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

January 12, 2018

Mr. Mano Nazar
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SUBJECT: SEABROOK STATION, UNIT NO. 1 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NO. MF6782; EPID NO. 000495/05000443/L-2015-JLD-0019)

Dear Mr. Nazar:

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 that licensees reevaluate flood-causing mechanisms using present-day methodologies and guidance. By letter dated November 7, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16314D429, Non-Public), NextEra Energy Seabrook, LLC (the licensee) responded to this request for Seabrook Station, Unit No.1 (Seabrook).

By letter dated December 21, 2016 (ADAMS Accession No. ML16356A468), the NRC staff sent the licensee a summary of the staff's review of Seabrook'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 local intense precipitation and storm surge flooding at Seabrook are not bounded by the plant's current design basis, additional assessments of these flood hazard mechanisms are necessary. The licensee submitted the additional assessment, the Focused Evaluation, by letter dated June 28, 2017 (ADAMS Accession No. ML17181A409). The Focused Evaluation is currently under review.

The NRC staff has no additional information needs at this time with respect to Seabrook's 50.54(f) response related to flooding. This staff assessment closes out the NRC's efforts associated with CAC No. MF6782.

If you have any questions, please contact me at (301) 415-1617 or e-mail at Frankie.Vega@nrc.gov.

Sincerely,

Frankie Vega, Project Manager
Beyond-Design-Basis Management Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket No. 50-443

Enclosure:
Staff Assessment of Flood Hazard
Reevaluation Report for Seabrook

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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

SEABROOKSTATION, UNIT NO. 1

DOCKET NO. 50-443

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) (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, 2011a). 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 Flood Hazard Reevaluation Report (FHRR) deadlines for each plant. On May 11, 2012 (NRC, 2012b, the NRC staff issued its prioritization of the FHRRs).

By letter dated September 25, 2015 (NextEra, 2015), NextEra Energy Seabrook, LLC (NextEra, the licensee) provided FHRR Revision 0 for Seabrook Station, Unit No.1 (Seabrook). By letter dated November, 7, 2016 (NextEra, 2016b), NextEra provided the FHRR Revision 1 for Seabrook; the information in this staff assessment is based on Revision 1 of the FHRR. The NRC staff conducted a site audit as documented in the audit report (NRC, 2017).

On December 21, 2016 (NRC, 2016a), the NRC issued an interim staff response (ISR) letter to the licensee. 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 staff assessment without change or alteration.

As mentioned in the ISR letter, the reevaluated flood hazard results for the local intense precipitation (LIP) and storm surge flood-causing mechanisms are not bounded by the plant's current design basis (CDB) hazard. Consistent with the 50.54(f) letter as amended by the process outlined in COMSECY-15-0019 (NRC, 2015), Japan Lessons-Learned Division (JLD)

Interim Staff Guidance (ISG) JLD-ISG-2012-01, Revision 1 (NRC, 2016a) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b), the NRC staff anticipates that the licensee will perform and document a focused evaluation for LIP 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 the storm surge flood-causing mechanisms, the NRC staff anticipates that the licensee will submit (a) a revised integrated assessment or (b) a focused evaluation confirming the capability of existing flood protection or implementing new flood protection consistent with the process outlined in COMSECY-15-0019 (NRC, 2015) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b). The licensee submitted its FE by letter dated June 28, 2017 (NextEra, 2017b). It is currently under review.

Additionally, for any reevaluated flood hazards that are not bounded by the plant's CDB hazard, the licensee is expected to develop any flood event duration (FED) and associated effects (AE) parameters currently not provided to conduct the Mitigating Strategies Assessment (MSA) and focused evaluations (FEs) or revised integrated assessments. By letter dated June 14, 2017 (NextEra, 2017), the licensee submitted its MSA. The NRC staff's review of the MSA will be documented separately from this staff assessment.

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 respective sites using present-day methods and regulatory guidance used by the NRC staff when reviewing applications for ESPs and COLs. This section describes present-day regulatory requirements that are applicable to the FHRR.

Sections 50.34(a)(1), (a)(3), (a)(4), (b)(1), (b)(2), and (b)(4), of 10 CFR, describe the required content of the preliminary and final safety analysis reports, including a discussion of the plant 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.

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 loss of capability to perform their intended safety functions. The design bases for these SSCs are to reflect appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area. The design bases are also to have sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

Section 50.2 of 10 CFR defines the "design bases" as the information 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 an 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 applications submitted 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 requests all power reactor licensees and construction permit holders to reevaluate all external flood-causing mechanisms at each site (NRC, 2012a). This includes current techniques, software, and methods used in present-day standard engineering practice.

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 the 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) section(s) and applicable ISG documents containing acceptance criteria and review procedures.

2.2.2 Associated Effects

The licensee should incorporate and report associated effects per JLD-ISG-2012-05, "Guidance for Performing the Integrated Assessment for External Flooding" (NRC, 2012c) in addition to the maximum water level associated with each flood-causing mechanism. Guidance document JLD-ISG-2012-05 (NRC, 2012c), 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." It should also be noted that for the purposes of this staff assessment, the terms "combined effects" and "combined events" are synonyms. Even if some or all of the 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 licensee should 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, 2012c) as the length of time during which the flood event affects the site. It begins when conditions are met for entry into a flood procedure, or with notification of an impending flood (e.g., a flood forecast or notification of dam failure), and includes preparation for the flood. It continues during the period of inundation, and ends when water recedes from the site and the plant reaches a safe and stable state that can be maintained indefinitely. Figure 2.2-1 illustrates flood event duration.

2.2.5 Actions Following the FHRR

For the sites where the reevaluated flood hazard is not bounded by the CDB probable maximum flood elevation for any flood-causing mechanisms, the 50.54(f) letter (NRC, 2012c) 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 are not required to perform an integrated assessment.

COMSECY-15-0019 (NRC, 2015) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b) outline 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 site and then evaluate and implement any necessary programmatic, procedural or plant modifications to address this 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, 2015 and NRC, 2016b).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of the Seabrook site. The licensee conducted the flood 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 FHRR, the licensee made calculation packages available to the NRC staff via an electronic reading room. These calculation packages were used to expand upon and clarify the information provided on the docket, and so are not docketed or cited.

3.1 Site Information

The 50.54(f) letter (NRC, 2012a) included the SSCs important to safety in the scope of the hazard reevaluation. The licensee included pertinent data concerning these SSCs in the FHRR (NextEra, 2016b). The licensee provided this additional information during a series of audits that were conducted over several interactions with the licensee via teleconferences and/or webinars on December 16, 2015, February 11, 2016, April 27, 2016, June 20, 2016, June 23, 2016, and August 10, 2016. This information was summarized in the NRC staff's audit report (NRC, 2017). The NRC staff reviewed and summarized this information in the sections below.

3.1.1 Detailed Site Information

The Seabrook FHRR (NextEra, 2016b) described the site-specific information related to the flood hazard reevaluation. The licensee used North American Vertical Datum of 1988 (NAVD88) and other vertical datums in the FHRR. All elevations in this staff assessment are referenced to NAVD88 unless otherwise stated. The licensee stated that mean sea level (MSL) and National Geodetic Vertical Datum of 1929 (NGVD29) were treated are interchangeable in the Seabrook Updated Final Safety Analysis Report (UFSAR) and that the "Plant Datum" is equivalent to NGVD29; this equivalence was used when necessary to convert licensee-provided elevation information from these two vertical datums to NAVD88 in this staff assessment.

The Seabrook site is located in Rockingham County, New Hampshire, about 1 mile (mi) from the western shore of Hampton Harbor at the confluence of the Browns and Blackwater rivers. The towns of Hampton, Hampton Falls, and Seabrook are located along the shore of Hampton Harbor. The towns of Hampton Beach and Seabrook are located north and south of the harbor entrance. The Seabrook site is shown on Figure 3.1-1 and Seabrook site layout is shown on Figure 3.1-2 of this assessment.

The site grade at the powerblock is elevation 19.2 feet (ft.) NAVD88 (NextEra, 2016b). Table 3.1-1 of this assessment summarizes the controlling reevaluated flood-causing mechanisms,

including associated effects, the licensee computed to be higher than the powerblock elevation. A broad marsh exists in site-adjacent areas to the north, east and south of the Seabrook site. The general elevation of the marsh areas is 3.2 ft. NAVD88. A stone revetment (crest elevation at 19.2 ft. NAVD88) and a seawall are located on the south and southeast perimeter of the Seabrook site. At other perimeter locations a sheet pile retailing wall is in place. All safety-related equipment is designed to withstand a stillwater elevation up to 20.2 ft. NAVD88.

3.1.2 Design-Basis Flood Hazards

The flood hazard levels described in the plant's CDB are summarized by flood-causing mechanism in Table 3.1-2 in this staff assessment. The licensee presented CDB flood hazard information in the FHRR Table 5-1. 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

As a result of the flood walkdown exercise that was requested in the 50.54(f) letter, the licensee reported the various licensing basis flood-related and flood protection changes from the UFSAR in the FHRR Section 3.0 (NextEra, 2016b). The licensee stated that the licensing basis reported in the FHRR was based on the UFSAR (NextEra, 2014) unless stated otherwise. In the FHRR, Section 3.0 revealed no other references associated with flood-related changes to the licensing basis.

The NRC staff reviewed the information provided in the FHRR 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

The licensee stated in its FHRR that there have been no significant changes to the local watershed (Seabrook area and Hampton Harbor watershed) since the license issuance. The licensee based their determination on a review of historical U.S. Geological Survey (USGS) topographic maps (USGS, 2015).

The NRC staff accessed the historical USGS topographic map from the source identified by the licensee (USGS, n.d.-a). The NRC staff found four historical maps from 1957, 1985, 1987 and 1992; all of which pre-date a recent UFSAR (NextEra, 2014). The NRC staff compared the 1992 map, with a more recent map "Hampton, NH-WA 2015" obtained from the USGS (USGS, n.d.-b). The NRC staff visually compared the 1992 and 2015 maps and agree with the licensee's conclusion that there have been no significant changes to the watershed and local area.

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

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The licensee stated in its FHRR that there have been no changes to flood protection features and any site "changes that had the potential to impact the site flooding analysis received appropriate review and evaluation."

The licensee described features along the site perimeter which are exposed to wave action in the harbor, including:

- A stone revetment on the south and southeast site perimeter provides wave protection,
- A vertical seawall on the southeast site perimeter,
- Compacted and slope structural fill covered with stone is provided on the east and northeast site perimeter, and
- Sheet pile on the north site perimeter.

The licensee also described the features that the site relies upon to mitigate the effects of wave overtopping during surge events. The licensee stated that "Seabrook relies on the exterior reinforced concrete walls of site structures and penetration seals to ensure external flood water does not enter buildings housing safety-related equipment."

The licensee stated in its FHRR that safety-related equipment is either above the expected maximum flood water level or is protected from potential external flood water and that "all safety-related equipment are designed to withstand a depth of still water not exceeding of 21 ft.-Plant Datum." The 21 ft.-Plant Datum is the equivalent of 20.2 ft. NAVD88.

The licensee described waterproofing on the exterior face of walls and minimization of leakage at waterstops at "all below-grade safety-related structures, other than the pumphouse, cooling tower, electrical duct banks and manholes."

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee provided electronic copies of the input files related to flood hazard reevaluations as part of the audit of Seabrook FHRR (NRC, 2017).

3.1.7 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 parts of 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 27, 2012 (NextEra, 2012), as supplemented by letter dated January 30, 2014, NextEra provided the flood walkdown report for the Seabrook site. On June 16, 2014 (NRC, 2014a), the NRC staff issued its assessment of the walkdown report which documented its review of that licensee action and concluded that the licensee's implementation of the flooding walkdown methodology met the intent of the walkdown guidance.

