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

November 3, 2016

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

SUBJECT: LIMERICK GENERATING STATION, UNITS 1 AND 2 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NOS. MF6107 AND MF6108)

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, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15084A586), Exelon Generation Company, LLC (the licensee) responded to this request for Limerick Generating Station, Units 1 and 2 (Limerick).

By letter dated December 24, 2015 (ADAMS Accession No. ML15357A517), the NRC staff sent the licensee a summary of its review of Limerick'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 local intense precipitation (LIP) reevaluated flood hazard mechanism at Limerick is not bounded by the plant's current design basis, additional assessments of the flood hazard mechanism are necessary.

For Limerick, the licensee provided an assessment of the LIP hazard mechanism in their March 12, 2015 submittal. The NRC staff has reviewed the submittal and confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter (ADAMS Accession No. ML16265A152). In reaching this determination, NRC staff confirmed the licensee's conclusions that Limerick has adequate protection reliability and margin against potential flood water infiltration.

This staff assessment closes out the NRC's efforts associated with CAC Nos. MF6107 and MF6108.

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

Sincerely,

Tekia Govan, Project Manager
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Office of Nuclear Reactor Regulation

Docket Nos. 50-352 and 50-353

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

LIMERICK GENERATING STATION, UNITS 1 AND 2

DOCKET NOS. 50-352 AND 50-353

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 Licenses" (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons-learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant as documented in the Near-Term Task Force (NTTF) report (NRC, 2011b). Recommendation 2.1 in that document recommended that the NRC 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 individual plants. On May 11, 2012, the staff issued its prioritization of the FHRRs (NRC, 2012c).

By letter dated March 12, 2015 (Exelon, 2015), Exelon Generation Company, LLC (Exelon, the licensee) provided its FHRR for Limerick Generating Station, Units 1 and 2 (Limerick). The licensee also discussed the need for interim actions in its Limerick FHRR, which were reviewed and documented by the NRC staff in a separate assessment (NRC, 2016b).

By letter dated December 24, 2015, the NRC issued an interim staff response (ISR) letter to the licensee (NRC, 2015b). The purpose of the ISR letter is to provide the flood hazard information suitable for the assessment of mitigating strategies developed in response to Order EA-12-049 (NRC, 2012b) and the additional assessments associated with Recommendation 2.1: Flooding. The ISR letter also made reference to this staff assessment, which documents the NRC staff's basis and conclusions. The flood hazard mechanism values presented in the letter's enclosures match the values in this staff assessment without change or alteration.

As mentioned in the ISR letter, the reevaluated flood hazard results for the local intense precipitation (LIP) flood-causing mechanism is not bounded by the plant's current design basis (CDB). Consistent with the 50.54(f) letter and amended by the process outlined in COMSECY-15-0019 and Japan Lessons-Learned Division (JLD) Interim Staff Guidance (ISG) JLD-ISG-2016-01, Revision 0 (NRC, 2015a; NRC, 2016d), the NRC staff anticipates that the licensee will perform and document a focused evaluation for LIP and associated site drainage that assesses the impact of the LIP hazard on the site and evaluates and implements any necessary programmatic, procedural, or plant modifications to address this hazard exceedance.

Additionally, for any reevaluated flood hazards that are not bounded by the plant's CDB hazard, the licensee is expected to develop flood event duration (FED) parameters and flood-related associated effects (AE) parameters. These parameters will be used to conduct the mitigating strategies assessment (MSA) and focused evaluations or revised integrated assessments.

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

As stated above, Enclosure 2 to the 50.54(f) letter (NRC, 2012a) 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 ESPs and COLs. This section of the staff assessment 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 reports, 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 10 CFR 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 the 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-basis as the information that 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 an 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 site 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, in part, that 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 discusses flood-causing mechanisms for the licensee to address in its FHRR (NRC, 2012a). Table 2.2-1 lists the flood-causing mechanisms the licensee should consider and lists the corresponding Standard Review Plan (SRP) (NRC, 2007) section(s) and applicable interim staff guidance (ISG) documents containing acceptance criteria and review procedures.

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, 2012d) defines "flood height and associated effects" as the maximum stillwater surface elevation plus:

- Wind waves and runup 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 effects 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 NRC 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 are plausible combined events and should be considered.

2.2.4 Flood Event Duration

Flood event duration was defined in JLD-ISG-2012-05 (NRC, 2012d), 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 elevation for any 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.

- Perform an integrated assessment to (a) evaluate the effectiveness of the CDB (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, 2015a) 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 will 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 a revised integrated assessment (NRC, 2015a).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of Limerick (Exelon, 2015). 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.

To provide additional information in support of the summaries and conclusions in the Limerick FHRR, the licensee made certain calculation packages available to the NRC staff via an electronic reading room. The NRC staff did not rely directly on these calculation packages in its review; they were found only to expand upon and clarify the information provided in the Limerick FHRR, and so those calculation packages were not docketed or cited.

In connection with the NRC staff's FHRR review, electronic copies of the computer input/output (I/O) files used in the numerical modeling were provided to the NRC staff and cited as part of the "Nuclear Regulatory Commission Report for the Audit of Exelon's Flood Hazard Reevaluation Report Submittals Relating to the Near-Term Task Force Recommendation 2.1-Flooding for Limerick" (NRC, 2016d).

The licensee used mean sea level (MSL) for elevations in the FHRR which were based on National Geodetic Vertical Datum 1929 (NGVD29) (Exelon, 2015a). There is no difference between MSL and NGVD29 at the Limerick site and all elevations in this staff assessment are reported in NGVD29.

3.1 Site Information

The 50.54(f) letter includes the SSCs important to safety in the scope of the hazard reevaluation. The licensee included pertinent data concerning these SSCs in the Limerick FHRR. The NRC staff reviewed and summarized this information as follows in the sections below.

3.1.1 Detailed Site Information

The Limerick FHRR (Exelon, 2015a) described the site-specific information related to the flood hazard reevaluation. The Limerick site is located in southeastern Pennsylvania near the left descending bank (LDB) of the Schuylkill River, approximately 21 miles northwest of Philadelphia, Pennsylvania. To the north of the site is Sanatoga Creek, a generally southwesterly flowing LDB tributary to the Schuylkill River less than 1 mile (1.6 km) upstream of the Limerick site. To the south and east of the site is Possum Hollow Run, a generally southwesterly flowing LDB tributary to the Schuylkill River, immediately downstream of the Limerick site.

The site grade at the powerblock is elevation 217.0 ft (66.14 m) NGVD29 (Exelon, 2015a). Table 3.1-1 provides the summary of controlling reevaluated flood-causing mechanisms, including wind, wave, and run-up, that the licensee computed to be higher than the powerblock elevation (Exelon, 2015a).

3.1.2 Design-Basis Flood Hazards

The CDB flood levels are summarized by flood-causing mechanism in Table 3.1-2 of this staff assessment. The licensee presented CDB flood level information in the Limerick FHRR, Table 4.0.1, and clarified the information in response to requests for additional information (RAIs) (Exelon, 2015b; Exelon, 2016) and in the context of an audit (NRC, 2016d). The NRC staff reviewed the information provided and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.3 Flood-Related Changes to the Licensing Basis

The licensee reported in the Limerick FHRR that there have been no flood-related changes to the licensing basis. The NRC staff reviewed the information provided and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

3.1.4 Changes to the Watershed and Local Area

In Section 2.4 of the Limerick FHRR (Exelon, 2015a), the licensee discusses changes to the local site topography and buildings since original construction and also notes that changes in the Schuylkill River drainage basin have occurred since the initial licensing basis analyses for Limerick were performed. The licensee stated that the impacts of these changes are considered very small percentages of the total drainage area; however, the licensee incorporated these changes in the reevaluation of hydrology as discussed in Limerick FHHR (Exelon, 2015a).

