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

October 3, 2018

Mr. Daniel G. Stoddard
Senior Vice President and
Chief Nuclear Officer
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SUBJECT: MILLSTONE POWER STATION UNITS 2 AND 3 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (EPID NOS. 000495\05000336\L-2015-JLD-0011 AND 000495\05000423\L-2015-JLD-0012)

Dear Mr. Stoddard:

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 March 12, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15078A204), Dominion Nuclear Connecticut, Inc. (Dominion, the licensee) responded to this request for Millstone Power Station, Units 2 and 3 (Millstone).

By letter dated December 21, 2016 (ADAMS Accession No. ML16267A131), the NRC staff sent the licensee a summary of the staff's review of Millstone 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, the reevaluated flood hazard results for the local intense precipitation (LIP) and tsunami flood-causing mechanisms were not bounded by the current design basis. In order to complete its response to Enclosure 2 to the 50.54(f) letter, the licensee is expected to submit a focused evaluation for LIP and a revised integrated assessment or a focused evaluation for tsunami in order to address this reevaluated flood hazards, as discussed in COMSECY-15-0019, "Closure Plan for the Reevaluation of Flooding Hazard for Operating Nuclear Power Plants," and Japan Lessons-Learned Division (JLD) Interim Staff Guidance (ISG) JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation; Focused Evaluation and Integrated Assessment." The licensee's analysis of the storm surge flood-causing mechanism is not yet completed and is under ongoing review by staff. The NRC staff review of the storm surge hazard mechanism and assessment of plant response will be finalized following submittal by the licensee of their final documentation of the analyses, which is currently anticipated in December 2018.

If you have any questions, please contact me at (301) 415-1617 or by 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 Nos. 50-336 and 50-423

Enclosure:
Staff Assessment of Flood Hazard
Reevaluation Report for Millstone

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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

MILLSTONE POWER STATION, UNITS 2 AND 3

DOCKET NOS. 50-336 AND 423

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, under Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f) (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons-learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant as documented in the Near-Term Task Force (NTTF) report (NRC, 2011a). Recommendation 2.1 of the NTTF report recommended that the NRC staff issue orders to all licensees to reevaluate seismic and flooding hazards for their sites against current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY-11-0124 (NRC, 2011c) and SECY-11-0137 (NRC, 2011d), directed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f) to address this recommendation.

Enclosure 2 to the 50.54(f) letter (NRC, 2012a) requested that licensees reevaluate flood hazards for their respective sites using present-day methods and regulatory guidance used by the NRC staff when reviewing applications for early site permits (ESPs) and combined licenses (COLs). The required response section of Enclosure 2 specified that NRC staff would provide a prioritization plan indicating Flooding Hazard Reevaluation Report (FHRR) deadlines for each plant. On May 11, 2012, the NRC staff issued its prioritization of the FHRRs (NRC, 2012c).

By letter dated March 12, 2015 (Dominion, 2015), Dominion Nuclear Connecticut, Inc. (Dominion, the licensee) provided an FHRR for Millstone Power Station Units 2 and 3 (Millstone).

On December 21, 2016 (NRC, 2016a), the NRC issued an interim staff response (ISR) letter to the licensee. The purpose of the ISR letter was 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 NTTF 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 tsunami flood-causing mechanisms are not bounded by the plant's current design basis (CDB) hazard. Consistent with the 50.54(f) letter and amended by the process outlined in COMSECY-15-0019 (NRC, 2015a) and Japan Lessons-Learned Division (JLD) Interim Staff Guidance (ISG) 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. For the tsunami flood-causing mechanism, 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, 2015a) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b). The licensee's analysis of the storm surge flood-causing mechanism is not yet completed and is under review by staff. As part of its review, the NRC staff conducted a site audit focused on the storm surge flood hazard in order to better understand the licensee's methodology and analysis. The results of the audit will be documented in an audit report and staff assessment to be issued upon conclusion of the staff's storm surge review. The NRC staff expects to complete its review following submittal by the licensee of their final documentation of the storm surge analyses, which is currently anticipated in December 2018.

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 in order to conduct the Mitigating Strategies Assessment (MSA), and focused evaluations or revised integrated assessments. By letter dated June 28, 2017 (Dominion, 2017c), the licensee submitted the 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.

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

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

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

2.2.3 Combined Effects Flood

The worst flooding at a site that may result from a reasonable combination of individual flooding mechanisms is sometimes referred to as a "combined effects flood." 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, 2012d) as the length of time during which the flood event affects the site. It begins when conditions are met for entry into a flood procedure, or with notification of an impending flood (e.g., a flood forecast or notification of dam failure), and includes preparation for the flood. It continues during the period of inundation, and ends when water recedes from the site and the plant reaches a safe and stable state that can be maintained indefinitely. Figure 2.2-1 illustrates flood event duration.

2.2.5 Actions Following the FHRR

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

- Submit an Interim Action Plan with the FHRR documenting actions planned or already taken to address the reevaluated hazard.
- Perform an integrated assessment to: (a) evaluate the effectiveness of the CDB (i.e., flood protection and mitigation systems); (b) identify plant-specific vulnerabilities; and (c) assess the effectiveness of existing or planned systems and procedures for protecting against and mitigating consequences of flooding for the flood event duration.

If the reevaluated flood hazard is bounded by the CDB flood hazard for all flood-causing mechanisms at the site, licensees are not required to perform an integrated assessment. COMSECY-15-0019 (NRC, 2015a) 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, 2015a and NRC, 2016b).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of the Millstone 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, and participated in several audit meetings at NRC headquarters via teleconferences and/or webinars. The 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 and the flood hazard in the FHRR (Dominion, 2015). The NRC staff reviewed and summarized this information in the sections below.

3.1.1 Detailed Site Information

The licensee has adopted the U.S. Coast & Geologic Survey mean sea level (MSL) datum as the Millstone site datum. The licensee states that the MSL is equivalent to the National Geodetic Vertical Datum of 1929 (NGVD29). The North American Vertical Datum of 1988 (NAVD88) was used for certain elevation measurements. Elevation 0 feet (ft.) NAVD88 is equivalent to elevation 1.0 ft. MSL. The datum used is cited for all elevation measurements. Unless otherwise stated, all elevations in this document are given with respect to NGVD29.

The site grades at the powerblocks are elevation 14 ft. NGVD29 for Millstone, Unit 2, and 24 ft. NGVD29 for Unit 3. Table 3.1-1 of this assessment provides the summary of controlling reevaluated flood-causing mechanisms the licensee computed to be higher than the site grade elevations. The current protection level for Unit 2 is 22 ft. NGVD29, and for Unit 3 it is the site grade of 24 ft. NGVD29.

Millstone is in Waterford, New London County, Connecticut. It is situated on the north shore of Long Island Sound on a point of land known as Millstone Point, located on the east side of Niantic Bay (which forms the mouth of the Niantic River). Millstone Point is bordered on the east by an inlet named Jordan Cove. Figure 3.1-1 of this assessment illustrates the setting and general layout of the site. Topography in the site vicinity is characterized by low rolling hills that rise inland from the shoreline; maximum elevation within 5 miles of the site is about 250 ft. NGVD29. Niantic Bay has a mean tide range of 2.7 ft. and a spring tide range of 3.2 ft. Mean high water (MHW) at Millstone Point is 1.3 ft. NGVD29, and mean low water (MLW) is -1.4 ft. NGVD29. Millstone Point is underlain by bedrock that is essentially impermeable. Perched groundwater occurs locally in overlying soil materials and surface water collects in depressions in marshy areas.

