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

February 14, 2018

Vice President, Operations
Entergy Nuclear Operations, Inc.
Palisades Nuclear Plant
27780 Blue Star Memorial Highway
Covert, MI 49043-9530

SUBJECT: PALISADES NUCLEAR PLANT – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NO. MF6128: EPID L-2015-JLD-0003)

Dear Sir or Madam:

By letter dated March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information under 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 11, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15114A209), Entergy Nuclear Operations, Inc. (Entergy, the licensee) responded to this request for Palisades Nuclear Plant (Palisades).

By letter dated December 23, 2015 (ADAMS Accession No. ML15356A765), the NRC staff sent Entergy the interim staff response (ISR) of the licensee's reevaluated flood-causing mechanisms. Also, by letter dated August 3, 2016 (ADAMS Accession No ML16174A248), the NRC staff sent Entergy a report for the audit of the flood hazard reevaluation documents. The enclosed staff assessment provides the documentation supporting the NRC staff's conclusions summarized in the ISR letter. As stated in the enclosed staff assessment, the reevaluated flood hazard result for local intense precipitation and storm surge are not bounded by the current design basis flood hazard.

This closes out the NRC's efforts associated with CAC No. MF6128.

If you have any questions, please contact me at (301) 415-2864 or e-mail at Milton.Valentin-Olmeda@nrc.gov.

Sincerely,

Milton Valentin-Olmeda, Project Manager
Beyond-Design-Basis Management Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket No. 50-255

Enclosure:
Staff Assessment of Flood Hazard
Reevaluation Report

cc w/encl: Distribution via Listserv

STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO FLOODING HAZARD REEVALUATION REPORT

NEAR-TERM TASK FORCE RECOMMENDATION 2.1

PALISADES NUCLEAR PLANT

DOCKET NO. 50-255

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 Review of Insights from the Fukushima Dai-ichi Accident (NRC, 2011b)[1]. 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 the Flood Hazard Reevaluation Report (FHRR) deadlines for each plant. On May 11, 2012 (NRC, 2012c), the NRC staff issued its prioritization of the FHRRs.

By letter dated March 11, 2015 (Entergy, 2015), Entergy Nuclear Operations, Inc. (Entergy, the licensee) provided the FHRR for Palisades Nuclear Plant (Palisades). The NRC staff conducted a site audit as documented in the audit report (NRC, 2016c).

On December 23, 2015 (NRC, 2015b), 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 are not bounded by the plant's current design basis (CDB). Consistent with the 50.54(f) letter and amended by the process outlined in COMSECY-15-0019 (NRC, 2015a), Japan Lessons-Learned Division (JLD) Interim Staff Guidance (ISG)

[1] Issued as an enclosure to Commission Paper SECY-11-0093 (NRC, 2011a).

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. For the storm surge 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).

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 or revised integrated assessments. By letter dated December 19, 2016 (Entergy, 2016), 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 the 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 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 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 flooding-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 (NRC, 2012a) discusses flood-causing mechanisms for the licensee to address in the FHRR. 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, 2012d), in addition to the maximum water level associated with each flood-causing mechanism. 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 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 these individual flood-causing mechanisms are less severe than their worst-case occurrence, their combination may still exceed the most severe flooding effects from the worst-case occurrence of any single mechanism described in the 50.54(f) letter (see SRP Section 2.4.2, Areas of Review (NRC, 2007)). Attachment 1 of the 50.54(f) letter describes the "combined effect flood" as defined in American National Standards Institute/American Nuclear Society (ANSI/ANS) 2.8-1992 (ANSI/ANS, 1992) as follows:

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

If two less severe mechanisms are plausibly combined per ANSI/ANS-2.8-1992 (ANSI/ANS, 1992), then the 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 should be plausibly combined.

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 elevation is not bounded by the CDB flood 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 Palisades site. The licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews. To provide additional information in support of the summaries and conclusions in the 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) includes SSCs important to safety in the scope of the hazard elevation. The licensee included this pertinent data concerning these SSCs in the FHRR (Entergy, 2015). The licensee provided this additional information during an audit that was conducted with the licensee via a teleconference on November 9, 2015. This information was summarized in the NRC staff's audit report (NRC, 2016c). The NRC staff reviewed and summarized this information in the sections below.

3.1.1 Detailed Site Information

The Palisades FHRR described the site-specific information related to the flood hazard reevaluation. All elevations in this staff assessment are relative to National Geodetic Vertical Datum of 1929 (NGVD29); NRC staff converted from other datums when necessary. The licensee used NGVD29, mean sea level (MSL), International Great Lakes Datum of 1985 (IGLD85) and Plant Datum for elevations in the FHRR (Entergy, 2015). The licensee stated in its FHRR that elevation values relative to NGVD29, MSL and Plant Datum are equal and elevations in IGLD85 are converted to NGVD29 by adding 0.9 feet (ft.). All elevations in this staff assessment are relative to NGVD29; the NRC staff used the licensee's conversion factor before rounding elevations to the nearest tenth of a foot and hundredth of a meter. Site, regional and local scale features are shown in Figures 3.1-1 and 3.1-2 for reference in subsequent sections of this report.

The Palisades site (432 acres), is located in Van Buren County, Michigan, approximately 4.5 miles (mi.) south of South Haven, Michigan (Figure 3.1-2). The Palisades site drainage basin (13.9 acres) which contributes flow past the Palisades facilities covers a small portion of the entire Palisades site; the remainder drains to Lake Michigan (Figures 3.1-2 and 3.1-3). The Palisades site is bordered on the west by Lake Michigan and on the remaining sides by sand dunes, which extend several miles to the east of the site. There are no perennial streams at the Palisades site. The licensee stated that the nearest stream to the Palisades site is Brandywine Creek, which is hydrologically isolated from the Palisades site by sand dunes (Entergy, 2015) (Figure 3.1-3).

The site grade at the powerblock is elevation 625 ft. NGVD29 at the upper level of the Palisades site. Table 3.0-1 summarizes the controlling reevaluated flood-causing mechanisms, including associated effects, the licensee computed to be higher than the powerblock elevation.

3.1.2 Design-Basis Flood Hazards

The CDB flood levels are summarized by flood-causing mechanism in Table 3.1-1. The CDB included the flood hazards from LIP in terms of ponding depths, and storm surge stillwater elevation. The CDBs for probable maximum flood (PMF) on rivers and streams, dam breaches and failures, tsunami, ice-induced flooding, channel migration and combined effects were not defined or addressed at the Palisades site (Entergy, 2015).

