fukushima Lessons Learned - Flood Hazard Reevaluation Report," Electronic Information Files, RS-14-194, July 14, 2014, ADAMS Accession No. ML14293A599.

Kaegi, G.T., 2015, "Exelon Generation Company, LLC Responses to Request for Additional Information Regarding Fukushima Lessons Learned - Flood Hazard Reevaluation Report," RS-15-111, May 26, 2015, ADAMS Accession No. ML16224A132.

NOAA (National Oceanic and Atmospheric Administration), 1978, "Probable Maximum Precipitation Estimates - United States East of the 105th Meridian," NOAA Hydrometeorological Report No. 51, June 1978.

NOAA, 1982, "Application of Probable Maximum Precipitation Estimates - United States East of the 105th Meridian," NOAA Hydrometeorological Report No. 52, August 1982.

NOAA, 2006, "Precipitation-Frequency Atlas of the United States," NOAA Atlas 14, Volume 2, Version 3, October 2006.

NRCS (National Resources Conservation Service), 1985, "Simplified Dam-Breach Routing Procedure: Technical Release No. 66, 3rd Edition," September 30, 1985.

USACE (U.S. Army Corps of Engineers), 1985a, "Lee County Flood Insurance Study – Rock, River, Job File HEC-2033B," USACE Rock Island District, July 1985.

USACE, 1985b, "Ogle County Flood Insurance Study – Rock River, Job File HEC-2035O," USACE Rock Island District, September 1985.

USACE, 1992, "Automated Coastal Engineering System, Technical Reference," Version 1.07, September 1992.

USACE, 1998, "Engineering and Design, Runoff from Snowmelt," EM1110-2-1406, Washington DC, March 31, 1998.

USACE, 2008, "Coastal Engineering Manual," Engineer Manual 1110-2-1100, available online at http://www.publications.usace.army.mil/USACEPublications/EngineerManuals.

USACE, 2010a, "River Analysis System (HEC-RAS), Version 4.1.0," Hydrologic Engineering Center, U.S. Army Corps of Engineers, January 2010.

USACE, 2010b, "Hydrologic Modeling System (HEC-HMS), Version 3.5.0," Hydrologic Engineering Center, U.S. Army Corps of Engineer, August 2010.

USACE, 2015, "Ice Jam Database," U.S. Army Corps of Engineers, Cold Region Research and Engineering Laboratory (CRREL), available online at http://icejams.crrel.usace.army.mil/. Accessed March 24, 2015.

USACE, n.d, "National Inventory of Dams," (Web site), http://nid.usace.army.mil.

USBR (U.S. Bureau of Reclamation), 1982, "Guidelines for defining inundated areas downstream from Bureau of Reclamation dams," Reclamation Planning Instruction No. 82-11, June 1982.

USGS (U.S. Geological Survey), 2015a, "The USGS Store – Oregon, IL, 7.5 minute by 7.5 minute quadrangle, 2012, (Web page for downloading topographic maps), http://store.usgs.gov/b2c_usgs/usgs/maplocator/(ctype=areaDetails&xcm=r3standardpitrex_prd&carea=%24ROOT&layout=6_1_61_48&uiarea=2)/.do, accessed March 23, 2015.

USGS, 2015b, The USGS Store – Oregon, Illinois, 15 minute by 15 minute quadrangle, 1922, (Web page for downloading topographic maps), http://store.usgs.gov/b2c_usgs/usgs/maplocator/(ctype=areaDetails&xcm=r3standardpitrex_prd&carea=%24ROOT&layout=6_1_61_48&uiarea=2)/.do, accessed March 23, 2015.

USGS, 2015c, "Landslide Overview Map of the Conterminous United States," (Web page for downloading topographic maps) accessed November 11, 2015.