The Millstone site has a total area of 524 acres. A total of three reactor units were located on the Millstone Point site, but Millstone, Unit 1 (the southernmost of the three units) is decommissioned. Millstone, Unit 2 is located north of the decommissioned unit, and Millstone, Unit 3 is north of Unit 2. Site grade at Millstone, Unit 2 is 14 ft. NGVD29, and associated SSCs and roads have a finished grade elevation of 14.5 ft. NGVD29. Site grade at Unit 3 is 24 ft.

NGVD29, and the associated SSCs have a finished grade elevation of 24.5 ft. NGVD29, with the exception of the circulating and service water pump house at operating grade elevation 14 ft. NGVD29.

The Millstone, Unit 2 containment building, auxiliary building, and warehouse building have exterior concrete walls to provide external flood protection up to at least elevation 54.5 ft. NGVD29. The Unit 2 turbine building and enclosure building have metal siding above elevation 22 ft. NGVD29 that is continuous over the exterior flood wall and is connected to the flood wall with waterproof caulked connections to prevent water from entering the buildings. Openings into the auxiliary and turbine buildings have hinged flood gates or stop logs to elevation 22 ft. NGVD29 to prevent ingress of water and debris. Flood protection for the Unit 2 auxiliary building is provided by the adjacent Unit 1 control building, which has flood protection up to at least 22 ft. NGVD29 on its southern and eastern walls. A flood wall with a minimum elevation of 22 ft. is located in the common area between Unit 1 and the Unit 2 turbine building to provide external flooding protection for the Unit 2 facilities. The only safety-related system in the Unit 2 intake structure is the service water system, which is protected up to 22 ft. NGVD29.

The Millstone, Unit 3 safety-related structures and equipment are located above the site grade elevation of 24 ft. NGVD29, except for the circulating and service water pumphouse. The service water pumps and pump motors in the service water pumphouse are located at elevation 14.5 ft. NGVD29 inside watertight cubicles that are protected up to elevation 25.5 ft. NGVD29. Accesses to safety-related structures and facilities are at an elevation of 24.5 ft. NGVD29, which is above the nominal site grade elevation of 24 ft. NGVD29. Two access doors to the service water cubicles in the pumphouse are at a lower elevation and are fitted with watertight steel doors, and the equipment access openings on the pumphouse roof over the service water cubicles are fitted with watertight covers. Entrances to Unit 3 safety-related facilities are at elevation 24.5 ft. NGVD29 or above, except for the Demineralized Water Storage Tank (DWST) Block House and Refueling Water Storage Tank (RWST) Valve Enclosure, which have entrance elevations of 24.3 ft. NGVD29.

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 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 in FHRR Section 1.3 that deficiencies with flood protection were noted in the Flood Walkdown Report (Dominion, 2012). However, there have been no changes to the CLB from what is provided in the Updated Final Safety Analysis Report. The licensee noted in its FHRR that the identified deficiencies (component rusting, degraded gaskets, seals, and weather stripping, and below grade unsealed penetrations) were entered into the Corrective Action Program. Additional information related to plant walkdowns is described in Section 3.1.7 of this staff assessment.

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 FHRR Section 1.4 that there have been no major changes to the local coastal watershed near Millstone since the license issuance.

The NRC staff accessed the historical U.S. Geological Survey (USGS) topographic maps (USGS, n.d.-a) and the NRC staff found four historical maps from 1934, 1938, 1958, and 1983. The 1983 historical map includes the footprint of the Millstone nuclear power plant. The NRC staff compared the 1938 map with the more recent map "Niantic, CT 2015," also obtained from the USGS (USGS, n.d.-a). The NRC staff visually compared the 1938 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 provided a discussion of flood protection and mitigation features in FHRR Section 1.5.1 for Unit 2, and in FHRR Section 1.5.2 for Unit 3.

For Unit 2, the FHRR discusses flood protection features for a probable maximum hurricane, for rainfall events, for the intake structure, and for electrical equipment. In general, flood protection is provided to a minimum elevation of 22 ft. NGVD29, with additional protection provided at some locations. The containment, auxiliary, and warehouse buildings are protected up to a minimum elevation of 54.5 ft. NGVD29 by exterior concrete walls. The turbine and enclosure buildings have metal siding above 22 ft. NGVD29 and are connected to the flood wall to prevent flooding from wave splashing. Openings in the auxiliary and turbine building are protected to 22 ft. NGVD29 with hinged flood gates or stop logs.

The flood boundary between the decommissioned Unit 1 and Unit 2 also provides protection to Unit 2 with a flood wall at a minimum elevation of 22 ft. NGVD29 between the common areas of Unit 1 and the Unit 2 turbine building. The Unit 1 control building provides protection to the Unit 2 auxiliary building on the south and east walls to a minimum elevation of 22 ft. NGVD29.

The Unit 2 Intake Structure is constructed of reinforced concrete. The service water system is the only safety-related system in the Intake Structure and it is protected to an elevation of 22 ft. NGVD29. For flood levels greater than 22 ft. NGVD29, flood protection provision is provided via plant personnel. The licensee stated that this would be accomplished by de-termination of electrical connections from one of the MPS2 service water pump motors and installation of a cover to protect the motor from potential flood waters in the intake structure.

The Unit 2 drainage system is designed for rainfall event protection with an intensity up to 3 inches per hour (h). Excess runoff accumulates in the yard and spills in Jordan Cove and Niantic Bay when accumulation reaches 14.5 ft. NGVD29. The drainage system includes backwater valves to prevent backflow into buildings. Stop logs and flood gates at entrances are provided to prevent the inflow of water.

Some Unit 2 electrical equipment is located below 22 ft. NGVD29, in close proximity to stairways or opening to lower floors to reduce water accumulation. Where this is not the case, the equipment is located on a 4 inch raised concrete pad. For the intake structure, electrical equipment below 22 ft. NGVD29 has watertight construction features that provide protection. Seals and cable raceways above 22 ft. NGVD29 are used for entry cables that connect to equipment inside flood protected areas.

For Unit 3, FHRR Section 1.5.2 discusses flood protection features related to seismic Category I structures and for a probable maximum precipitation (PMP) event. Generally, safety-related structures are flood protected up to the site grade of 24 ft. NGVD29, with the exception of the circulating service water pumphouse. Access to safety-related structures is at an elevation of 24.5 ft. NGVD29. Within the service water pumphouse, the pumps and motors are protected inside watertight cubicles to an elevation of 25.5 ft. NGVD29. Sump pumps are used to drain the cubicles during flooding conditions. Storm drains convey runoff to Niantic Bay.

During a PMP, accumulating runoff can back up and enter safety-related structures, except for the control building and emergency generator enclosure. The licensee has evaluated the quantity and location of flow and determined it does not interfere with safety-related equipment.

3.1.6 Additional Site Details to Assess the Flood Hazard

Additional details related to the flood hazard reevaluations were reviewed as part of the ongoing audit. As stated above, the results of the audit will be documented in an audit report to be issued upon conclusion of the staff's storm surge review.

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 (Dominion, 2012), Dominion provided the flood walkdown report for Millstone. On March 20, 2014 (NRC, 2014a), the NRC staff issued its assessment of the walkdown report 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, including associated effects, for LIP and associated site drainage is based on a stillwater-surface elevation of 17.5 ft. NGVD29 for Unit 2 and 24.8 ft. NGVD29 for Unit 3. Additional effects of wind waves and runup were not considered.

This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevation for LIP and associated site drainage is based on a stillwater-surface elevation of 14.5 ft. NGVD29 for Millstone, Unit 2 and 24.8 ft. NGVD29 for Millstone, Unit 3.

3.2.1 Model Configuration for Local Intense Precipitation Flooding

The licensee used the two-dimensional (2D) hydrodynamic computer model FLO-2D Pro (FLO-2D, 2014a), Build No. 14.03.07, in its assessment of the flood hazard from local LIP.