The during the FHRR audit the licensee stated for the purposes of the Palisades FHRR, CDB and current licensing basis (CLB) have the same meaning (NRC, 2016c). In this NRC staff assessment, the NRC staff adopted the use of CDB. The NRC staff reviewed the information provided in the FHRR (Entergy, 2015) and determined that it is sufficient to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.3 Flood-Related Changes to the Licensing Basis

The licensee stated that the licensing basis related to the safe shutdown flood level was lowered from 594.7 ft. NGVD29 to 594.4 ft. NGVD29 (Entergy, 2012a). The licensee stated that the "limiting component important to safety" had been changed from the service water pump motor windings to the motor lower bearing lube oil reservoir, which is at the lower elevation (Entergy, 2015). The NRC staff reviewed the information provided in the FHRR (Entergy, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.4 Changes to the Watershed and Local Area

The licensee stated that its review of the Brandywine Creek (nearest stream to the Palisades site) watershed topography revealed no significant watershed changes from the mid-1960s to 2011 (Figure 3.1-3). The licensee stated that the Palisades site drainage is independent of the Brandywine Creek watershed (Entergy, 2015). The licensee stated that the addition and relocation of security barriers has occurred and assessed the potential impact of these changes as part of the LIP reevaluation. The NRC staff reviewed the information provided in the FHRR (Entergy, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The licensee stated in its FHRR (Entergy, 2015) that: 1) Class I structures were designed to be adequate for resisting storm surge effects, 2) the Intake Structure was designed to be able to withstand the effects of up to about 8 ft. of wave runup, 3) the Containment Building is watertight, 4) marine-type watertight doors protect important-to-safety equipment up to a flood elevation of 594.4 ft. NGVD29, and 5) Class I structures are designed against the PMF. The licensee stated in the FHRR that ponding was assumed to occur as a result of the LIP on the east side of the Service Building to a depth of 5 ft. as part of the CDB. The licensee stated that because the Service Building is not a Class I structure, its design was not evaluated in the FHRR against the LIP ponding. However, the licensee included the ponding depth in the CDB.

The licensee stated in its FHRR that other than the site topography and the site drainage systems, the credited flood protections features at the Palisades site include: 1) the wall and floors of the Auxiliary Building, Turbine Building and Screen House/Intake Structure and penetration seals through exterior walls, 2) the concrete top for the T-10A, and tank penetration caps, 3) watertight doors in the Auxiliary Building and Turbine Building, and 4) check valves in the Auxiliary Building. The NRC staff reviewed the information provided in the FHRR (Entergy, 2015) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee reported updated topographic information based on a 2014 aerial light detection and ranging (LiDAR) survey and high resolution orthoimagery. The licensee used the information derived from this topographic survey to develop the reevaluated flood hazard estimates.

3.1.7 Results of Plant Walkdown Activities

The 50.54(f) letter (NRC, 2012a) requested that the licensees plan and perform plant walkdown activities to verify that current flood protection systems are available, functional, and implementable.[2] 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 (Entergy, 2012b), Entergy provided the flood Walkdown Report for the Palisades site. The NRC staff issued a staff assessment on June 17, 2014 (NRC, 2014), which documented its review of the Flooding 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 (Entergy, 2015) that the reevaluated flood hazard for LIP and associated site drainage is based on the stillwater water surface elevation (WSE) at the safety-related structures. The WSE ranges from 592.5 ft. NGVD29 near the North Entrance to the Screen House/Intake Structure to 626.1 ft. NGVD29 at the Administration Building Hallway East Entrance of the plant. The maximum flood depths of 9.8 ft. or WSE of 605.8 ft. NGVD29 were calculated to occur on the east side of the Service Building. The maximum flood depth ranged from 1.0 to 5.3 ft., or a WSE range from 592.5 to 626.1 ft. NGVD29, in the rest of the powerblock with varying ground surface elevations. Locations of the safety-related structures are presented in Figure 3.2-1.

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 flood protection elevation of 594.4 ft. NGVD29, and maximum flood depths of 5 ft. (corresponding to an WSE of 601.0 ft. NGVD29) on the east side of the Service Building and less than 0.5 ft. in the rest of the powerblock with varying ground surface elevations.

The NRC staff sought clarification from the licensee to supplement the FHRR. The licensee provided information to clarify NRC questions during a site audit conducted on November 9, 2015. The audit summary (NRC, 2016c) was docketed and is discussed in the appropriate sections below.

3.2.1 Probable Maximum Precipitation

The licensee considered the 1-h, 1-mi^2, and the 6-h, 10-mi^2 probable maximum precipitation (PMP) events for the LIP event as suggested in NUREG/CR-7046, "Design-Basis Flood

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[2] Enclosure 4, Requested Actions, Item 1 and Enclosure 4, Requested Information, Item 2.

Estimation for Site Characterization at Nuclear Power Plants in the United States of America" (NRC, 2011e). The total rainfall depths for the 1-h PMP and 6-h PMP were derived using the methods described in Hydrometeorological Reports (HMR) 51 and HMR 52 (National Oceanic and Atmospheric Administration (NOAA), 1978 and 1982). The estimated 1-h PMP is 17.3 in. with a peak intensity of 5.85 in during the first 5 minutes of the event. The 6-hour (h) PMP rainfall depth is 25.5 in. with a hyetograph distribution using the 1-h PMP for the first hour and equal rainfall increments for the subsequent 5 hours. The NRC staff reviewed the HMR 51 and HMR 52 calculations based on the location of Palisades and confirms that the PMP depths are appropriate.

3.2.2 LIP Model Construction

The licensee performed the LIP analysis using the two-dimensional (2D) hydrodynamic FLO-2D model, build version 14.03.07 (FLO-2D, undated), for the Palisades FHRR (Entergy, 2015). The following key assumptions were made in the FLO-2D model: (a) all the storm water drainage structures are completely blocked during the LIP event and not included in the model and (b) buildings are assigned as elevated grid elements to ensure that precipitation on building roofs flows off the building to the surrounding ground and the overland flow runs around the buildings.

The NRC staff reviewed these assumptions and concludes that they are conservative and consistent with guidance in NUREG/CR-7046 (NRC, 2011e) and ANSI/ANS 2.8 (ANSI/ANS, 1992). The FLO-2D model was constructed using the ground surface topography, a digital terrain model (DTM), developed from an aerial survey using LiDAR technology (Entergy, 2015). The vertical datum of the DTM was converted from North American Vertical Datum of 1988 (NAVD88) to NGVD29 to make the elevation data from various sources consistent in the FLO-2D model. The NRC staff reviewed the conversion and confirms it is correct.