Table 2.2-1. Flood-Causing Mechanisms and Corresponding Guidance

Flood-Causing Mechanism	SRP Section(s) and JLD-ISG
Local Intense Precipitation and Associated Drainage	SRP 2.4.2 SRP 2.4.3
Streams and Rivers	SRP 2.4.2 SRP 2.4.3
Failure of Dams and Onsite Water Control/Storage Structures	SRP 2.4.4 JLD-ISG-2013-01
Storm Surge	SRP 2.4.5 JLD-ISG-2012-06
Seiche	SRP 2.4.5 JLD-ISG-2012-06
Tsunami	SRP 2.4.6 JLD-ISG-2012-06
Ice-Induced	SRP 2.4.7
Channel Migrations or Diversions	SRP 2.4.9

SRP is the Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (NRC, 2007)

JLD-ISG-2012-06 is the "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment" (NRC, 2013a)

JLD-ISFG-2013-01 is the "Guidance for Assessment of Flooding Hazards Due to Dam Failure" (NRC, 2013b)

Table 3.1-1. Summary of Controlling Flood-Causing Mechanisms

Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation (869.0 ft (264.87 m))[1]	ELEVATION msl
Local Intense Precipitation and Associated Drainage	870.8 ft (265.42 m)

[1] Flood height and associated effects as defined in JLD-ISG-2012-05.

Table 3.1-2. Current Design Basis Flood Hazards for Use in the MSA

Mechanism	Stillwater Elevation	Waves/ Runup	Design Basis Hazard Elevation	Reference
Local Intense Precipitation	870.9 ft NGVD29	Not applicable	870.9 ft NGVD29	FHRR Section 2.2.1
Streams and Rivers	708.3 ft NGVD29	Not applicable	708.3 ft NGVD29	FHRR Section 2.2.2
Failure of Dams and Onsite Water Control/Storage Structures	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Section 2.2.3
Storm Surge	Not included in DB	Not included in DB	Not included in DB	FHRR Section 2.2.4
Seiche	Not included in DB	Not included in DB	Not included in DB	FHRR Section 2.2.4
Tsunami	Not included in DB	Not included in DB	Not included in DB	FHRR Section 2.2.5
Ice-Induced Flooding	No impact identified	No impact identified	No impact identified	FHRR Section 2.2.6
Channel Migrations/Diversions	Not included in DB	Not included in DB	Not included in DB	FHRR Section 2.2.7

Note: Reported values are rounded to the nearest one-tenth of a foot.

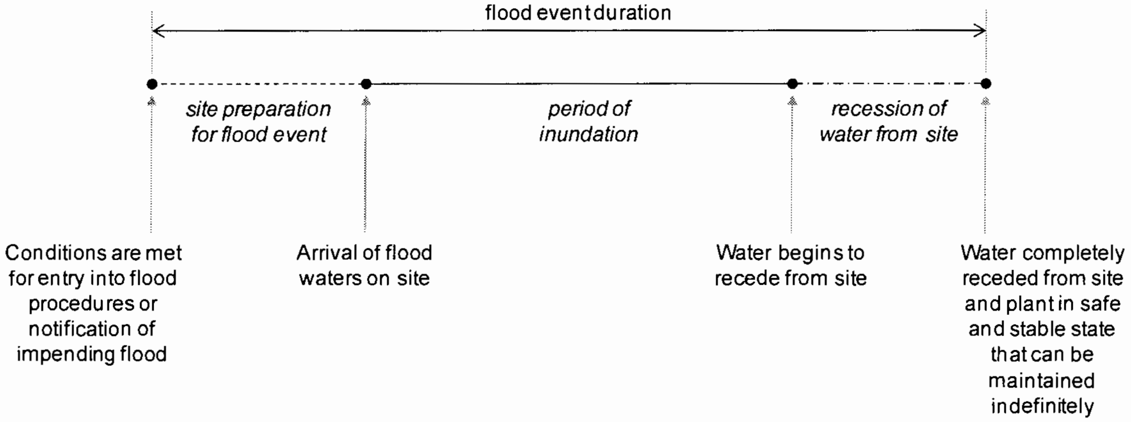


Figure 2.2-1 Flood Event Duration (NRC, 2012c)

Figure 3.1-1 General Area Map showing the locations of the Byron Site, the River Screen House, and Oregon Dam in relation to Rock River and Woodland Creek, Derived from USGS (2015a).

Figure 3.1-2 Locations of the Natural Draft Cooling Towers (NDCT) Flume and the Essential Service Cooling Tower/Ultimate Heat Sink (UHS) Basin on the Site (Kaegi, 2015).

