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

October 07, 2016

Mr. Peter P. Sena, III
President
PSEG Nuclear LLC-N09
P.O. Box 236
Hancocks Bridge, NJ 08038

SUBJECT: SALEM NUCLEAR GENERATING STATION, UNITS 1 AND 2 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NOS. MF3790 AND MF3791)

Dear Mr. Sena:

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 11, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14071A401), PSEG Nuclear LLC (the licensee) responded to this request for Salem Nuclear Generating Station, Units 1 and 2 (Salem).

By letter dated September 10, 2015 (ADAMS Accession No. ML15244B266), the NRC staff sent the licensee a summary of its review of Salem'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 Salem is not bounded by the plant's current design basis, 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.

This staff assessment closes out the NRC's efforts associated with CAC Nos. MF3790 and MF3791.

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
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos. 50-272 and 50-311

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

SALEM GENERATING STATION, UNITS 1 AND 2

DOCKET NOS. 50-272 AND 50-311

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

By letter dated March 11, 2014 (PSEG, 2014a), PSEG Nuclear, LLC (PSEG, licensee), provided its FHRR for the Salem Generating Station, Units 1 and 2 (Salem). The NRC staff issued requests for additional information (RAIs) to the licensee by letter dated June 28, 2014 (NRC, 2014b). These RAIs applied to both the Salem and the Hope Creek Generating Station (Hope Creek) sites, and focused on the analysis of three flood hazards: local intense precipitation (LIP), the probable maximum river flood (PMF), and storm surge. The licensee responded by letter dated July 28, 2014 (PSEG, 2014b). Additionally, on June 22, 2015, and July 16, 2015, the NRC staff conducted an audit of the licensee's FHRR submittal at which time the RAI responses were discussed (NRC, 2016a). The audit was summarized in the "Nuclear Regulatory Commission Report for the Audit of PSEG Nuclear LLC's Flood Hazard Revaluation Report Submittals Relating to the Near-Term Task Force Recommendation 2.1-Flooding for Salem Nuclear Generating Station, Units 1 and 2" (NRC, 2016a).

On September 10, 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 NRC staff's basis and conclusions. The flood hazard mechanism values presented in the letter's enclosures match the values in this SA without change or alteration.

As mentioned in the ISR letter (NRC, 2015b), the reevaluated flood hazard results for the 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 JLD-ISG-2016-01, Revision 0 (NRC, 2015a and NRC, 2016c), 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 that the licensee should consider, and the corresponding Standard Review Plan (SRP) (NRC, 2007) sections and applicable 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, 2012e) 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 Effect 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, 2012e) 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 Salem (PSEG, 2014a and 2014b). 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 Salem 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 Salem 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 PSEG Nuclear LLC's Flood Hazard Revaluation Report Submittals Relating to the Near-Term Task Force Recommendation 2.1-Flooding for Salem" (NRC, 2016a).

Unless otherwise stated, all elevations in this staff assessment are given with respect the North American Vertical Datum of 1988 (NAVD88). Table 3.0-1 provides the summary of controlling reevaluated flood-causing mechanisms, including associated effects, the licensee computed to be higher than the powerblock elevation.

3.1 Site Information

The 50.54(f) letter (NRC, 2012a) includes the SSCs important to safety in the scope of the hazard reevaluation. The licensee included pertinent data concerning these SSCs in the Salem

FHRR. The NRC staff reviewed and summarized this information as follows in the sections below.

3.1.1 Detailed Site Information

The Salem FHRR (PSEG, 2014a) states that the site is located on the east bank of the Delaware River, on the southern portion of an artificial island. This artificial island was constructed by the U.S. Army Corps of Engineers (USACE) on behalf of PSEG to site both the Salem and the Hope Creek reactor complexes; the two reactor complexes are contiguous to each other and are located on the western (river-facing) portion of the island. The PSEG property extends over an area of approximately 741 acres (299 hectares) in an estuarine setting of which 220 acres (89 hectares) are dedicated to the Salem reactor complex containing two power units (See Figure 3.1-1). By way of comparison, the Hope Creek site property consists of 153 acres (62 hectacres) or about 21 percent of the PSEG site. The topography of the artificial island is generally flat; elevations rise gently from sea level and throughout most of the Atlantic Coastal Plain. Natural elevations in the vicinity of the Salem site are less than 11 ft (3.4 m) above mean sea level and extend for a distance of 1 to 4 mi (1.6 to 6.4 km) to the west and east of the PSEG complex, although there is significant natural variation. The highest elevations in the vicinity of the Salem site are manmade embankments which intermittently line the river; those embankments are less than 21 ft (6.4 m) high. The plant grade of the powerblock (e.g., all personnel entrances to Category I seismic structures) is at an elevation of approximately 9.7 ft (3 m) NAVD88. The ground floor levels of the turbine and auxiliary buildings are at an elevation of 10.2 ft (3.1 m) NAVD88 (PSEG, 2014a).

The Salem site itself is generally flat with drainage directing flood waters toward the surrounding estuarine marshes and the Delaware Bay (PSEG, 2014a). At a location approximately 2 miles (3.2 km) south of the PSEG site, the Delaware River transitions into the Delaware Bay, which itself is hydrodynamically-coupled with the Atlantic Ocean. Because the bay is broad and enjoys unrestricted access to the sea, both the Delaware Bay and the Atlantic Ocean are the main hydrologic features of interest for the purposes of the Salem FHRR. The maximum tidal flow measured 20 mi (32.2 km) above the PSEG site (at Wilmington, DE) has previously been reported as 600,000 cubic feet per second (cfs) (17,000 m^3/s) compared to an estimated 12,000 cfs (340 m^3/sec) fresh water discharge (measured at Trenton, NJ) from the Delaware River (Miller, 1962). Given the disproportionally high tidal flow conditions at the PSEG site, riverine-based flooding scenarios have been previously viewed to be inconsequential relative to marine-derived ones (Miller, 1962). Based on these facts, the licensee noted that the Salem site is not considered to be susceptible to flooding by rivers, dam failures, ice flooding, or channel migration (PSEG, 2014a). However, the site is adjacent to the coast and, therefore, potentially vulnerable to flooding by marine-based phenomena. The licensee also stated that the Salem site was not vulnerable to flooding due to tsunamis or seiche.

The Salem site has a drainage system that consists of ditches that collect and passively convey surface runoff to pipes that ultimately discharge into the Delaware Estuary (PSEG, 2014a). Other hydrologic features of interest near the Salem site include the Alloway Creek, Hope Creek, and the Chesapeake and Delaware Canal. All of these features are contiguous with the greater Delaware River Basin whose total drainage area is about 12,765 mi^2 (5,165 hectares); this river basin is comprised of about 14 distinct watersheds that contain numerous tributaries.

It was noted in the 50.54(f) walkdown report that large ocean-generated waves would break before reaching the Salem powerblock owing to the construction of a seawall along the shoreline adjacent to the PSEG reactor complex (NRC, 2014a). The top elevation of that seawall is reported in the 50.54(f) walkdown report to be 18.2 ft (5.6 m) NAVD88, or about 8.5 ft (2.6 m) above plant grade.

The service water intake structure (SWIS) was described by the licensee at a location along the strand line. Vital components of the SWIS are housed in a watertight compartment that is protected to a stillwater elevation of 36.2 ft (11.0 m) NAVD88. Protection of the SWIS from wave runup extends to an elevation of 38.2 ft (11.6 m) NAVD88 (NRC, 1996). Structures at the site provide protection against waves from the southerly direction. Those structures include sheetpile retaining walls and riprap construction, extending 100 ft (30.5 m) on both sides of the SWIS, provide protection against slope failure and minimize shoreline erosion (NRC, 2005).

3.1.2 Design-Basis Flood Hazards

The CDB flood levels for Salem are summarized by flood-causing mechanism in Table 3.1-1. The CDB flood hazard for the Salem site is the probable maximum hurricane (PMH) surge occurring in association with wave runup coincident with the 10 percent exceedance high tide. The licensee noted previously that the Salem site is not considered to be susceptible to flooding by LIP, rivers and streams, dam failures, ice flooding, channel migration, tsunamis, or seiche and no water surface elevations (WSEs) were reported for these flood-causing mechanisms (PSEG, 2014a).

The NRC staff reviewed the flood hazard information provided in the Salem FHRR (PSEG, 2014a) and determined that sufficient information on the CDB was provided to be responsive to the information request described in Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.3 Flood-Related Changes to the Licensing Basis

The licensee noted in the Salem FHRR that there have been no flood-related changes or changes to flood protection measures beyond the flood protection measures in place for the CDB (PSEG, 2014a). The NRC staff reviewed the flood hazard information provided and determined that sufficient information on the flood-related changes to the licensing basis was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.4 Changes to the Watershed and Local Area

The licensee reported that local changes to the watershed have been minimal since the plant has been licensed to operate. Reported changes within the Salem site itself include the addition of a materials center, a low-level radioactive waste storage facility, a nuclear department administration building, and a processing center and security entrance buildings. Additionally, a vehicle barrier system (VBS) has been added around the plant for security purposes. Lastly, an independent spent fuel storage installation (ISFSI) storage facility has been added under a separate NRC fuel-cycle license. The ISFSI is situated north of the Salem reactor building and located within the perimeter created by the VBS. None of the additions described have resulted in changes to the site grade (PSEG, 2014a).