The FLO-2D model domain covers the entire site, including the power block area, switchyard, parking lots, and some upstream contributing areas. In the model, the licensee used a grid cell size of 10 ft. by 10 ft. to incorporate detailed site structures. The NRC staff reviewed the model domain and grid size and agrees that they are reasonable for FLO-2D modeling of the site.

The FLO-2D model includes inland and lake boundaries. The licensee assigned a normal depth flow to the grid elements along the inland boundary and a constant stage for the model boundary condition along Lake Michigan. In its FHRR, the licensee conservatively determined the constant lake elevation based on the highest recorded monthly-mean elevation of Lake Michigan, 583.2 ft. NGVD29. The licensee used this value as a "reservoir water elevation", a feature of the FLO-2D model, assigned as a model boundary condition to all grid elements in the Lake Michigan portion of the model. The NRC staff examined the licensee's model input files and found that no "reservoir water elevation" was assigned in the model. The licensee revised its FLO-2D model by assigning maximum monthly mean lake level of 583.2 ft. NGVD29 over a surface depression zone close to the model's western boundary. The licensee demonstrated that adding the lake boundary condition to this portion of the FLO-2D model has a minimal effect on the maximum WSE at critical locations (NRC, 2016c); these locations were identified as critical in the FHRR (Entergy, 2015) and shown in Figure 3.2-1.

The NRC staff reviewed the revised input and output files and found that the reservoir assigned in the model was filled up to the specific lake level (583.2 ft. NGVD29) within the first time step (0.1 hour), but was not maintained at the specified lake level for the rest of the simulation period (24 hours). The lake level dropped by about 2 ft. through the simulation period. Therefore, the NRC staff determined that using the reservoir method to define the boundary condition along the lake in a FLO-2D model does not correctly reflect a constant lake stage over the LIP event as assumed by the licensee. The NRC staff performed an independent run by using the stage-time relationship function available in the FLO-2D model. In this approach, the specified lake level is maintained at 583.2 ft. NGVD29 throughout the simulation period. The NRC staff's examination of results from this model run indicate that the maximum WSEs at the critical locations have a minimal increase. On the basis of the results, the NRC staff agrees with the licensee's conclusion regarding minimal effects of the lake boundary on the critical locations.

The highest recorded monthly mean elevation of Lake Michigan (582.3 ft. NGVD29) at the Palisades site was derived from the NOAA Holland tide station 31 miles north of the site, which was reported relative to IGLD85. The NRC staff examined the locations of other NOAA tide stations (Ludington, MI about 90 mi. north of the site; Calument Harbor, IL about 75 mi. southwest of the site; and Milwaukee, WI about 94 mi. northwest of site) in the southern portion of Lake Michigan. Of these, the NRC staff found that the Holland tide station is the closest to the Palisades site and the only NOAA station that, like the Palisades site, is located on the eastern lake shore. The NRC staff reviewed the licensee's conversion of the vertical datum from IGLD85 to NAVD88 and then NGVD29 and found that the conversion from IGLD85 to NAVD88 is location dependent. However, the error due to the incorrect elevation used by the licensee is less than 0.2 ft. The NRC staff agrees that this difference in lake level would not affect the WSEs at the critical locations at the Palisades site.

3.2.3 LIP Model Parameters

The licensee assigned elevated grid elements for buildings/barriers in FLO-2D model. The NRC staff compared the model grid map showing plant structures and barriers with Google Earth aerial imagery (Google Earth, not dated (n.d.); image taken on August 22, 2013), and found that major buildings and barriers are well represented in the model.

For LIP analysis, the licensee considered the selected infiltration process (initial and constant losses) in FLO-2D model using the Soil Conservation Service (SCS) curve number (CN), which is identified based on a combination of land use type, hydrological soil group type, and hydrological conditions and is further adjusted to the saturated soil condition (Antecedent Runoff Condition III). Although the CN method is commonly used to approximate the infiltration loss rate, guidance in NUREG/CR-7046 (NRC, 2011e) suggests using minimum infiltration loss rates recommended by the Federal Energy Regulatory Commission (FERC) (FERC, 2001), if the estimated infiltration loss rate cannot be validated. During the audit, the licensee estimated an overall constant infiltration loss rate, which is the difference between total infiltration loss and initial loss over the period of the LIP event. Based on the total infiltration loss computed by the FLO-2D model for the LIP event and initial loss estimated by a composite CN for all grid elements in the FLO-2D model, the licensee confirmed that the overall constant infiltration loss rate (0.44 in./h) is within the range of 0.3 to 0.45 in./h for soil type "A" recommended by FERC (FERC, 2001) (NRC, 2016c). The total infiltration depth computed in the FLO-2D model is 3.23 in. (13 percent of PMP). Considering the conservative nature of the HMR PMP and that the total infiltration depth is a small fraction of PMP depth, the NRC staff agrees that the infiltration loss rate estimated using CN method in the FLO-2D model is reasonable.

In order to determine the Manning's n roughness coefficients, the licensee identified the land cover types and their extents based on high resolution orthoimagery (Entergy, 2015). For each specific land cover type, the licensee considered the suggested n-value ranges in the FLO-2D Reference Manual (FLO-2D, undated) and then assigned appropriate n values to the grid elements from 0.05 for concrete or paved areas to 0.4 for trees and brush areas. The NRC staff reviewed the site in Google Earth imagery (Google Earth, n.d.; taken on August 22, 2013), and determined that the selected Manning's n is reasonable.

3.2.4 LIP Model Results

The model results for the LIP analysis indicate that the maximum WSEs at the Palisades site range from 592.5 ft. NGVD29 near the North Entrance to the Screen House/Intake Structure (See Figure 3.2-1; location 20) to 626.1 ft. NGVD29 at the Administration Building Hallway East Entrance (see Figure 3.2-1; location 35). The licensee evaluated 15 critical locations as shown in Figure 3.2-1 and found that most of them have maximum WSEs below the protection elevation of 594.4 ft. NGVD29, except for four that are located at ground surface above 594.4 ft. NGVD29. The maximum water depths at these four locations ranges from 1.0 ft. to 2.2 ft.

The simulated maximum flood depths are 9.8 ft. on the east side of the Service Building and 1.0 ft. to 5.3 ft. in the rest of the powerblock. The CDB for LIP event includes maximum flood depths of 5 ft. on the east side of the Service Building and less than 0.5 f.t in the rest of the powerblock. On the basis of maximum flood depths computed from the FLO-2D model, the reevaluated LIP flood hazard is not bounded by the CDB.