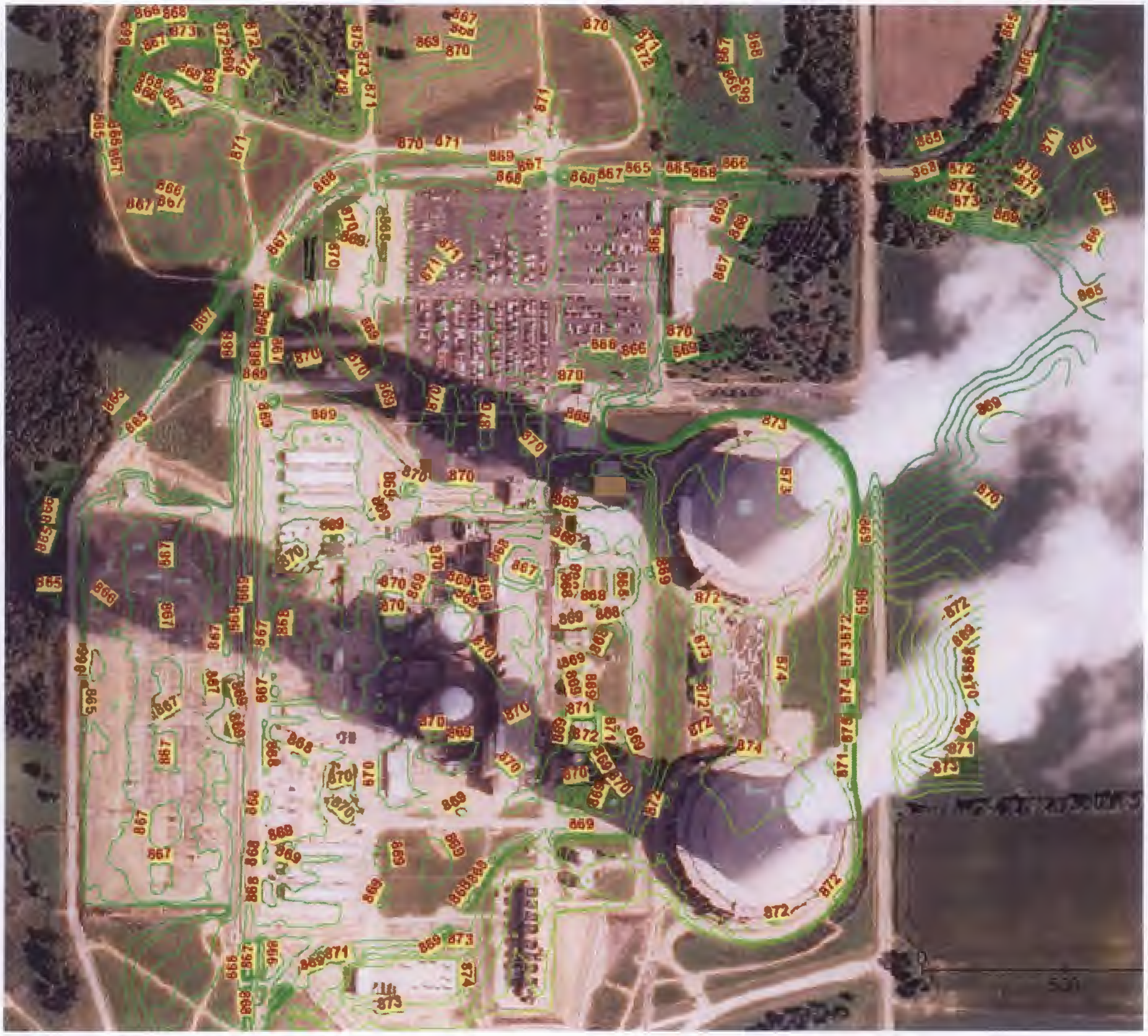


Figure 3.1-3: Byron Nuclear Generating Station Topography derived from Kaegi (2014).