PSEG Power LLC and PSEG Nuclear LLC submitted an ESP application in May 2010 for a new nuclear plant that would be located generally to the north of the existing Salem site. The licensee states that the exact location and design of storm water management systems for the new plant have not been determined; however, the licensee noted that it expects to integrate infrastructure for the new proposed reactor with the existing Salem infrastructure. The licensee notes that the addition of a new reactor complex is not expected to impact the hydraulic characteristics of the existing Salem site (PSEG, 2010).

The NRC staff reviewed the flood hazard information provided and determined that sufficient information on changes to the watershed and local area was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

In the Salem FHRR (PSEG, 2014a), the licensee stated that there were no changes either to the licensing basis flood elevations or to flood protection design features. Details regarding all of these features were previously described by the licensee (PSEG, 2012 and 2013) and reviewed by the NRC staff (NRC, 2014a). In the matter of these design features, the NRC staff reviewed the flood hazard information provided and determined that sufficient information on CLB flood protection and pertinent flood mitigation features was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

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 (NRC, 2012a).

3.1.7 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 were 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.

By letter dated November 26, 2012, PSEG provided the requisite flood Walkdown Report for the Salem site (PSEG, 2012). The NRC staff prepared a staff assessment Report, dated June 16, 2014 (NRC, 2014a), to document its review of that report. The NRC staff concluded that the licensee's implementation of the 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 Salem FHRR that the reevaluated flood hazard, including associated effects, for LIP and associated site drainage is based on a maximum stillwater WSE of 12.2 ft (3.7 m) NAVD88 (PSEG, 2014a). The WSEs, evaluated at a set of critical door locations, ranged from 11.3 to 12.2 ft (3.5 to 3.7 m) NAVD88. The effects of wind waves and

runup were not included in the flood reevaluation for LIP as those effects were considered inconsequential.

3.2.1 Site Drainage and Elevations

The licensee reevaluated the flood hazard resulting from LIP and site drainage over the combined power block areas containing both the Salem and the adjacent Hope Creek site. The relatively flat PSEG site is bounded on the east and north by tidal marshes and on the west and south by the Delaware River Estuary. The nominal grade for the artificial island containing both reactor sites is 9.0 ft (2.7 m) NAVD88; the Salem powerblock is slightly higher at elevation 9.7 ft (3 m) NAVD88 (PSEG, 2014a). The composite power block area is drained by a system of ditches that convey meteoric water to an underground drainage system that ultimately discharges into the Delaware River Estuary. The drainage system for the Salem site is shown in Figure 3.2-2 (PSEG, 2014a). The licensee previously noted that this drainage system is designed to accept a maximum rainfall rate of 4 in/hr (10 cm/hr) for time periods less than 20 minutes (NRC, 1998); in the event of a precipitation events that exceeds this design envelope, excess meteoric water would accumulate in catchment basins. Ground-surface elevations being reported were based on a 2008 Light Detection and Ranging (LiDAR) survey of the site whose horizontal resolution was 1 ft (0.3 m). Subsequent changes to site topography were evaluated in connection with a 2013 site walkdown performed in connection with the 50.54(f) letter (PSEG, 2014a).

3.2.2 Local Intense Precipitation

The LIP event described in the Salem FHRR was based on the 1 hr., 1mi^2 probable maximum precipitation (PMP) derived from National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) Hydrometeorological Report (HMR) Nos. 51 (HMR 51) (NOAA, 1978) and 52 (HMR 52) (NOAA, 1982). Using these sources, the licensee reported that the 1-hr, 1-mi^2 (3-km^2) PMP depth is 18.1 in (46.0 cm). The licensee used multiplier factors from NOAA (1982) to estimate the 30-, 15-, and 5-minute (min) PMP depths for a 1-mi^2 (3-km^2) drainage area (PSEG, 2014a). Table 3.2-1 describes the cumulative LIP depths estimated by the licensee. The NRC staff used the location of the Salem site to verify, from HMR 52 (NOAA 1982), that the licensee's LIP depth estimates are accurate; the NRC staff determined that those estimates were reasonable.

The licensee stated that the PMP precipitation hyetograph, shown in Figure 3.2-3 was developed using the methodology described in NUREG/CR-7046 (NRC 2011e).

The licensee used 5-min increments to construct the hyetograph, with the most intense precipitation flux applied during the initial 5-min increment with the precipitation rate decreasing during successive time increments (PSEG, 2014a). The NRC staff verified that the licensee followed the example described in Appendix B of NUREG/CR-7046.

3.2.3 Runoff Analysis

The licensee reevaluated the flood from an LIP event using the FLO-2D computer model (Build No. 09-13.01.12) (FLO-2D Software, Inc., 2009). The licensee relied on a 10-ft by 10-ft (3.0-m by 3.0-m) grid system to provide computational coverage of both the Hope Creek and Salem

reactor sites. This grid system consisted of 277,011 cells covering an area of 6.4 acres (2.6 hectare) or about 10 mi^2 (25.8 km^2). The licensee assigned an average surface elevation to each grid cell based on the 1-ft (0.3-m) resolution LiDAR data, as well as information obtain in connection with the earlier site walkdown. The licensee also assigned a uniform elevation of 50.6 ft (15.4 m) NAVD88 to grid cells corresponding to powerblock buildings, as well as the intake structure location.

The licensee provided the FLO-2D I/O files used to compute the WSE results described in the Salem FHRR for the NRC staff's review (PSEG, 2014b). Using the computer files, the NRC staff verified that the configuration of the FLO-2D computational domain used in the LIP analysis was consistent with the description provided in the Salem FHRR. The NRC staff compared available topographic data for the site to the grid elevations at a select number of locations in the FLO-2D computational model and determined that the licensee's computer model accurately represented the actual ground-surface elevation of the Salem site. The NRC staff also determined that the location of the VBS and other building structures within the Salem powerblock were properly represented in the model. In the matter of how meteoric runoff from buildings was treated, the NRC staff determined that the representation of buildings as overland-flow grid cells with elevations significantly higher than the surrounding terrain was a reasonable way to account for these flow effects. The NRC staff also determined that the licensee's use of a uniform elevation of 50.6 ft (15.4 m) NAVD88 for all grid cells corresponding to powerblock structures was reasonable in this regard in that meteoric water would shed-off the tops of those structures onto the ground surface and in doing so result in relatively uniform flow around those structures.

Furthermore, the NRC staff reviewed the configuration of the computer model and determined that storm water-conveyance structures on-site were assumed to be blocked and that infiltration losses were neglected, consistent with guidance in NUREG/CR-7046 (NRC, 2011e). Because the site grade is well above the average elevation of the Delaware River, the NRC staff found the licensee's use of the normal flow depth of the river as the downstream boundary condition for the FLO-2D computer model was reasonable.

3.2.4 Water Level Determination

The licensee reported reevaluated flood elevations at nine critical door locations within the powerblock and at the intake structure location in response to a 1-hr, 1-mi^2 (3-km^2) PMP event. The locations of these critical doors are shown in Figure 3.2-4.

The licensee evaluated the time-dependent flood response of the powerblock site to the local PMP over a 12-hr time period with 0.1-hr output intervals. The licensee reported the maximum reevaluated WSE for each critical door location, the elapsed time to reach the maximum flood elevation, and the period of time the WSE of 10.2 ft (3.1 m) NAVD88 was above the elevations of critical door sills. The results reported are shown in Table 3.2-2. As indicated by that table, the maximum reevaluated WSEs range from 11.3 ft (3.5 m) NAVD88 to 12.2 ft (3.7 m) NAVD88. The flood depths estimated by the FLO-2D computer model from approximately 1 ft to 2 ft (0.3 m to 0.6 m) above existing door sill elevations at 12 critical door locations (PSEG, 2014a).

The NRC staff verified by the licensee's results by independently executing the FLO-2D model using the input files provided by the licensee. The NRC staff also reviewed the output produced

by that computer model and determined that: (a) mass balance errors were small (less than 0.001 percent); (b) the inundation areas and flow pathways appeared reasonable; and (c) the flow velocities were reasonable, with no indication of numerical instabilities and no supercritical flow conditions near the critical door locations of interest. Based on those results, the NRC staff concluded that the licensee's FLO-2D model was a reasonable basis for evaluating the estimated WSEs and associated site drainage due to LIP.

In describing the configuration of the FLO-2D model, the licensee stated that the use of lower Manning's n values was consistent with observations concerning both the character of the site ground surface, as well as the manner in which the site is actively maintained by PSEG ground-keeping personnel. However, the Manning's roughness coefficient values selected for use in the computer simulations were at the low end of the ranges recommended in the FLO-2D reference manual. To evaluate the significance of that decision, the NRC staff conducted an independent LIP simulation using the licensee's FLO-2D model using larger Manning's n values (roughly doubled) to evaluate the parametric sensitivity of the WSEs to this particular parameter. The increase in the WSEs based on the parametric sensitivity analysis was found to be less than 2.5 in (6.4 cm) at all critical door locations; this increase was judged by the NRC staff to be negligible. Thus, based on the inconsequential change in the estimated WSE, the NRC staff determined that the Manning's n values used by the licensee were reasonable.