3.2.5 Conclusion

The licensee performed a LIP analysis for the Palisades site using a two-dimensional hydrodynamic model, FLO-2D. The NRC staff reviewed the analysis and concluded that the licensee's approach is consistent with present-day methodologies and regulatory guidance for the LIP analysis.

The NRC staff confirms the licensee's conclusion that the reevaluated flood hazard for LIP and associated site drainage is not bounded by the CDB flood hazard. Therefore, the NRC staff expects that the licensee will submit a focused evaluation for LIP and associated site drainage for the Palisades site.

3.3 Streams and Rivers

The licensee reported in its FHRR that the reevaluated hazard for streams and rivers does not inundate the plant site, but did not report a maximum flood elevation. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee stated in its FHRR that there are no perennial streams that drain the Palisades site. The licensee based its conclusion on the examination of the site terrain. The licensee stated in its FHRR that flooding from local drainage courses at the Palisades site was evaluated during the reevaluation of the LIP flooding mechanism as discussed in Section 3.2 of this report.

The NRC staff reviewed the information presented by the licensee and evaluated it against the topographic and hydrographic information provided by the online U.S. Geological Survey (USGS) mapping tool, the National Map Viewer (USGS, n.d.-a). The NRC staff determined that the licensee appropriately delineated the site drainage area and determined a lack of persistent streams based on staff's review of USGS information.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from streams and rivers could not inundate the plant site. Therefore, the NRC staff determined that flooding from streams and rivers 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 does not inundate the plant site, but did not report a maximum flood elevation. This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee discussed the failure of dams on the Great Lakes and the interconnections between the five Great Lakes in the FHRR. The licensee stated that Lake Huron flows into Lake Michigan, on which the Palisades site is located, and these two lakes function as one based on their hydraulic connection.

The licensee referenced literature that concluded that the water diversions to, and from, these water bodies had an insignificant impact on the WSE within them (U.S. Army Corp of Engineers (USACE), 1999). The licensee assumed that water controls limiting flow to Lake Michigan fail and therefore maximize flow into Lake Michigan. The licensee determined this would result in a 5.0 ft. rise in Lake Michigan WSE, which would then return to its pre-man-made control value. The licensee added this to the maximum recorded lake WSE of 583.2 ft. NGVD29 for a flood hazard level due to these failures of 588.2 ft. NGVD29. During the FHRR audit, the licensee confirmed that there are no onsite water control/storage structures located on the Palisades site (NRC, 2016c).

The NRC staff confirmed the licensee's conclusion that the reevaluated flood hazard for failure of dams and onsite water control or storage structures could not inundate the plant site. Therefore, the NRC staff determined that flooding due to dam failure 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 593.1 ft. NGVD29 and a wave setup of 0.8 ft., resulting in a combined Stillwater elevation of 593.9 ft. NGVD29. The licensee stated that "Floods along shores of enclosed water bodies (NUREG/CR-7046 Scenario H.4)" was the controlling combined event which is discussed in this NRC staff assessment under the storm surge section. The H.4 scenario is the probable maximum storm surge (PMSS) with wind-wave activity and the 100-year Lake Michigan water surface elevation (Entergy, 2015). Including wind waves and runup results in a maximum total WSE elevation of 602.2 ft. NGVD29 at the lakeward side of the circulation water pipes with lower peak total WSEs at other site locations (e.g., landward of circulation water pipes, landward of the turbine building and north of the turbine building).

This flood-causing mechanism is discussed in the licensee's CDB. The CDB probable maximum flood elevation for storm surge is based on a stillwater-surface elevation of 594.1 ft. NGVD29, and an elevation of 602.1 ft. NGVD29 including wind waves and runup at the lakeward side of the circulation water pipes.

The licensee identified the controlling historic storm for development of the probable maximum wind storm (PMWS) parameters based on review and analysis of the USACE Great Lakes Study (USACE, 2012b), NOAA's National Climatic Data Center (NCDC) water level data from the closest NOAA Tides and Currents station (NOAA, 2014a), and the NOAA National Hurricane Center data (HURDAT2) (NOAA, 2014b). The licensee evaluated storms in accordance with procedures outlined in ANSI/ANS-2.8-1992 to determine the PMWS. The licensee also made adjustments to reach a maximum wind speed 100 mph and minimum atmospheric pressure of 950 mbars as part of the H.4 scenario, thus making the design storm winds and pressure more severe than controlling historical events. This also follows the guidance proposed in ANS-2.8-1922. The licensee used an antecedent 100-year water level of 583.4 ft NGVD29 using lake level data at Holland, Michigan (NOAA, 2014a) to couple with the PMWS for the H.4 scenario.

The licensee's storm surge simulations were performed for the candidate extra-tropical storms identified in the PMWS calculation using the USACE ADvanced CIRCulation (ADCIRC) model (Luettich et al., 1992). The USACE study validated ADCIRC's ability to predict water level at many locations under various conditions, and provided a strong degree of confidence in the model's ability to predict water levels at locations around Lake Michigan (USACE, 2012a).

The licensee determined that the largest extra-tropical storm surge height near the Palisades site was 9.7 ft., which was the result of an extra-tropical storm traveling at 17 mi/h and crossing southern Lake Michigan at a bearing of 45 degrees east from north. The licensee's storm surge stillwater elevation (surge on top of the antecedent water level) was 593.1 ft. NGVD29. The licensee performed wave runup calculations for a combined effect flood (FHRR Section 3.9) using ADCIRC coupled with the Simulating Waves Nearshore (SWAN) as the representation of the H.4 scenario. The licensee added the PMSS stillwater elevation of 593.1 ft. NGVD29 to the ADCIRC/SWAN wave setup value of 0.8 ft. yielding a WSE of 593.9 ft. NGVD29 without inclusion of wave runup. The licensee stated that the resultant maximum combined events (H.4) flood WSE was 594.2 ft. NGVD29 at the Screen House/Intake Structure (FHRR Table 3-14 and FHRR Figure 3-32).