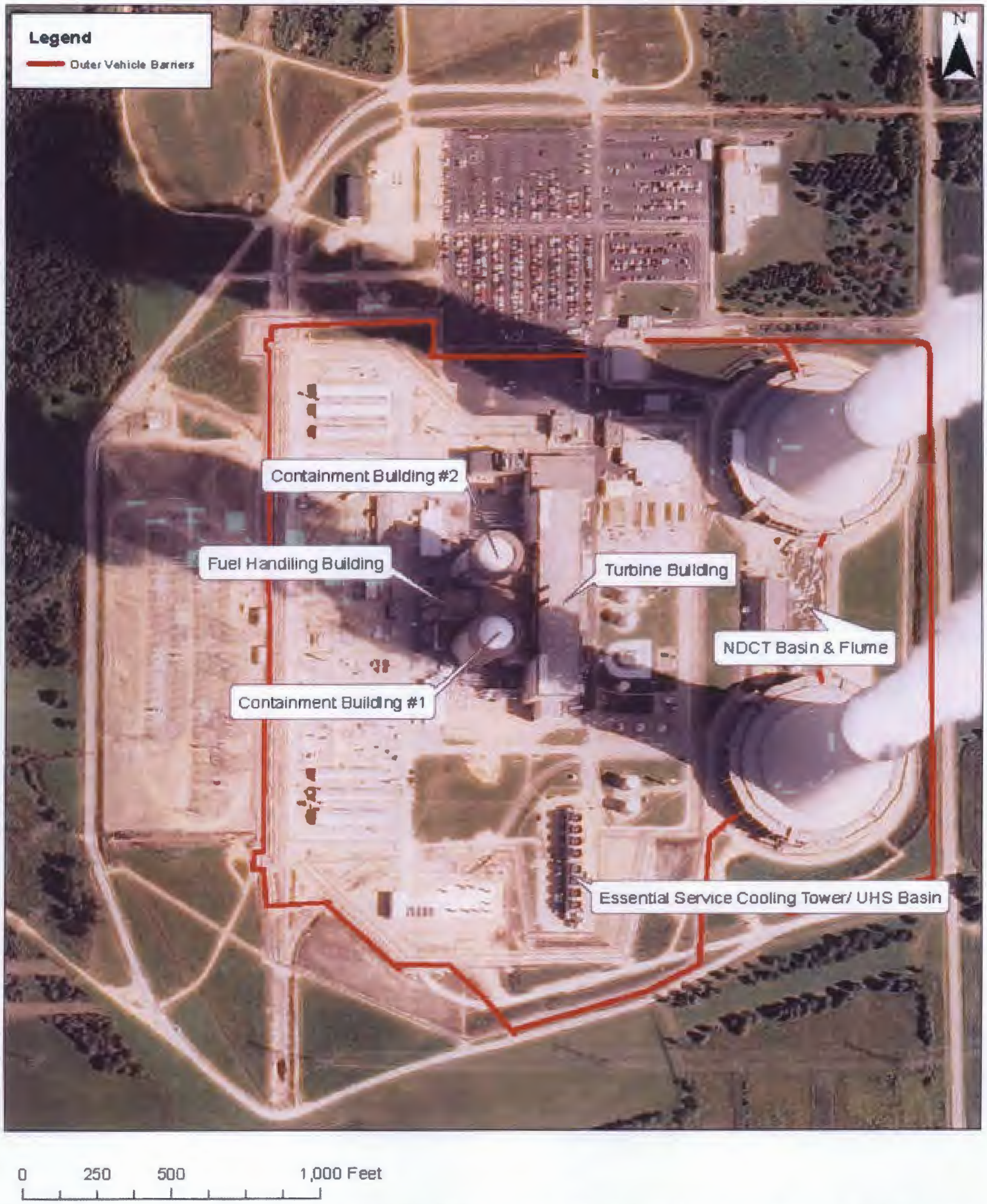