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported in its FHRR that the reevaluated flood hazard for LIP and associated site drainage is based on each of the stillwater-surface elevations at 83 critical locations around various buildings. The location of the site buildings are shown in Figure 3.1-2 of this assessment. The reevaluated maximum stillwater elevation for each building ranges from 20.3 ft. NAVD88 at the cooling tower to 25.1 ft. NAVD88 at the dry fuel storage pad.

This flood-causing mechanism is discussed in the licensee's CDB. The CDB probable maximum flood elevation for LIP and associated site drainage is based on a stillwater-surface elevation of 19.9 ft. NAVD88. Wind waves and runup associated with LIP were not stated as part of the CDB for LIP.

3.2.1 Site Drainage

The Seabrook site is located between the Browns River on the north and Hunts Island Creek on the south as shown in Figure 3.1-1 of this assessment. Both rivers are less than three river miles long and carry very little surface runoff; they mainly contribute freshwater flow to Hampton Harbor without significant impact to the tidal elevations within the harbor. The local drainage area of the plant site is approximately 2×10^6 square ft. (0.07 square mile). The site grade is 19.2 ft. NAVD88 and the plant is surrounded with broad, flat marsh areas. The natural drainage features discharge surface runoff to Hampton Harbor. The licensee used a digital data set from a recent site topographic survey as a local drainage basin for the plant site to simulate the surface runoff. The buildings, temporary structures, and vehicle barriers of the plant were added in the digital topographical data. The NRC staff found that the licensee's topographical data are consistent with the ground elevations shown on USGS topographical maps (USGS, n.d.-b). During the audit the licensee clarified the treatment of runoff from roof drains in the analysis (Information Need 3) (NRC, 2017).

3.2.2 Local Intense Precipitation

For the CDB, the licensee reported the LIP probable maximum precipitation (PMP) would be 8.6 inches (in.) for 1 hour (h) rainfall duration over 10 square mile (mi^2) area.

In its FHRR, the licensee used a storm-based approach, which is detailed in Hydrometeorological Report (HMR) No.33 (National Oceanic and Atmospheric Administration (NOAA), 1956) and HMR 51 (NOAA, 1978). The NRC staff noted that the licensee followed similar procedures described in HMR 52 to develop the site-specific LIP PMP. A total of 11 historical storms were selected and used to develop the 11.4 in. of total LIP depth for the 1-h duration over 1-mi^2 area. The NRC staff found that the licensee's site-specific LIP is less than the conventional HMR 52's LIP by approximately 30 percent.

The NRC staff performed a sensitivity study comparing water depths produced by the FLO-2D model (see Section 3.2.3 below) at safety-related structures after changing the rainfall rate to the HMR 52 value of 16.1 in/h to determine if the site-specific LIP PMP needed staff review. The NRC staff found that the maximum increase in water depth at safety-related structures was less than 0.5 ft. Based on these relatively-small increases in water depths between the two LIP depths, the NRC determined that the licensee's site-specific LIP rate of 11.4 in./hr. is reasonable for use in the flood hazard reevaluation without additional review since the HMR LIP values are acceptable for staff use per NUREG-0800, Section 4.2, without review.

The licensee created five potential temporal distributions for the site-specific distribution of LIP (11.4 in.) over the 1-h rainfall event. The five temporal distributions had different peak intensity periods that occurred at either the front, front third, center, end third, or end of the 1-hour rainfall event. The time period intervals within the 1-hour hyetographs were uniformly set to 5 minutes. The NRC staff reviewed the five temporal distributions and found these rainfall distributions are similar to the methodology recommended by HMR 52, which is acceptable to the NRC staff per NUREG-0800, Section 2.4.2.

3.2.3 Runoff Analysis and Hydraulic Model

In its FHRR, the licensee indicated that a roadway embankment would be a control feature to determine the flood elevation at the Seabrook site. The licensee applied a weir flow equation to simulate a surface runoff over the roadway embankment. The computed average flow rate of the surface runoff was 398 $ft.^3/s$ while the CDB's 1-h PMP of 8.6 in. occurred over the plant site without rainfall loss. The computed maximum flood elevation for the CLB was 19.9 ft. NAVD88 for all buildings.

In its FHRR, the licensee applied the FLO-2D (FLO-2D, 2009) model to simulate flood elevations across the Seabrook site. Using FLO-2D for flood simulations, the licensee considered the hydraulic effects, including roof edge barriers, surface runoff obstructions, nonfunctional surface drainage, and existing buildings and structures. The licensee used a recent survey of site topography in the FLO-2D model. The boundary conditions were set at boundary grids as water elevations were from 5 ft. to 15 ft. lower than the site grade elevation. The licensee used the site-specific 1-hour LIP discussed in Section 3.2.2, and conservatively assumed no rainfall losses due to infiltration, vegetal interception, or other mechanisms. The licensee also performed a sensitivity study using the five temporal distributions of rainfall discussed in Section 3.2.2 and determined that a peak rainfall rate at the end 1-h rainfall event creates the highest water surface elevation at the safety-related structures.

The NRC staff reviewed the licensee's model setup including the hydraulic parameters, surface topography, hydraulic boundary conditions, and the grid resolution in the FLO-2D model. The NRC staff checked the modeling's mass conservation error, and found the value to be reasonable. The licensee's LIP maximum flood depths and peak water surface elevations are shown for the east portion of the site in Figure 3.2-1 and Figure 3.2-2, respectively in this assessment. The licensee's LIP maximum flood depths and peak water surface elevations are shown for the west portion of the site in Figure 3.2-3 and Figure 3.2-4, respectively in this assessment. These figures also show the locations of the 83 points of interest.

3.2.4 Sensitivity Analyses

Manning's roughness coefficient is one of the hydraulic parameters in the FLO-2D model and it can affect the computed flood elevations. The NRC staff noted that the licensee tested the sensitivity to flood elevation by adjusting the Manning's roughness coefficient in a range between 0.025 and 0.5 for asphalt and concrete areas. Examining the numerical values of the Manning's roughness coefficient used in the FLO-2D model, the NRC staff found those numerical values were within a reasonable range for a sensitivity study, and that the numerical model results were not sensitive to variations in Manning's roughness coefficient.

The grid size in the two-dimensional FLO-2D model was 5 ft. by 5 ft. The licensee chose this grid size to fit the resolution of local flow path and to represent 83 critical locations within the plant site. The computational time step was set to satisfy a Courant number less than one. The NRC staff found that both grid size and computational time step were reasonably selected for the flood hazard analysis.

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 expected that the licensee would submit a focused evaluation for LIP and associated site drainage for the Seabrook site. The licensee submitted its FE by letter dated June 28, 2017 (NextEra, 2017b). It is currently under review.

3.3 Streams and Rivers

The licensee did not provide a probable maximum flood (PMF) elevation for this flood-causing mechanism in Revision 0 of the FHRR. In a supplement document (NextEra, 2016a) the licensee reported that the reevaluated flood hazard, including tidal effects, for streams and rivers is a stillwater surface elevation of 4.6 ft. NAVD88 at the Hampton Harbor based on a PMF flow rate of 26,160 $ft.^3/s$.

This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevation is based on a stillwater-surface elevation of 8.1 ft. NAVD88 at Hampton Harbor with the PMF flow rate of 136,500 $ft.^3/s$.

The licensee did not report wind wave setup and runup results for this flood-causing mechanism since the PMF elevation of this flood-causing mechanism is well below the water surface elevation of 17.0 ft. NAVD88 of the reevaluated probable maximum storm surge (PMSS) scenario and the plant grade elevation of 19.2 ft. NAVD88.

During the audit the licensee clarified differences between the methods used to estimate PMF flow and those used for the CDB and the reevaluated hazards (Information Need 4) (NRC, 2017).

3.3.1 Probable Maximum Precipitation

The licensee computed rainfall depth-area-duration (DAD) in various combinations for the warm/all (hereafter warm) and cool season PMPs. For the warm season PMP, the licensee used the procedures addressed in HMR 51 (NOAA, 1978). For the cool season PMP, the licensee used the procedures described in) HMR 33 (NOAA, 1956) and HMR 53 (NOAA, 1980). Further, the licensee used the HMR 52 computer program (U.S. Army Corps of Engineers (USACE), 1987) to distribute the seasonal PMPs among sub-basins of the Hampton Harbor watershed, including the cases of five different storm-centers located in the watershed. Each of those 5 storms was designated by different storm-centers from SC1 through SC5 but would have a rainfall duration of 72 hours. Also, the licensee set up 5 temporal distributions that were different from the most intensive precipitation occurring at the front, front-third, center, end-third, or end of the 72-hour duration. The licensee analyzed a total of 25 storm patterns according to the five temporal and the 5 spatial rainfall distributions.

During the audit (NRC, 2017), the NRC staff noted that the licensee's controlling reevaluated PMP rainfall in the Seabrook watershed would be the 50-mi^2, 72-hour warm season PMP (30.3 in.). The controlling PMP could create a maximum PMF flow rate. The NRC staff further identified the controlling PMP in the licensee's HEC-HMS model (NRC, 2017) that simulated the most intensive rainfall occurring at the end-third rainfall duration and at the storm-center SC5. The NRC staff considers the licensee's computational results for the PMPs appropriate since the licensee followed the procedures of HMRs to generate the spatial and temporal distributions for the PMPs.

3.3.2 Runoff Estimation

For the surface runoff estimation, the licensee applied the warm and cool season PMPs of all storm cases, described in Section 3.3.1 of this staff assessment, as input data to the hydrologic model of HEC-HMS (USACE, 2010a). The licensee considered 40 percent PMP depth as an antecedent condition for all storm cases. The licensee adopted the Soil Conservation Service (SCS) Delmarva unit hydrograph method (MDE, 2000 and USACE, 2010a) to convert the rainfall into surface runoff in HEC-HMS (NRC, 2017). Based on the results of multiple model runs in HEC-HMS for all storm cases, the licensee determined a maximum peak flow rate from the warm season PMP. The licensee used a non-linear unit hydrograph adjustment of 26,160 $ft.^3/s$ as the PMF at Hampton Harbor.

In its FHRR, the licensee addressed the inability to calibrate HEC-HMS due to lack of stream gauge data. The NRC staff recognizes the difficulty of performing a model calibration without stream gauge data. The NRC staff determined that the licensee's hydrologic parameters used in HEC-HMS need to be conservative as an alternative approach to calibrating HEC-HMS.

The NRC staff examined the licensee's hydrologic parameters used in HEC-HMS during the audit and found that two hydrologic parameters, the time of concentration (*Tc)*, and the Muskingum coefficient, *K*, were not conservative (NRC, 2017). Sections 3.3.4 and 3.3.5 in this staff assessment further discuss this issue. The NRC staff performed a sensitivity analysis and found that *Tc* and *K* could increase the maximum peak flow rate when compared to the licensee's computed peak flow rate of 26,160 $ft.^3/s$. However, the NRC staff concludes that the maximum flow rate resulting from the adjusted *Tc* and *K*, as determined by the NRC staff, is bounded by the licensee's CDB of 136,500 $ft.^3/s$. The flood elevation at the CDB of 136,500 $ft.^3/s$ is 8.1 ft. NAVD88, which is over 10 ft. below the grade elevation 19.2 ft. NAVD88 of the Seabrook site. Thus, the NRC staff's maximum flow rate due to the changes of those two hydrologic coefficients, *Tc* and *K*, would not impact the plant site.

The NRC staff reviewed the licensee's other hydrologic parameters, including percentage of impervious area and infiltration rates and found that those parameters are appropriate because of the impervious areas being identified with current land use maps, and the infiltration rates for rainfall loss being generated from conservative values based on soil types and soil coverage. The NRC staff notes that it is reasonable for the licensee to exclude the base flows, which would be less than 12 $ft.^3/s$, in the HEC-HMS model because the licensee's computed base flows were negligible when compared to the flows of other floods. Also, the NRC staff notes that the licensee's computed base flows would be consistent with a realistic situation for the Seabrook site. Through the sensitivity study, the NRC staff determined that using the SCS standard unit hydrograph method would not generate a peak flow exceeding the CDB of 13,600 $ft.^3/s$ and would not change the conclusion of using SCS Delmarva unit hydrograph method. Therefore, the NRC staff concluded that the use of the SCS Delmarva unit hydrograph method was reasonable.