The NRC staff reviewed the set combined effect scenarios (H.1 to H.5) outlined in Appendix H of NRC/CR-7046 (NRC, 2011e). These combinations include floods caused by precipitation events (H.1), by seismic dam failures (H.2), surges along open and semi-enclosed bodies of water (H.3), and surges along the shores of enclosed bodies of water (H.4), and by tsunamis (H.5). The NRC staff agree with the licensee that the lack of stream and rivers, dams, or open or semi-enclosed water bodies near the Palisades site preclude the need for detailed evaluation of the H.1, H.2, and H.3 scenarios. The NRC staff conclude that flooding at the Palisades site due to tsunami events was not significant, which is in agreement with the licensee's conclusion (see Section 3.7), and therefore agree that further evaluation of the H.5 scenario is not warranted. The NRC staff agree that the H.4 scenario is the only remaining applicable combined event at the Palisades site. Therefore, the NRC staff reviewed the combination PMSS and associated wave effects as the controlling combined event.

The NRC staff reviewed the NOAA databases cited by the licensee, including the climatology of Lake Michigan (USACE, 2012a), and confirmed that the controlling storm for PMSS calculations is an extra-tropical storm. The NRC staff concluded that the licensee applied the appropriate storm parameters per ANSI/ANS-2.8-1992 consistent with NRC guidance.

The NRC staff independently ran the NOAA Great Lakes Storm Surge Planning Program (SSPP) model for a sustained wind speed of 100 mi/h and varied the wind direction in 10 degree increments between 10 and 360 degrees to determine the wind direction which results in the greatest surge elevation at the site. The SSPP model is described in Schwab et al. (1981) and Schwab and Lynn (1987). The NRC staff note that the staff's SSPP model is based on a coarser bathymetry, with less site information, and simplified representation of physical process than the licensee reported was incorporated into the ADCIRC model. The NRC staff examined the long-term (1918-2012) monthly maximum Lake Michigan-Huron water levels (USACE, 2012). Based on this examination the NRC staff used a lake level of 583.1 ft. NGVD29 for the antecedent water level. The lake is currently at 580 ft. with a historical maximum of 582 ft. (year 1886) (NOAA, 2016; Canada, 2016; USACE 2012a and 2012b). The resulting SSPP simulations predicted a PMSS maximum stillwater elevation of 594 ft. NGVD29 compared to the licensee's 593.1 ft. NGVD29 using ADCIRC. The NRC staff therefore found that the licensee's PMSS result was reasonable based on the staff's independent use of SSPP.

The NRC staff calculated wave runup heights at the site by applying the methods presented in the USACE Coastal Engineering Manual (USACE, 2008), H.O. Pub. No. 603 (Pierson et al., 1971), World Meteorological Organization-WMO-No. 702 (WMO, 1998) and U.S. Navy (1995). The limited fetch length and storm duration limits the maximum offshore wave height to approximately 22 ft. to 44 ft. The NRC staff confirmed that the maximum wave height observed offshore Lake Michigan was 23 ft. during Hurricane Sandy in October 2012. Nearshore, the gentle beach slope at the Palisades site (Coastal Dynamics, 2008; Table 1, Figures 9-11) dampens the largest waves resulting in spilling breakers. The NRC staff found the mean wave height approaching the Palisades site is approximately 2.5 ft. to 3 ft. with periods in the 4 to 5 second range. During Hurricane Sandy, wave heights of 4 ft. to 8 ft. were observed near the Palisades site during sustained winds in excess of 50 mph. Based on the aforementioned wave characteristics, the NRC staff calculated a maximum wave runup of approximately 1 ft. for a total water level 595 ft. NGVD29 compared to the licensee's reevaluated 594.2 ft., a difference of 0.8 ft. with the NRC staff using a more conservative wind speed. The NRC staff estimated a reasonable maximum wave setup associated with these conditions would be about 10 to 20 percent of the nearshore wave height based on general observations described in FEMA (2014). The NRC staff used a 3.0 to 8.0 ft. mean wave height range to estimate the wave setup range as 0.6 to 1.6 ft. The NRC concluded that the 0.8 ft. wave setup determined by the licensee was reasonable based on the NRC staff's estimated and the reported observation wave height range. The NRC staff therefore concluded that the licensee's total water flood hazard (including wave effects) was reasonable.

In summary, the CDB for storm surge stillwater elevation is 594.1 ft. NGVD29. The licensee's reevaluated stillwater elevation for site flooding due to storm surge is 593.1 ft. NGVD29 (without inclusion of wave setup and runup), and ranges between elevation 593.9 to 602.1 ft. NGVD29 with the inclusion of wave setup and runup. The CDB design wave height is 8-ft, producing a combined CDB total water elevation of elevation 602.1 ft. NGVD29 along the lakeward side of the circulation water pipe. Additional site locations are subject to stillwater plus wave effects at lower total water surface elevations than 602.1 ft., but these locations were not evaluated against the CDB.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from storm surge is not bounded by the CDB flood hazard. Therefore, the NRC staff expects that the licensee will submit a focused evaluation or revised integrated assessment for storm surge.

3.6 Seiche

The licensee reported in its FHRR that the reevaluated hazard for site flooding from seiche would not inundate the site but did not report a maximum flood elevation. This flood-causing mechanism is described in the licensee's CDB as having no impact on the site.

The licensee stated in its FHRR that seiche can occur in Lake Michigan generating elevated stillwater elevations near the Palisades site. The licensee also stated that there are no onsite enclosed water basins on the Palisades site; therefore, the reevaluation focused on Lake Michigan seiches only.

The licensee used the hierarchical hazard assessment approach described in NUREG/CR-7046 (NRC, 2011e) to determine whether a seiche in Lake Michigan could result in flooding of the Palisades site. First, the licensee determined the natural periods of Lake Michigan seiche modes but concluded that the flood hazard elevation from a landslide-induced seiche would not exceed that produced by an initial tsunami wave. Therefore, the licensee screened out landslide-induced seiche as a controlling scenario at the Palisades site. The licensee referenced existing literature (Saylor et al., 1980) to quantify the resonant (i.e. seiche) period (about 4 days) in Lake Michigan precluding the generation of seiche due to earthquakes, which have much shorter periods. The licensee discussed post-surge event seiche generation and concluded that these potential seiche flooding elevations would be less than the initiating surge elevation.