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

In Section 2.4 of the Limerick FHRR, the licensee discusses a number of flood protection features and procedures implemented at Limerick (Exelon, 2015a). The licensee further clarified details of the site vehicle barrier system (VBS) in response to RAIs (Exelon, 2015b; Exelon, 2016) in the context of an audit with Limerick (NRC, 2016d). The NRC staff reviewed

the information provided in the Limerick FHRR and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee made available for review electronic copies of the I/O files for the computer models and calculation packages used in connection with the flood hazard reevaluations. The NRC staff reviewed that material and determined that sufficient information had been provided in response to Enclosure 2 of the 50.54(f) letter (Exelon, 2015a; Exelon, 2016).

3.1.7 Results of Plant Walkdown Activities

The 50.54(f) letter (NRC, 2012a) requested that licensees plan and perform plant walkdown activities to verify that current flood protection systems are available, functional, and implementable. Other requests described in the 50.54(f) letter asked the licensee to report any relevant information from the results of the plant walkdown activities (NRC, 2012a).

By letter dated November 19, 2012 (Exelon, 2012), Exelon provided the requisite flood walkdown report for Limerick. The walkdown report was supplemented by letters dated July 31, 2013 (Exelon, 2013), and May 7, 2014 (Exelon, 2014b). By letter dated December 23, 2013 (NRC, 2013c), the NRC staff requested additional information related to the walkdown report. By letter dated January 31, 2014 (Exelon, 2014a), Exelon provided a response to the NRC RAI. The NRC staff issued a staff assessment on June 17, 2014 (NRC, 2014a), which documented its review of the flooding walkdown report and concluded that the licensee's implementation of flooding walkdown methodology met the intent of the 50.54(f) letter.

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported in the Limerick FHRR that the reevaluated flood hazard, including AE, for LIP and associated site drainage is based on a stillwater surface elevation of 218.4 ft (66.57 m) NGVD29 at the north exterior door of the turbine building. The licensee did not include wind waves in its analysis, stating that the limited fetch lengths and flow depths would result in negligible effects (Exelon, 2015a). This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevation for LIP and associated site drainage is based on a stillwater surface elevation of 218.6 ft (66.63 m) NGVD29. Wind-wave activity was not considered in combination with the LIP flood for the CDB (Exelon, 2014; Exelon, 2015a).

The licensee used a two-dimensional hydrodynamic model, FLO-2D Build 13.11.06, to estimate water surface elevations at the Limerick site for the modeled LIP event. The site layout and FLO-2D model domain are shown in Figure 3.2-1. The licensee concluded that the maximum reevaluated flood hazard elevation for the LIP was bounded by the CDB at the 23 critical doors (Exelon, 2015a). However, eight critical doors located on the south side of the diesel generator building were not analyzed for the CDB flood water surface elevation; therefore, the licensee considered LIP to be not bounded by the CDB in this area (Exelon, 2015a).

3.2.1 Probable Maximum Precipitation

The LIP event was estimated using National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Reports (HMR) 51 and 52 (NOAA, 1978 and 1982, respectively). The licensee estimated the 1- and 6-hour LIP depths of 17.9 (45.5 cm) and 26.9 in (68.3 cm), respectively. The licensee assumed that the LIP event would be front-loaded, consistent with heavy precipitation from mature cells of a mesoscale convective system (Exelon, 2015a).

The NRC staff reviewed the licensee's LIP estimates using HMR 51 and 52 and found the estimates to be acceptable. The NRC staff also agreed that the licensee selected, front loaded temporal distribution for the LIP event at the Limerick site is appropriate.

3.2.2 Digital Terrain Model and Site Drainage

The licensee determined the local drainage area using the site topographic data based on combining a site topographic survey and digital base maps data from the Pennsylvania map (PAMAP) program (Exelon, 2015a). The PAMAP program used light detection and ranging (LiDAR) to collect elevation data.

The licensee assessed the Limerick site land cover types using aerial imagery and field observations (Exelon, 2015a). The licensee also used the assessed land cover types to estimate Manning's roughness coefficients in the FLO-2D model. The modeled domain extends beyond the VBS to the south and the west (Figure 3.2-1) (Exelon, 2015b; Exelon, 2016). The northern boundary of the model domain is located north of the cooling towers and spray pond (Exelon, 2015b; Exelon, 2016). The eastern boundary is located east of the plant access road. FLO-2D model grid cells along the boundary are designated as outflow cells (Exelon, 2015b; Exelon, 2016). Figure 3.2-2 shows details of the FLO-2D model in the powerblock area including critical door locations.

The licensee represented building and structures on the FLO-2D computation grid by increasing the elevation of the occupied grid cells (Exelon, 2015b; Exelon, 2016). Precipitation falling on roofs was allowed to freely drain on all sides of the buildings. The VBS was simulated using the levee feature in the FLO-2D software (Exelon, 2015b; Exelon, 2016).

The NRC staff reviewed the PAMAP program and determined that the licensee appropriately developed the terrain model for the site combining the PAMAP data with a site topographic survey. In its review of the licensee's LIP flood model, the NRC staff found that the model was set up and implemented appropriately in the FLO-2D software and represents buildings and the VBS that modify flow patterns on the site.

3.2.3 Antecedent Conditions

The licensee did not specifically describe the antecedent conditions for the LIP flood analysis (Exelon, 2015a). The staff's review of the FLO-2D model input files determined that the site was dry before the LIP event (Exelon, 2015b; Exelon, 2016). The NRC staff determined that the expected antecedent water surface elevations in the nearby streams and the Schuylkill River are sufficiently low that they would not directly influence the LIP flood water surface elevations

(Exelon, 2015b; Exelon, 2016). The NRC staff's evaluation of the effects of antecedent water surface elevations around the site is described below in Section 3.2.7, "Sensitivity Analyses."

3.2.4 Runoff Analyses

To maximize runoff from the LIP event, the licensee ignored precipitation losses during the LIP event (Exelon, 2015a; Exelon, 2015b; Exelon, 2016). The licensee also assumed that the site drainage network would not be functional during the LIP event, which maximizes the overland flow depths (Exelon, 2015a; Exelon, 2015b; Exelon, 2016).

The NRC staff's review determined that the licensee followed standard engineering practice in implementing the hydrology and hydraulics of the Limerick site in the FLO-2D software. Because the licensee did not use any infiltration losses in the model, runoff from the LIP event would be maximized. The NRC staff determined that the licensee's choice was conservative.

3.2.5 Hydraulic Model

The licensee used FLO-2D to implement the site hydraulics that control LIP flood flow on the Limerick site (Exelon, 2015a). As described above in Section 3.2.2, the licensee modeled buildings, the VBS, and other structures that influence flow on the site (Exelon, 2015a; Exelon, 2015b; Exelon, 2016).

The NRC staff reviewed the FLO-2D model software and its documentation and the FLO-2D model input files provided by the licensee. The NRC staff determined that the licensee's hydraulic model of the site, implemented in FLO-2D software, is appropriate and captures the effects of site layout and topography.