3.3.3 Breach Flows of Hypothetical Dam Failures for PMF Event

The licensee screened the national inventory of dams (NID) (USACE, n.d.-a) and found four local dams in the Taylor River and Hampton River and Hampton Harbor watersheds to be ranked as potentially critical dams that might create a flood hazard to the plant site if they were to fail. The four potentially critical dams are Big Dodge Pond Dam, Taylor River Pond Dam No.1 and No. 2, and Cains Brook Dam. The heights of all four dams are less than 19 ft.

The reservoir storage volumes of the four dams range from 18 acre-feet to 824 acre-ft. The straight-line distances from the Seabrook site to the four dams are no further than 3 miles.

The licensee estimated the total flow from all hydrological dam failures under the assumption of all peaks of breach flows arriving at the Hampton Harbor to be aggregated without time lag. During the audit (NRC, 2017), the NRC staff noted that the licensee computed the dam breach flows by a regression equation (Froehlich, 1995) and then routed the breach flows downstream by an empirical equation (USBR, 1982). The regression equation for breach flows contained two dam breach parameters, dam height and reservoir storage volume, while the empirical equation was used to attenuate the peaks of breach flows at a downstream interest point and contained two parameters, the distance of flow path and the peak breach flow. The licensee used the straight-line distances between the dam and the Seabrook site to estimate the attenuated peak flows by the empirical equation. According to the empirical equation (USBR, 1982) the computed attenuation of peak flows could be further reduced if the flow distance between the dam and its downstream interest point is along the meandering flow path, which is longer than the straight-line path. Based on these equations, the licensee concluded that the total aggregated dam breach flow, including the peak attenuation effect, would be 18,360 $ft.^3/s$.

However, in its FHRR, the licensee did not report a numerical value for the flood elevation for the dam breach flows or for the combined PMF and dam breach flows. Instead, the licensee provided a diagram to show that the sensitivity of the flood elevations to the combined events that included tidal waves, PMF, and dam breach flows (NextEra, 2016b). By graphically scaling FHRR Figure 4-32, the NRC staff estimated that the maximum flood elevation was 4.7 ft. NAVD88 for the combined PMF, dam breach flows and the high tide.

The NRC staff found that the licensee followed current NRC guidance (NRC, 2013b and 2011e) to compute the breach flows for hydrologic dam failures. The NRC staff notes that the licensee's computed peak flows resulting from dam failures were attenuated after the flow was routed downstream. The NRC staff computed the attenuation rates and found that the attenuation rates were within a range from 3 percent to 7 percent using the USBR's empirical equation (USBR, 1982). The NRC staff considered the attenuation of breach flows to be less than 7 percent, and also considered that the licensee's 18,360 $ft.^3/s$ could be reasonably conservative due to the licensee's conservative estimation of the peak flows attenuated by the short straight-line distance rather than the long distance meandering streamflow path. Also, the NRC staff notes that the licensee conservatively aggregated the peaks of breach flows by summing the peak flows without considering the lag times, which were routed in different straight-line distances from the four dams to the Seabrook site. Additional details of the manner in which dam breach flows were incorporated into the flood licensee's flood hazard evaluation evaluated were discussed during the audit (NRC, 2017).

3.3.4 Time of Concentration for Surface Runoff

The time of concentration for surface runoff, *Tc*, is one of the primary parameters that can affect the peak of a unit hydrograph for a sub-basin or watershed. The licensee adopted a regression equation published by the American Society of Agricultural and Biological Engineers (Sheridan, 1994) to compute the time of concentration for each of 13 sub-basins of the Hampton Harbor watershed. The regression equation (Sheridan, 1994) was developed from two sets of observed data, one from the agricultural watershed within a southern coastal plain, and another from the southern Florida Flatwoods province.

The NRC staff questioned the licensee's selected computed time of concentration, *Tc*, for each sub-basin which is generally longer than 2 hours while the computed *Tc* for the major sub-basin, SB3, is longer than 24 hours although the flow path is approximately 10 miles (NRC, 2016 and 2017). The NRC staff found that because the regression equation (Sheridan, 1994) counts only a flow path distance of surface runoff, the equation can reflect the long *Tc* if the flow path distance is very long. The SB3 is comprised of approximately 30 percent sub-urban area, and it is not an agricultural watershed and the selected regression equation cannot reflect urbanization influences, including urban drainage systems or overland flow roughness that can affect the time of concentration. The NRC staff found that using other equations can reduce the time of concentration by reducing the overland flow roughness due to urbanization. The NRC staff examined the characteristics of the Hampton Harbor watershed, and found that the Hampton Harbor watershed should not be compatible with the experimental and agricultural watershed and the Florida Flatwood province (Sheridan, 1994). Therefore, the NRC staff did not find the licensee's computed *Tc* values to be reasonable. However, the NRC staff's sensitivity study, as described in Section 3.3.2 of this staff assessment, determined that the reduction of the licensee's *Tc* would not impact the flood hazard for the Seabrook site.

3.3.5 Tributary Routing

The licensee applied the Muskingum method (NRC, 2017) to simulate channel flow routing from the tributary outlets of upstream sub-basins to downstream points of interest. During the audit (NRC, 2017), the NRC staff examined the coefficients of the Muskingum method and the routing time steps used in the HEC-HMS model. The NRC staff independently generated the Muskingum *K* value and applied the *K* values in the HEC-HMS model to evaluate the sensitivity of the computed peak flows of each sub-basins. The NRC staff found that the staff's independently-generated *K* values could have greater peak flows when compared to the licensee's computed peak flows. However, the NRC staff's independently computed maximum peak flow was bounded by the CDB peak flow of 13,600 $ft.^3/s$ for the Seabrook site. The NRC staff reviewed the licensee's justification for the reevaluation approach and model parameters. The NRC staff concluded that although it does not agree with the justification for some of the Muskingum coefficient parameters used by the licensee, changing these parameters to values reasonable to the NRC staff would not alter the licensee's overall conclusions (NRC, 2017) for this flood-causing mechanism (see Section 3.3.6 below).

3.3.6 Probable Maximum Flood Elevations

As reported in its FHRR, the licensee evaluated the impact of the PMF in combination with storm surge on the Seabrook site. The licensee incorporated the PMF flow rate as a part of the input data to the Delft 3D-FLOW model (Deltares, 2011) to evaluate the impact of the PMF flow rate on the PMSS elevation. The results showed an increase of 0.2 ft. on the PMSS elevation by adding the PMF flow rate on the PMSS, which the licensee concluded is a negligible impact on the PMSS elevation.

The NRC staff requested the PMF elevation for the Seabrook site, which the licensee provided as described in Section 3.3 of this staff assessment. The licensee generated the PMF elevation based on Delft 3D-FLOW model that was the same model to be used for PMSS elevation. Because the PMSS elevation and high tide elevation are below the plant grade, as well as the negligible increase of 0.2 ft. on the PMSS elevation by adding the PMF, the NRC staff concludes that the PMF event alone would not inundate the plant site.

3.3.7 Coincident Wind and Wave Activity

For the streams and rivers flood-causing mechanism, the licensee did not add the wind wave setup and runup to the PMF elevations but considered the wind wave with PMSS. Because the licensee's computed PMF elevation was well below the PMSS elevation, the NRC staff agrees that the coincident wind and wave activity reasonably does not need to be analyzed for this flood-causing mechanism.

3.3.8 Conclusion

The NRC staff concludes that the flood elevation of the PMF event, as described in Section 3.3 of this staff assessment, is reasonable based on the results of Delft3D-FLOW model. Based on its review of the licensee's information provided for the PMF analysis, the NRC staff confirms the licensee's conclusion that the reevaluated hazard for flooding from rivers and streams is bounded by the CDB. Therefore, flooding from rivers and streams does not need to be analyzed in a FE or a revised integrated assessment.

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in its FHRR that the reevaluated hazard for failure of dams and onsite water control or storage structures 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. In the CDB, the licensee did not evaluate the flood hazard resulting from this flood-causing mechanism because the flood hazard from dam failure alone would not impact the Seabrook site.

In its FHRR, the licensee did not report the reevaluated flood elevation for the Seabrook site due to the failure of dams and onsite water control or storage structures. However, the licensee computed the upstream dam breach flows for hydrologic dam failures combined with the PMF as discussed in Section 3.3.3 of this staff assessment. In its FHRR, the licensee reported that the combination of the dam breach flows with a PMF event and high tide is not the controlling flood hazard at the Seabrook site.

Although the licensee did not reevaluate the flood hazards due to sunny-day and seismic dam failures, the licensee stated that it was reasonable to exclude sunny-day and seismic dam failures because the upstream dams would not have greater breach flows than the one resulting from hydrological dam failure because of a lesser storm that combined with the seismic failure, such as a 500-year flood. The NRC staff agrees that it is reasonable to exclude sunny-day and seismic dam failures from the reevaluation because these events would produce flood elevations less than the hydrologic dam failure scenario at the Seabrook site.

The NRC staff confirmed 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 failure of dams or onsite water control or storage structures does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.5 Storm Surge

The licensee reported in its FHRR that the reevaluated flood hazard for storm surge is based on a stillwater-surface elevation of 17.8 ft. NAVD88 at the seawall. Including wind waves and runup results in an elevation of 23.4 ft. NAVD88 at the seawall. The licensee reported in its

FHRR that the reevaluated hazard elevation varies over the site and provided hazard elevations at many points of interest; this information is summarized in Section 4.1 of this staff assessment and in the ISR letter (NRC, 2016c and 2016d).

The licensee considered Nor'easters and hurricanes as possible mechanisms for generation of the PMSS and these are discussed in Sections 3.5.1 and 3.5.2 of this staff assessment, respectively. Some aspects of the licensee's evaluation are relevant to both the Nor'easter or hurricane surge evaluation. However for brevity, these aspects are only discussed as part of the controlling hurricane event below rather than in the less-severe Nor'easter storm surge section.

3.5.1 Storm Surge from Nor'easter Events

The licensee used NRC guidelines to assess the potential for Nor'easter events to cause the PMSS at the Seabrook site. The licensee conducted a climatology study including an extensive data search to characterize the storm parameters associated with such events. The licensee applied a wave model, Delft 3D-WAVE, to estimate wave transformation in coupled mode with Delft 3D-FLOW (Deltares, 2011). The licensee configured the hydrodynamic models using bathymetric and topographic data, tide record observations, and sea level rise projection. The licensee's approach included calibration (Hurricane Bob) and validation (Hurricane Donna), as discussed in Section 3.5.2 of this staff assessment. In the NRC staff's judgement, the hydrodynamic model validation and calibration effort is generally applicable across the types of wind-dominated storms; as such, a hydrodynamic model that performs reasonably for the hurricane events could be expect to perform similarly for Nor'easter events.

The licensee applied Delft 3D Version 4.00.01 model software package to simulate the storm surge in response to Nor'easter storm forcing; the same model configuration used in the evaluation of the controlling, surge-inducing hurricane events. The configuration, antecedent water level, tides, sea level rise, model calibration and validation are consistent with that described in Section 3.5.2 of this staff assessment.

The licensee stated that the PMSS stillwater elevation associated with the Nor'easter events was 13.2 ft. NAVD88 based on the modeling analysis. The licensee compared this result with that from the hurricane simulations (17.8 ft. NAVD88), and the revetment (flood barrier) crest elevation (19.2 ft. NAVD88). The licensee used this comparison to determine the controlling storm for the PMSS and found that to be hurricane-driven events.