The NRC staff reviewed the licensee's determinations as drawn from the associated literature and confirmed the licensee's statements regarding seiche resonance. The NRC staff used Merian's formulas (USACE, 2008) for closed bodies of water to capture the natural periods along the longitudinal and lateral axis of Lake Michigan. The NRC staff determined that the time periods of events that could cause wave excitations in the estuary were not aligned with the natural periods of the lake. Therefore, constructive interference within the estuary was precluded and seiche growth would not be enhanced from an initiating event such as a storm surge. For Lake Michigan, the seiche period for primary mode oscillation along the lake's long axis is approximately 9 hours while the cross-lake primary-mode period is approximately 2 hours. Typical seiche events last for 1- to 3-days with amplitudes of 1 to 5 ft. (USACE, 2012c). The NRC staff confirmed these seiche periods results based on the use of Merian's formulas. These seiche periods and the durations are consistent with the licensee's statement that the resonant period of Lake Michigan is approximately 4 days (Saylor et al., 1980). The NRC staff concluded that because constructive interference was not indicated any seiche phenomena would be dampened from its initial excitation due to frictional effects. The NRC staff concurs with the licensee's conclusion that seiche events in Lake Michigan would produce water elevations equal to or lower than a reevaluated storm surge event (USACE, 2012c; FEMA, 2014).

The NRC staff confirms that licensee's conclusion that the reevaluated hazard from flooding from Lake Michigan seiche is bounded by the reevaluated hazard from Lake Michigan surge, and would likely by initiated by a surge event. Therefore, flooding from seiche does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.7 Tsunami

The licensee reported in its FHRR that the reevaluated hazard for site flooding from tsunami does not inundate the plant site. This flood-causing mechanism was not included in the CDB.

The licensee based the maximum tsunami evaluation on historical records, databases and relevant scientific literature using available guidance (NRC, 2009). The licensee stated that the Palisades site is an inland site and not subject to oceanic tsunamis, but that tsunami-like waves have occurred within the Great Lakes region based on the licensee identification of historical events described in the Global Historical Tsunami Database (NOAA, 2014c). The licensee noted that these events were attributed to meteorological events, earthquakes, and landslides based on a review of historical information (NOAA, 2014c). The licensee stated that tsunamis generated by earthquakes are limited in magnitude because the required level of seismic activity for development of a significant tsunami is absent within a 100-mile (160-km) radius of the Palisades site. The licensee stated that submarine landslides are unlikely to generate an observable tsunami-like wave due to the limited bathymetric relief of ridges and orientation based on a review of the Lake Michigan bathymetry (NOAA, 2014d).

The licensee added the maximum historical runup of 9.0 ft. identified in the Global Historical Tsunami Database that was not attributed to meteorological forcing and added this to the maximum recorded water level in Lake Michigan (583.2 ft. MSL) to determine a maximum hypothetical tsunami flood hazard elevation of 592.2 ft. MSL, which is 2.2 ft. below the Palisades protection level. The NRC staff confirmed the licensee's search results from the NRC staff's used of the Global Historical Tsunami Database (NOAA, n.d.). The NRC staff concluded the time period and regional extent of the licensee's search was reasonable in geographical extent and comprehensive in the period searched.

The NRC staff reviewed the methodologies and references 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 NRC staff finds the licensee's analysis and use of these methodologies appropriate.

The NRC staff confirmed the licensee's conclusion that the PMF from tsunami alone could not inundate the site. Therefore, flooding from tsunami does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.8 Ice-Induced Flooding

The licensee reported in the Palisades FHRR that the reevaluated hazard for ice-induced flooding does not inundate the plant site, but did not report a maximum flood elevation (Entergy, 2015). This flood-causing mechanism is not discussed in the licensee's CDB.

In its FHRR, the licensee evaluated ice-induced flooding hazards (ice jams and ice dams). The licensee also evaluated the potential for ice formation at the site. The licensee reviewed historical data and simplifying assumptions to evaluate ice-induced flooding at the Palisades site (USACE, 2014). The licensee identified two historical records of ice jams, one north of the site at South Haven, Michigan (Figure 3-1.2) and a second south of the site at Benton Harbor, Michigan (Figure 3.1-3). The licensee also described a 1984 Lake Huron and Lake Michigan ice jam event that increased both lake's WSE by 0.2 ft. The licensee concluded that due to the review of historical information, an assessment of ice-induced flooding at the site was warranted.

The licensee noted that warm water is discharged from the site and while environmental conditions indicate the potential for formation of frazil ice, plant operations, including warm water discharges, inhibit the formation of ice in the lake near the Palisades site. The licensee evaluated Muskegon, MI air temperature records and determined that a 2.5 ft. ice thickness could develop on the lake surface and that this incremental increase above the highest monthly mean lake WSE would be several feet below the shoreline grade elevation. The licensee based its selection of the Muskegon, MI station as being representative of the site meteorology due to the station and site being on the same (eastern) shore of Lake Michigan. The licensee concluded that ice-induced flooding would not impact the Palisades site (Entergy, 2015).

The NRC staff searched the USACE Ice Jam Database (USACE, n.d.) using USGS hydrologic units "04050001" (south of the Palisades site), "04050002" (encompassing and north of the Palisades site) for the queries. The search yielded two events: 1) February 16, 2003, freeze-up event (index number 20030225113912) that occurred at the Palisades site, and 2) January 24-25, 2005, freeze-up event (index number 20050125140913) that occurred on the St. Joseph River. The 2003 event resulted in the partial blockage of an offshore submerged intake that required pumps to shut down until the ice could be removed (USACE, n.d.). The NRC staff found no indication of flooding at the Palisades site associated with either of these events within the database description.

The NRC staff reviewed the characterization of historical ice thickness observed from 1965 to 1979 for the nearshore areas of Lake Michigan (NOAA, 1988), which reported that the Lake Michigan station average station maximum ice thickness was 1.7 ft. with the range of 1.1 ft. to 2.0 ft. The NRC staff examined other NOAA stations for which ice thickness was evaluated in the southern portion of Lake Michigan and concluded that the Muskegon station was the most appropriate station from which to characterize the ice-induced flood hazard at the Palisades site; the NRC staff evaluation is based on proximity of the NOAA station and its similar orientation with respect to the Palisades site with respect to the Lake Michigan. The NRC staff concluded that the licensee estimated 2.5 ft. maximum ice thickness (based on air temperatures at Muskegon, MI) is a reasonable value to assess ice-induced flood risk at the Palisades site.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for ice-induced flooding of the site is could not inundate the plant site. Therefore, ice-induced flooding does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.9 Channel Migrations or Diversions

The licensee reported in its FHRR that the reevaluated hazard for channel migrations or diversions does not inundate the plant site, but did not report a maximum flood elevation (Entergy, 2015). This flood-causing mechanism is not discussed in the licensee's CDB.