3.2.6 Width and Area Reduction Factors

The licensee did not use width and area reduction factors in the FLO-2D model (Exelon, 2015a; Exelon, 2015b; Exelon, 2016). The NRC staff's review of the licensee's FLO-2D model determined that the licensee appropriately implemented the buildings, the VBS, and other structures that influence flow on the Limerick site (Exelon, 2015b; Exelon, 2016).

3.2.7 Sensitivity Analyses

The licensee performed two sensitivity analyses that were reviewed by the NRC staff—one related to the VBS and one related to selection of surface roughness coefficient values (Exelon, 2015a). As noted in Section 3.2.2, the VBS was simulated using the levee feature in FLO-2D (Exelon, 2015b; Exelon, 2016). The licensee provided a sensitivity run for the effects of the VBS and found that including the VBS in the model generally results in higher flood water surface elevations while excluding the VBS from the model resulted in lower flood water surface elevations at 10 doors, the same water surface elevation at 11 doors, and minor increases (0.01 ft (0.003 m)) at two doors (Exelon, 2015a; Exelon, 2015b; Exelon, 2016). The licensee's surface roughness coefficients were generally near the lower end of the recommended range of values for the land cover classes. Because higher values of surface roughness coefficients can lead to increased flood water surface elevations, the licensee provided a sensitivity run in which the surface roughness coefficients for all land cover classes were set to the upper end of the

recommended range. As expected, the water surface elevations increased; however, at critical doors, the maximum water surface elevations remained below the CDB (Exelon, 2015a; Exelon, 2015b; Exelon, 2016). However, the licensee stated that the south side of the plant area near the emergency diesel generators was not previously analyzed for the CDB (Exelon, 2015a).

The NRC staff reviewed the licensee-provided sensitivity run for the effects of the VBS, and confirmed the licensee's results (Exelon, 2015b; Exelon, 2016). Predictions of the FLO-2D model that included the VBS at 23 critical door locations at the Limerick site are provided in Table 3.2-1; the critical door locations are shown in Figure 3.2-3. The NRC staff also confirmed the licensee's finding that increasing the surface roughness coefficient values increased the water surface elevations slightly (up to 0.3 ft (0.09 m)) at the 23 critical door locations, but remained below the CDB (Exelon, 2015b; Exelon, 2016). Table 3.2-1 identifies the eight critical doors located on the south side of the plant area near the emergency diesel generators (not previously analyzed for CDB) that are potentially exposed to LIP flood hazards (NRC, 2016d).

The NRC staff also performed an additional sensitivity run for the LIP flood model by setting the boundary condition along the Possum Hollow Run to 196.1 ft (59.77 m) NGVD29. The boundary condition elevation, 196.1 ft (59.77 m) NGVD29 resulted from the staff's sensitivity run for the PMF in streams and rivers under the no-loss scenario. Details of this streams and rivers sensitivity run are provided in Section 3.3. The NRC staff found that the change in the flood water surface elevations at the 23 critical doors was minor; and, at all doors, the water surface elevations remained below the CDB.

3.2.8 Conclusion

The licensee concluded that the maximum reevaluated flood hazard elevation for the LIP was bounded by the CDB at the 23 critical doors (Exelon, 2015a). However, eight critical doors located on the south side of the diesel generator building were not analyzed for the CDB flood water surface elevation; therefore, the licensee considered LIP to be not bounded by the CDB in this area (Exelon, 2015a).

The NRC staff confirmed the licensee's conclusion that the maximum reevaluated flood hazard elevation for LIP and associated site drainage is bounded by the CDB flood hazard; however, the NRC staff also confirms that the LIP flood hazard is not bounded by the CDB at eight critical doors located on the south side of the diesel generator building that were not analyzed for the CDB.

As part of the licensee's response to the 50.54(f) letter, the Limerick FHRR contained a limited integrated assessment (IA) of the LIP hazard at the Limerick site. The NRC staff has reviewed the limited integrated assessment and confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter (NRC, 2016e). In reaching this determination, NRC staff confirmed the licensee's conclusions that Limerick has adequate protection reliability and margin against potential flood water infiltration.

3.3 Streams and Rivers

The licensee reported in the Limerick FHRR that the reevaluated flood hazard, including AE, for streams and rivers is based on a stillwater surface elevation of 163.9 ft (49.96 m) NGVD29 at

the Schuylkill River, 167.8 ft (51.15 m) NGVD29 for Possum Hollow Run, and 153.7 ft (46.85 m) NGVD29 for Sanatoga Creek (Exelon, 2015a). In its reevaluation, the licensee did not consider wind-wave activity in combination with flooding from streams and rivers (Exelon, 2015a). Because the Schuylkill River flood stillwater elevation for a dam breach coincident with a PMF exceeded that from PMF only, the licensee estimated the coincident wind-wave effects for the dam breach flood mechanism in Section 3.4.

This flood-causing mechanism is discussed in the licensee's CDB (Exelon, 2015a; NRC, 2016d). The CDB PMF elevation for streams and rivers is based on stillwater surface elevations of 174 ft (53.0 m) NGVD29 for the Schuylkill River and 159 ft (48.5 m) NGVD29 in Possum Hollow Run (flooding in Sanatoga Creek was not considered in the CDB) (Exelon, 2015a). The licensee did not consider wind-wave activity in combination with flooding from rivers and streams in its design basis (Exelon, 2015a).

Watershed subdivisions, PMP cumulative temporal distributions, and PMP spatial distributions are shown in Figure 3.2-1, Figure 3.2-2, and Figure 3.2-3, respectively. The licensee concluded that the reevaluated stillwater elevation for flooding from streams and rivers at Possum Hollow Run was bounded by the CDB for the Schuylkill River, but was not bounded by the CDB for Possum Hollow Run (Exelon, 2015a). The licensee also stated that the maximum reevaluated stillwater elevation for Possum Hollow Run (167.8 ft (51.15 m) NGVD29) was lower than both the CDB for flooding from streams and rivers (174 ft (53.0 m) NGVD29 on the Schuylkill River) and the lowest entrance to an SSC (217 ft (66.1 m) NGVD29). There is no stated CDB for Sanatoga Creek; however, the licensee stated that the reevaluated maximum flood stillwater elevation of 153.7 ft (46.85 m) NGVD29 is 20.3 ft (6.19 m) below the CDB flood elevation for the Schuylkill River (Exelon, 2015a).

The NRC staff reviewed the information provided by the licensee regarding the PMF analysis and confirms that the licensee's reevaluation of the hazard from flooding of streams and rivers uses present-day methodologies and regulatory guidance. The NRC staff confirms the licensee's conclusion that the reevaluated hazard for flooding from streams and rivers relative to Schuylkill River and adjacent tributary sources, including Possum Hollow Run and Sanatoga Creek, is bounded by the Schuylkill River CDB flood hazard. Therefore, flooding from streams and rivers does not need to be analyzed in a focused evaluation or a revised integrated.

3.4 Failure of Dams and Onsite Water Control or Storage Structures

The licensee reported in the Limerick FHRR that the reevaluated flood hazard, including AE, for failure of dams and onsite water control or storage structures is based on a stillwater surface elevation of 192.5 ft (58.67 m) NGVD29. Including wind waves and runup results in an elevation of 202.2 ft (61.63 m) NGVD29 (Exelon, 2015a). This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevation for failure of dams and onsite water control or storage structures is based on a stillwater surface elevation 201 ft (61.3 m) NGVD29, including wind waves and runup results in an elevation of 207 ft (63.1 m) NGVD29 (Exelon, 2015a).