Model implementation is described in the FHRR. A 220-acre drainage area was modeled (Figure 3.1-1 of this assessment). An aerial photogrammetric survey conducted by the licensee in 2012 provided topographic data for the site. The drainage area was modeled with a uniform grid of square elements, 10 ft. on each side.

Buildings were treated as elevated grid elements at least 5 ft. higher than the surrounding topography, so rainfall incident to roofs would be evenly distributed onto surrounding areas. Roof drains were assumed to be blocked. The Vehicle Barrier System (VBS) and freestanding walls on the site were modeled as levees; the VBS was modeled with a height of 2.7 ft. based on the site topographic survey and walls were assigned an arbitrary height of 20 ft., which exceeds the maximum water depths predicted in the model. The location and widths of openings in the VBS were verified in the field and these openings were modeled as small weirs. Figure 3.2-1 of this assessment shows the locations of features modeled as levees.

Manning's n values were assigned based on site conditions, using guidance in the FLO-2D manual (FLO-2D, 2104b) and Chow (1959). Assigned n values ranged from 0.02 for concrete or pavement (including building roofs), to 0.3 for wooded areas, and 0.8 for a line of boulders (Figure 3.2-2 of this assessment). The entire drainage area was assumed to be impervious, with zero infiltration, and storm drains were assumed to be nonfunctional. A large swale on the western side of the site (between buildings 475 and 305 in Millstone Unit 3) that normally discharges to Niantic Bay through an underground culvert was treated as blocked due to the assumption that the culvert was nonfunctional.

Grid elements at the computational boundary of the model, where water enters Niantic Bay, Jordan Cove, or Long Island Sound, were assigned as outflow grid elements. Long Island Sound was treated as having a constant water elevation of 4.2 ft. NGVD29 that correspond to the ten percent exceedance high tide elevation plus long-term changes in sea level.

3.2.2 HMR-based Modeling and Sensitivity Analyses

The PMP rainfall event for the licensee's initial simulation of LIP effects was a 6-h duration PMP event that included a 1-h PMP event at its peak and was determined using methodology from hydrometeorological report (HMR) -52 (National Oceanic and Atmospheric Administration (NOAA), 1982). The water depth for 6-h PMP event over a 10-mi^2 area was determined to be 26.0 in. A 1-h PMP value of 17.4 in. depth was determined for a 1-mi^2 area. Using FLO-2D, the licensee analyzed the sensitivity of water levels in the plant area to different timings of peak PMP within the 6-h PMP event. Rainfall increments within the peak hour were split into 5-minute increments according to guidance in HMR-52, and the remainder of the 6-h PMP was evenly distributed throughout the other 5 hours of the event. The sensitivity analysis considered a front-loaded temporal rainfall distribution (that is, the most intense 5-minute and 1-h rainfall occur at the beginning of the 6-h event), a middle-loaded distribution, and an end-loaded distribution. The analysis found that locating the most intense part of the PMP event at the end of the storm results in the most conservative (largest) flood depths and the front-loaded distribution resulted in the least conservative (smallest) flood depths.

The licensee also assessed the sensitivity to the presence or absence of the VBS. This analysis found that the presence of the VBS increased water levels in the Unit 2 area by approximately 0.2 ft. In the Unit 3 area, the VBS had a smaller effect and sometimes resulted in lower water levels; effects in either direction were 0.1 ft. or less. Based on this result, the licensee determined that the VBS should be included in its final LIP analysis.

3.2.3 HMR-based Flooding Results

The licensee reported model predictions for every grid element in the model domain, but the licensee's interpretation of the modeling results focuses on grid elements that correspond to doors and other relevant flood-hazard potential locations identified by Millstone site personnel. Using FLO-2D with PMP rainfall values based on HMR-52, the licensee's modeling analysis found the maximum LIP flood elevations at the relevant locations to be 18.5 ft. NGVD29 in the Unit 2 area and 25.3 ft. NGVD29 in the Unit 3 area, in both cases exceeding the elevation of the doors and openings.

3.2.4 Analysis of LIP Flooding Based on Site-Specific PMP

The final PMP analysis that the licensee presented in its FHRR is a refined analysis using the results of a site-specific meteorological study conducted to determine 1-h PMP and 6-h PMP values for a 1-mi^2 area. The licensee based its approach to the site-specific meteorological study on recommendations in ANSI/ANS-2.8-1992 (ANSI/ANS, 1992) and followed guidance in HMR 53 (NOAA, 1980) and HMR 51 (NOAA, 1978), which are consistent with the World Meteorological Manual for PMP determination (WMO, 2009), as well as HMR 57 Section 7.4 (NOAA, 1994). While the site-specific PMP (ssPMP) approach follows similar methodology to that used in the HMRs, it accounts for unique, site-specific considerations that affect several aspects of PMP development, most notably 1) storm transposition and 2) storm maximization.

The procedure for developing ssPMP involves first identifying the most extreme storms that have occurred near (or can be reasonably transpositioned to) the site location in the past and refining them to a "short list." This refinement process involves enforcing several objective and subjective criteria to produce a reduced set of appropriate historical storms which may influence ssPMP values and which require further evaluation.

To support its review of the licensee's ssPMP, and following the audit plan dated June 16, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16267A131), the staff identified several information needs on the ssPMP analysis, including a list of storms that were considered for possible inclusion in its analysis, meteorological data for those storms, dew-point and sea-surface temperature data used, and calculation sheets. The licensee responded by supplying the requested information via the electronic reading room.

Historical storms that the licensee screened for possible inclusion in the site-specific PMP analysis included all storms used in development of HMR 51 (NOAA, 1978) and HMR 52 (NOAA, 1982), all storms included in the U.S. Army Corps of Engineers (USACE) Storm Analyses (USACE, 1973), and more recent storms that occurred through November 2014. Guidelines used in historical screening of storms included a rule that storms should not be moved across the Appalachian Mountains, should not be moved more than 1000 ft. in elevation, and should not be moved more than 5 to 6 degrees in latitude.

Once the "short list" was derived, additional actions were taken to transposition and maximize each historical storm to the location of interest. The various steps followed during ssPMP development are documented in the NRC's audit report (NRC, 2015b) of Applied Weather Associates (AWA). Using these guidelines, 11 storms were selected for inclusion in the analysis. Storm maximization was performed, storms were transposed to the Millstone site, and Depth-Area Duration (9) curves were computed using the Storm Precipitation Analysis System (SPAS) computer program (Parzybok et al., 2014).

The 1-h and 6-h ssPMP values identified for the analysis were 11.0 in. and 23.3 in., respectively. The site-specific study found that the 1-h PMP event was most likely to occur in either the second hour of the storm or the fourth hour of the storm. Considering the sensitivity analysis that showed more conservative results from a later peak rainfall, the licensee constructed a 6-h PMP hyetograph including the peak 1-h PMP event during the fourth hour. Rainfall increments within the peak hour were distributed in 5-minute increments according to guidance in HMR-52, and the remainder of the 23.3-in 6-h PMP was evenly distributed throughout the other 5 hours of the event.

3.2.5 Site-specific PMP Flooding Results

The resulting ssPMP hyetograph was used as input to FLO-2D to calculate the reevaluated LIP water elevations. The highest calculated water surface elevation at a relevant grid element location in the Unit 2 area was 17.5 ft. NGVD29, corresponding to a water depth of 4.2 ft. at the Flood Gate 13 at the northern perimeter of the Containment Enclosure building. This water elevation exceeds the CDB.

For the Unit 3 area, the highest calculated water surface elevation at a relevant grid element location was 24.8 ft. NGVD29 at a door in the alleyway south of the Service Building. This elevation does not exceed the CDB for Unit 3.