As described above, the powerblock buildings are represented in the licensee's FLO-2D model using grid cells with elevations significantly higher than the reported ground elevations. Upon inspection of the licensee's computer model, it was observed that there were narrow passageways (i.e., grid cells at ground elevation) between some of the buildings (e.g., between the reactor buildings and the auxiliary building) within the powerblock. Based on information presented in the Salem FHRR, it was not clear to the NRC staff whether these passageways would freely permit site drainage inflows or outflows during an LIP event or whether they would behave as obstacles to surface water flow. The NRC staff modified the licensee's FLO-2D model to evaluate the sensitivity of the flood elevations at the critical door locations to closure of the passageways between the reactor and fuel handling buildings and the auxiliary building. The NRC staff raised the grid cell elevations to prevent flow through these passageways during the LIP simulation. The NRC staff determined that the resulting increase in the water-surface elevations at the critical door locations was less than 1.5 in (3.8 cm). As a result, the NRC staff found the licensee's representation of power block buildings reasonable. Overall, the NRC staff determined that the licensee's estimated maximum WSE of 12.2 ft (3.7 m) NAVD88 for the LIP flood-causing mechanism was reasonable.

3.2.5 Conclusion

The NRC staff confirmed the licensee's conclusion that the reevaluated flood hazard for LIP and associated site drainage is not bounded by the CDB flood hazard. Therefore, the NRC staff expects that the licensee will submit a focused evaluation for LIP and associated site drainage for Salem consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

3.3 Streams and Rivers

The licensee reported in the Salem FHRR that the reevaluated flood hazard, including associated effects, for streams and rivers is based on a WSE of 14.4 ft (4.4 m) NAVD88 (stillwater). This elevation represents the combined effects of the PMF, 10 percent exceedance high tide, and the 25-yr storm surge. The effect of wind waves and runup was not included in the Salem FHRR analysis.

The licensee's reevaluation of flooding on streams and rivers described in the Salem FHRR included three components: developing PMP events, simulating the PMFs from those storm events, and evaluating the effect of combined events (PSEG, 2014a). The licensee reported that it had relied on an earlier PSEG analysis to determine the applicable PMP events and the reevaluated PMF for the Delaware River at the Salem location. In that analysis (PSEG, 2013), the licensee previously stated that the methods it used comported with guidance found in ANSI/ANS-2.8-1992 (1992) and Regulatory Guide 1.59 (NRC, 1977). The licensee further stated that the combined events analysis was performed consistent with the guidance contained in ANSI/ANS-2.8-1992 (1992) and NUREG/CR-7046 (NRC, 2011e).

3.3.1 Probable Maximum Precipitation

The licensee considered two alternative precipitation scenarios based on PMP depths and methods from HMR Nos. 51 (NOAA, 1978) and 52 (NOAA, 1982). The licensee adjusted the size and orientation of the thunderstorm events to maximize the rainfall depth, and used center-weighted, 96-hr hyetographs (PSEG, 2013). One of the alternative PMP events considered was a 15,000 mi^2 (38,900 km^2) storm centered approximately 25 mi (40.2 km) north of Philadelphia and oriented in such a fashion to cover the entire Delaware River watershed, with a peak rainfall intensity of 3.3 in/hr (8.3 cm/hr) and a 72-hr average rainfall depth of 12.1 in (30.7 cm). The second alternative PMP event considered was a 2,150 mi^2 (5,570 km^2) storm, also centered over Philadelphia, and oriented in such a fashion to maximize rainfall depth in the sub-basin directly upstream of the Salem site, with a peak rainfall intensity of 9.5 in/hr (24 cm/hr) and a 72-hr average rainfall depth of 22.2 in (56.4 cm).

The NRC staff reviewed the documents provided by the licensee (PSEG, 2014b) to develop the respective PMP estimates, and verified that the methods used to derive the PMP depths (PSEG, 2013) were consistent with HMR Nos. 51 and 52. The NRC staff also reviewed the isohyetal patterns of the two preferred PMP events (Figures 2.4.3-2 and 2.4.3-3 of PSEG, 2013) and determined that the size and orientation of those rainfall events were consistent with guidance in HMR No. 52 for maximizing surface runoff.

3.3.2 Snowpack and Snowmelt

The NRC staff observed that the Salem FHRR did not address flooding due solely to snowpack/snowmelt (PSEG, 2014a). Both ANSI/ANS-2.8-1992 (1992) and NUREG/CR-7046 (NRC, 2011e) recommend that consideration of snowpack/snowmelt-derived flooding take place as part of the PMF analysis. During the June 2015 audit (NRC, 2016a), the licensee stated that snowmelt was not considered as part of the flood hazard reevaluation because it was determined that the WSE attributed to storm surge was estimated to be much greater than any potential WSE due to a streams and rivers PMF that would also take into account the influence

of snow melt. In support of this position, the licensee referred to the analysis it conducted in connection with the failure of an ice jam (see Section 3.8 of this staff assessment). The licensee further stated that snowmelt would tend to occur in the spring, whereas storm surge would occur in the summer and fall; because these events are out-of-phase, the licensee indiacted that a higher postulated WSE associated with snowmelt was unlikely, as was the case for a combined scenario involving snowmelt discharge and storm surge.

In considering these arguments, the NRC staff was also aware that tidal flux dominates flow conditions at the Salem site, as previously reported by Miller (1962). Based on the totality of the information presented, the NRC staff determined that the licensee's decision to not consider this particular parameter in the PMF calculation was reasonable.

3.3.3 Probable Maximum Flood

The licensee estimated the PMF at River Mile 52 (the approximate upstream location of the PSEG ESP site, about 1 mi (0.6 km) north of the Salem intake structure) using the USACE's Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) model (USACE, 2010b) to calculate runoff from the PMP events, and the complimentary Hydrologic Engineering Center River Analysis System (HEC-RAS) computer code (USACE, 2010a) to route the runoff through the Delaware River and its tributaries (PSEG, 2013). Sub-basins in the HEC-HMS model ranged from 1 to 676 mi^2 (1.6 to 1,088 km^2) in size. The licensee used the Soil Conservation Service hydrograph method (NRCS, 2007) to calculate runoff hydrographs from the sub-basins. The licensee also selected nearly-saturated soil-moisture conditions (impervious) in the model to provide greater surface runoff (PSEG, 2013). A further conservatism was that no credit was given to the attenuation of the flood wave as it traveled downstream. The licensee described the calculation of base flow values as initial conditions for upland tributaries, and stated that routing of the flood hydrographs did not include attenuation or diffusion processes.

Using input files provided, the NRC staff verified that the configuration of the HEC-HMS model used in the licensee's analysis were consistent with the Salem FHRR description. For example, the NRC staff spot-checked sub-basin soil moisture values and verified they were consistent with nearly-saturated conditions. The NRC staff calculated area-weighted sub-basin losses and determined that they were insignificant (less than 0.25 percent). The NRC staff evaluated the HEC-HMS input parameters provided by the licensee and determined that they were reasonable for the conditions of the watershed. The licensee reduced the calculated time of concentration for each sub-basin by 40 percent, which the NRC staff notes is consistent with NUREG/CR-7046 (NRC, 2011e). Lastly, the NRC staff independently ran the HEC-HMS model using the licensee's input files and determined that there were no error messages nor any significant warning messages.

The HEC-RAS model extended from Trenton, which is north of the site, to the mouth of the Delaware River at the Delaware Bay. The licensee obtained bathymetric and topographic data from multiple sources, and merged these data into a terrain model to develop 69 cross-sections used in the hydraulic model. The licensee calibrated the Manning's n coefficients for the tidal portion of the HEC-RAS model using astronomical tidal data and Delaware River discharge data for the Trenton location. The licensee also used the HEC-HMS model results as lateral and

upstream inflows to the HEC-RAS model, and stated that a downstream boundary condition of 0 ft (0.0 m) NAVD88 was used (PSEG, 2013).

Using input files provided by the licensee, the NRC staff determined that the configuration of the HEC-RAS model was consistent with the description in the Salem FHRR. The NRC staff verified the distances along the Delaware River using the U.S. Geological Survey's (USGS) National Map Viewer (USGS, 2016). The NRC staff observed that five bridges spanning the river were not included in the model, and that in some areas, some cross sections that include lateral inflows appear to have been blocked off. The NRC staff concluded that these assumptions are reasonable[1]. The NRC staff determined that the primary conservative assumptions in the licensee's models were associated with the HEC-HMS model.

Of the two PMP events considered, the licensee stated that the thunderstorm centered over the greater Philadelphia area resulted in greater flow at River Mile 52; peak discharge for this case was 1,478,000 cfs (41,900 m^3/s) with a corresponding maximum WSE of 2.6 ft (0.8 m) NAVD88 (PSEG, 2013). Using the HEC-RAS files provided by the licensee and a constant downstream boundary of elevation 0 ft (0.0 m) NAVD88, the NRC staff confirmed the licensee's results and determined that maximum water surface elevations were reasonable.