The licensee used the USACE National Inventory of Dams to identify 64 dams upstream of the Limerick site (Exelon, 2015a). These dams are shown in Figure 3.4-1. There are no dams on Possum Hollow Run or Sanatoga Creek. The licensee added the storages of all upstream

reservoirs to obtain the storage of the hypothetical representative reservoir. The licensee estimated the height of the hypothetical representative dam as the average of individual dams' height weighted by the corresponding storages. The estimated height was compared to tallest dams in the Schuylkill River drainage, and the licensee adjusted the height of the hypothetical dam upward (slightly higher than estimated) for conservatism. The hypothetical dam was placed 7.8 mi (12.6 km) upstream of the Limerick site, which is the location of the closest upstream dam. The licensee estimated the peak dam breach outflow from the hypothetical representative dam using the U.S. Bureau of Reclamation attenuation equation, (NRC, 2013b). The licensee estimated that the attenuated dam breach discharge at the Limerick site would be 431,000 cubic feet per second (cfs) (12,205 cubic meters per second). The licensee applied the attenuated dam breach discharge to the Hydrologic Engineering Center – River Analysis Center PMF model at the location of the Limerick site and performed a steady-state simulation to estimate the flood water surface elevation resulting from the breach of the hypothetical representative reservoir coincident with a PMF in the Schuylkill River drainage. The licensee reported that the reevaluated maximum flood stillwater surface elevation at the Limerick site is 192.5 ft (58.67 m) NGVD29, which is 8.5 ft (2.59 m) below the CDB for Schuylkill River dam failure water surface elevation of 201 ft (61.3 m) NGVD29 (Exelon, 2015a).

The licensee evaluated the coincident wind-wave effects using the maximum reevaluated Schuylkill River stillwater elevation of 192.5 ft (58.67 m) NGVD29 resulting from a postulated hydrologic dam failure coincident with a PMF in the drainage area (Exelon, 2015a). The licensee estimated the fastest 2-minute, 2-year wind speed using the NOAA National Climatic Data Center Global Historical Climatology Network (NOAA, 2015b; see Exelon, 2015a). The licensee fit the Gumbel statistical distribution to the observed fastest 2-minute wind data and estimated the 2-year return period wind speed as 39.7 mph. The licensee estimated the straight-line fetch in the critical direction using PAMAP digital elevation data (PADCNR, 2016). The licensee estimated the wave height and period, wave setup, and wave runup using USACE Coastal Engineering Design and Analysis System-Automated Coastal Engineering System computer software (USACE, 1992) distributed by Veritech Enterprises, LLC (Veritech, 2016) and the wind setup using the approach described in USACE Engineering Manual 1110-2-1420 (USACE, 1997). The licensee reported the wind setup, wave setup, and wave runup to be 0.8, 2.3, and 6.6 ft (0.24, 0.70, and 2.01 m), respectively (Exelon, 2015a). Therefore, the licensee stated that the combined events Schuylkill River maximum flood water surface elevation is 202.2 ft (61.63 m) NGVD29, which is 4.8 ft (1.46 m) below the CDB combined events water surface elevation of 207 ft (63.1 m) NGVD29. The licensee concluded that the reevaluated hazard for failure of dams and onsite water control or storage structures was bounded by the CDB (Exelon, 2015a).

The NRC staff reviewed the flooding hazard from failure of dams and onsite water control or storage structures against the relevant regulatory criteria based on present-day methodologies and regulatory guidance and confirms the licensee's conclusion that the reevaluated flood hazard for failure of dams and onsite water control or storage structures is bounded by the CDB flood hazard. Therefore, flooding from this hazard does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.5 Storm Surge

The licensee reported in the Limerick FHRR that the reevaluated hazard for storm surge does not inundate the plant site, but did not report a PMF elevation. This flood-causing mechanism is discussed in the licensee's CDB, but no PMF elevation was reported because storm surge was not postulated to impact the site.
The licensee used a screening analysis in its reevaluation of surge flood hazards (Exelon, 2015a). The licensee evaluated the Schuylkill River and the spray pond as the only water bodies applicable for their screening analysis. The licensee stated that Limerick is not a coastal site. The licensee concluded the Limerick site is not subject to flood hazards associated with coastal surge due to the distance between the site and water body. The licensee concluded the Limerick site is not subject to flood hazards associated with surge on the spray pond due the pond's limited fetch. The licensee stated in the Limerick FHRR that the screening analysis done for this mechanism supports their conclusion that surge does not pose a flood hazard at the Limerick site; the licensee stated that this conclusion is consistent with the CDB (Exelon, 2015a).

The NRC staff reviewed the information provided by the licensee and confirms the licensee's screening conclusion that the reevaluated flood hazard for flooding from storm surge does not impact the plant site and is bounded by the CDB. Therefore, flooding from storm surge does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.6 Seiche

The licensee reported in the Limerick FHRR that the reevaluated hazard for seiche does not inundate the plant site, but did not report a flood elevation. This flood-causing mechanism is discussed in the licensee's CDB, but no flood elevation was reported because seiche was not postulated to impact the site.

The licensee stated in the Limerick FHRR (Exelon, 2015a) that evaluation for this mechanism were performed using guidance found in NUREG/CR-7046 (NRC, 2011e), JLD-ISG-2012-06 (NRC, 2013a), and NUREG/CR-6966 (NRC, 2009). The licensee evaluated the Schuylkill River and the spray pond as the only water bodies applicable for their screening analysis. The licensee stated that Limerick is not a coastal site (Exelon, 2015a). The licensee considered the Limerick site setting, topography, and the alignment of the Schuylkill River relative to the site in its evaluation of seiche hazard from the river. Based on these considerations, the licensee concluded the Limerick site is not subject to flood hazards associated with seiche on the Schuylkill River. The licensee considered the natural periods of the spray pond and their lack of coherence to the natural periods of the external forcing mechanisms that could trigger seiche formation. The licensee also considered the water volume within the spray pond and topographic relief near the site. The licensee concluded the Limerick site is not subject to flood hazards associated with seiche on the spray pond due the factors considered. The licensee stated in the Limerick FHRR that the screening analysis done for this mechanism supports their conclusion that seiche does not pose a flood hazard at the Limerick site; the licensee stated that this conclusion is consistent with the CDB (Exelon, 2015a).

The NRC staff examined the location of the Limerick site and confirmed that the location (not being near a large water body) and the geometry of the Schuylkill River and spray pond limit the

development of any seiche near the Limerick site. The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from seiche could not impact the Limerick site. Therefore, flooding from seiche does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.7 Tsunami

The licensee reported in the Limerick FHRR that the reevaluated hazard for tsunami does not inundate the plant site, but did not report a PMF elevation (Exelon, 2015a). This flood-causing mechanism is discussed in the licensee's CDB, but no PMF elevation was reported because tsunamis were not postulated to impact the site (Exelon, 2015a).