3.2.6 Staff Review

3.2.6.1 Site-Specific PMP for LIP

The NRC staff reviewed the licensee's descriptions of its analyses and its rationale for the selected approaches to evaluating effects of LIP and confirmed that the licensee's technical approach was consistent with current regulatory guidance, including guidance on conservatism in analysis. Staff reviewed and compared the licensee's FLO-2D input parameters against the cited technical references, examined the licensee's FLO-2D input files to verify the model structure, ran FLO-2D to confirm the licensee's results, and conducted limited sensitivity analysis using FLO-2D. The results of the staff's confirmatory analyses were consistent with the licensee's reported results.

The NRC staff conducted a detailed review and independent analyses to evaluate the LIP ssPMP. The NRC staff had previously reviewed the licensee's short list of storms as part of the Indian Point FHRR review (NRC, 2018a) and found that its application to the Millstone site was appropriate. While assessing the licensee's ssPMP, the NRC staff also performed the following:

- Review of the USACE 'Black Book' storm catalog
- Independent evaluation of the short list storms

The NRC staff noted that the licensee's analysis focused on the storms that provided the maximum amount of rainfall on the site. The NRC staff analysis indicated that differences resulting from the sensitivity of the Depth-Area-Duration (DAD) values would not have a noticeable impact on the PMP.

For comprehensiveness, the NRC staff reviewed all historical rainfall observations documented in the USACE 'Black Book' storm catalog. The NRC staff identified the Ewan, NJ, and

Smethport, PA, storms as the two biggest historic storms that could control Millstone ssPMP. While this review identified one of those storms (the record-holding Smethport, PA, storm) as potentially critical; given the storm's limited transpositionability, the NRC staff considered the exclusion of the storm to be justified.

The NRC staff conducted a detailed independent analysis to assess the LIP short list storms. As a part of its assessment, the NRC staff independently computed storm elevation, storm dew point (including storm representative, in-place maximum, and transpositioned maximum dew point values), and total adjustment factors following methodologies similar to those used by the licensee. Regarding the storm elevation data, while staff observed some moderate differences from the values provided by the licensee, the results would not impact the ssPMP calculation. The most notable difference between the NRC staff's and licensee's methodologies relates to the way in which the dew point climatology values (in-place maximum and transpositioned maximum) are determined (Figure 3.2-3). Using the values presented in Figure 3.2-3, the in-place maximization factor and transposition adjustment factor were combined to compute a total adjustment factor (TAF), which is applied to observed DAD data to obtain adjusted DAD data for the ssPMP analysis. The staff-calculated TAF for most storms is not significantly different from the AWA value, ranging from 11 percent lower to 8 percent higher. While the licensee determined dew point climatology values using smoothed maps, the NRC staff relied on its independent gauge-based calculations of climatology values to infer appropriate values.

For some storms, the two approaches resulted in moderately different maximized DAD values, with the staff-calculated values being 3.7 percent to 4.7 percent higher. While the controlling LIP storm (Ewan, NJ) was found to have higher ssPMP values when using staff's results, the differences were driven by small (0.5 to 1.0 degrees Fahrenheit) differences in dew point climatology values at the storm representative and transpositioned locations. Since the licensee's sea-based climatological values were based on NOAA sea surface temperature maps, the NRC staff finds the values used in the licensee's analysis to be reasonable.

3.2.6.2 *<u>Predicted Flooding Level</u>*

As discussed in Section 3.2.4 of this assessment, the 1-hr, 1-mi^2 precipitation calculated by the licensee was reduced from 17.4 in. using HMR methods to 11.0 in. using the ssPMP method. The change in method was accompanied by a change in time distribution of rainfall. The NRC staff sensitivity analysis focused on changing the rainfall distributions for comparison of the HMR PMP and ssPMP rainfalls. An HMR sensitivity analysis run was made to include a centered rainfall distribution with a peak rainfall intensity occurring at 3.5-hr, consistent with the distribution used in the ssPMP analysis. Similarly, an ssPMP sensitivity analysis run was made to include an end-loaded rainfall distribution, consistent with the distribution used in the HMR analysis. The results of these sensitivity analyses indicate that changes in the distribution result in relatively minor changes in the maximum water surface elevation (WSE) at various site locations. Overall, an end-loaded rainfall distribution produces (on average) slightly higher maximum WSE's compared to a centered rainfall distribution; however, the differences are less than 0.1 ft. for the ssPMP sensitivity analysis.

Considering that the licensee's ssPMP 1-hr, 1-mi^2 value for the Millstone site is 37 percent lower than the HMR-based PMP and produced a maximum water surface of 1.09 ft. lower than the HMR-based PMP, the NRC staff consider that a 4.7 percent increase in PMP would be unlikely to have significant effects on flooding impacts at the site.

3.2.7 Conclusion

For Millstone, Unit 3, the NRC staff confirmed the licensee's conclusion that the reevaluated flood hazard for local intense precipitation and associated site drainage is bounded by the CDB flood hazard.

For Millstone, Unit 2, the 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 licensee is expected to assess the impact of LIP and associated site drainage in a Focused Evaluation for LIP Hazard for Unit 2.

3.3 Streams and Rivers

The licensee reported in its FHRR that the reevaluated flood hazard, including associated effects, for flooding from streams and rivers is based on a stillwater-surface elevation of 11.2 ft. NGVD29 for Unit 2 and 11.2 ft. NGVD29 for Unit 3. Additional effects of wind waves and runup were not considered.

This flood-causing mechanism is discussed in the licensee's CDB. It was concluded that flooding from stream and rivers will not inundate the site and that no design-basis flood elevation was necessary.

For this flood hazard reevaluation, the PMF analysis was conducted on a small coastal stream near the Millstone site. The reevaluation followed the Hierarchical Hazard Assessment approach and started with a simplified and conservative assumptions discussed in the following Sections. Flooding of the Niantic River was not analyzed since the site is located on a peninsula adjacent to Niantic Bay. Any floodwater from the Niantic River would dissipate within the bay and would not inundate the Millstone site.

3.3.1 Watershed Characterization

The small watershed of the coastal stream (approximately 87 acres) to the northeast of the Millstone site was delineated by the licensee based on the topography. Hydrologic characteristics for use in the modeling analysis were estimated based on the watershed topographic information.

3.3.2 Probable Maximum Precipitation

The licensee included an examination of an all-season PMP and a cool-season PMP in the analysis. The all-season PMP used methodology from HMR-51 (NOAA, 1978) and HMR-52 (NOAA, 1982) to estimate the 72-hour duration rainfall depth of 39.2 inches. For the cool-season PMP calculation, HMR-53 (NOAA, 1980) was used to estimate seasonal variation of rainfall for a 10 mi^2 storm with a 72-hr duration and an energy budget approach to estimate snowmelt (USACE, 1998). The licensee estimated the rainfall for the rain-on-snow melt as the product of (1) the ratio of November (monthly maximum) and the all-season PMP for a 10 mi^2 storm and (2) the 6-hr incremental all season PMP, which gives a total depth was 38 inches.

Based on a comparison of the two PMP estimates, the licensee selected all-season PMP as the controlling event because of the larger precipitation depth.

3.3.3 Probable Maximum Flood

The licensee used the hydrologic model Hydrologic Engineering Center- Hydrologic Modeling System (HEC-HMS) (USACE, 2010a) to compute the transformation of rainfall to runoff (via a unit hydrograph) using the Natural Resource Conservation Service (NRCS) (NRC, 1986) curve number (CN) method. The CN was set to 99 to represent no infiltration. The lag time of the runoff from the small watershed was estimated to be 50 minutes.

To account for non-linearity effects of extreme precipitation on runoff, the peak of the unit hydrograph was increased by 20 percent and the time to peak reduced by 33 percent. The volume on the falling limb was adjusted to conserve volume (NRC, 2011e). An antecedent storm with 40 percent of the 72-hr PMP was also included. Based on the PMP and watershed characteristics, the computed discharge for the 72-hr all-season PMP including the non-linearity effects was 1,100 cubic feet per second (cfs).