3.3.4 Combined Events

The licensee considered two alternatives to estimate the flooding effects from the combined events flood (PSEG, 2014a). For both alternatives, the PMF in the Delaware River was based on the PMP thunderstorm centered over the Philadelphia area. The NRC staff reviewed the combined events alternatives evaluated by the licensee and determined that they are consistent with guidance in ANSI/ANS-2.8-1992 (1992).

3.3.4.1 PMF Alternative 1

For the first alternative, the licensee combined one-half of the PMF for the Delaware River, the 10 percent exceedance high tide, and the surge and seiche from the worst regional hurricane reported in the literature (PSEG, 2014a). The licensee calculated the one-half PMF by reducing the HEC-HMS hydrographs from the PMF simulation by 50 percent and then used that reduced hydrograph as an input to the HEC-RAS model of the Delaware River basin (described in Section 3.3.3) (PSEG, 2013). Using the 10 percent exceedance high tide (4.5 ft (1.4 m) NAVD88 at River Mile 52) as a HEC-RAS downstream boundary condition, the licensee calculated a maximum WSE at River Mile 52 of 6.6 ft (2.0 m) NAVD88 (PSEG, 2014a).

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[1] In the case of the former modeling assumption, the five bridges that were not included in the HEC-RAS model were upstream of the site at River Mile 81.9, so excluding these could be conservative if their presence would affect the flood wave by blocking (attenuating) downstream flow. In the case of the latter modeling assumption, by blocking-off lateral inflows at some river cross-sections, the potential flux (flood storage) attributed to these inflowing streams would not be included in the model. This reduction in flood storage would tend to increase the downstream flood elevations by virtue of slower river base-flow velocities, and is thus conservative.

The NRC staff reviewed the information presented in PSEG (2013) and determined that the licensee's calculation of the 10 percent exceedance high tide was consistent with guidance in ANSI/ANS-2.8-1992 (1992). Using the input files provided by the licensee (PSEG, 2014b), the NRC staff also confirmed the licensee's maximum elevation at River Mile 52 for the combined one-half PMF and 10 percent exceedance high tide.

The licensee reviewed available water level data for the Delaware Bay and determined that the 2012 Hurricane Sandy (October 29-30) resulted in the highest storm surge elevation and therefore was the worst storm of record (PSEG, 2014a). Using the combined ADvanced CIRCulation and Simulating WAves Nearshore (ADCIRC/SWAN) model, the licensee performed a simulation of this particular hurricane event and reported that the storm surge alone (i.e., without the influence of astronomical tides or river discharge) resulted in a maximum WSE at River Mile 52 of 6.5 ft (2 m) NAVD88 (PSEG, 2014a). The NRC staff reviewed the tidal gage data at Reedy Point, DE (located at about River Mile 58.5, to the north of the Salem site) observed during Hurricane Sandy (NOAA, 2015), and determined that the maximum storm surge was about 5.8 ft (1.8 m). Because this observed value is less than the value obtained from the licensee's computer simulation, the NRC staff determined that the licensee's estimate of the surge from the worst storm of record was conservative.

The licensee combined the 2012 Hurricane Sandy WSE (6.5 ft (2 m) NAVD88) with the WSE obtained from the one-half PMF computer simulation and the 10 percent exceedance high tide (6.6 ft (2.0 m) NAVD88), and reported a maximum WSE of 13.1 ft (4.0 m) NAVD88 for the Alternative 1 *Scenario* (PSEG, 2014a). The NRC staff notes that wind-wave runup for the Alternative 1 scenario were not included. Calculation of wave runup at the PSEG ESP site, coincident with two separate hurricane events (PSEG, 2013), was estimated by the ESP applicant to be 3.1 ft (0.9 m). The NRC staff estimated the maximum total WSE for the PMF Alternative 1 scenario at the Salem Site, including wind-wave activity consistent with ANSI/ANS-2.8-1992 (1992), was 16.2 ft (4.9 m) NAVD88 (the sum of the licensee's stillwater elevation from the Salem FHRR and the wave runup from PSEG) (PSEG, 2013). The maximum WSE for PMF Alternative 1 is also less than the storm surge scenario discussed in Section 3.5 below.

3.3.4.2 PMF Alternative 2

For the second alternative, the licensee combined three scenarios: the PMF for the Delaware River, the 10 percent exceedance high tide, and the 25-yr surge event. Using the 10 percent exceedance high tide as a downstream boundary condition in the HEC-RAS computer model (described in Section 3.3.3), the licensee calculated a maximum WSE at the River Mile 52 location (i.e., the Salem site) of 7.3 ft (2.2 m) NAVD88 (PSEG, 2014a). Using the input files provided by the licensee (PSEG, 2014b), the NRC staff's independent estimate at the same location was 7.6 ft (2.3 m) NAVD88. Although this value is 0.3 ft (0.1 m) higher than the licensee's estimate, the NRC staff determined that the difference was inconsequential and would have no impact on the NRC staff's conclusions regarding the extent of flooding for this hazard mechanism.

The licensee evaluated the scenario using data obtained from the USACE for a coastal flood study, and reported an elevation of 7.1 ft (2.2 m) NAVD88 for this event, without the tidal component (PSEG, 2014a). The NRC staff reviewed information that reported 25-yr return period WSEs of 6.1 ft (1.9 m) NAVD88 at Lewes, DE (at the mouth of the bay, about 50 miles to

the south of the site), and 5.8 ft (1.8 m) NAVD88 at Reedy Point (USACE, 1997). Based on these WSE magnitudes, as well as the 2012 Hurricane Sandy surge (6.5 ft (2 m) NAVD88, from Section 3.3.4.1), the NRC staff determined that the licensee's stillwater value of 7.1 ft (2.2 m) NAVD88 was a reasonable estimate of the maximum WSE at the Salem site for the 25-yr surge event.

The licensee summed the 25-yr surge WSE (7.1 ft (2.2 m) NAVD88) with the combined elevation for the PMF in the Delaware River simulation and the 10 percent exceedance high tide (7.3 ft (2.2 m) NAVD88), and reported a total (maximum) WSE of 14.4 ft (4.4 m) NAVD88 for PMF Alternative 2 scenario (PSEG, 2014a). The licensee stated that this composite elevation does not include coincident wave runup at the site (PSEG, 2014a). As discussed in Alternative 1 PMF scenario, the coincident wave runup for two separate hurricane events was estimated to be 3.1 ft (0.9 m) (PSEG, 2013). The NRC staff estimated the maximum total WSE for the PMF Alternative 2 scenario at the Salem site, including wind-wave activity consistent with ANSI/ANS-2.8-1992 (1992), is 17.8 ft (5.4 m) NAVD88.

The maximum flood elevation estimated for the Alternative 2 PMF scenario was 17.8 ft (5.4 m) NAVD88. Although this WSE exceeds the nominal site grade of 11.7 ft (3.6 m) NAVD88, it is significantly lower than the CDB elevation for storm surge scenario discussed in Section 3.5, below. The NRC staff also notes that the Delaware River PMF contributes less than 3 ft (0.9 m) to the total WSE at the site, while the dominant contributor is the storm surge.

3.3.5 Conclusion

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding due to streams and rivers is bounded by the CDB flood hazard at the Salem site. Therefore, the NRC staff determined that flooding from streams and rivers does not need to be analyzed in a focused evaluation or an additional assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

3.4 <u>Failure of Dams and Onsite Water Control/Storage Structures</u>

The licensee reported in the Salem FHRR (PSEG, 2014a) that the reevaluated flood hazard, including associated effects, for failure of dams and onsite water control or storage structures is a WSE of 7.4 ft (2.3 m) NAVD88 (stillwater).

The licensee stated in the Salem FHRR (PSEG, 2014a) that the evaluation of flooding from dam failure followed the simplified modeling approaches described in JLD-ISG-2013-01 (NRC, 2013b). Citing the USACE's National Inventory of Dams (USACE, 2015b) database, the licensee identified 1,024 dams upstream of the Salem site; dam height and reservoir storage information contained in the database were used in the licensee's dam failure analysis. Dam heights reported in the database ranged from 3.5 to 280 ft (1.1 to 85.3 m).

The licensee then developed an attenuation function for each dam (PSEG, 2013). Using these attenuation functions, and the distance of each dam from the Salem site, the licensee calculated an attenuated discharge value for each individual dam in the drainage basin. The results of that calculation produced a cumulative discharge of 908,000 cfs (25,700 m3/s) for all 1,024 dams; this cumulative discharge produced a WSE of 0.9 ft (0.3 m) above the base hydrologic

conditions. The base hydrologic conditions were a WSE of 6.5 ft (2.0 m) NAVD88, defined by the licensee as the 10 percent exceedance high tide (a WSE of 4.5 ft (1.4 m) NAVD88) plus the 500-yr PMF (2.0 ft (0.6 m)) (PSEG, 2013). The licensee's estimated maximum WSE is therefore 7.4 ft (2.3 m) NAVD88 (stillwater) for the reevaluated dam failure scenario at the Salem site, which is much lower than the CDB still water WSE of 24 ft (7.3 m) NAVD88.