The licensee stated in the Limerick FHRR (Exelon, 2015a), that evaluation for this mechanism was performed using guidance found in NUREG/CR-7046 (NRC, 2011e), JLD-ISG-2012-06 (NRC, 2013a), and NUREG/CR-6966 (NRC, 2009). The licensee evaluated the Schuylkill River and the spray pond as the only water bodies applicable for their screening analysis (Exelon, 2015a). The licensee stated that Limerick is not a coastal site. The licensee reviewed the Global Historical Tsunami Database and defined the search region to be 34 to 46 degrees N latitude and 69 to 81 degrees E longitude. The licensee reviewed USGS Earthquake Hazard Data and historical records of earthquakes in the region and did not find earthquake events with sufficient magnitudes to generate tsunamis. The licensee considered the Schuylkill River channel and found that the topographic relief in the vicinity of the site was not conducive to landslides which could trigger tsunamis. The licensee noted that at more distant locations along the channel, the topography is steeper and therefore landslides could occur at these locations; but, due to the distance from the Limerick site, the resultant tsunamis would not result in inundation of the Limerick site. The licensee stated in the Limerick FHRR that the screening analysis done for this mechanism supports their conclusion that tsunami does not pose a flood hazard at the Limerick site; the licensee stated that this conclusion is consistent with the CDB (Exelon, 2015a).

The NRC staff confirms the licensee's conclusion that the reevaluated hazard for flooding from tsunami does not impact the plant site. Therefore, flooding from tsunami does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.8 Ice-Induced Flooding

The licensee reported in the Limerick FHRR that the reevaluated flood hazard, including AE, for ice-induced flooding is based on a stillwater surface elevation of 137.8 ft (42.00 m) NGVD29. Wind waves and runup results were not reported (Exelon, 2015a). This flood-causing mechanism is discussed in the licensee's CDB, but no PMF elevation was reported because ice-induced flooding was determined to be not applicable to the Limerick site.

The licensee queried the USACE ice jam database to identify historical ice jam events in the Schuylkill River watershed (Exelon, 2015a). No ice jams were reported for Sanatoga Creek and Possum Hollow Run. The licensee stated it is possible that ice jams could form on these drainages, particularly at their confluence with the Schuylkill River. However, the licensee concluded that the effects of these ice jams would be bounded by flooding resulting from a downstream ice jam on the Schuylkill River (Exelon, 2015a).

On the Schuylkill River, the licensee postulated that ice jams could form at the nearest upstream and downstream bridges (Exelon, 2015a). The licensee chose a railroad bridge as the upstream ice jam location and a roadway bridge as the downstream location. The licensee selected the March 6, 1920, ice jam in Reading, Pennsylvania, the largest reported, as the hypothetical ice jam to form at the two selected locations. The licensee estimated the ice jam height to be 11.8 ft (3.60 m) (Exelon, 2015a).

The licensee assumed that a 100-year flood would exist in the Schuylkill River at the time of the breach of the upstream ice jam (Exelon, 2015a). The licensee postulated that, without any attenuation, the flood wave produced by the breach of the upstream ice jam would translate to the Limerick site. Therefore, the licensee estimated the flood stillwater elevation at the Limerick site from breach of an upstream ice jam as the sum of the 100-year flood water surface elevation at the Limerick site and the height of the postulated ice jam. The licensee reported that the upstream ice jam resulted in a flood stillwater elevation of 137.8 ft (42.00 m) NGVD29 (Exelon, 2015a).

For the downstream ice jam location, the licensee estimated the backwater effects at the Limerick site during a 100-year flood event on the Schuylkill River (Exelon, 2015a). The licensee estimated the backwater elevation at the Limerick site from a 11.8 ft (3.6 m) high ice jam at the downstream bridge location by adding the height of the ice jam to the 100-year flood stillwater elevation at the Limerick site. The licensee added the backwater effects during the 100-year flood events to the backwater effects from the downstream ice jam to estimate the flood backwater elevation at the Limerick site as 137.8 ft (42.00 m) NGVD29. The licensee concluded that the effects of ice jams are bounded by the effects of the PMF in the Schuylkill River that resulted in a flood stillwater elevation of 163.9 ft (49.96 m) NGVD29, which is more than 26 ft (7.9 m) above the ice-induced flood stillwater elevation (Exelon, 2015a).

The NRC staff reviewed the licensee's process for identifying historical ice jams and determined that the licensee followed guidance to appropriately identify relevant ice jams. The NRC staff determined that the licensee's choice of the Reading, Pennsylvania, historical ice jam was appropriate because it is the largest reported ice jam. The NRC staff also determined that the licensee's calculations of the ice jam height were conservative. Because of the limited drainage area contributing to runoff that could accumulate behind ice jams at the confluence of the two local streams, Sanatoga Creek and Possum Hollow Run, with the Schuylkill River and the substantial difference between normal water levels in the local streams and the design basis flood for the Schuylkill River, the NRC staff confirmed the licensee's conclusion that the effects of an ice jam on the local streams would be bounded by a downstream ice jam on the Schuylkill River was reasonable. The NRC staff reviewed the licensee's calculations and determined that the licensee followed staff guidance in bounding the effects of ice-induced flooding at the Limerick site. The NRC staff determined that the licensee's approach for estimating the ice-induced flood stillwater elevation at the Limerick site is conservative because it ignores attenuation effects and uses a 100-year coincident flood. Therefore, the NRC staff agrees that ice-induced flood effects would be bounded by the reevaluated Schuylkill River PMF stillwater elevation. The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for ice-induced flooding of the site is bounded by the Schuylkill River CDB flood hazard. Therefore, the ice-induced flooding does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.9 Channel Migrations or Diversions

The licensee reported in the Limerick FHRR that the reevaluated hazard, including AE, for channel migrations or diversions does not inundate the plant site because this mechanism is not a potential contributor to flooding at the Limerick site (Exelon, 2015a). This flood-causing mechanism is discussed in the licensee's CDB, but no PMF elevation was reported because channel migration or diversion-induced flooding was determined not to be a potential contributor at the Limerick site (Exelon, 2015a).

The licensee examined USGS topographic maps from 1906 and 2013 and geologic data from the Pennsylvania Geological Survey to determine whether the Schuylkill River near the Limerick site may migrate or divert (Exelon, 2015a). The licensee reviewed historical landslides in the vicinity to determine the possibility of blockage of streams and rivers and subsequent diversion toward the Limerick site. The licensee evaluated the foundations of critical structures at the Limerick site to determine if they could be affected by erosion from a stream diverting toward the site. The licensee also evaluated channel stabilization and maintenance that may help prevent migration of the Schuylkill River. Based on the information reviewed, the licensee concluded that the Schuylkill River does not have a tendency to divert toward the Limerick site. The licensee stated that all Category I structures are founded on bedrock except for part of the spray pond. The licensee also stated that the USACE actively maintains the current channel (Exelon, 2015a).

The NRC staff reviewed the information presented by the licensee and agree with the licensee's conclusion that the Schuylkill River is unlikely to divert toward the Limerick site given channel configuration, side slopes, and active maintenance by the USACE. The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from channel migrations or diversions is bounded by the CDB flood hazard for other flooding sources for streams and rivers. Therefore, the flooding from channel migration and diversions does not need to be analyzed in a focused evaluation or a revised integrated assessment.