To estimate the maximum water surface elevation from the maximum discharge, Millstone Road was assumed to impound the small coastal stream and control its water surface elevation. The road was assumed to act as a broad-crested weir, with a length of 190 ft., and weir coefficient of 2.6. The invert elevation of the road was 9.5 ft. NGVD29. The depth of discharge over the weir from the weir equation calculation was 1.7ft., so that the PMF elevation is 11.2 ft. NGVD29.

3.3.4 Conclusion

The NRC staff reviewed the information provided for the licensee and concludes that the flood elevation of the PMF event is reasonable. 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 focused evaluation 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 could not inundate the plant site, so no PMF elevation was reported for the flood-causing mechanism.

This flood-causing mechanism is discussed in the licensee's CDB for Units 2 and 3. The licensee concluded there were no dams on the Niantic River and there are no major rivers in the vicinity of the Millstone site. Therefore, the licensee determined that the potential dam failures are not an applicable flood-causing mechanism for the Millstone site (Dominion 2017a and 2017b).

For the reevaluated analysis, the licensee examined the State of Connecticut Dams database (CDEEP, n.d.) and the National Inventory of Dams (NID) database (USACE, n.d) for dams in the vicinity of the Millstone site. The licensee identified a small dam (Gardners Wood Road Pond Dam) on a separate small coastal stream as the nearest dam. Because this dam is located on a drainage basin separated from the Millstone, its failure is not considered to be a potential flood hazard. For dams located upstream of the Millstone site on the Niantic River, the licensee states that any drainage from dam failure would be dissipated within Niantic Bay and not present a flooding hazard.

The NRC staff also examined the CDEEP (CDEEP, n.d.) and NID (USACE, n.d) databases and confirmed the licensee's information regarding the Gardners Wood Road Pond Dam and the lack of dams of sufficient size to produce a significant effect on water levels of Niantic Bay from a dam failure. The examination applies to all potential dam-failure modes: hydrologic, seismic, and sunny day failures. 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 not applicable and is bounded by the CDB flood hazard. Therefore, the NRC staff determined that flooding from failure of dams and onsite water control or storage structures do not need to be analyzed in a focused evaluation or a revised integrated assessment for Millstone.

3.5 Storm Surge

The staff's review of the storm surge flooding mechanism continues and future documentation of the staff's review will be forthcoming. The licensee has indicated to the NRC that final documentation of the storm surge and combined effects flood hazard analyses will be submitted in December 2018. Consequently, the staff's evaluation is ongoing, and is expected to be completed following the licensee's submittal.

3.6 Seiche

The licensee reported in its FHRR that the reevaluated hazard for seiche does not inundate the Millstone site. This flood-causing mechanism is not described in the licensee's CDB.

The licensee evaluated seiche at the Millstone site with consideration of meteorological, astronomical, and seismic forcing as the causative mechanism for low frequency water surface oscillations or seiche in Long Island Sound (LIS) and the discharge basin.

The licensee applied Merian's Formula to evaluate both semi-enclosed and enclosed basins (Scheffner, 2008 and Rabinovich, 2009). The FHRR states that LIS is approximately 94 miles in length and 19 miles in width at its widest point with an average depth of 79 ft. The licensee determined that Merian's formula predicts a seiche period of 9.6 hours in the longitudinal direction and 0.4 to 0.9 hours in the transverse direction based on the geographic parameters of the LIS.

The FHRR states that the typical period of earthquakes falls outside the range of the estimated natural period of LIS. Resonance within LIS will not occur due to the difference in the natural period of the LIS, and the typical range of ground motion (shaking) periods from earthquakes which typically do not exceed 10 seconds (Chung et al., 2008). Wind generated wave periods, which can range from 4 to 20 seconds (Wells, 1997), are too short to drive a resonant seiche in the longitudinal or transverse directions in LIS. Synoptic scale forcing is on a scale of 3 to 7 days (Wells, 1997) and would not persist over many cycles with a constant period.

The FHRR discusses the semi-diurnal tide, which does exhibit a significant resonant amplification in the western end of LIS. However, the Millstone site is located at the eastern end of the basins near the node of the longitudinal basin oscillation. The licensee found no evidence of tidal forcing for a transverse seiche mode in the water level data near the Millstone site. The licensee based this conclusion on the period predicted by linear theory, which results in a computed period that is too short for diurnal and semidiurnal resonance.

The FHRR states that for the cooling water discharge basin the longitudinal seiche period was estimated at 83.3 to 92.5 seconds and the transverse seiche period is estimated at 6.9 to 12.1 seconds. Thus, the period of the primary mode of the discharge basin (83 to 93 seconds) in the longitudinal direction is not within the typical range of ground motion (shaking) periods. In the transverse direction, the licensee states that resonant seiching within the discharge basin will not impact the Millstone site because the transverse sides of the discharge basin consist of the remains of the prior quarry operation, or are undeveloped. For wind generated waves, the periods are too short (4 to 20 seconds) to drive a resonant seiche in the longitudinal direction (Wells, 1997). In the transverse direction, the FHRR states that the discharge basin is too narrow and sheltered by the surrounding grades to allow the generation of wind waves. Finally, the licensee concludes that the astronomical tides in the LIS have periods that are several orders of magnitude larger than the longitudinal period of the discharge basin and will not cause resonance.

The NRC staff reviewed the licensee's evaluation of site flooding from seiche, including associated effects, using relevant regulatory criteria based on present-day NRC methodologies and regulatory guidance and estimation methods (USACE Costal Engineering Manual (CEM) methods) as discussed below.

The NRC staff applied the seiche equations presented in the CEM (Coastal Engineering Manual) (USACE, 2002) and confirmed the primary and secondary mode periods with representative length and depth values for the LIS and cooling water discharge basin. The NRC staff also reviewed the licensee's reference articles and confirmed the licensee's statements regarding wind, seismic and tidal effects on seiche resonance are reasonable.

In summary, the staff confirmed the licensee's conclusion that the PMF from seiche alone could not inundate the site. The NRC staff confirmed that the reevaluated hazard for flooding from seiche is bounded by the CDB flood hazard. Therefore, the NRC staff determined that flooding from seiche do not need to be analyzed in a focused evaluation or a revised integrated assessment for Millstone.

3.7 Tsunami

The licensee reported in its FHRR that the reevaluated flood hazard elevation, including associated effects, for site flooding due to tsunami is 14.7 ft. NGVD29. This flood-causing mechanism is described in the licensee's CDB with no site inundation expected.
The FHRR discusses three possible mechanisms for tsunamis: submerged landslides, volcanic cone collapse, and a subduction zone earthquake. Information about each of the possible sources is taken from the published literature, and simulations are performed for each type of source. The FHRR does not discuss any relevant historical or paleo-tsunami events that have occurred in the vicinity of the Millstone site.

The licensee evaluated several different tsunami sources from the published scientific literature (Grilli et al, 2010, 2011, 2013a, and 2013b and Locat et al., 2009) to establish the probable maximum tsunami (PMT) at the site, including a subduction zone event in the Hispaniola Trench, a volcanic cone collapse in the Canary Islands, and a Currituck landslide event on the continental shelf margin. The licensee conducted the tsunami analysis using the numerical model FUNWAVE-TVD (Fully Nonlinear Wave - Total Variation Diminishing Scheme), with appropriate document referencing to support the technical basis of the model. Specific information regarding bathymetry sources and grid development was provided. Recent and appropriate data sources are utilized within applications of FUNWAVE (Kennedy et al., 2000; Kirby et al, 2013).

The FHRR presents an antecedent water level, composed of the 10-percent exceedance high tide and long-term sea level rise expected over the next 50 years. Tide information is extracted from the Newport, Rhode Island, NOAA tide gage, which is then multiplied by an offset factor (0.74) to yield the tide levels near to the site. The 10-percent tide at the site is given as 3.7 ft. NGVD29, and the expected 50-year rise in sea level is 0.5 ft. Thus, the total antecedent water level is 4.2 ft. NGVD29.