In reviewing the Salem FHRR analysis, the NRC staff notes the licensee followed simplified modeling methodologies discussed in JLD-ISG-2013-01 (NRC, 2013b). Using information from USACE (2015b) and Delaware River Basin Commission (DRBC) Reservoirs Map (DRBC, 2015), the NRC staff verified that the licensee included the major Delaware River Basin reservoirs in the dam failure analysis. For those dams, the NRC staff spot-checked the dam height and storage values used by the licensee, verified the peak discharge values, and determined that the distances from the Salem site were reasonable. The NRC staff verified the licensee's attenuated discharge values at the River Mile 50.8 location (the approximate location of the Salem site). The NRC staff determined that the licensee's linear extrapolation of the stage-discharge relationship would lead to cumulative discharge values approximately equal to 900,000 cfs (25,000 m^3/s); in the NRC staff's estimation, the licensee's estimate of 908,000 cfs (25,700 m^3/s) is therefore a reasonable estimate. Lastly, the NRC staff used the stage-discharge relationship described in the Salem FHRR (PSEG, 2013) to perform a sensitivity analysis. The NRC staff hypothesized an 85 percent increase in the licensee's estimated sum of attenuated discharges and determined that this would only increase the WSE 1.1 ft (0.3 m) above the licensee's estimate at the Salem site.

Coincident wind setup and wave runup activity was not considered as part of the licensee's dam failure scenario in the Salem FHRR. However, as part of the PSEG ESP, the licensee estimated an increase in WSE of 2.6 ft (0.8 m) due to these coincident activities. Therefore, the NRC staff conservatively estimated the maximum dam-failure WSE, including wind-wave activity and discharge uncertainty, to be 11.1 ft (3.4 m) NAVD88 (i.e., the sum of the licensee's stillwater elevation 7.4 ft (2.3 m) NAVD88 plus 2.6 ft (0.8 m) for setup/runup plus an additional 1.1 ft (0.3 m) for the discharge uncertainty). The NRC staff notes this maximum WSE is much less than the storm surge CDB stillwater WSE if 24 ft (7.3 m) NAVD88, which is discussed in Section 3.5 below.

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding due to the failure of dams and onsite water control or storage structures is bounded by the CDB flood hazard at the Salem site. Therefore, the NRC staff determined that flooding from dam failure does not need to be analyzed in a focused evaluation or an additional assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

3.5 Storm Surge

The licensee reported in the Salem FHRR (PSEG, 2014a) that the reevaluated flood hazard for storm surge is a stillwater WSE of 22.5 ft (6.9 m) NAVD88. The reevaluated total WSE, which includes associated effects for each of the critical locations around the Salem site, are summarized in Table 3.5-1 and are lower than the CDB storm surge WSE. The CDB stillwater storm surge WSE is 24 ft (7.3 m) NAVD88. The CDB total WSE for storm surge, which includes wind setup and wave runup, is provided at two locations within the greater Salem site: 30.6 ft (9.3 m) NAVD88 at the auxiliary building and 37.5 ft (11.4 m) NAVD88 at the SWIS location.

The licensee used a probabilistic-deterministic storm surge methodology for developing the 10^{-6} annual exceedance probability (AEP) storm surge flood elevation at the Salem site. The licensee stated that the approach follows the current state-of-practice used by both the Federal Emergency Management Agency (FEMA) and the USACE for storm surge inundation analyses (FEMA, 2012 and Divoky and Resio, 2007), as well as the methodologies discussed in NUREG/CR-7134 (NRC, 2012d).

In lieu of completing the review of the licensee's probabilistic-deterministic methodology, the NRC staff relied on an independent analysis the NRC staff had recently developed for the adjacent PSEG site in connection with the recently-issued ESP (NRC, 2015c). For this analysis, the NRC staff performed an independent deterministic storm surge analysis using a combination of the two-dimensional ADCIRC hydrodynamic model and the SWAN wave model. For the Salem site, the NRC staff applied these independently-developed models to calculate deterministic WSEs, including site-specific associated effects (wave runup). Wave runup calculations developed for the Salem site by the NRC staff are based upon the latest design guidance found in the USACE's (2002, Chapter VI-5) Coastal Engineering Manual (CEM) (Taylor, 2015).

Using results obtained from NRC staff's ADCIRC and SWAN models, the NRC staff independently calculated a stillwater elevations at the Salem site. The NRC staff also calculated a maximum total WSE, including wave runup. The NRC staff's independent calculations support the conclusion that the reevaluated flood hazard due to storm surge is bounded by the CDB for the Salem site. Further information regarding the NRC staff's independent analysis can be found in Taylor Engineering (Taylor, 2015).

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding due to storm surge is bounded by the CDB flood hazard at the Salem site. Therefore, the NRC staff determined that flooding from storm surge does not need to be analyzed in a focused evaluation or an additional assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

3.6 Seiche

The licensee reported in the Salem FHRR (PSEG, 2014a) that the reevaluated hazard, including associated effects, for site flooding from seiche does not inundate the plant site. The licensee concluded that seiche is not likely at the Salem site for the following reasons: (a) large amplitude oscillations are not possible in the Delaware Bay Estuary, (b) the most probable forcing mechanisms lack a period of oscillation close enough to the fundamental period (corresponding to the dimensions of the Delaware Bay Estuary) to be of concern, and (c) a magnitude and duration great enough to supply a significant amount of energy into the basin is unlikely to occur.

The licensee stated that free oscillation period of the fundamental mode seiche propagating along the length of the Delaware Bay Estuary from its mouth (at River Mile 0) to the head of tide at Trenton (River Mile 134) is 31 hours (USACE, 2002). The periods for wind-generated waves in the Delaware Estuary could range from between one to seven seconds. Since these periods are much shorter than the fundamental period of free oscillation for the Delaware Estuary

(Wong and Garvin, 1984), the licensee concluded that no wave resonance would occur. The licensee also stated that the Delaware Bay would not resonate in response to seismic activity. Seismic waves generally have a period of 1 hour or less (Oliver, 1962). Lastly, the astronomical tide for this location has a period on the order of 12 hours, which is approximately one half to one third of the maximum oscillation period of the Delaware Estuary. Thus, the astronomical tide would not provide the forcing mechanism necessary to generate resonance.

The NRC staff applied the seiche equations presented in the USACE's CEM (USACE, 2002), and confirmed the primary and secondary mode periods with representative length and depth values for the Delaware Bay Estuary system. According to the CEM, an open basin whose length is 134 mi (216 km) and whose average depth is 20 ft (6.1 m) results in a primary seiche mode equal to 31.1 hours. Based on these physical dimensions, the first fundamental seiche mode (first harmonic) is estimated to be about 10.4 hours. These seiche periods confirm the values stated by the licensee.

The NRC staff also reviewed the two journal articles (studies) of sub-tidal (lower frequency than the tide) water level fluctuations in Delaware Bay referenced in Section 2.4.5.8, "Seiche and Resonance," of the PSEG ESP Site Safety Analysis Report (PSEG, 2015b). The NRC staff's review of those cited journal articles (Wong and Moses-Hall, 1998; and Wong and Garvin, 1984) confirmed the licensee's positions concerning wind effects on sub-tidal water level fluctuations and the periods of those fluctuations.

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding due to seiche is bounded by the CDB flood hazard at the Salem site. Therefore, the NRC staff determined that flooding from seiche does not need to be analyzed in a focused evaluation or an additional assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

3.7 Tsunami

The licensee reported in the Salem FHRR (PSEG, 2014a) that the reevaluated hazard, including associated effects, for site flooding from tsunami does not inundate the plant site. This flood-causing mechanism is described in the licensee's CDB. The reevaluated PMF elevation, including associated effects, for site flooding due to tsunami reported in the Salem FHRR is 5.7 ft (2.0 m), including associated effects (but assuming no friction effects).

The Salem FHRR analysis began with an examination of the scientific literature to establish the probable maximum tsunami (PMT) at the site based on the published reports. Next, the licensee performed a numerical tsunami simulation using the Method of Splitting Tsunami (MOST) computer code developed by Titov and others (1997 and 1998). That computer model considered a range of near-field and far-field seismogenic sources capable of generating a tsunami, and could be used to reconstruct the WSEs reported in the literature. Those seismogenic source-zones (scenarios) considered included a subduction zone event occurring within the Hispaniola Trench (Caribbean), the collapse of a volcanic cone in the Canary Islands (Atlantic Ocean), and a Currituck-like submarine landslide event on the continental shelf margin (North America). The MOST computer simulations suggest that the PMT at the Salem site was found to be due to a Currituck-like submarine landslide event.