The licensee noted that, because there are no perennial streams at the Palisades site and the Lake Michigan shoreline adjacent to the site was not identified as being a high erosion area, there is "very limited potential for diversions of the Lake Michigan shoreline" at the Palisades site (Entergy, 2015). The FHRR states that there are shoreline areas identified as being at high risk of erosion south of the site but notes that the shoreline riprap at the Palisades site reduces the potential for shoreline migration at the Palisades site. The licensee referenced Michigan Department of Environmental Quality (MDEQ) high risk erosion areas and critical dune areas map for the shoreline areas to the south of the Palisades site (MDEQ, 1995) in their reevaluation of the potential impact to the site. The licensee described the stability of the pathway of Brandywine Creek which runs into Lake Michigan to the south of the Palisades site. The licensee reviewed historical topographic maps from 1981 and 2011 and noted changes in the pathway over that period. The licensee concluded that considering the Lake Michigan shoreline stability in the vicinity of the Palisades site, the site's shoreline protection system, the absence of streams in the Palisades site drainage area, and the historical pathway stability of Brandywine Creek, flooding of the Palisades site due to channel migration or diversion is not possible (Entergy, 2015).

The NRC staff reviewed the drainage area topography using the USGS National Map Viewer (USGS, n.d.-a) and agrees with the licensee's conclusion that there are no perennial streams within the Palisades site drainage area. The NRC staff reviewed the MDEQ evaluation of shoreline erosion in for shoreline areas to the Palisades site and verified that the MDEQ designation of "high risk erosion areas" did not include the shoreline areas directly adjacent to the site. The NRC staff noted that the shoreline areas about 2,000 ft. south (MDEQ, 1995) and about 4,000 ft. north (MDEQ, 1994) of the Palisades site were designated as being a high risk erosion area (MDEQ, n.d.). These findings are consistent with those stated by the licensee.

The NRC staff also compared the Brandywine Creek pathway from the 1981 USGS Covert topographic quadrangle 1:24,000 from the USGS Topoview website (USGS, n.d.-b) to that from Google Earth (Google Earth, n.d.) imagery obtained in April 2016 and determined a maximum distance between these two pathways of about 50 ft. The NRC staff agrees with the licensee that because the difference is small, on the order of the width of the creek itself, the potential for migration of Brandywine Creek to cause flooding at the Palisades site is minimal. Additionally, the NRC staff concurs with the licensee that, in general, the flood hazard related to channel migration does not impact the Palisades site.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from channel migrations or diversions could not inundate the plant site. Therefore, flooding from channel migrations does not need to be analyzed in a focused evaluation or a revised integrated assessment.

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

4.1 Reevaluated Flood Water Surface Elevation for Hazards Not Bounded by the CDB

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

The NRC staff anticipates the licensee will submit a focused evaluation for LIP. For storm surge, the NRC staff anticipates the licensee will perform additional assessments of plant response, either a focused evaluation or an integrated assessment.

By letter dated December 19, 2016 (Entergy, 2016), the licensee submitted its MSA (Entergy, 2016). The NRC staff's review of the MSA will be documented separately from this staff assessment.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in Entergy's 50.54(f) response (Entergy, 2015) regarding the FED parameters needed to perform the additional assessments of the plant response for flood hazards not bounded by the CDB. The FED parameters for the flood-causing mechanisms not bounded by the CDB are summarized in Table 4.2-1.

However, the licensee did not provide all FED parameters for the flooding mechanisms not bounded by the CDB. The licensee is expected to develop FED parameters for these flood-causing mechanisms in the MSA and focused evaluations or integrated assessment. The NRC staff will review these FED parameters as part of future additional assessments of plant response, if applicable to the assessment and hazard mechanism.

By letter dated December 19, 2016 (Entergy, 2016), the licensee submitted the MSA. The NRC staff's review of the MSA will be documented separately from this staff assessment.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in Entergy's response (Entergy, 2015) regarding AE parameters needed to perform future additional assessments of plant response for flood hazards not bounded by the CDB. During the FHRR audit, additional information (NRC, 2016c) was provided by the license with regard to the erosion potential resulting from the LIP event; the licensee determined that, if erosion were to occur over a limited duration, it would not affect critical structures related to safety. The AE parameters directly related with maximum total WSE, such as waves and runup, are provided in Table 4.1-1. The AE parameters not directly associated with total WSE are listed in Table 4.3-1. The AE parameters not submitted as part of the FHRR are noted as "not provided" in Table 4.3-1. The NRC staff will review these AE parameters as part of the future additional assessments of plant response, if applicable to the assessment and hazard mechanism.

In the FHRR, Table 4-2 states that, for the flooding due to LIP, debris loading was not considered credible due to limited debris sources, sediment deposition/erosion effects were not anticipated due to landcover types and due to the short duration of high LIP flow rates. The NRC staff found no indication that sediment or debris sources identified by licensee would be mobilized under the reevaluated LIP event and therefore concluded that the licensee made a reasonable assessment with regard to sediment and debris associated impacts to flood hazards.

In the FHRR, Table 4-4 states that, for the flooding due to the Storm Surge (H.4 Combined Flood Event), hydrodynamic and wave loads were only evaluated at the lakeward side of the circulation water pipes, the effects of sediment deposition/erosion were not evaluated, a 100-year lake WSE was used as an antecedent water level, and the short duration of surge inundation would have a minimal impact on ground water elevations. The NRC staff reviewed the licensee's calculations regarding the hydrodynamic loadings resulting from the surge and wave effects, relative to the design allowable loadings for the circulation water pipes, and found that the licensee's conclusions are based on a reasonable evaluation of the substantial margin between the allowable loading and reevaluated loadings associated with the NUREG/CR-7046 H.4 scenario. The NRC staff also reviewed the licensee's calculations regarding the debris loadings resulting from the surge and wave effects and the licensee's determination that there is no significant debris sources within the protected area. The NRC staff found the licensee's conclusions are based on a reasonable evaluation that the margin between the allowable loading and reevaluated loadings associated with the H.4 scenario is substantial.

For the AE parameters provided, the NRC staff confirms the licensee's AE parameter results are reasonable for use in additional assessments. By letter dated December 19, 2016, the licensee submitted the MSA (Entergy, 2016). The NRC staff's review of the MSA will be documented separately from this staff assessment.

4.4 Conclusion

Based upon the preceding analysis, the NRC staff confirms that the reevaluated flood hazard information defined in the Section 4.1 is an appropriate input to the additional assessments of plant response as described in the 50.54(f) letter, COMSECY-15-0019 (NRC, 2015a), and the associated guidance.