The FHRR states that the PMT arises from the distant Canary Islands cone collapse, with a maximum flood elevation along the western side of the Millstone Unit 3 site of approximately 21.1 ft. NGVD29 and 14.7 ft. NGVD29 within the Millstone Unit 2 site. The licensee states that ground elevations along the western side of the site, near the Millstone paved parking lot, are around 30.0 ft. NGVD29, providing a natural barrier for the safety-related structures at the southern end of the site from flooding of the northwest area. The licensee stated that this 21.1 ft. NGVD29 water level elevation causes inundation along the undeveloped coastal area northwest of Millstone, Unit 3 (west of the parking lots). Because of a natural barrier, the maximum WSEs further south, near Millstone Unit 2, only reached 14.7 ft. NGVD29. On the eastern side of the Millstone site, the maximum WSE reaches 12.0 ft. NGVD29.

The FHHR also provided results from a numerical simulation of a large landslide offshore of the site. The licensee's maximum predicted water levels from this Currituck source near the Millstone site ranged from 10.3 to 15.1 ft. NGVD29.

The NRC staff conducted an independent confirmatory analysis to determine the PMT at the Millstone site. The NRC staff performed numerical modeling of three tsunami sources consisting of both far-field seismogenic (Puerto Rico subduction zone) and far-field (Canary Islands and near-field (Currituck landslide) as potential generators for the PMT (ten Brink et al, 2008).

The NRC staff used the Boussinesq-based numerical model COULWAVE (Lynett and Liu, 2002) for three different types of tsunami sources. Conservative source parameters were employed to compute an upper limit on the possible tsunami effects at the Millstone Site. The NRC staff found that the Currituck-like landslide source generated the maximum tsunami water level near the Millstone site. The NRC staff's upper limit of the flood hazard elevation falls in the range of those reported in the FHRR in the vicinity of the site for the tsunami source. The NRC staff therefore concludes, that the licensee's tsunami flood hazard elevation of 14.7 ft. NGVD29 at the Millstone site is reasonable.

The NRC staff reviewed the methodologies used by the licensee to determine the severity of the tsunami phenomena reflected in this analysis and noted that they are consistent with present-day methodologies and guidance. In the context of the above discussion, the staff finds the licensee's analysis and use of these methodologies acceptable.

In summary, the NRC staff confirmed the licensee's conclusion that the tsunami-generated flood height would inundate the Millstone, Unit 2, site to depths of one foot or less and would not inundate the Unit 3 site. The NRC staff confirmed that the reevaluated hazard for flooding from tsunami is not bounded by the CDB flood hazard for Unit 2. Therefore, the NRC staff expects that the licensee will submit either a focused evaluation or a revised integrated assessment for flooding from tsunami.

3.8 Ice-Induced Flooding

The licensee reported in its FHRR that the reevaluated hazard for ice-induced flooding could not inundate the Millstone site, however a maximum flood elevation was not reported for this hazard mechanism.

For the reevaluated analysis of ice-induced flooding, the licensee searched for historical ice events in the USACE Ice Jam Database (USACE, 2012). The licensee found no records for waterways adjacent to the site (i.e., the Niantic River, CN or LIS). The licensee also considered the salinity of the waters for the Niantic River, which would depress the freezing point. The Amtrak Niantic River Bridge is the closest structure upstream that could produce an ice jam. Using the bridge clearance height of 16 ft. as the potential height of an ice jam, the licensee used dam breach equations (Wahl, 2004), along with Manning's equation, to estimate the discharge and water level rise from an ice jam failure. The analysis estimated the peak flow to be 12,645 cfs producing a water level rise of 2.9 ft. Assuming a mean tidal level, the resulting WSE would be well below the site grades of Millstone, Units 2 and 3.

The NRC staff examined the USACE Ice Jam Database (USACE, 2018) and confirmed that no records of ice jams are available for the Niantic River and LIS. The staff also examined the topographic map of the site (USGS, n.d.-a) and identified the Amtrak (CONRAIL) track along the Bar that crosses the mouth of the Niantic River and noted the opening to be roughly 200 ft. wide. The staff reviewed the licensee's analysis of peak discharge and water level rise from a hypothetical ice jam failure and found it reasonable.

The NRC staff also made an independent bounding estimate of the effect of a potential ice-jam failure using a similar approach as made by the licensee. However, using an estimate of the upper bound of discharge from the dam failure based on the maximum estimate of uncertainty in (Wahl, 2004), staff computed a rise in water level of 6.5 ft. While this rise is larger than what was computed by the licensee, it is well below the site grade elevations of Millstone, Units 2 and 3.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for ice-induced flooding could not inundate the Millstone 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 Millstone.

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 flood elevation. This flood-causing mechanism is discussed in the licensee's CDB, but a flood elevation was not reported.

The licensee examined the historical records to ascertain the presence of diversions of the Niantic River or the small coastal stream adjacent to the site. The licensee compared the 1958 and 2012 topographic maps from the USGS and found the river course to not have changed over the period. The Millstone site is located near the mouth of Niantic Bay with a width of about 2.1 miles. The licensee stated that the high velocity flows exiting the Niantic River that could potentially produce erosion and migration are not likely to be extensive since the flow's momentum would dissipate over the width of the bay. Additionally, the licensee discussed the stability of the foundation material that the various structures are constructed upon and stated that they are stable and are not susceptible to erosion. The licensee concluded that there is no plausible effect of channel diversions or shoreline migration on the safety functions at the Millstone site.

The NRC staff examined the USGS Niantic quad topographic maps from 1934, 1958, 1983, 2012, and 2015 (USGS, n.d.-a) and found that the shorelines between the periods are similar indicating limited or no shoreline erosion. The NRC staff noted in the 2015 topographic map the presence of a shoal upstream of the mouth of the Niantic River which was not shown on previous editions (up through 2012) of the topographic maps of the area. This is likely due to a change in mapping methods of shallow waters.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from channel migrations or diversions could not inundate the Millstone site and 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 Millstone.

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's 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 tsunami are the flood-causing mechanisms not bounded by the CDB. The NRC staff anticipates the licensee will submit a focused evaluation for LIP and either a focused evaluation or a revised integrated assessment for flooding from tsunami.

The licensee's analysis of the storm surge flood-causing mechanism is not yet completed and is under ongoing review by staff. Staff's review of the storm surge hazard mechanism and assessment of plant response will be finalized following submittal by the licensee of their final documentation of the analyses, which is currently anticipated in December 2018.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

By letter dated June 28, 2017 (Dominion, 2017c), the licensee submitted its MSA, which included the FED parameters for the LIP flood hazard. The tsunami flood hazard did not require any changes to the mitigating strategies, so no FED parameters were provided. The NRC staff's review and conclusions regarding the FED parameters provided in the MSA have not yet been completed because the storm surge and combined effects analyses and reviews are ongoing.

4.3 Associated Effects for Hazards Not Bounded by the CDB

By letter dated June 28, 2017 (Dominion, 2017c), the licensee submitted its MSA, which included the AE parameters for the LIP hazard. The tsunami flood hazard did not require any changes to the mitigating strategies, so no AE parameters were provided. The NRC staff's review and conclusions regarding the AE parameters provided in the MSA have not yet been completed because the storm surge and combined effects analyses and reviews are ongoing.

4.4 Conclusion

Based upon the preceding analysis, the NRC staff confirmed that the reevaluated flood hazard information defined in Section 4.1 was 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.