The NRC staff reviewed the licensee's approach for evaluating the surge associated with Nor'easter storm events, including a climatology study of historical Nor'easter events, evaluation of storm data, development of Nor'easter storm wind fields to use as model input and a presentation of storm forcing results. The NRC staff also reviewed the storm surge model and results. The NRC staff determined that the licensee developed a reasonable probable maximum wind storm for surge analysis and used a reasonable method to determine the antecedent water level for the storm surge analysis including adjustments for 10-percent exceedance high tide and sea level rise and for selecting model parameters. The NRC staff evaluated the model bathymetry and shoreline configuration of the Delft 3D-FLOW and Deflt3D-WAVE surge model. During the audit the NRC staff identified necessary corrections to the models which the licensee included in the revised FHRR (NextEra, 2016b). The NRC staff concluded that the revised model was appropriately configured.

The NRC staff reviewed the modeling software that the licensee used and found it that was suitable for evaluating the storm conditions that were developed to estimate the stillwater surface elevation associated with Nor'easter storm events.

3.5.2 Storm Surge from Hurricane Events

3.5.2.6 Analysis Approach

The licensee's storm surge evaluation for the Seabrook site involved components that were probabilistically informed, focused on development and statistical analysis of synthetically derived data, the details of which are discussed as follows.

3.5.2.6 Development of Hurricane Storm Tracks

The licensee performed a hurricane climatology study for the area near the Seabrook site. The licensee applied methods described by WindRiskTech (2014) to generate large numbers of synthetic hurricane tracks to represent the events that may occur near the Seabrook site over an extended time period.

3.5.2.6 Antecedent Water Levels

The licensee used recorded maximum monthly tide elevations from NOAA's Portland, Maine (NOAA 8418150; NOAA, 2014a) tidal station to calculate the 10-percent exceedance high tide for the antecedent water levels (AWLs). The licensee applied the Weibull plotting position to estimate a 10-percent exceedance high tide of 7.4 ft.-NAVD88 and a normal distribution to estimate a 95- percent confidence interval of 7.3 to 7.5 ft.-NAVD88 for the 10-percent exceedance high tide. The licensee estimated sea level rise from many nearby stations between the end of 2013 and years 2030, 2050, and 2113 and selected the sea level rise rate at Boston, MA for the AWL estimation. Based on the estimated sea level rise rate at Boston, MA, the licensee estimated the sea level rise between the end of 2013 and 2030, 2050, and 2113 to be 0.2 ft., 0.4 ft., and 1.0 ft., respectively.

3.5.2.4 Storm Surge and Wave Models

The licensee used the SLOSH model (NOAA, 1992) and the previously described 20,400 tropical cyclone events to represent the events that may occur near the Seabrook site and identify a subset of those events for further analysis. The licensee selected ten tracks with maximum wind velocity near the site, ten tracks with maximum storm surge from the SLOSH simulations, and ten tracks that map the range of the relationship between the SLOSH simulated surge and the Delft 3D simulations yielding 27 synthetic storm tracks for further analysis. The licensee used these 27 storm tracks to determine the effect of nearshore bathymetry, more accurate representation of the hurricane and detailed hydrodynamics on the predicted storm surge.

The licensee applied the two-dimensional depth-averaged Delft 3D Version 4.00.01 model software package (Deltares, 2011) to simulate the storm surge. The licensee developed five Delft3D rectangular model grids for storm surge modeling: one sufficiently large coarse domain to capture all potentially significant regions and features that could affect the storm surge results and analyze appropriate boundary conditions; and four refined grids located close to the Seabrook site. Model simulations used domain decomposition to convey the information from

the coarse grid to provide boundary conditions for the finer grids, which varies with time during the evolution of the simulation (NextEra, 2016b).

The licensee applied a bottom roughness value of 0.02 and 0.04 for deep-ocean and nearshore, respectively. The licensee also applied 538 $ft.^2/s$ in the overall model domain for horizontal eddy viscosity and horizontal eddy diffusivity (NextEra, 2016b). The licensee stated that the model application guidelines were followed during model grid development. The licensee applied astronomical tidal components to describe a water level forcing at the model boundary during the storm surge model calibration phase.

The licensee applied the Delft 3D-WAVE (which incorporates Simulating WAVEs Nearshore (SWAN)) model software package to simulate wave transformation, which represents the physics relevant for the development of the sea state in two dimensions without assumptions regarding the wave spectral space. In order to reasonably represent coastal wave effects near the Seabrook site, the SWAN model included energy terms with the addition of bottom dissipation and reflection, diffraction, and refraction processes, while Delft3D-WAVE accounted for depth-induced breaking, non-linear triad interactions, bottom friction, wind growth, whitecapping, refraction, and frequency shift (Deltares, 2011).

Following the audit (NRC, 2017), the licensee adjusted its use of the coastal bathymetry data from the Generalized Bathymetric Charts of the Ocean (GEBCO) project, the 1/9 Arc Second (approximately 3 m) National Elevation Dataset (NED) from the U.S. Geological Survey (USGS) National Map Viewer; and the local site bathymetry and topography from NOAA (1947, 1954, 1983) and USGS (2011).

The licensee selected Hurricane Bob (August 16 to 21, 1991), and Hurricane Donna (September 3 to 13, 1960), to provide data for calibration and verification of various Delft 3D model parameters because the storm tracks for these hurricanes passed near Seabrook and calibration data was available for these events (NextEra, 2016b).

The licensee reported the procedure for the Seabrook Delft 3D-FLOW and Delft 3D-WAVE model calibration and verification in the FHRR. Based on the procedure, the licensee conducted a quantitative comparison of observed to modeled water surface elevations as a means to assess model performance.

For model uncertainty and error, the licensee performed a series of sensitivity simulations for the model wind drag coefficient and Manning's roughness coefficient during the model calibration and concluded that the model was reasonable for the Seabrook site.

3.5.2.6 Storm Surge Water Levels

The licensee developed a hurricane storm surge stillwater elevation of 17.8 ft. NAVD88 based on a 7.5. ft NAVD88 10-percent exceedance high tide, a sea level rise of 0.2 ft., a wind, pressure and wave setup of 6.1 ft., and a sensitivity adjustment of 4.0 ft. To address the uncertainty associated with the probabilistically-informed assessment, as well as the sensitivity of results to various modeling decisions and assumptions, the licensee added a 4.0 ft. sensitivity adjustment to the probabilistically-informed PMSS elevation. The licensee determined that the wave effects would combine with the stillwater level to a total water surface elevation of 23.4 ft. NAVD88 at the site seawall but would differ at site structures due to the effect of wave

overtopping of the shoreline revetment at elevation of 19.2 ft. NAVD88. The storm surge water surface elevations at specific locations are discussed in Section 4.1.

3.5.2.6 Staff Assessment of Probabilistically-informed Approach

The NRC staff reviewed the licensee's probabilistically-informed approach, including performance of several initial sensitivity studies. As part of its review, NRC staff identified several topics which were discussed with the licensee during the audit (NRC, 2017). These topics related to the licensee's methodological approach for development of the aleatory model, consideration of epistemic uncertainties (including sensitivity of results to modeling decisions and assumptions), as well as treatment of tides and sea level rise, storm parameter ranges and discretization used in generation of synthetic storm parameter sets, the approach used to assign return periods to wind speeds, the sufficiency of sample size for large surge events, the assumed linear relationship between SLOSH and Delft 3D results, and the non-parametric approach used to fit a distribution to synthetic surge data. To address the uncertainty associated with the probabilistically-informed assessment as well as the sensitivity of results to various modeling decisions and assumptions, the licensee added a 4.0 ft. sensitivity adjustment to the probabilistically-informed PMSS elevation. As noted in Section 3.5.2.5 above, the resultant stillwater elevation was 17.8 ft. NAVD88. The NRC staff noted that this stillwater elevation is consistent with the results of independent, deterministic assessments performed by NRC staff as discussed in Section 3.5.3 of this staff assessment. Therefore, the NRC staff concluded that the results (only) of the licensee's assessment were reasonable and no further review of the licensee's probabilistically-informed storm surge methodology was necessary.

3.5.3 NRC Independent Evaluation

The NRC staff relied on an independent modeling study performed by its technical assistance contractor, Taylor Engineering, to inform staff's review of the licensee-identified controlling, surge-inducing event (Taylor, 2017c). Because hurricanes are the controlling event, Nor'easters were not evaluated. The results of Taylor Engineering's independent hurricane storm surge simulations provide additional estimates of the deterministic storm surge water levels near the Seabrook site. Taylor Engineering's independent simulations applied the SWAN+ADCIRC model to develop the water level and waves conditions near the Seabrook site. The simulations applied the SWAN+ADCIRC mesh developed for the New England region with detailed mesh areas for the Seabrook and Pilgrim sites. The independent model's numerical mesh was applied in a test simulation with Hurricane Sandy (2012) forcing parameters. The results demonstrate the ability of the numerical model to reasonably reproduce measured values in New England. Details of Taylor Engineering's independent study are available in Taylor (2017c).

The independent simulations applied time-varying, two-dimensional wind and pressure fields for tropical storms with varying parameters. The independent simulations also developed the tropical storm parameter combinations to produce the probable maximum intensity storm conditions at the Pilgrim site. The NRC staff's judgement is that the two sites are located sufficiently close to support using the same storm parameter combinations. The Seabrook site location, north of Cape Cod (about 70 miles north of the Pilgrim site) and interior of an inlet to the east of the site created a complex storm surge response at the site, which required examination of many storm track angles and landfall locations.

The initial test simulations applied only the ADCIRC (hydrodynamic) model to expedite run times which allowed examination of storm surge sensitivity to the tropical storm parameters.

Based on these results, the final simulations applied the SWAN+ADCIRC model, which couples the hydrodynamic model to a spectral wave model (SWAN) to include wave-induced water level effects near the site. Review of the refined simulation results showed angles at landfall of 0, 10, and 30 degrees counter-clockwise from north produced the highest water levels at the site. The NRC staff evaluated the licensee's modeling approach and agree with the licensee that the approach used included significant uncertain terms, assumptions and a 4.0 ft. uncertainty adjustment. During the audit the inclusion of an additional 4 ft. was found to be a reasonable accumulated uncertainty value for the storm surge analysis (NRC, 2017).

3.5.4 Conclusion

The NRC staff reviewed the licensee's methodology for the storm surge analysis and concludes that the results are appropriate for the purposes of the 50.54(f) letter. The NRC staff confirmed the licensee's conclusion that the reevaluated flood hazard for storm surge is not bounded by the CDB flood hazard. Therefore, the NRC staff expected that the licensee would submit either a focused evaluation or revised integrated assessment for storm surge. The licensee submitted its FE by letter dated June 28, 2017 (NextEra, 2017b). It is currently under review.

3.6 Seiche

The licensee reported in its FHRR that the reevaluated flood hazard for seiche does not inundate the plant site, but did not report a probable maximum flood elevation. This flood-causing mechanism is discussed in the licensee's CDB, but no PMF elevation was reported. The FHRR reported that seiche was previously identified as not a significant hazard (NextEra, 2016b).

Based on the guidance in ANSI/ANS (ANS/ANSI, 1992), the licensee noted that probable maximum surge with wind-wave activity coupled with the 10-percent exceedance high tide may potentially contribute to seiche formation at shore locations (Hampton Harbor) near the Seabrook site. The licensee considered present-day and future conditions as modified by sea level rise in addition to free- and forced-oscillations as triggering mechanisms for seiche formation. The licensee noted that the natural periods of the oscillation in Hampton Harbor with and without consideration of sea level rise could match those of wind events and thus could not preclude wind-event generation of seiche within Hampton Harbor but that the oscillations in water surface elevations were not significant.