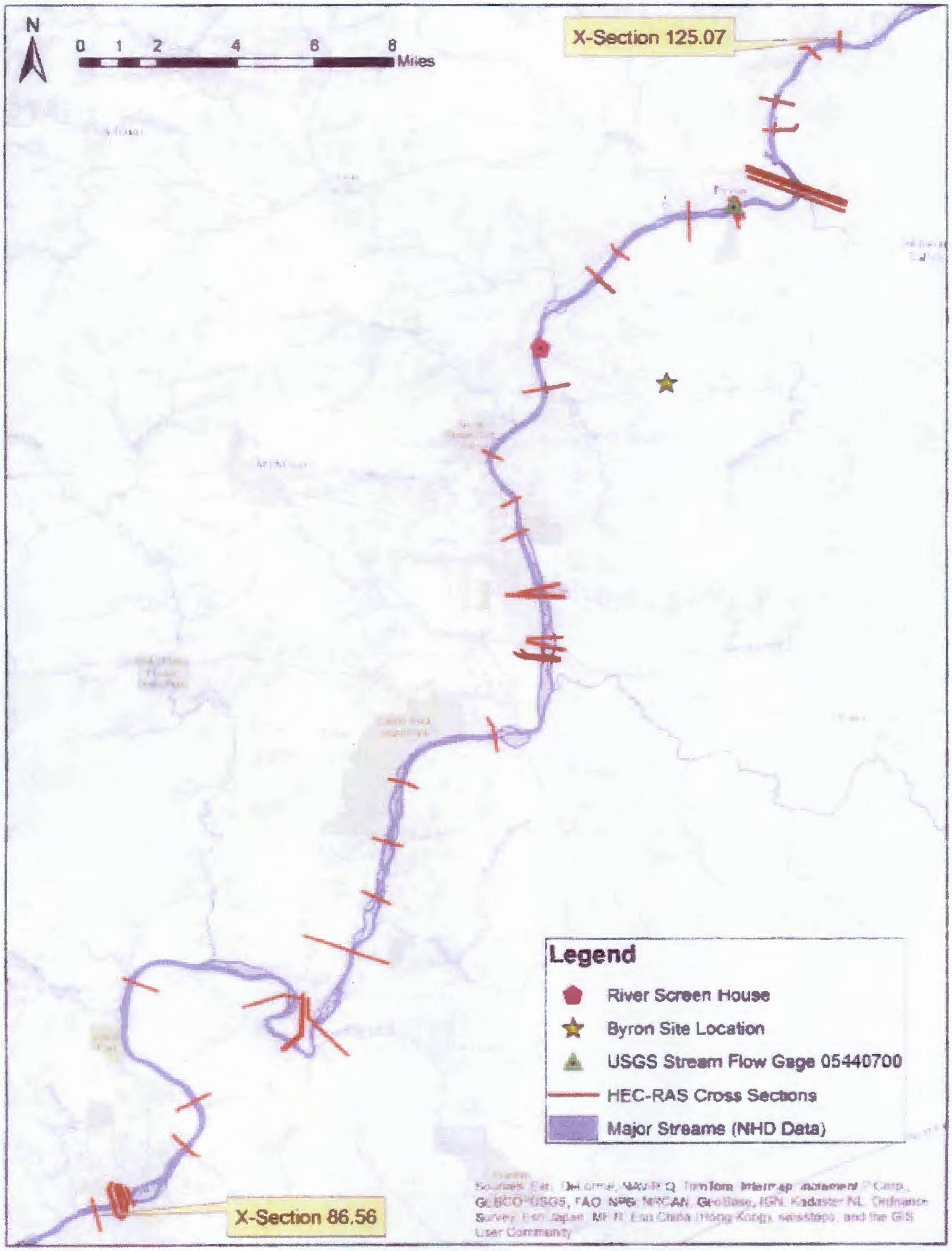