The runup values calculated during the MOST simulations were reported to be comparable to the 10 percent exceedance high tide at the site, which serves as the initial static water level condition in the tsunami computer simulations. The 10 percent exceedance high tide is 5.3 ft (1.6 m) NAVD88 and is based on historical observation data from the NOAA tidal gage at Reedy Point (NOAA, 2015). Using the MOST computer model (and ignoring bottom friction effects), the maximum runup at the Salem site was estimated to be 6.5 ft (2.0m) NAVD88; by way of comparison, the elevation of the powerblock is 9.7 ft (3 m) NAVD88.

The NRC staff conducted an independent analysis to confirm the magnitude of the PMT at the Salem site. The NRC staff performed numerical modeling of three tsunami sources consisting of both the far-field and far-field seismogenic source zones as potential PMT generators (ten Brink et al, 2008). In conducting its independent analysis, the NRC staff relied on the Boussinesq-based Cornell University Long and Intermediate Wave Modeling Package (COULWAVE) (Lynett and Liu, 2002) computer model to evaluate the three tsunami scenarios described above. In performing those simulations, the NRC staff relied on conservative modeling parameters, some even physically implausible, to provide a highly conservative (absolute upper limit) of a PMT at the PSEG Site. That independent computer analysis found that the PMT at the Salem site was estimated to be 8.5 ft (2.6 m) NAVD88; the seismogenic source for the tsunami was the Currituck-like landslide. This estimate included consideration of both high tide and sea level rise. As mentioned above, the elevation of the powerblock is 9.7 ft (3 m) NAVD88.

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding due to tsunamis is bounded by the CDB flood hazard at the Salem site. Therefore, the NRC staff determined that flooding from tsunamis does not need to be analyzed in a focused evaluation or an additional assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

3.8 Ice-Induced Flooding

The licensee reported in the Salem FHRR (PSEG, 2014a) that the reevaluated hazard, including associated effects, for site flooding from ice-induced flooding does not inundate the plant site. The licensee reported in the Salem FHRR that the reevaluated flood hazard for ice-induced flooding is 5.3 ft (1.6 m) NAVD88. When wind waves and runup effects were considered, the resulting WSE was 8.1 ft (2.5 m) NAVD88.

The licensee stated that the evaluation of ice-induced flooding is applicable to the Salem site (PSEG, 2013). In its evaluation of this flood-causing mechanism, the licensee initially queried the Cold Regions Research and Engineering Laboratory (CRREL) ice jam database maintained by the USACE (USACE, 2015a) for information on water levels and discharges associated with past ice jams reported on the Delaware River. Based on that review, the licensee determined that the most severe event reported in the CRREL database was a 1904 event, with an estimated water level of 29.6 ft (9.0 m) NAVD88 at Trenton (USGS, 2014). The licensee then used the HEC-RAS computer model (USACE, 2010a) to simulate the consequences of the failure of that 1904 ice dam, routing the discharge downstream to the location of the PSEG ESP site (PSEG, 2013). The computer simulation included consideration of the 10 percent exceedance high tide (4.5 ft (1.4 m) NAVD88 at the PSEG ESP site), as well as average spring base flow which, when combined, produced a WSE of 5.2 ft (1.9 m) NAVD88 at the location of

the PSEG ESP site. The licensee's simulation of the 1904 ice dam failure resulted in increase in the river elevation of 0.1 ft (0.03 m) at the PSEG ESP, site leading to a stillwater elevation of 5.3 ft (1.6 m) NAVD88 (PSEG, 2013). The licensee stated that coincident wave runup, taking into account a 2-yr wind speed in the critical-direction, contributed an additional 2.8 ft (0.9 m) of flooding, resulting in a total WSE of 8.1 ft (2.5 m) NAVD88 (PSEG, 2013) at the site.

In connection with their independent review of the Salem FHRR, the NRC staff also reviewed the CRREL ice jam database (USACE, 2015a) for records of historical ice jams on the Delaware River, and found that the ice jams reported nearest to the Salem site were at Trenton. The NRC staff verified that the 1904 ice jam resulted in the highest reported WSE at Trenton (USGS, 2014). The NRC staff found no other accounts of ice dams occurring on the main stem of the Delaware River below Trenton. Under the flooding scenario considered by the licensee, the WSE at the Salem site increased only 0.1 ft (0.03 m) following failure of the 1904 ice dam. The NRC staff did a comparison of the magnitude of the discharges considered in connection with the review of the dam failure scenarios (earlier Section 3.4), the NRC staff determined that the ice dam failure-induced flood elevation at the Salem site would be less than the elevation resulting from any credible dam failure scenario within the Delaware River watershed.

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding due to ice jams is bounded by the CDB flood hazard at the Salem site. Therefore, the NRC staff determined that flooding from ice jams does not need to be analyzed in a focused evaluation or a revised integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

3.9 Channel Migrations or Diversions

The licensee reported in the Salem FHRR (PSEG, 2014a) that the reevaluated hazard, including associated effects, for channel migrations or diversions does not impact the plant site. The Salem FHRR (PSEG, 2013) states that the Delaware River has existed in its current location for at least the last 10,000 years. The licensee further noted that there was no geomorphic/geologic evidence of channel diversion within the greater Delaware River basin. The licensee stated that the potential for flooding from landslides, mudslides, or other temporary channel diversions is highly unlikely due to the relatively low topography of the terrain contiguous to the Delaware River and the shallowness of the river channel itself (PSEG, 2014a). Lastly, there are no levees on the main stem of the Delaware River that would be used to prevent the river from demonstrating natural meander behavior (Leopold and Wolman, 1960) further suggesting the absence of channel migration.

The NRC staff guidance described in NUREG/CR-7046 (NRC, 2011e) acknowledges that there are no well-established predictive models for estimating the potential for channel diversion in a riverine environment. However, the potential for channel migrations or diversions to take place at a particular location can be assessed by reviewing certain types of information, such as topographic maps that are generally recognized to reflect evidence of the horizontal movement (meandering) of rivers and streams. If there were evidence of channel migration or river meandering in the past, there would be evidence to that effect present on the topographic map reviewed of the area. The particular geomorphic features of interest are generally recognized to include river meanders, meander belts, flood plains, oxbow lakes, natural levees, and the like (Salisbury and Atwood, 1908). The NRC staff's review of this topic involved reviewing the

USGS's historic topographic map digital data base (USGS, 2015). The goal was initially to identify the earliest map published for the area and then inspecting those map for geomorphic evidence of channel diversion (including river meandering). After completing that review, the NRC staff would then inspect more recently-prepared map of the reactor site to see if there had been changes in the topography in the intervening years.

The NRC staff's review of the USGS's historic data base of topographic map of the Salem site and environs did not reveal any evidence of meandering. This comparison leads the NRC staff to conclude that there is no physical evidence of river meandering and/or channel diversion for at least the last century. In addition, the NRC staff also independently reviewed and confirmed that landslide incidence in the lower Delaware River is low (USGS, 1982). Lastly, the Delaware River shoreline adjacent to the PSEG site is known to be protected from erosion through the use of rip-rap, groins, or other engineered devices.

In summary, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding due channel migration or diversion is bounded by the CDB flood hazard at the Salem site. Therefore, the NRC staff determined that flooding from channel migration or diversion does not need to be analyzed in a focused evaluation or a revised integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a).

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

4.1 Reevaluated Flood Elevation 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 results, including waves and runup, 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 is the only hazard mechanism not bounded by the CDB. Consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015a), NRC staff anticipates the licensee will submit a focused evaluation for LIP and associated site drainage.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in PSEG's 50.54(f) response (PSEG, 2014a; PSEG, 2014b; 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 provided FED parameter values for the LIP flood causing mechanism. Based on the LIP analysis and associated site drainage scenario described in the Salem FHRR, the WSEs estimated by the licensee exceeds door sill elevations at multiple locations for critical structures within the Salem powerblock. The licensee's computer simulations suggested that the door sill elevations at certain locations are exceeded within 15 minutes of the onset of the LIP event and remained above those door sills for approximately 5 to 8 hours (PSEG, 2014a). Because current flood protection procedures require advance notice of 2 hours to close critical

watertight doors, the licensee proposed interim actions to determine the advance notice needed for an LIP flood event and to provide revised operating procedures.

The licensee is expected to use the estimated LIP FED parameter values reported in the Salem FHRR (PSEG, 2014a) when it conducts the MSA and focused evaluations or revised integrated assessments.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in PSEG's 50.54(f) response (PSEG, 2014a; PSEG, 2014b; and NRC, 2016) regarding associated effects (AE) parameters needed to perform future additional assessments of plant response for flood hazards not bounded by the CDB. The AE parameters directly related to the maximum WSE, such as wave height and runup, are provided in Table 4.1-1 of this staff assessment. The AE parameters not directly associated with a maximum WSE are listed in Table 4.3-1. The AE parameters not submitted as part of the Salem FHRR are designated as "not provided" in this table.

The licensee is expected to develop AE parameters for LIP to conduct the MSA and focused evaluations or revised integrated assessments. The NRC staff will review the values for these parameters as part of future assessments of the plant response to the identified flood-causing mechanism, if applicable.

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 is expected to develop missing AE parameters to conduct the MSA and the focused evaluations or revised integrated assessments. The NRC staff will evaluate the missing associated effects marked as "not provided" in Table 4.3-1 during its review of the MSA and focused evaluations or revised integrated assessments.