4.0 INTEGRATED ASSESSMENT AND ASSOCIATED HAZARD DATA

4.1 Reevaluated Flood Height for Hazards Not Bounded by the CDB

Section 3 of this staff assessment documents the NRC staff review of the licensee's flood hazard water elevations results. Table 4.1-1 contains the maximum flood height results, including waves and run-up, for flood mechanisms not bounded by the CDB presented in Table 3.1-1. The NRC staff agrees with the licensee's conclusion that LIP, at the diesel generator building, is the only hazard mechanism not bounded by the CDB. However, as part of the licensee's response to the 50.54(f) letter, the Limerick FHRR contained a limited IA of the LIP hazard at the Limerick site. The NRC staff has reviewed the limited IA and confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter (NRC, 2016e). In reaching this determination, NRC staff confirmed the licensee's conclusions that Limerick has adequate protection reliability and margin against potential flood water infiltration.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in Exelon's 50.54(f) response (Exelon, 2015 and NRC, 2016) regarding the FED parameters needed to perform the additional assessments of plant response for flood hazards not bounded by the CDB. The FED parameter values for the flood-causing mechanisms identified in Section 4.1 of this staff assessment are summarized in Table 4.2-1.

The licensee did not provide FED parameter values in the Limerick FHRR for the LIP flood-causing mechanism at the diesel generator building. The licensee stated in Section 3.9.3 of the Limerick FHRR that warning time associated with the LIP flood is negligible (Exelon, 2015a).

The NRC staff confirmed the licensee's conclusion that the reevaluated LIP flood maximum water surface elevations at critical doors remain below the CDB. The warning time for LIP flood is expected to be minimal because of the front loaded LIP temporal distribution and quick runoff response of the Limerick site. At the end of the FLO-2D simulation (8 hours after start of the LIP), significant flow depths were predicted adjacent to the 23 critical doors. Therefore, the NRC staff concluded that the period of flood recession is longer than 8 hours.

The licensee has submitted flood event duration details for LIP specific to the diesel generator building in its Limerick MSA which is currently under review by the NRC staff.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The licensee reported that the maximum hydrostatic and hydrodynamic loads associated with the LIP flood event are bounded by the design basis missile protection loads (Exelon, 2015a). The licensee stated that debris impact loading is not applicable because of the estimated shallow depths and the limited velocities of the LIP flood. The licensee stated that wave conditions are not applicable to the LIP flood due to limited fetch lengths and shallow depths. The licensee concluded that groundwater ingress would not adversely affect safety-related equipment because of the low permeabilities of the site ground cover and the relatively short duration of the LIP flood. The licensee also concluded that erosion and deposition are not anticipated because maximum estimated flow velocities for the LIP flood are lower than the permissible mean velocity threshold for erosion on concrete and paved surfaces (Exelon, 2015a).

The NRC staff reviewed the licensee's AE parameters, and confirms the licensee's conclusion that AE from LIP would be minimal. A summary of NRC staff's results are documented in Table 4.3-1. The NRC staff concludes that these AE parameters are appropriate input for future assessment of plant response. Therefore, AE of LIP flooding do not need to be analyzed in a focused evaluation.

4.4 Conclusion

Based upon the preceding analysis, NRC staff confirmed that the reevaluated flood hazard information defined in the Section 4 is an appropriate input to the additional assessments of plant response as described in the 50.54(f) letter (NRC, 2012a), COMSECY-15-0019, and associated guidance.

The licensee has submitted the missing FED parameters in the Limerick MSA. The NRC staff will evaluate the missing FED parameters (i.e., warning time, period of inundation, and recession time) marked as "not provided" in Table 4.2-1 during its review of the MSA.

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms of Limerick. Based on the review of available information provided in Exelon's 50.54(f) response (Exelon, 2015 and NRC, 2016d), 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 upon 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, NRC staff confirmed the licensee's conclusions that (a) although the reevaluated flood hazard results for LIP are not bounded by the CDB flood hazard, the limited IA demonstrates that the Limerick site has adequate protection reliability and margin against potential flood water infiltration, and (b) the reevaluated flood-causing mechanism information is appropriate input to the additional assessments of plant response as described in the 50.54(f) letter and COMSECY-15-0019 (NRC, 2015a), and associated guidance.

The NRC staff has no additional information needs with respect to Exelon's 50.54(f) response.

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

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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 3.0-1. Summary of Controlling Flood-Causing Mechanisms

Reevaluated Flood-Causing Mechanisms and AE that May Exceed the Powerblock Elevation (217.0 ft (66.1 m))	ELEVATION [NGVD29])
Local Intense Precipitation and Associated Drainage	217.1 ft (66.17 m) (diesel generator building)

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

Table 3.1-1. Current Design Basis Flood Hazards

Flooding Mechanism	Stillwater Elevation [NGVD29]	Associated Effects (Waves/Runup)	Current Design Basis Flood Elevation [NGVD29]	Reference
Local Intense Precipitation and Associated Drainage				
Turbine Building	218.6 ft (66.63 m)	Minimal	218.6 ft (66.63 m)	FHRR Section 2.2.1, and Table 4.0.2
Diesel Generator Building	Not included in CDB	Not included in CDB	Not included in CDB	FHRR Section 2.2.1 & Transmittal Letter
Streams and Rivers				
Schuylkill River	174.0 ft (53.0 m)	No impact on the Site Identified	174.0 ft (53.0 m)	FHRR Section 2.2.2
Sanatoga Creek	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 2.2.1
Possum Hollow Run	159.0 ft (48.5 m)	No impact on the Site Identified	159.0 ft (48.5 m)	FHRR Section 2.2.1 & Table 4.0.3
Failure of Dams and Onsite Water Control/Storage Structures				
Schuylkill River Hydrologic Failure	201 ft (61.3 m)	6.0 ft (1.8 m)	207.0 ft (63.1 m)	FHRR Section 2.2.3
Storm Surge	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 2.2.4
Seiche	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 2.2.4
Tsunami	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 2.2.5
Ice-Induced	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 2.2.6

Channel Migrations or Diversions	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 2.2.7

Table 3.2-1. Maximum Water Surface Elevations at Critical Doors Resulting From Local Intense Precipitation

Door ID[a]	Reevaluated Maximum Water Surface Elevation (ft (m) NGVD29)
194	217.48 (66.29)
195	217.48 (66.29)
211[b]	217.13 (66.18)
213[b]	217.15 (66.19)
215[b]	217.18 (66.20)
217[b]	217.34 (66.25)
219[b]	217.17 (66.19)
221[b]	217.17 (66.19)
223[b]	217.19 (66.20)
225[b]	217.21 (66.21)
241	217.50 (66.29)
242	217.56 (66.31)
247	217.77 (66.38)
249	218.22 (66.51)
249N	218.29 (66.53)
257	217.81 (66.39)
259	218.37 (66.56)
259N	218.32 (66.54)
273	217.92 (66.42)
278	218.25 (66.52)
280N	217.94 (66.43)
280S	217.94 (66.43)
293	217.53 (66.30)

Source: Exelon, 2016.

a. Doors are identified on Figure 3.2-3.

b. Doors on south side of diesel generator buildings.

Table 4.1-1. Reevaluated Flood Hazards for Flood-Causing Mechanisms to be Examined in the Integrated Assessment

Flood-Causing Mechanism	Stillwater Elevation, [NGVD29]	Associated Effects	Reevaluated Flood Hazard [NGVD29]	Reference
Local Intense Precipitation and Associated Drainage (diesel generator building)	217.1 ft (66.17 m)	Minimal	217.1 ft (66.17 m)	FHRR Section 3.1.3 and transmittal letter

Table 4.2-1. Flood Event Duration for Flood-Causing Mechanisms Not Bounded by the CDB

Flood-Causing Mechanism	Time Available for Preparation for Flood Event	Duration of Inundation of Site	Time for Water to Recede from Site
Local Intense Precipitation and Associated Drainage (diesel generator building)	Negligible (FHRR Section 3.9.3, Exelon, 2015a)[b]	Not provided in FHRR[a]	Not provided in FHRR[a]

a. Flood duration parameters are considered "not applicable" in the FHRR because "SSCs important to safety are currently protected by means of permanent/passive measures," and because the peak LIP flood elevation is bounded by the CDB (Exelon, 2015a).
b. The licensee has the option to use NEI guideline 15-05 (NEI, 2015 and NRC, to estimate the warning time necessary for flood preparation.