The licensee determined the natural periods of oscillation using a numerical model of Hampton Harbor and Merian's formulas (Ichinose et al., 2000). The licensee found that the natural periods of oscillations of Hampton Harbor matched the frequency of observed winds and as a result of this match, a seiche oscillation of about 1 centimeter could occur.

The NRC staff used Merian's formula to estimate the primary periods of oscillation in Hampton Harbor and found that these periods did not match those associated with wind-waves, seismic events, and astronomical forcing which precludes seiche formation from these phenomena. Similar to the licensee, the NRC staff noted that the period of meteorological forcing could match the natural periods within the harbor and trigger seiche formation. However, the NRC staff noted that considering the shallow depths of the harbor, the seiche would be very small, and seiche will likely spill over roadways or flow outward to the ocean before spilling over the Seabrook site. Therefore, the NRC staff agrees with the licensee that flooding hazard due to meteorological triggering of seiche within Hampton Harbor and at the Seabrook site is negligible.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from seiche would not inundate the Seabrook site. Therefore, the NRC staff determined that 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 its FHRR that the reevaluated flood hazard for tsunami is based on a stillwater-surface elevation of 16.1 ft. NAVD88. This flood-causing mechanism is discussed in the licensee's CDB, but no PMF elevation was reported.

3.7.1 Historical Tsunami Record

The licensee examined the historical record of tsunami events that occurred along the U.S. Atlantic coast using the NOAA Geophysical Data Center (NGDC) tsunami database (NOAA, n.-d.-d). The licensee identified two historical events, excluding those that were identified within the database, as being generated by meteorological sources. The licensee identified the 1917 Nova Scotia near-field event associated with accidental explosion and the 1929 Grand Banks landslide triggered event. The licensee determined that the 1917 Nova Scotia event was unlikely to occur again. The license determined that the 1929 Grand Banks event was unlikely to recur based on the time necessary to accrue the necessary deposited sediments (NextEra, 2016b). The licensee reviewed other literature to identify near- and far-field earthquake, landslide and volcano sources that could produce a credible tsunami for further evaluation.

The NRC staff reviewed the tsunami and tsunami-like waves along the Atlantic seaboard of the U.S. given by Lockridge et al. (2002). The NRC staff excluded events that were judged to be erroneous or identified as seiche events. The NRC staff identified the 1886 Charleston, South Carolina event as the most relevant to the Seabrook site. The NRC staff found historical observations of tsunami hazards along the U.S. east coast. These events included tsunami runup elevations of 3 ft. or less.

3.7.2 Potential Tsunami Generating Sources

The licensee identified tsunami sources in addition to the historical events. The licensee identified each source by type (volcanic, explosion, landslide, earthquake), and proximity to Seabrook site (near- or far-field). The licensee identified probable maximum tsunami (PMT) sources considered to potentially generate a credible tsunami that could reach the Seabrook site with a wave height greater than about 3 ft. wave. These sources are: earthquake/landslide along the Azores-Gibraltar plate boundary (Marques de Pombal Fault) near Portugal, earthquakes near the Puerto Rico/Hispaniola Trenches, and earthquake/landslide at Grand Banks, Newfoundland.

The NRC staff determined that PMT sources relevant to the evaluation of the Seabrook site are subaerial and submarine landslides, volcanic sources, near-field intra-plate earthquakes, and inter-plate earthquakes. The NRC staff determined that the submarine landslides was the controlling tsunami-generating mechanism for the PMT at the Seabrook site.

3.7.3 Tsunami Analysis

The licensee analyzed the tsunami sources identified in the previous section. The licensee used the Delft3D modeling software (Deltares, 2011) to evaluate tsunami flood hazards at the Seabrook site. The licensee focused the evaluation at a location near the Hampton Harbor inset east of Seabrook rather than at the Seabrook site itself in order capture simulation results for cases where the site would not inundated if the harbor itself was not effected first. The licensee used evaluated seismic and landslide tsunami source types. The licensee used the Delft3D model to determine the peak water surface elevations for both the seismic and landslide sources. The licensee's seismic approach required the specification of the tsunami source parameters (depth, length, width, slip, dip, strike, rake and the tensile strength component). The licensee's landslide approach required the specification of the tsunami source areas (Orphan Basin, Flemish Pass, Salar Basin, areas on the Scotian Slope, and Georges Bank). For both source cases the licensee compared the resultant peak water surface elevations to identify the bounding seismic and landslide source tsunami case. The licensee then added the 10-percent exceedance high tide and expected sea level rise to the bounding seismic and landslide tsunami peak water surface elevation estimates. These specific values are discussed in the following section.

The NRC staff reviewed the licensee's general approach for the reevaluation of the tsunami hazard and concludes that it is reasonable because the licensee selected an appropriate modeling software for the tsunami analysis.

3.7.4 Antecedent Water Level

The licensee set the AWL as the sum of the estimates for the 10-percent exceedance high tide and the sea level rise (SLR) from 2013 to 2040. The licensee estimated the 10-percent exceedance high tide as 7.5 ft. NAVD88. The licensee projected SLR from 2013 to 2030 using long term records at NOAA stations 8443970 (NOAA, 2014b), 8418150 (NOAA, 2014a), 8454000, and 8410140. The licensee stated the SLR near Seabrook would be about 1 ft. from 2013 to 2113 based on this observational history at these stations. The tsunami analysis used the 2013 to 2040 SLR of 0.2 ft. The licensee set the AWL to 6.7 ft. NAVD88.

The NRC staff independently estimated the AWL as including 4.6 ft. for tide, 0.9 ft. for 100-year SLR, 0.7 ft. for sea level anomaly for an AWL of 6.0 ft. NAVD88. On the basis of the licensee's AWL being greater the NRC staff's estimate, the NRC staff determined that the licensee AWL used for the tsunami reevaluation was reasonable.

3.7.5 Tsunami Analysis Results

The licensee analyzed the seismic scenarios including the Grand Banks seismically-induced tsunami, the Puerto Rico Trench earthquake, the Hispaniola Trench earthquake, and the Marques de Pombal Fault/Lisbon earthquake. The licensee identified the Hispaniola Trench earthquake as the worst-case seismic scenario in terms of maximal peak water surface elevations near the Seabrook site. The worst-case seismic scenario yielded a peak water stillwater surface elevation near the Seabrook site of 16.1 ft. NAVD88 (6.6 ft. tsunami surge added to the AWL).

The licensee analyzed the submarine landslides scenarios including the Grand Banks landslide, Shelburne Mass Transport Deposit (MTD) Slump and Debris landslides, and the East Scotian MTD landslide. The licensee identified the East Scotian Rise MTD landslide as the worst-case

landslide scenario in terms of maximal peak water surface elevation near the Seabrook site of 12.5 ft. NAVD88.

The licensee identified the controlling PMT to be generated by an earthquake on the Hispaniola Trench resulting in a flood hazard elevation of 16.1 ft. NAVD88 near the Seabrook site. The NRC staff determined subaerial landslides would not be the controlling cause of tsunamis near the site due to the lack of major coastal cliffs along the coast. The NRC staff evaluated the history of tsunamis and tsunami-like waves along the Atlantic seaboard. The NRC staff identified tsunami observations near the Seabrook site, but noted that the historical record of tsunami runup in the region shows no evidence of a tsunami of more than 3 ft.

The NRC staff independently conducted tsunami simulations using a worst-case approach. Based on the NRC staff's modeling analysis, the NRC staff determined that, of the several tsunami-generating sources, the postulated landslide in the Canary Islands would generate the controlling PMT. The NRC staff found the peak water surface elevation is 13.4 ft. due to tsunami prior to the addition of the AWL; adding the AWL of 5.9 ft. yields a PMT surface water elevation of 19.4 ft. NAVD88 as a worst-case estimate based on the assumption of a rapidly moving, entirely coherent landslide failure. The maximum water surface elevation of 19.4 ft. NAVD88 represents a near-upper limit on a possible tsunami from any plausible source; the site grade elevation for Seabrook is 20.0 ft. NAVD88.

3.7.6 Conclusion

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from tsunami is bounded by the CDB flood hazard. Therefore, the NRC staff determined that flooding from tsunami does not need to be analyzed in a focused evaluation or a revised integrated assessment for Seabrook.

3.8 Ice-Induced Flooding

The licensee reported in its FHRR that the reevaluated flood hazard for ice-induced flooding is based on a stillwater-surface elevation of 12.4 ft. NAVD88. This flood-causing mechanism is discussed in the licensee's CDB, but no flood elevation was reported. In its FHRR, the licensee stated that the reevaluated hazard for ice-induced flooding would not inundate the plant site.

The licensee searched the USACE Ice Jam Database (USACE, 2014) and found that there have not been any recorded ice jams near the Seabrook site. The licensee computed the ice-induced flood elevation to be 12.4 ft. NAVD88 and the plant grade elevation is 19.2 ft. NAVD88. For the computation, the licensee summed the marsh elevation at Seabrook of 3.2 ft. NAVD88 and the recorded maximum gauge height ice jam flood of 9.2 ft. in Kennebunk, Maine, at approximately 35 mi northeast from the Seabrook site.

The NRC staff noted that the licensee transposed the 9.2 ft. recorded maximum height of ice jam flood from outside the Hampton Harbor watershed to the plant site, despite no record of ice jams at the Seabrook site in the past. Therefore, the NRC staff considered the licensee's ice-induced flood elevation of 12.4 ft. NAVD88 to be a reasonable worst-case scenario.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for ice-induced flooding is bounded by the CDB flood hazard at the Seabrook site.

Therefore, the NRC staff determined that ice-induced flooding effects do not need to be analyzed in a focused evaluation or a revised integrated assessment for Seabrook.

3.9 Channel Migrations or Diversions

The licensee reported in its FHRR that the reevaluated flood hazard for channel migrations or diversions 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.

The licensee stated in itd FHRR that the site is approximately 7,000 ft. from Hampton Beach on the Atlantic Ocean. The licensee concluded that there is no plausible effect of channel diversions or shoreline migration on the safety functions at the Seabrook site.

The NRC staff reviewed Seabrook Station UFSAR Revision 8 Section 2.4, which states that local loss or deterioration of the local beaches through erosion and wave action is mitigated by federal and state protection measures implemented in response to increased shore-front development and use. The NRC staff also noted that Hampton Beach has remained relatively stable since the stabilization of Hampton Harbor inlet by jetties in 1935. The NRC staff confirmed that statements made within the FHRR are consistent with the USFAR that upstream diversions or rerouting will not affect the cooling water supply.

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. Therefore, the NRC staff determined that channel migration or diversion-related flooding does not need to be analyzed in a focused evaluation or a revised integrated assessment for Seabrook.

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

4.1 Reevaluated Flood Height for Hazards Not Bounded by the CDB

Section 3 of this staff assessment documents the NRC staff review of the licensee's flood hazard water height results. Table 4.1-1 contains the maximum flood height results, including waves and runup, for flood mechanisms not bounded by the CDB. The NRC staff agrees with the licensee's conclusion that LIP and storm surge, including the combined storm surge event, are the flood-causing mechanisms not bounded by the CDB.

The NRC staff anticipated that the licensee would submit an FE for LIP. For the storm surge, the NRC staff anticipated the licensee would perform an additional assessment of plant response, either an FE or a revised integrated assessment. The licensee submitted its FE by letter dated June 28, 2018 (NextEra, 2017b). It is currently under review.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided by in NextEra's 50.54(f) response (NextEra, 2016b; NRC, 2017a) regarding the FED parameters needed to perform the additional assessments of plant response for flood hazards not bounded by the CDB. During the audit, the licensee discussed the provision of FED parameters (Information Need 5) (NRC, 2017a). The FED parameters for the flood hazards not bounded by the CDB are summarized in Table 4.2-1.