The licensee developed FED parameters and applicable flood AEs to conduct future additional assessments as discussed in NEI 12-06, Revision 2, Appendix G (NEI, 2015), JLD-ISG-2012-05 (NRC, 2012d), and JLD-ISG-2016-01, Revision 0 (NRC, 2016b). The NRC staff review and conclusions for the FED and AE parameters, which were provided in the MSA (Dominion, 2017c), and any subsequent update will be documented separately from this staff assessment.

5.0 CONCLUSION

The NRC staff reviewed the information provided for the reevaluated flood-causing mechanisms for Millstone. Based on the review of the above available information provided in Dominion's 50.54(f) response (Dominion, 2015), the NRC staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

Based 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. In reaching this determination, the NRC staff confirmed the licensee's conclusions that (a) the reevaluated flood hazard results for LIP and tsunami are not bounded by the CDB flood hazard, (b) additional assessments of plant response will be performed for LIP and tsunami, 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 Dominion's 50.54(f) response for the non-probabilistic storm-surge analysis flood hazard mechanisms. The NRC staff's review and conclusions regarding probabilistic storm surge and combined effects have not yet been completed because the analyses and reviews are ongoing.

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 14 ft. NGVD29 for Unit 2 and 24 ft. NGVD29 for Unit 3 [1]	ELEVATION, ft. NGVD29 [2]
Local Intense Precipitation and Associated Drainage Unit 2 Unit 3	 17.5 24.8
Storm Surge[2] Unit 2 Unit 3	 Under Review Under Review
Tsunami Unit 2 Intake	 14.7 14.7

[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]The storm surge elevation includes the combined effects with wind-wave activity.

Table 3.1-2. Current Design Basis Flood Hazards

Flooding Mechanism	Stillwater Elevation (ft. NGVD29)	Waves/Runup	Design Basis Hazard Elevation (ft. NGVD29)	Reference
Local Intense Precipitation				
Unit 2	14.5	Minimal	14.5	FHRR Table 1.2-1
Unit 3 RWST/SIL Valve Enclosure	24.9	Minimal	24.9	FHRR Tables 1.2-3 and 3.0-3
Unit 3 Demineralized Water Storage Tank Block House	24.9	Minimal	24.9	FHRR Table 1.2-3
Unit 3 Fuel Building	24.9	Minimal	24.9	FHRR Table 1.2-3
Unit 3 Auxiliary Building Door A-24-6	24.9	N/A	24.9	FHRR Table 3.0-3
Unit 3 Engineered Safety Features Building	24.9	Minimal	24.9	FHRR Table 1.2-3
Unit 3 Hydrogen Recombiner Building	24.9	Minimal	24.9	FHRR Table 1.2-3
Unit 3 Main Steam Valve Building	24.9	Minimal	24.9	FHRR Table 1.2-3
Unit 3 Emergency Generator Enclosure	24.3	Minimal	24.3	FHRR Table 1.2-3
Unit 3 Auxiliary Building Door A-24-1	24.9	Minimal	24.9	FHRR Table 3.0-3
Unit 3 Control Building	24.3	Minimal	24.3	FHRR Table 1.2-3
Streams and Rivers				
Unit 2	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 1.2-1
Unit 3	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 1.2-2
Failure of Dams and Onsite Water Control/Storage Structures				
Unit 2	Not included in design basis	Not included in design basis	Not included in design basis	FHRR Sections 2.3.3 & 3.3
Unit 3	Not included in design basis	Not included in design basis	Not included in design basis	FHRR Sections 2.3.3 & 3.3
Storm Surge				
Unit 2 within Intake Structure	26.5	Not applicable	26.5	FHRR Sections 1.5 and 3.4

Unit 2 at the Powerblock	18.1	7.0	25.1	FHRR Section 3.9 and FHRR Tables 1.2-1 and 3.0-1
Unit 3 seaward wall of Intake Structure	19.7 ft.	21.5	41.2 ft.	FHRR Section 3.9
Unit 3 at Powerblock	19.7	4.1	23.8	FHRR Section 1.5 and FHRR Table 1.2-2
Seiche				
Unit 2	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 1.2-1
Unit 3	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 1.2-2
Tsunami				
Unit 2	Not included in design basis	Not included in design basis	Not included in design basis	FHRR Table 1.2-1
Unit 3	Not included in design basis	Not included in design basis	Not included in design basis	FHRR Table 1.2-2
Ice-Induced				
Unit 2	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 1.2-1
Unit 3	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 1.2-2
Channel Migrations or Diversions				
Unit 2	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 1.2-1
Unit 3	No Impact on the Site Identified	No Impact on the Site Identified	No Impact on the Site Identified	FHRR Table 1.2-2

Note 1: Reported values are rounded to the nearest one-tenth of a foot.

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

Flood-Causing Mechanism	Stillwater Elevation (ft. NGVD29)	Waves/Runup	Reevaluated Hazard Elevation (ft. NGVD29)	Reference
Local Intense Precipitation				
Unit 2	17.5	Minimal	17.5	FHRR Section 3.1
Storm Surge				
Unit 2	UNDER REVIEW	UNDER REVIEW	UNDER REVIEW	UNDER REVIEW
Unit 3	UNDER REVIEW	UNDER REVIEW	UNDER REVIEW	UNDER REVIEW
Tsunami				
Unit 2	14.7	Not applicable	14.7	FHRR Section 2.6
Unit 3	14.7	Not applicable	14.7	FHRR Section 2.6

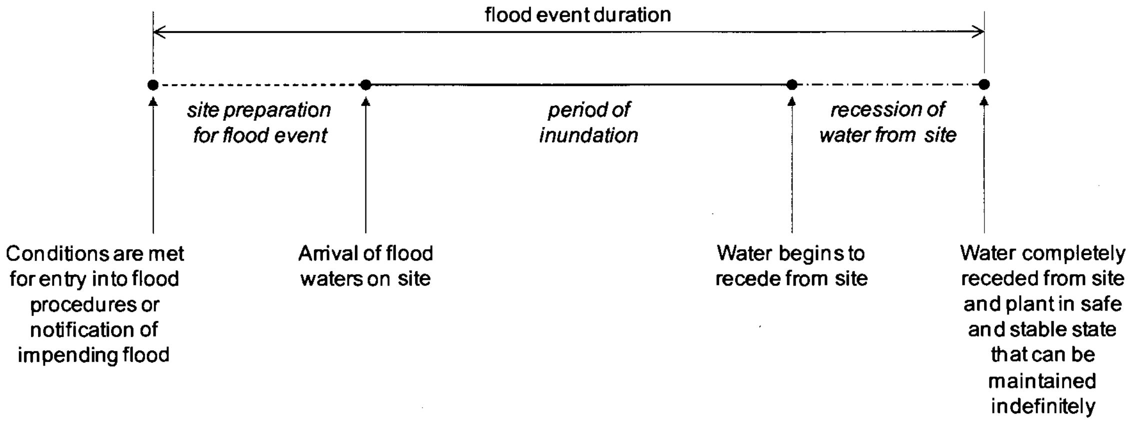

Figure 2.2-1 Flood Event Duration
(Source: JLD-ISG-2012-05 (NRC, 2012c), Figure 6.)

Figure 3.1-1. Millstone Power Station site and vicinity. (Source: Dominion 2015a, Figure 2.1-2).