Table 4.3-1 Associated Effects Parameters Not Directly Associated with Total Water Elevation For Flood-Causing Mechanisms Not Bounded by the CDB

	Flooding Mechanism	
Associated Effects Factor	**Local Intense Precipitation**	**Reference**
Hydrodynamic loading at plant grade	Minimal	FHRR, Section 3.9.3, Table 4.0-2
Hydrostatic loading for critical doors	Minimal	FHRR, Section 3.9.3
Debris loading at plant grade	Minimal because of shallow water depths, low water velocities, and lack of large floatable debris	FHRR, Section 3.9.3, Table 4.0-2
Sediment loading at plant grade	Minimal because of low water velocities	FHRR, Section 3.9.3
Sediment deposition and erosion	Minimal because of low water velocities	FHRR, Section 3.9.3
Concurrent conditions, including adverse weather	N/A because no manual actions are required to protect the plant from high winds	FHRR, Section 3.9.3, Table 4.0-2

N/A = Not applicable

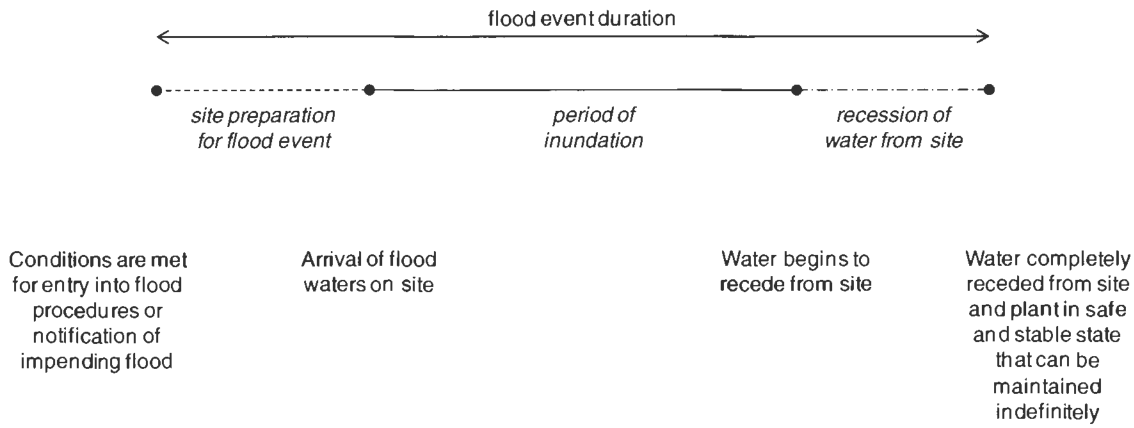

Figure 2.2-1. Flood Event Duration

Figure 3.2-1. Limerick Generating Station Site Layout and FLO-2D Model Boundary

Figure 3.2-2. FLO-2D Model Boundary in the Powerblock Area

Figure 3.2-3. Location of Critical Doors

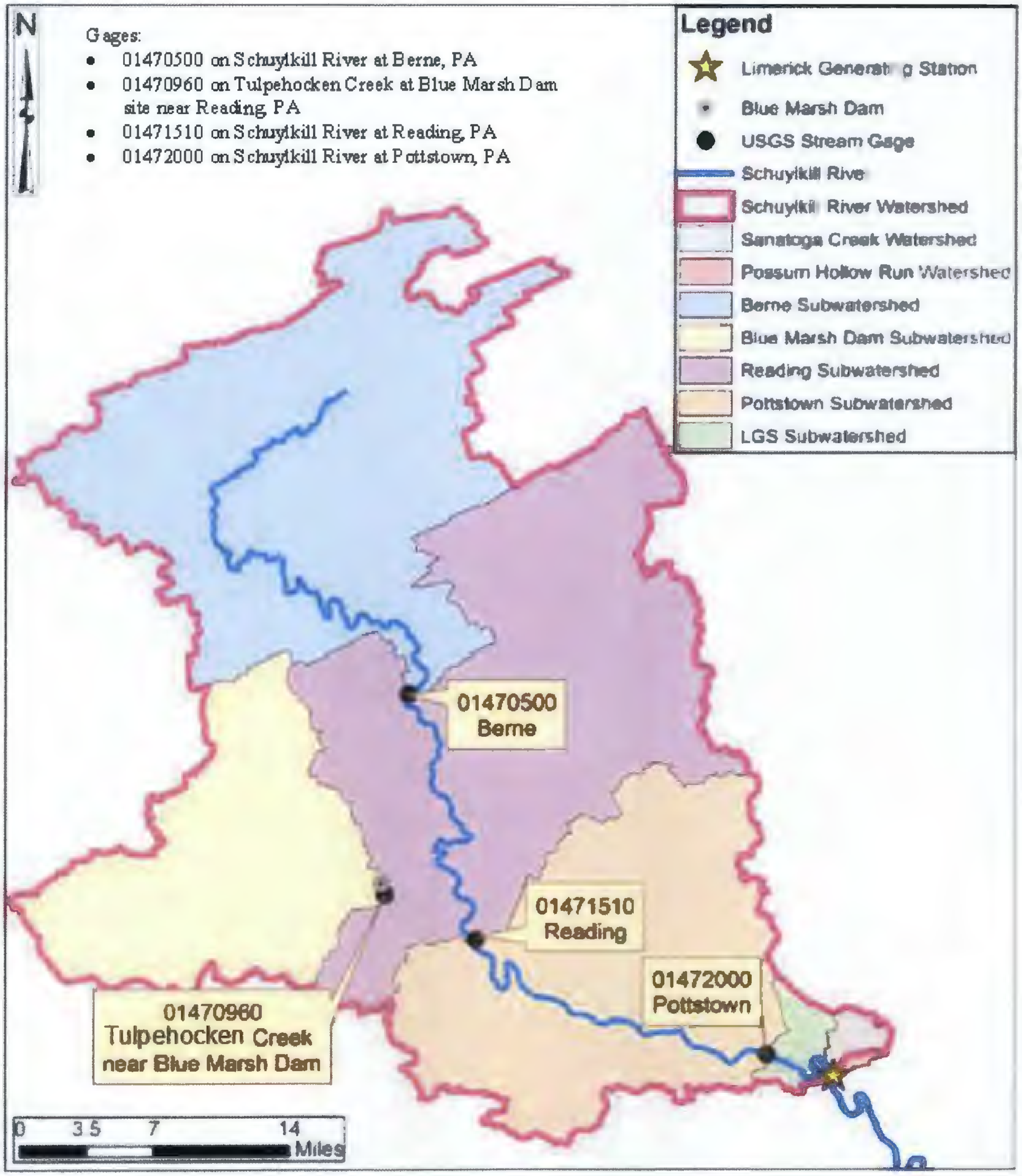

Figure 3.3-1. Schuylkill River Watershed, Subwatersheds, and USGS Stream Gages Above Limerick Generating Station (Exelon, 2015b)