For LIP and PMSS, the licensee did not evaluate the FED parameters in the FHRR. The licensee was expected to develop and provide the missing FED parameters for the flood-causing mechanisms in order to conduct the MSA and FEs or revised integrated assessments. By letter dated June 14, 2017, the licensee submitted the MSA (NextEra, 2017a), which included the FED parameters for the LIP and PMSS flood-causing mechanisms. The NRC staff's review and conclusions regarding the FED parameters provided in the MSA are documented in a separate staff assessment that was issued on November 29, 2017 (NRC, 2017b). The NRC staff concluded that the FED parameters are reasonable and acceptable for use in the MSA and FE.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided by in NextEra's 50.54(f) response (NextEra, 2016b) regarding the AE parameters needed to perform the additional assessments of plant response for flood hazards not bounded by the CDB. The AE parameters directly related to maximum total water height, such as wave and runup, are presented in Table 4.1-1. The AE parameters not directly associated with total wave height are listed in Table 4.3-2.

For LIP and PMSS, the licensee summarized the evaluation of AE parameters in FHRR Section 4.11. The licensee provided an evaluation of hydrodynamic loading, debris and projectile loads for these flood-causing mechanisms. The licensee did not evaluate sediment loading, sediment erosion/deposition, groundwater ingress, or concurrent conditions associated with these flood-causing mechanisms in the FHRR.

The licensee was expected to develop the missing AE parameters for these flood-causing mechanisms to conduct the additional assessment. For AE parameters noted as minimal or not applicable, the NRC staff confirms the licensee's AE parameter results are reasonable for use in additional assessments of plant response. By letter dated June 14, 2017, the licensee submitted its MSA (NextEra, 2017a), which included the AE parameters for LIP and PMSS flooding mechanisms. The NRC staff's review and conclusions regarding the AE parameters provided in the MSA are documented in a separate staff assessment that was issued on November 29, 2017 (NRC, 2017b). The NRC staff concluded that the AE parameters are reasonable and acceptable for use in the MSA and FE.

4.4 Conclusion

Based upon the preceding analysis, NRC staff confirmed that the reevaluated flood hazard information defined in Section 4 is appropriate input to the additional assessments of plant response as described in the 50.54(f) letter, COMSECY-15-0019 (NRC, 2015), and the associated guidance.

5.0 CONCLUSION

The NRC staff reviewed the information provided for the reevaluated flood-causing mechanisms for Seabrook. Based on the review of the above available information provided in NextEra's 50.54(f) response (NextEra, 2016b, NRC (2017)), 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, the NRC staff confirmed the licensee's conclusions that (a) the reevaluated flood hazard results for LIP and storm surge are not bounded by the CDB flood hazard, (b) additional assessments of plant response will be performed for LIP and storm surge, 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 and COMSECY-15-0019, and associated guidance. The NRC has no additional information needs with respect to NextEra's 50.54(f) response.

6.0 REFERENCES

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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 3.1-1. Summary of Controlling Flood-Causing Mechanisms

Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation 19.2 ft. NAVD88 [1]	ELEVATION, ft NAVD88 [2]
Local Intense Precipitation and Associated Drainage	20.7 to 21.8
Storm Surge	20.0 to 21.3

[1]Flood height and associated effects as defined in JLD-ISG-2012-05, "Guidance for Performing the Integrated Assessment for External Flooding" (NRC, 2012c).
[2] Range of values is based on licensee's limiting the points of interest to those determined to floodwater entering buildings containing critical safety equipment (NextEra, 2016b; Table 6-1).

Table 3.1-2. Current Design Basis Flood Hazards

Flooding Mechanism	Stillwater Elevation (ft. NAVD88)	Associated Effects (ft.)	CDB Flood (CDB) Elevation	Reference
Local Intense Precipitation and Associated Drainage	19.9 ft. NAVD88	Minimal	19.9 ft. NAVD88	FHRR Section 3.1
Streams and Rivers	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 5-1 Note 1
Failure of Dams and Onsite Water Control/Storage Structures	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 3.3 and FHRR Table 5-1
Storm Surge: Seawall	14.8 ft. NAVD88	Minimal	14.8 ft. NAVD88	FHRR Section 5.4 and FHRR Table 5-1
Storm Surge: Site Ponding due to surge (waves overtopping seawall)	20.2 ft. NAVD88	0.8 ft.	21.0 ft. NAVD88	FHRR Table 5-1
Seiche	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 5-1
Tsunami	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 5-1
Ice-Induced	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 5-1
Channel Migrations or Diversions	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Section 3.9

[1]The CLB and FHRR consider the riverine flooding as input to the PMSS analysis rather than a distinct flood hazard itself.

Table 3.5-1. Tropical Storm Parameters used in NRC Staff's ADCIRC Sensitivity Simulations

Central Pressure (millibars)	920, 925
Radius to Maximum Winds, RMW (nautical mi (nm))	30, 45
Forward Velocity (knots)	25, 40
Track Angle at Landfall (degrees counter-clockwise from north)	30, 10, 0, -10, -20, -30
Landfall Location (RMW nm from reference site; to west of point along Cape Cod south shoreline	0, 0.25, 0.5, 1

Table 4.1-1. Reevaluated Hazard Elevations for Flood-Causing Mechanisms Not Bounded by the CDB

Flood-Causing Mechanism	Stillwater Elevation	Waves/ Runup	Reevaluated Hazard Elevation	Reference
Local Intense Precipitation				
Pump House /Site-Specific PMP – Point-of-Interest (POI) 12	20.7 ft.	minimal	20.7 ft.	FHRR Table 4-3
Containment Unit 1 /Site-Specific PMP – POI 59	21.8 ft.	minimal	21.8 ft.	FHRR Table 4-3
Turbine Building/Site-Specific PMP – POI 57	20.6 ft.	minimal	20.6 ft.	FHRR Table 4-3
Fuel Storage Building/Site-Specific PMP – POI 19	20.8 ft.	minimal	20.8 ft.	FHRR Table 4-3
Waste Process Building/Site-Specific PMP – POI 25	23.8 ft.	minimal	23.8 ft.	FHRR Table 4-3
Administration Building/Site-Specific PMP – POI 36	20.9 ft.	minimal	20.9 ft.	FHRR Table 4-3
Cooling Tower/Site-Specific PMP – POI 69	20.3 ft.	minimal	20.3 ft.	FHRR Table 4-3
Dry Fuel Storage Pad/Site-Specific PMP – POI 83	25.1 ft.	minimal	25.1 ft.	FHRR Table 4-3
Storm Surge				
Seawall	17.8 ft.	5.6 ft.	23.4 ft.	FHRR Table 5-1
Surge+Wave Overtopping at Intake Building (POI 1)	20.2 ft.	minimal	20.2 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Pump House Building (POI 9, 10, 12, and 13)	20.3 ft.	minimal	20.3 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Pump House Building (POI 3 and 6)	20.4 ft.	minimal	20.4 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Pump House Building (POI 7 and 8)	20.6 ft.	minimal	20.6 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Pump House Building (POI 5 and 14)	20.7 ft.	minimal	20.7 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Pump House Building (POI 4)	20.8 ft.	minimal	20.8 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at (POI 15)	20.2 ft.	minimal	20.2 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Containment Unit 1 (POI 62)	20.3 ft.	minimal	20.3 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Unit 1 (POI 16 and 17)	20.5 ft.	minimal	20.5 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9

Flood-Causing Mechanism	Stillwater Elevation	Waves/ Runup	Reevaluated Hazard Elevation	Reference
Surge+Wave Overtopping at Containment Unit 1 (POI 63)	20.6 ft.	minimal	20.6 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Containment Unit 1 (POI 61)	20.8 ft.	minimal	20.8 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Containment Unit 1 (POI 60)	20.9 ft.	minimal	20.9 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Containment (POI 59)	21.0 ft.	minimal	21.0 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Containment Unit 1 (POI 18)	22.1 ft.	minimal	22.1 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Waste Process Building (POI 21)	20.2 ft.	minimal	20.2 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Waste Process Building (POI 22	20.5 ft.	minimal	20.5 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Waste Process Building (POI 23)	20.6 ft.	minimal	20.6 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Waste Process Building (POI 27)	20.8 ft.	minimal	20.8 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Waste Process Building (POI 24)	21.0 ft.	minimal	21.0 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Waste Process Building (POI 26)	23.1 ft .	minimal	23.1 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Waste Process Building (POI 25)	24.6 ft.	minimal	24.6 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 50	20.2 ft.	minimal	20.2 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 49	20.4 ft.	minimal	20.4 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 31)	20.5 ft.	minimal	20.5 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 28, 36, 37, and 51)	20.6 ft.	minimal	20.6 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 44, 45, 46 and 47)	20.7 ft.	minimal	20.7 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9

Flood-Causing Mechanism	Stillwater Elevation	Waves/ Runup	Reevaluated Hazard Elevation	Reference
Surge+Wave Overtopping at Administration Building (POI 35, 38, and 42)	20.8 ft.	minimal	20.8 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 32 and 39)	20.9 ft.	minimal	20.9 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 43)	21.0 ft.	minimal	21.0 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 33 and 41)	21.1 ft.	minimal	21.1 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 40)	21.2 ft.	minimal	21.2 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 34)	21.3 ft.	minimal	21.3 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Administration Building (POI 30)	24.3 ft.	minimal	24.3 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Turbine Building (POI 58)	20.4 ft.	minimal	20.4 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Turbine Building POI 53)	20.5 ft.	minimal	20.5 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Turbine Building (POI 52)	20.6 ft.	minimal	20.6 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Cooling Tower POI 65 and 66)	20.3 ft.	minimal	20.3 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Cooling Tower (POI 64 and 72)	20.4 ft.	minimal	20.4 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Cooling Tower (POI 73)	20.6 ft.	minimal	20.6 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Cooling Tower (POI 74)	20.7 ft.	minimal	20.7 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Cooling Tower Cooling Tower (POI 71 and 75)	20.8 ft.	minimal	20.8 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Cooling Tower (POI 67)	20.9 ft.	minimal	20.9 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9
Surge+Wave Overtopping at Cooling Tower (POI 68 and 70)	21.0 ft.	minimal	21.0 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9

Flood-Causing Mechanism	Stillwater Elevation	Waves/ Runup	Reevaluated Hazard Elevation	Reference
Surge+Wave Overtopping at Cooling Tower (POI 69)	21.2 ft.	minimal	21.2 ft.	FHRR Table 4-3, FHRR Table 4-41 and FHRR Figure 4-9

Note 1: Reevaluated hazard mechanisms bounded by the current design basis (see Table 1) are not included in this table.
Note 2: Reported values are rounded to the nearest one-tenth of a foot.
Note 3: Storm surge elevations at locations other than the seawall reflect water elevations on the site as a result of waves overtopping the seawall and water flowing across the site. The NRC staff added the resulting overtopping depths (FHRR Table 4-41) and ground elevations to compute the stillwater elevations at the POIs associated with site buildings as shown in FHRR Figure 4-9 and FHRR Figure 4-10. The PMSS ponding level (given as the wave-overtopping effected stillwater elevation in this table) exceeds that of the CDB. The licensee stated that the reevaluated wave runup on building walls can be expected to be somewhat more than that described in the CDB (FHRR Section 5.4).
Note 4: To develop storm surge elevations at locations other than the seawall, the NRC staff sorted and grouped the stillwater elevations values by site building and then by stillwater elevation value. The NRC staff developed table scenarios based on the site building and stillwater elevation groups at no finer than 0.1-ft increments.
Note 5: With respect to storm surge elevations at locations other than the seawall, the licensee stated in FHRR Table 4-3 that "it is apparent that the stated WSEL for POI 30 is not the general surface elevation of the floodwater in that location, particularly given the minimal flood depth. Local topography and nearby POIs 31 and 32 should be referenced to determine a reasonable, conservative flooding level for this point."
Note 6: With respect to storm surge elevations at locations other than the seawall, the licensee stated in FHRR Table 4- 41 that "POI 29 is located on top of the RHR vault roof; therefore, flood depths do not accumulate because the RHR Vault roof is higher than the maximum flood water levels in the area." The licensee does not provide the definition of RHR within the FHRR.
Note 7: Values reported for local intense precipitation are representative values for each building.