Figure 3.2-1: Byron Nuclear Generating Station Site Features (derived from FHRR Figure 2.1.2 (Exelon, 2014a)).



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Figure 3.3-1. Locations of upstream and downstream boundaries and cross sections in the HEC-RAS model, the river Screen House, and USGS gage 05440700 (Kaegi, 2015).

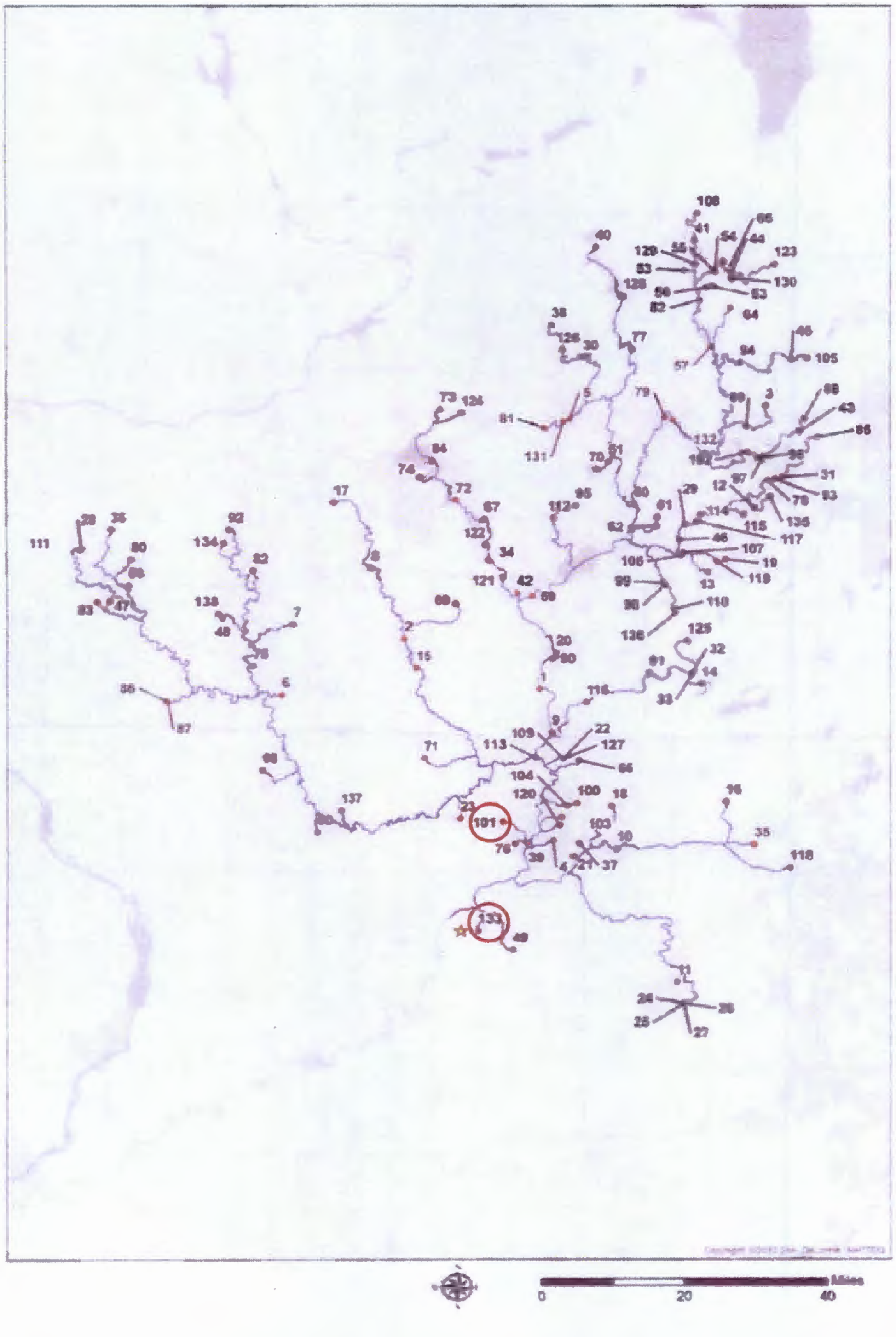


Figure 3.4-1 Locations of the Dams obtained from the National Inventory of Dams (USACE, n.d.) that were Examined by the Licensee for Individual Dam Failures (Kaegi, 2015). The numbering system corresponds to dams listed in Kaegi (2015). The circled dam identifiers are discussed in Section 3.4.1.1 of this SA.

If you have any questions, please contact me at (301) 415-6197 or e-mail at Tekia.Govan@nrc.gov.

Sincerely,

/RA/

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

Docket Nos. 50-454 and 50-455

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Reevaluation Report

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