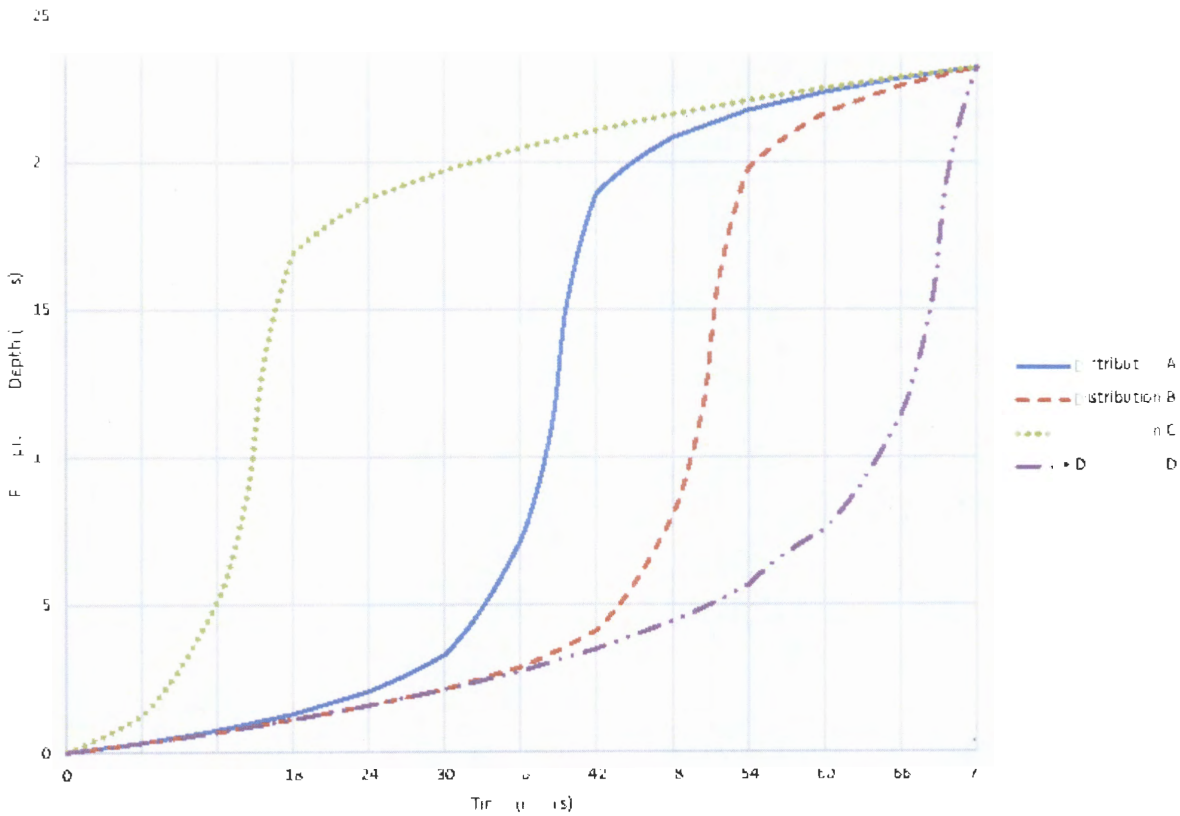

Figure 3.3-2. All-Season PMP Cumulative Temporal Distributions (Exelon, 2015b)

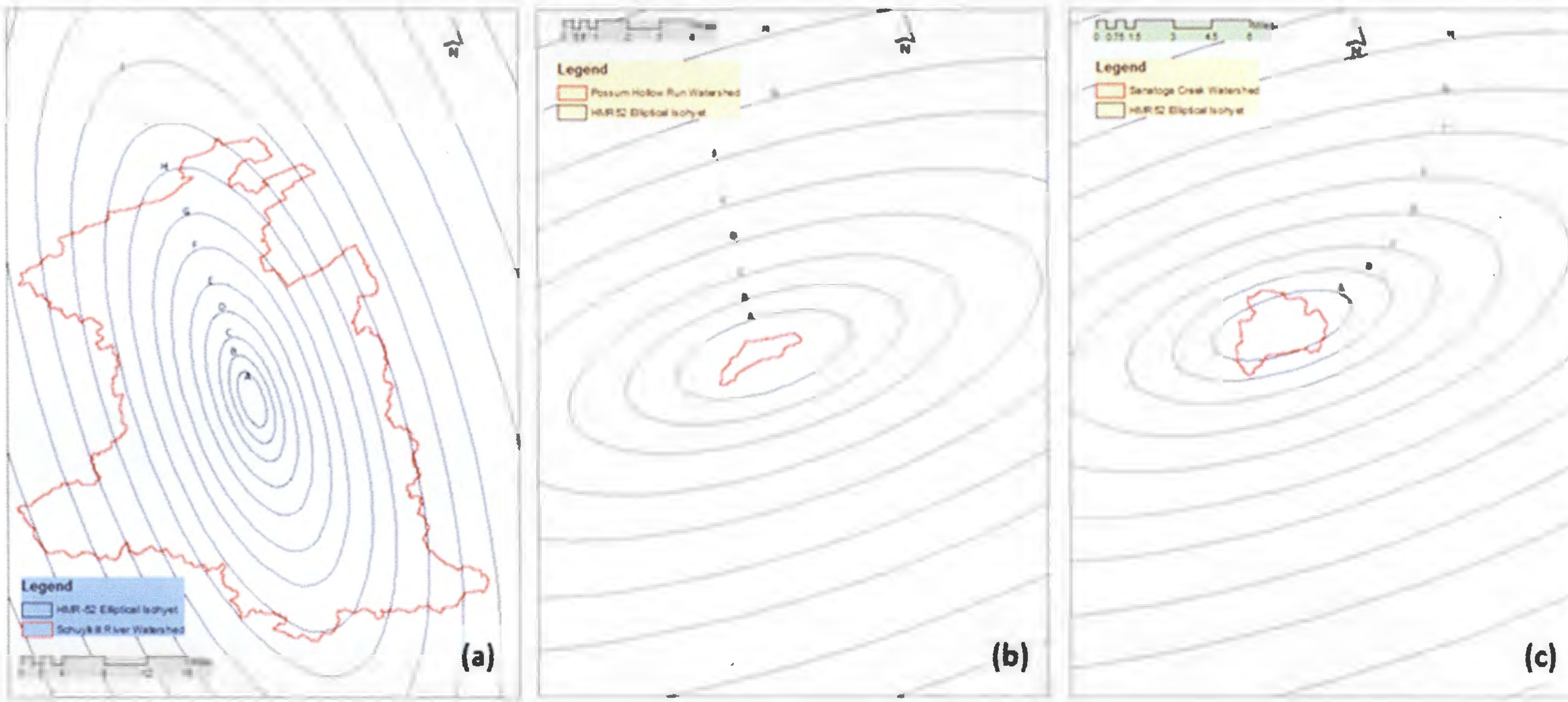

Figure 3.3-3. PMP Storm Spatial Distribution, and Orientation for (a) Schuylkill River (Exelon, 2015b), (b) Possum Hollow Run (Exelon, 2016), and (c) Sanatoga Creek (Exelon, 2016) Drainages

Figure 3.4-1. Locations of Upstream Dams and the Hypothetical Dam Considered for Dam Failure Analysis (Exelon, 2015b)

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

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