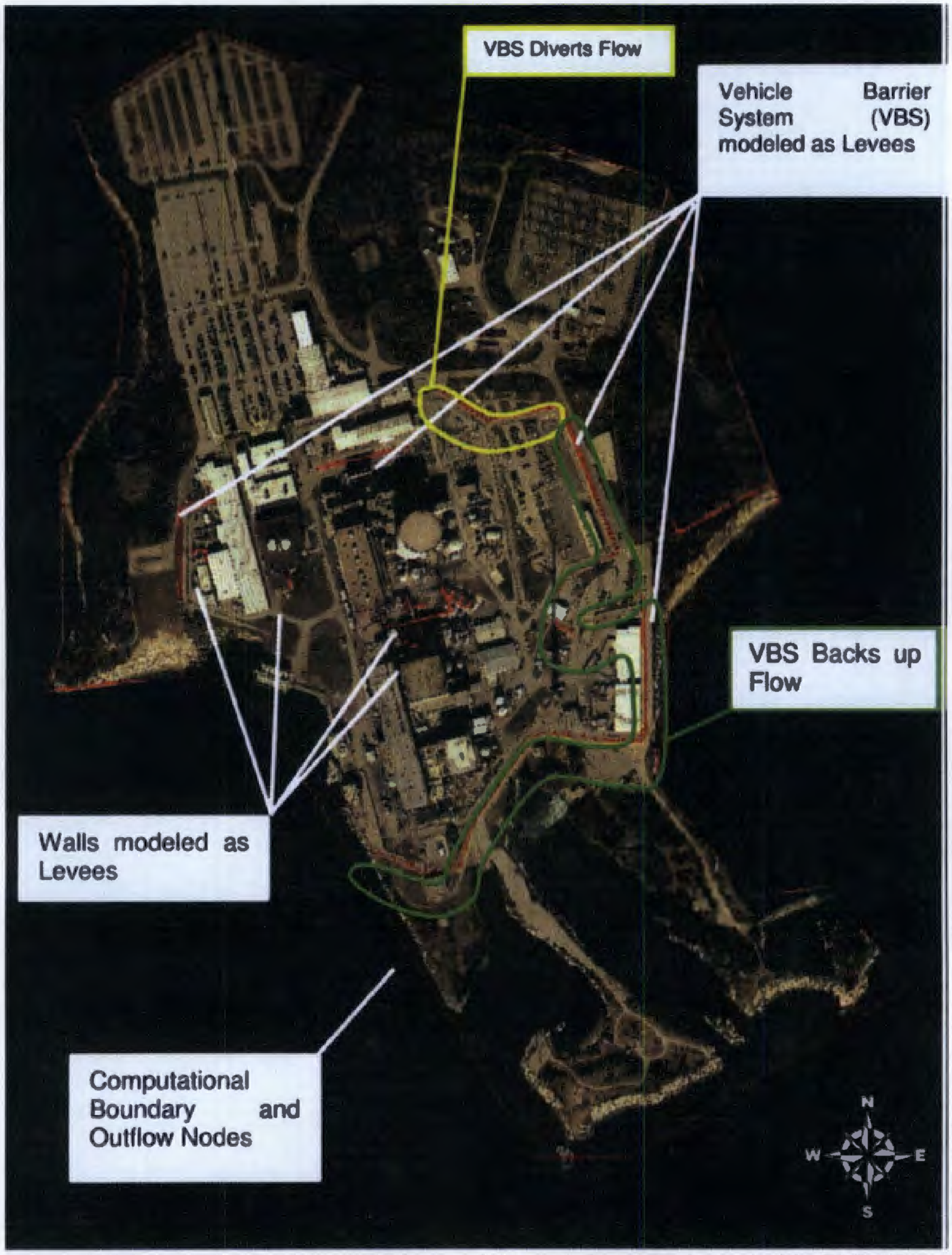

Figure 3.2-1. Locations of boundaries and "levee" features included in FLO-2D modeling of Millstone Power Station site. (Source: Dominion, 2015, Figure 2.1-3).

Figure 3.2-2. Manning's n values used in FLO-2D modeling of Millstone Power Station site. (Source: Dominion, 2015, Figure 2.1-4).

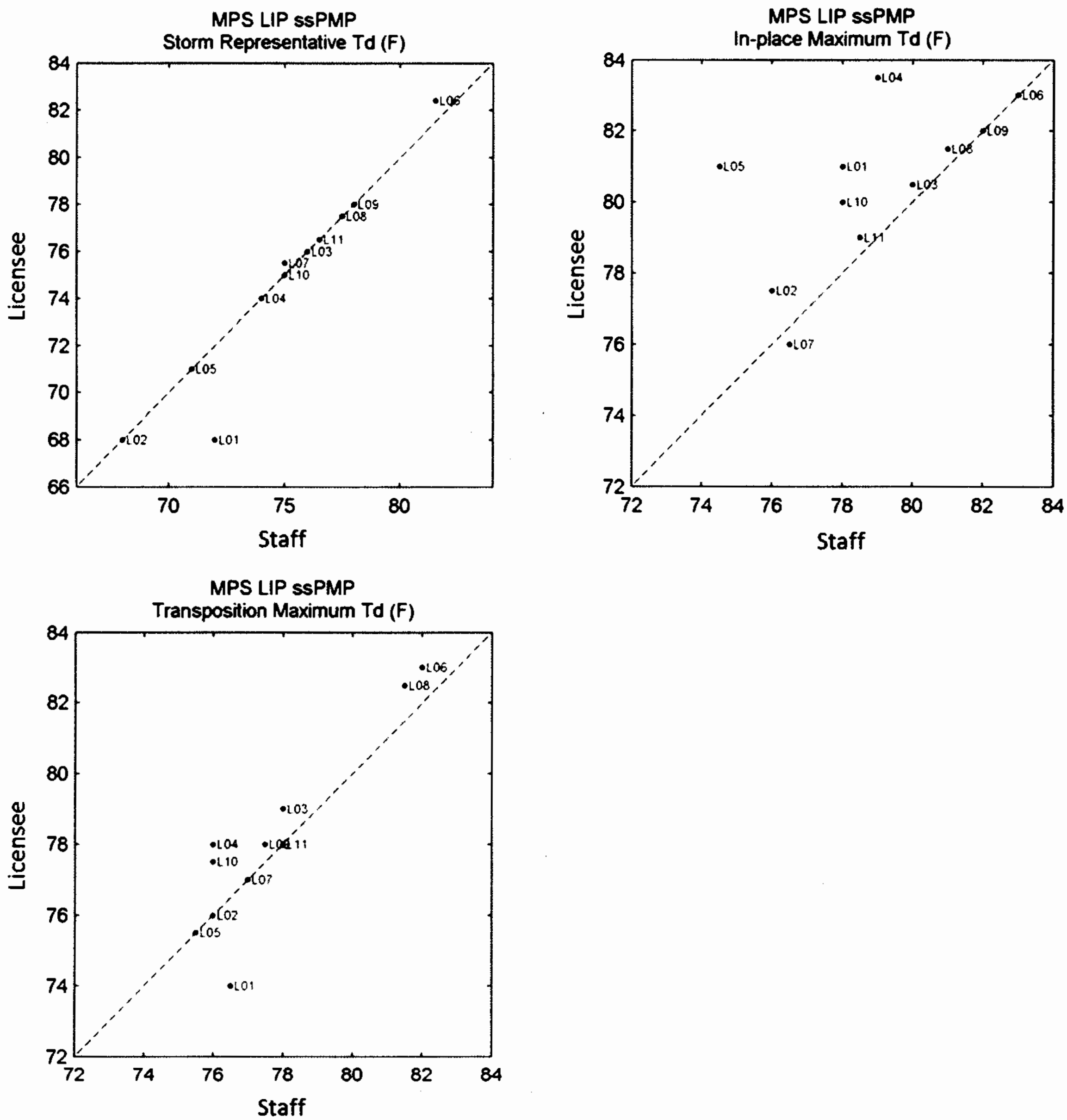

Figure 3.2-3 Comparison of AWA- and NRC staff- computed storm representative, in-place maximum, and transpositioned maximum dew point values

SUBJETC: MILLSTONE POWER STATION UNITS 2 AND 3 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (EPID NOS. 000495\05000336\L-2015-JLD-0011 AND 000495\05000423\L-2015-JLD-0012) OCTOBER 3, 2018

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