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms for Salem. Based on the review of available information provided in PSEG's 50.54(f) response (PSEG, 2014a; PSEG, 2014b; and NRC, 2016), 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) the reevaluated flood hazard results for LIP are not bounded by the CDB flood hazard, (b) additional assessments of plant response will be performed for the LIP flooding mechanism, and (c) the reevaluated flood-causing mechanism information is appropriate input to the additional

assessments of plant response as described in the 50.54(f) letter, COMSECY-15-0019 (NRC, 2015a), and associated guidance.

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

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Notes: ADAMS Accession No. 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	STANDARD REVIEW PLAN (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

Table 3.0-1. Summary of Controlling Flood-Causing Mechanisms at the Salem Site

Reevaluated Food-Causing Mechanisms and Associated Effects That May Exceed The Powerblock Elevation (9.7 ft (3 m) NAVD88)[(1)]	ELEVATION (NAVD88)
Local Intense Precipitation and Associated Drainage	12.2 ft (3.7 m)[(2)]

(1) Flood Height and Associated Effects as defined in JLD-ISG-2012-05
(2) Maximum water-surface elevation at critical door sills.

Table 3.1-1. Current Design Basis (CDB) Flood Hazards for the Salem Site (PSEG, 2014a)

MECHANISM	STILLWATER ELEVATION	WAVES/RUNUP	DESIGN BASIS HAZARD ELEVATION	REFERENCE
Local Intense Precipitation and Associated Drainage	Not included in DB	Not included in DB	Not included in DB	FHRR Section 1.2.1
Streams and Rivers	Not included in DB	Not included in DB	Not included in DB	FHRR Section 1.2.2
Failure of Dams and Onsite Water Control/Storage Structures	Not included in DB	Not included in DB	Not included in DB	FHRR Section 1.2.3
Storm Surge				
Auxiliary Building	24.0 ft NAVD88	6.6 ft	30.6 ft NAVD88	FHRR Section 1.2.4
Service Water Intake Structure	24.0 ft NAVD88	13.5 ft	37.5 ft NAVD88	FHRR Section 1.2.4 and Table 3-1
Seiche	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 1.2.5
Tsunami	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 1.2.6
Ice-Induced Flooding	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 1.2.7
Channel Migrations or Diversions	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 1.2.8

Note 1: Reported values are rounded to the nearest one-tenth of a foot.
Note 2: Based on the NRC staff's independent (deterministic) hazard assessment using present-day regulatory guidance and methodologies of storm surge, the NRC staff concludes that the site's current design basis remains bounding. For this reason, the NRC staff concludes it is appropriate to utilize the current design-basis storm surge elevation in conjunction with the mitigating strategies assessment.

Table 3.2-1. Local Intense Precipitation Depths for the Salem Site

DURATION (min)	AREA (mi^2)	MULTIPLIER	APPLIED TO	CUMULATIVE DEPTH (in)
60	1	---	---	18.10 (HMR-52, Fig. 24)
30	1	0.753 (HMR-52, Fig. 38)	1-hr, 1 mi^2 (3 km^2) PMP	13.63
15	1	0.525 (HMR-52, Fig. 37)	1-hr, 1 mi^2 (3 km^2) PMP	9.50
5	1	0.334 (HMR-52, Fig. 36)	1-hr, 1 mi^2 (3 km^2) PMP	6.05

Source: PSEG, 2014a (FHRR, Table 2.1-1)

Table 3.2-2. LIP Maximum Water-Surface Elevations (NAVD88) at Critical Door Locations

DOOR ID[a]	DOOR SILL ELEVATION[b] [c]	MAXIMUM FLOOD WATER SURFACE ELEVATION	FLOOD DEPTH ABOVE DOOR SILL	TIME TO MAXIMUM FLOOD DEPTH (hr)	DURATION OF FLOODING ABOVE DOOR SILL ELEVATION (hr)
10	10.20 ft (3.11 m)	12.07 ft (3.68 m)	1.87 ft (0.57 m)	1.01	7.70
11	10.20 ft (3.11 m)	11.68 ft (3.56 m)	1.48 ft (0.45 m)	1.05	6.60
12	10.20 ft (3.11 m)	11.52 ft (3.51 m)	1.32 ft (0.40 m)	1.00	5.90
13	10.20 ft (3.11 m)	11.52 ft (3.51 m)	1.32 ft (0.40 m)	1.00	5.90
14	10.20 ft (3.11 m)	11.43 ft (3.48 m)	1.23 ft (0.38 m)	1.01	5.40
15	10.20 ft (3.11 m)	11.49 ft (3.50 m)	1.29 ft (0.39 m)	1.00	5.50
16	10.20 ft (3.11 m)	12.16 ft (3.71 m)	1.96 ft (0.60 m)	0.99	7.90
17	10.20 ft (3.11 m)	12.14 ft (3.70 m)	1.94 ft (0.59 m)	0.99	7.90
18	10.20 ft (3.11 m)	12.24 ft (3.73 m)	2.04 ft (0.62 m)	1.00	8.00
19	10.20 ft (3.11 m)	12.24 ft (3.73 m)	2.04 ft (0.62 m)	1.00	8.10
20	10.20 ft (3.11 m)	11.36 ft (3.46 m)	1.16 ft (0.35 m)	0.99	4.70
21	10.20 ft (3.11 m)	11.34 ft (3.46 m)	1.14 ft (0.35 m)	1.01	4.80

Source: PSEG, 2014a (FHRR, Table 2.1-3)

(a) Door ID locations shown in Figure 3.2-3.

(b) To implement flood protection above this elevation, water tight doors must be closed (PSEG, 2014a).

(c) The licensee report WSE values to the hundredth of a foot and these values have been duplicated here. Values reported in the NRC staff assessment text were rounded to the nearest one-tenth of a foot.

Table 3.5-1. Storm Surge Maximum Total Water Surface Elevations

SALEM POWERBLOCK LOCATION*	TOTAL WATER SURFACE ELEVATIONS	
	meters (NAVD88)	**feet** (NAVD88)
1	7.3	23.9
2	9.6	31.5
3	10.9	10.9
4	8.0	26.2
5	6.7	22.0
6	10.9	35.8
7	10.8	35.6
8	7.9	25.8
9	7.5	24.7
10	7.8	25.4
11	9.0	29.4
12	9.0	29.4
13	8.4	27.5
14	8.5	27.9
15	8.0	26.2
16	7.0	23.1
17	6.7	22.0
18	7.3	23.9
19	7.9	26.0
20	9.0	29.7
21	6.7	22.0
22	8.1	26.4
*Most locations are noted in Figure 3.2-4, however FHRR Figure 2.1-3 provides complete location.		

(Modified from PSEG (2014a, Table 2.4-14))

Table 4.1-1. Reevaluated Hazard Elevations (NAVD88) for Flood-Causing Mechanisms Not Bounded by the Salem's CDB

MECHANISM	STILLWATER ELEVATION	WAVES/RUNUP	REEVALUATED HAZARD ELEVATION	REFERENCE
Local Intense Precipitation and Associated Drainage	12.2 ft NAVD88	Minimal	12.2 ft NAVD88	FHRR Section 3.1

Note 1: The licensee is expected to develop flood event duration parameters and applicable flood associated effects to conduct the MSA. The NRC staff will evaluate the flood event duration parameters (including warning time and period of inundation) and flood associated effects during its review of the MSA.

Note 2: Reevaluated hazard mechanisms bounded by the current design basis (see Table 1) are not included in this table.

Note 3: Reported values are rounded to the nearest one-tenth of a foot.

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

MECHANISM	TIME AVAILABLE FOR PREPARATION FOR FLOOD EVENT	DURATION OF INUNDATION OF SITE	TIME FOR WATER TO RECEDE FROM SITE	REFERENCE
Local Intense Precipitation and Associated Drainage	24 hours	1.0 hour	8.10 hours	PSEG (2014a)

Table 4.3-1. Associated Effects Parameters not Directly Associated with Total Water Height for Flood-Causing Mechanisms not Bounded by the Salem's CDB

ASSOCIATED EFFECTS FACTOR	FLOOD-CAUSING MECHANISM
	Local Intense Precipitation and Associated Drainage
Hydrodynamic Loading at Plant Grade	Not provided
Debris Loading at Plant Grade	Not provided
Sediment Loading at Plant Grade	Not provided
Sediment Deposition and Erosion	Not Applicable
Concurrent Conditions, Including Adverse Weather	Not provided
Other Pertinent Factors (e.g., Waterborne Projectiles)	Not provided