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	Not Provided	Not Provided	Not Provided
Storm Surge	Not Provided	Not Provided; "duration of overtopping was approximately 4.5 h" FHRR Section 4.4.9.4	Not Provided

Table 4.3-2. Associated Effects for Flood-Causing Mechanisms Not Bounded by the CDB

	Flooding Mechanism	
Associated Effects Factor	**Local Intense Precipitation**	**Surge**
Hydrodynamic loading at Plant Grade[1]	Equal to or less than 62.4 lb/ft.	Equal to or less than 62.4 lb/ft.
Debris loading at plant grade[2]	Minimal	Minimal
Sediment loading at plant grade[3]	Not Provided	Not Provided
Sediment deposition and erosion[4]	Not Provided	Not Provided
Concurrent Conditions, including adverse weather[5]	Not Provided	Not Provided
Groundwater ingress[6]	Not Provided	Not Provided
Other pertinent factors (e.g., waterborne projectiles)[7]	Minimal	Minimal

[1] FHRR Section 4.11 states that hydrodynamic loads were calculated for LIP and PMSS. FHRR Table 4-52 gives the hydrostatic and hydrodynamic impact force and total force for each POI; the maximum total force at any of the Points of Interest for either LIP or PMSS is 62.4 lb/ft.
[2]FHRR Section 4.11 states that debris loadings were not calculated for LIP and PMSS but provided basis for concluding that very few or no debris are available in drainage area for these loadings.
[3]FHRR Section 4.11 states that sediment loadings were not calculate for LIP and PMSS.
[4, 5, and 6] Not specifically stated in the FHRR.
[7]FHRR Section 4.12 states that the water depths associated with LIP and PMSS are shallow and transient and would not support significant waterborne projectiles.

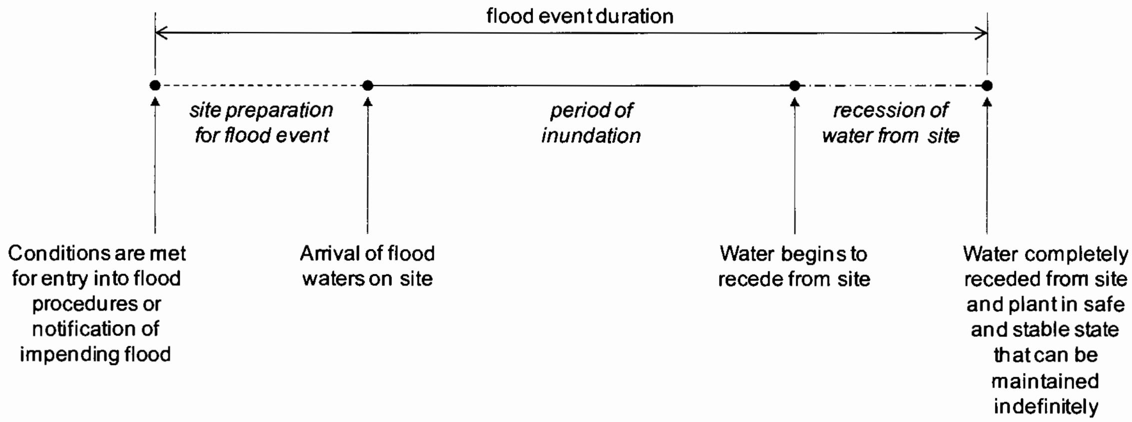

Figure 2.2-1 Flood Event Duration
(Source: JLD-ISG-2012-05 (NRC, 2012c), Figure 6.)

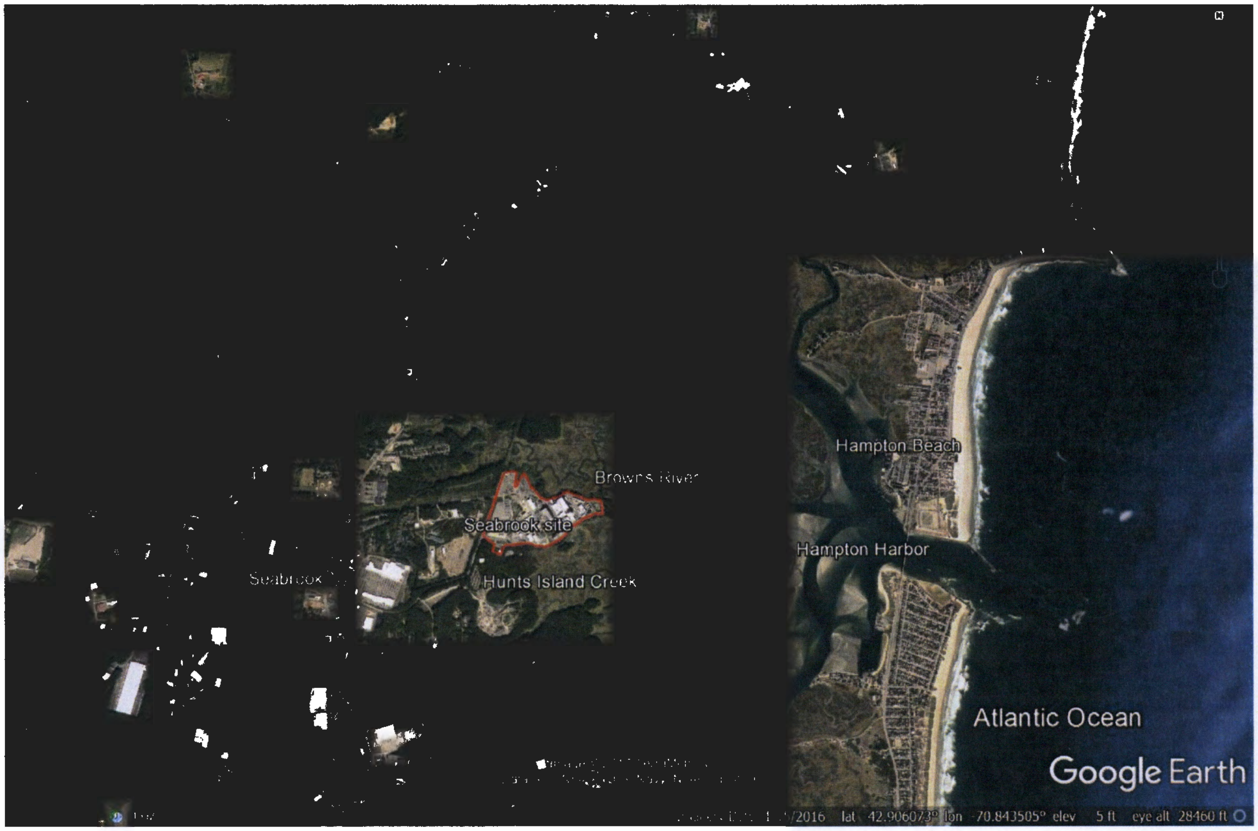

Figure 3.1-1. Seabrook Site locations (adapted from FHRR Figure 2-1).

Figure 3.1-2. Seabrook site (adapted from FHRR Figure 4-1); Intake Building (IB), Discharge Building (DB), Pump House Building (PHB), Fuel Storage Building (FSB), Containment Unit 1 (CU1), Turbine Building (TB), Administration Building (AB), Waste Handling Building (WB), Cooling Tower (CT) are shown.

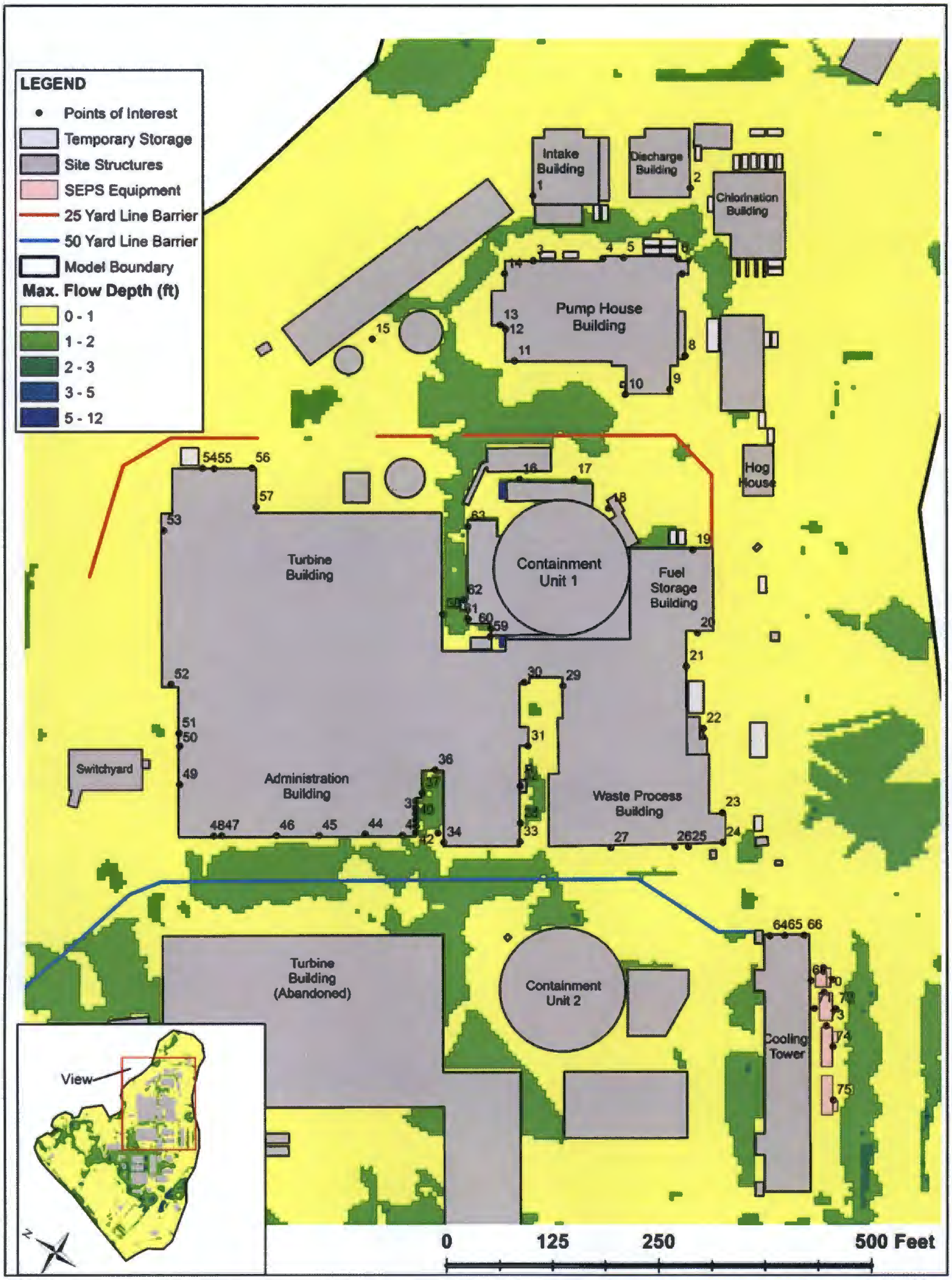

Figure 3.2-1. Maximum LIP flow depth (east portion of site). Indices of POIs included. (Source: FHRR Figure 4-12).