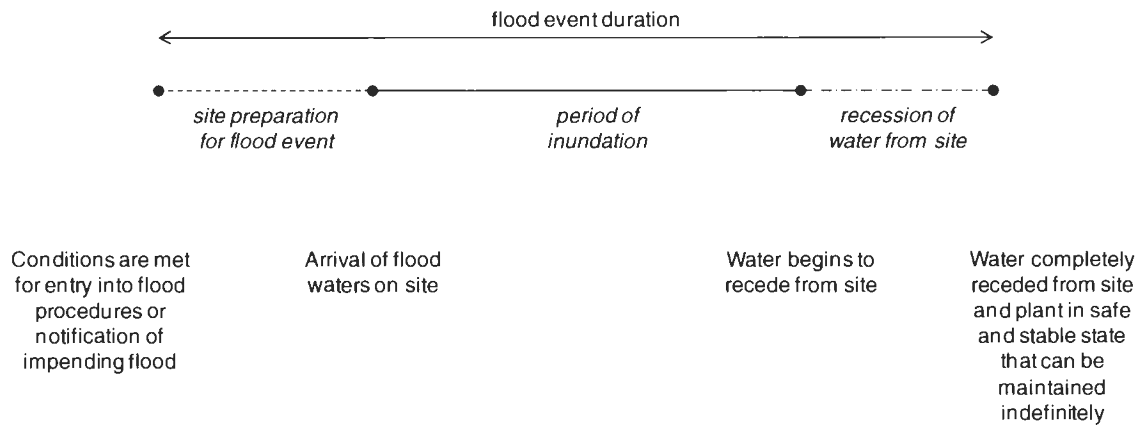

Figure 2.2-1 Flood Event Duration (NRC, 2012e)

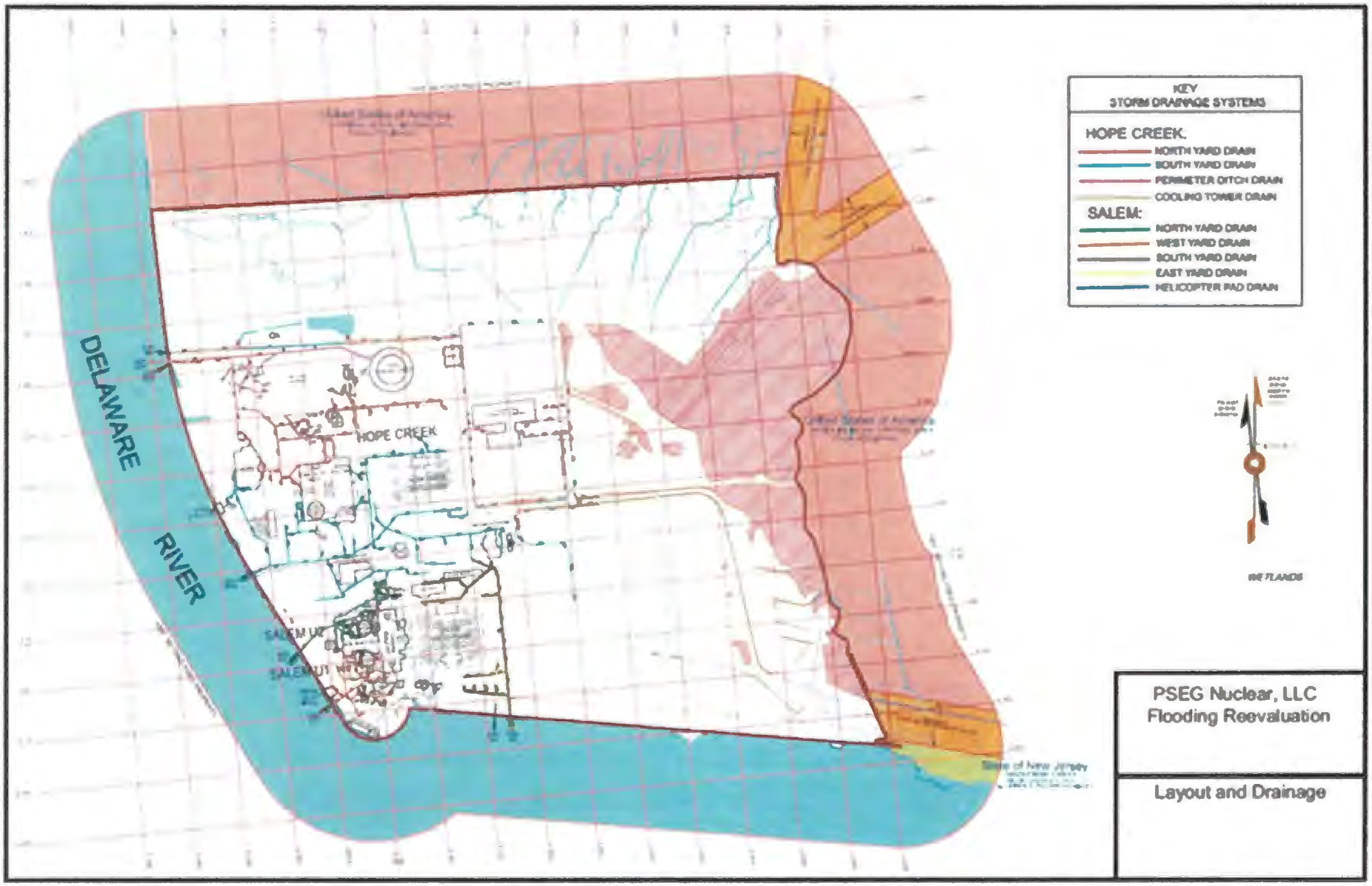

Figure 3.2-1. PSEG Site Showing Hope Creek and Salem Reactor Complexes.˙ Modified from PSEG (2014a)


PROCESSING CENTER
NUCLEAR SERVICES
FACILITIES BUILDING
DSN
463A
STORE ROOM
FAB. SHOP
SERVICE
BLDG
SALEM U2
AUX BUILDING
TURBINE
BUILDING
ADMIN
BLDG
SALEM
SWITCHYARD
DSN
487
SALEM U1
SERVICE
WATER
INTAKE
DSN
488
WATER INTAKE
DSN
490
DSN
491

Figure 3.2-2. PSEG Site Layout and Drainage (detail from PSEG, 2014a, FHRR Figure 1.1-2)

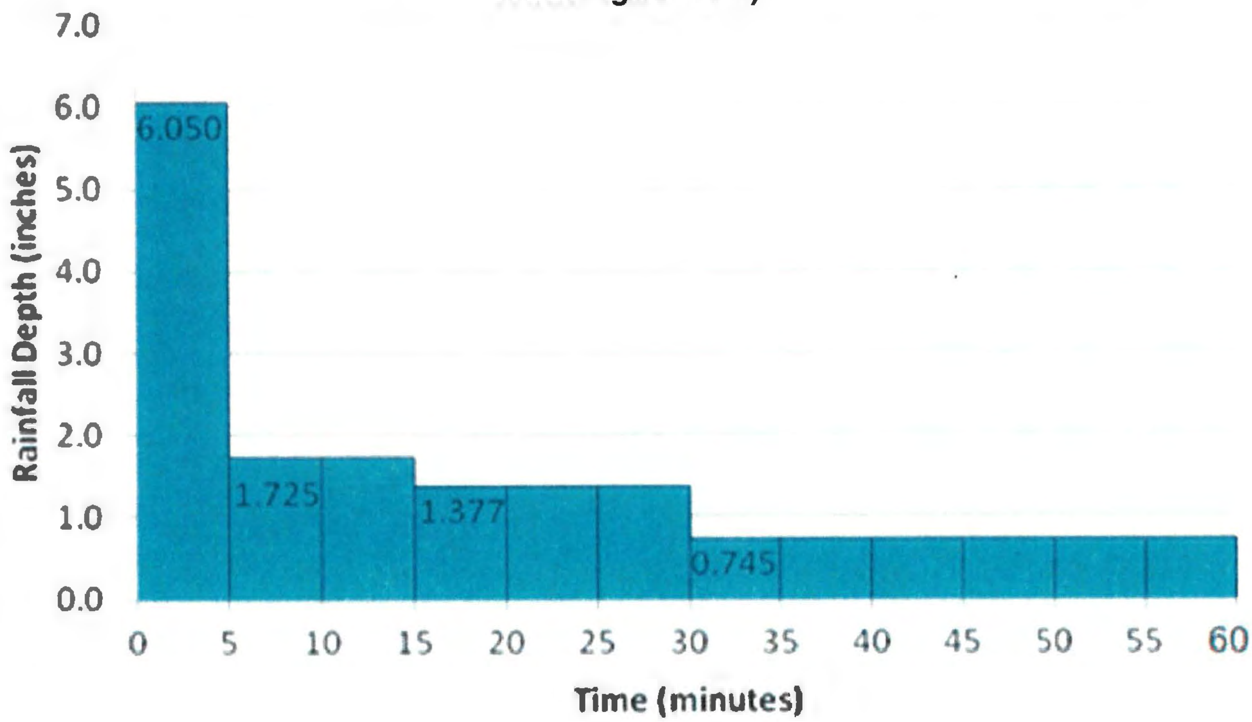

Figure 3.2-3. Precipitation Hyetograph Used in the Local Intense Precipitation Analysis (PSEG, 2014a, FHRR Figure 2.1-2)

Figure 3.2-4. Critical Door Locations Used for Local Intense Precipitation Analysis at the Salem Site (modified detail from PSEG, 2014a, FHRR Figure 2.1-3)

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. 50-272 and 50-311

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Reevaluation Report

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