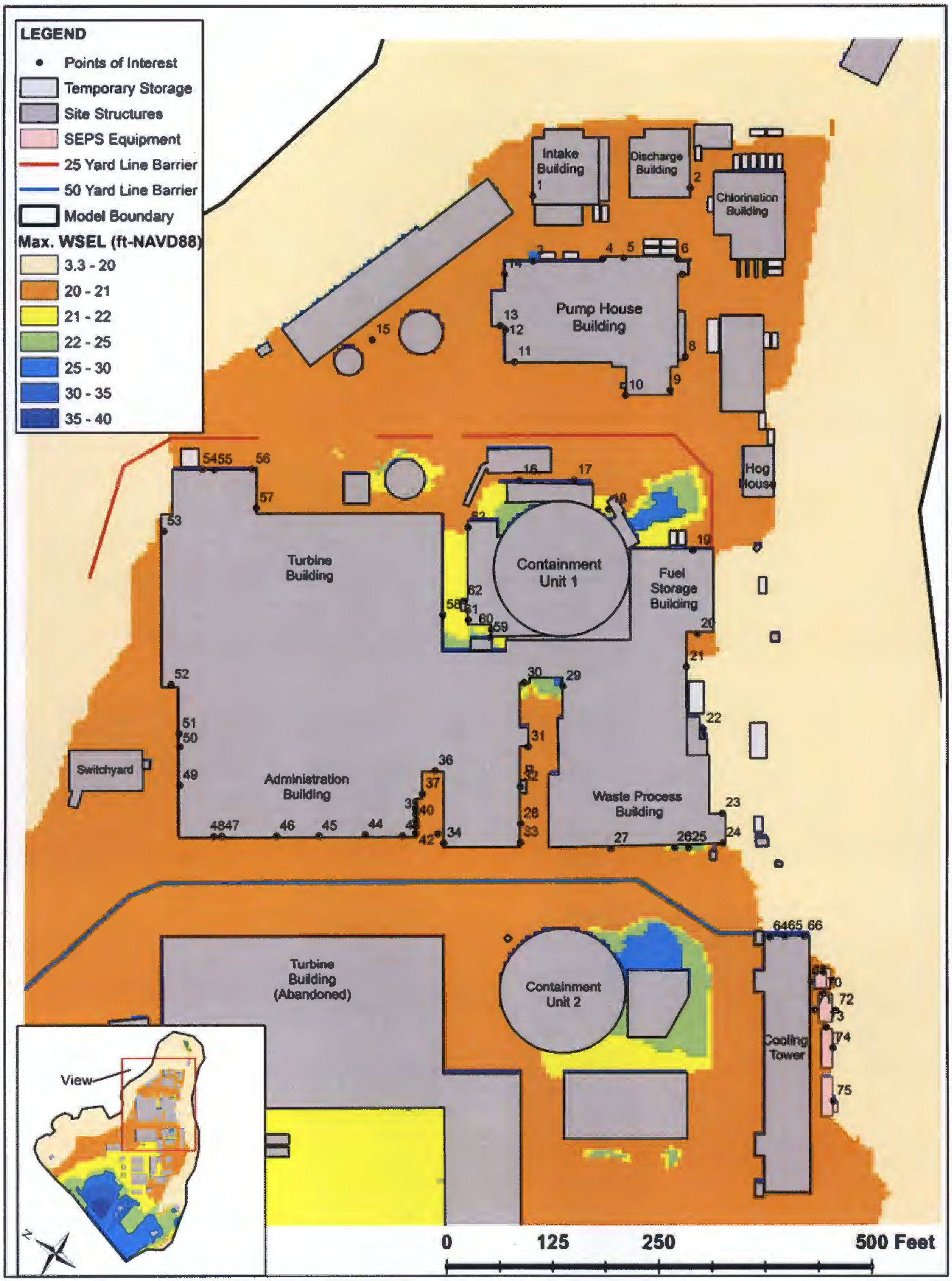

Figure 3.2-2. Maximum LIP water surface elevation (east portion of site). Indices of POIs included. (Source: FHRR Figure 4-13).

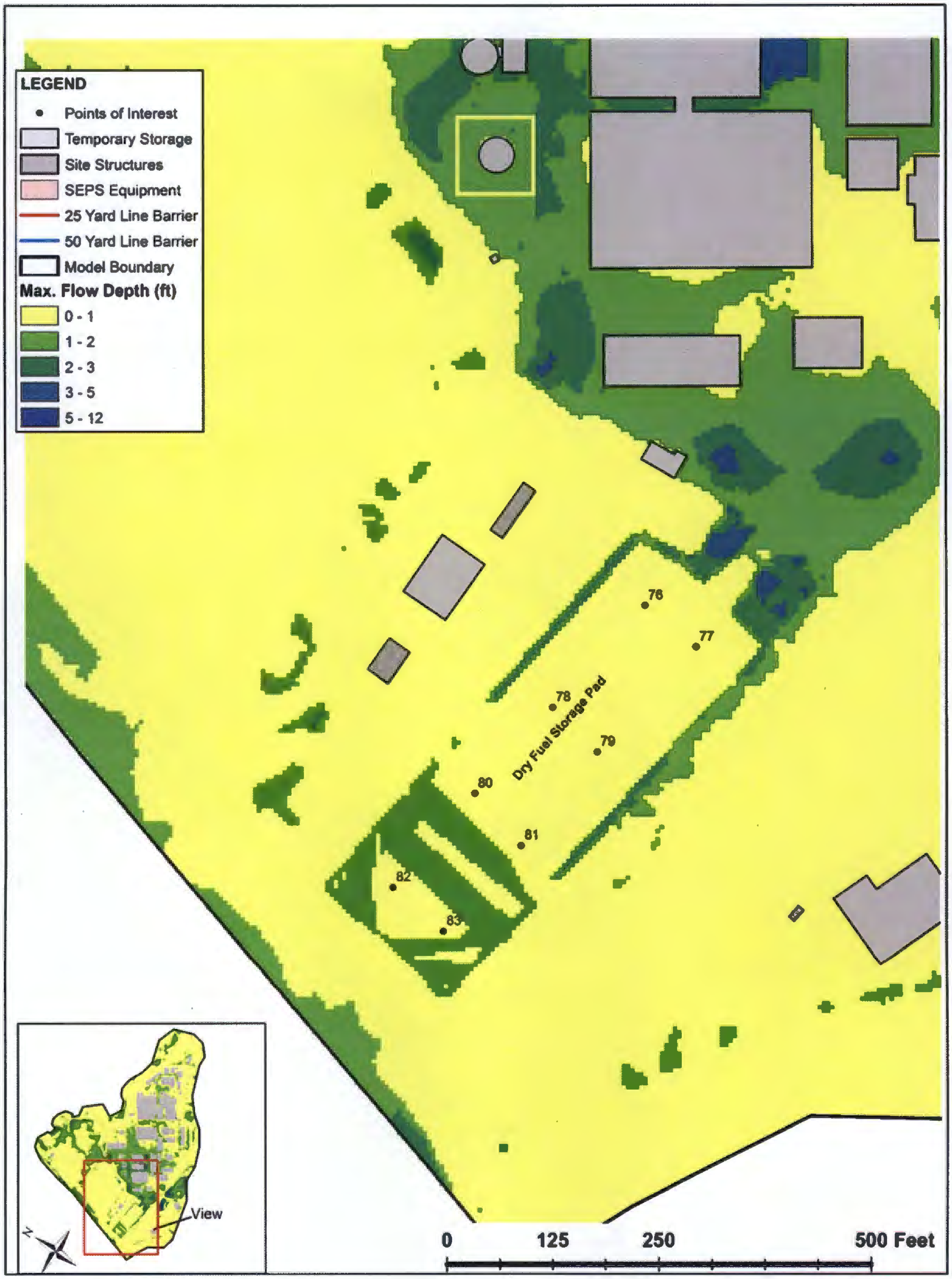

Figure 3.2-3. Maximum LIP flow depth (west portion of site). Indices of POIs included. (Source: FHRR Figure 4-14).

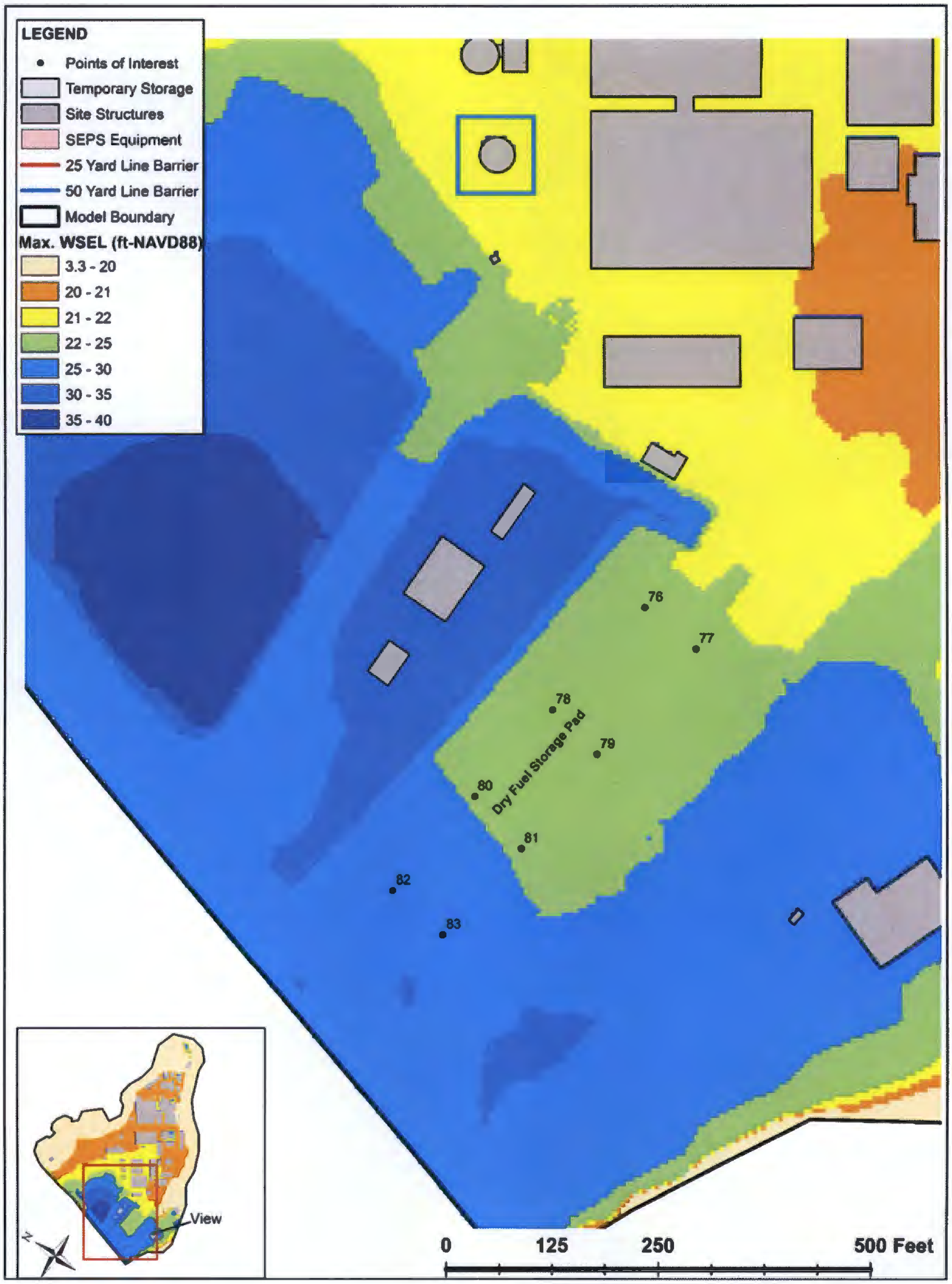

Figure 3.2-4. Maximum LIP water surface elevation (west portion of site). Indices of POIs included. (Source: FHRR Figure 4-15).

SEABROOK STATION, UNIT NO. 1 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION DATED JANUARY 12, 2018

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OFFICE	NRR/DLP/PBMB/BC	NRR/DLP/PBMB/PM	
NAME	MShams	FVega	
DATE	01/01/2018	01/12/2018	

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