The licensee is expected to develop FED parameters and applicable flood AEs as discussed in the Nuclear Energy Institute (NEI) 12-06, Revision 2, Appendix G (NEI, 2015). The NRC staff will evaluate the missing FED and AE parameters marked as "not provided" in Table 4.2-1 and Table 4.3-1 during its review of future additional assessments. By letter dated December 19, 2016 (Entergy, 2016), the licensee submitted the MSA. The NRC staff's review of the MSA 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 Palisades. Based on its review of the above available information provided in Entergy's 50.54(f) response (Entergy, 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, 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 for combined event that includes storm surge (H.4 Combined Event) are not bounded by the CDB flood hazards, (b) additional assessments of plant response will be performed for LIP and for storm surge (H.4 Combined Event), 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.

6.0 REFERENCES

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

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

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

SRP is the NUREG-0800, 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-ISG-2013-01 is the "Guidance for Assessment of Flooding Hazards Due to Dam Failure" (NRC, 2013b)

Table 3.0-1. Summary of Controlling Flood-Causing Mechanisms at Palisades

Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation (590 ft. NGVD29)[1]	ELEVATION, ft. NGVD29
Local Intense Precipitation and Associated Drainage	594.4 to 626.1
Storm Surge	593.9 to 602.2

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

Table 3.1-1. Current Design Basis Flood Hazards for Palisades

Flooding Mechanism	Stillwater Elevation, ft. (NGVD29)	Associated Effects, ft.	Current Design Basis (CDB) Flood Elevation, ft. NGVD29	Reference
Local Intense Precipitation and Associated Drainage				
East Side of Service Building	601.0	Minimal	601.0	FHRR Section 2.3.1.1
Site Locations Other than the Service Building	0.5 depth	Minimal	0.5 depth	FHRR Section 2.3.1.1 & Table 4-1
Streams and Rivers	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Failure of Dams and Onsite Water Control/Storage Structures	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Storm Surge	594.1	8.0	602.1 at lakeward side of circulation water pipes	FHRR Table 4-1 FHRR Table 4-4
Seiche	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Table 4-1
Tsunami	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Ice-Induced	Not included in DB	Not included in DB	Not included in DB	FHRR Table 4-1
Channel Migrations or Diversions	Not included in DB	Not included	Not included in DB	FHRR Table 4-1

Note 1: Reported values are rounded to the nearest one-tenth of a foot.
Note 2: For LIP scenario 2, the total stillwater ponding depth is reported to be up to a maximum of 0.5 ft. For total elevation, add ponding depth to ground elevation.

Table 3.2.1 FLO-2D model results for LIP analysis at Palisades including maximum WSEs and flood depth at critical locations. Note that the design-basis for maximum flood depth is 0.5 ft. for these locations except for the east side of the Service Building where the design-basis is a maximum flood depth of 5.0 ft. (or 601.0 ft. NGVD29). Note that the east side of the Service Building location, the maximum LIP flood depth of 9.8 ft. as indicated in FHRR Table 4-1 is not included in this table.

ID Number	Description	Ground Surface Elevation, ft. NGVD29	Maximum Flood Elevation, ft. NGVD29	Maximum Flood Depth, ft.	Time to Maximum Flood Elevation (hours)	Bounded (B) or Not Bounded (NB)
19	Screen House/Intake Structure Roll-Up (Door #14)	589.9	593.1	3.3	0.5	NB
20	North Entrance to Screen House/Intake Structure (Door #33)	589.7	592.5	2.7	0.5	NB
21	Turbine Building Laydown Area Access (Door #12)	589.7	593.4	3.8	0.5	NB
22	Turbine Building Southwest Roll-Up Door (Door #13)	589.7	593.4	3.8	0.5	NB
23	Diesel Generator Fuel Oil Tank T-10A Vent	591.9	593.6	1.8	0.5	NB
25	Door To Transformer Yard from Feedwater Pumps (Door #11)	589.8	594.2	4.4	0.5	NB
26	Turbine Building Southside Roll-Up Door to Transformer	589.7	594.3	4.6	0.5	NB

ID Number	Description	Ground Surface Elevation, ft. NGVD29	Maximum Flood Elevation, ft. NGVD29	Maximum Flood Depth, ft.	Time to Maximum Flood Elevation (hours)	Bounded (B) or Not Bounded (NB)
	Yard (Door #10)					
27	Containment Post Tension Tunnel Hatch (Door #10A)	589.1	594.4	5.3	0.5	NB
28	Manhole #4 (East of Containment Building)	623.9	626.1	2.2	0.5	NB
29	North Chained Double Door to Diesel Generators (Door #170)	589.7	592.5	2.8	0.5	NB
33	Turbine Building North Entrance Door	589.9	592.5	2.6	0.5	NB
34	Track Alley Roll-up Door	624.9	626.0	1.1	0.2	NB
35	Administration Building Hallway East Entrance (Door #28)	624.7	626.1	1.4	0.2	NB
36	North Penetration Room (Door #106)	625.0	626.1	1.0	0.2	NB
230	South Stairwell (Service Building Addition) Across from Elevator (Door #123)	589.8	592.5	2.7	0.5	NB

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

Mechanism	Stillwater Elevation, ft. NGVD29	Waves/ Runup, ft.	Reevaluated Hazard Elevation, ft. NGVD29	Reference
LIP Service Building-East Side (Non-Category 1 Structure	605.8	Minimal	605.8	FHRR Section 2.3.1.1 and FHRR Table 4-1
Upper Level (Category 1 Structures)	626.1	Minimal	626.1	FHRR Section 2.3.1.1, FHRR Table 4-1 and FHRR Table 5-2
Lower Level (Category 1 Structures)	594.4	Minimal	594.4	FHRR Section 2.3.1.1, FHRR Table 4-1 and FHRR Table 5-1
Storm Surge (H.4 Combined Flood Event): Lakeward of Circulation Water Pipes	593.9	8.3	602.2	FHRR Section 3.9.2.1.2, FHRR Table 4-5 and FHRR Figure 3-29
Landward of Circulation Water Pipes	593.9	0.4	594.3	FHRR Section 3.9.2.1.2, FHRR Table 4-5 and FHRR Figure 3-29
Landward of Turbine Building	593.9	0.4	594.3	FHRR Section 3.9.2.1.2, FHRR Table 4-5 and FHRR Figure 3-29
North of Turbine Building	593.9	1.1	595.0	FHRR Section 3.9.2.1.2, FHRR Table 4-5 and FHRR Figure 3-29

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

Note 2: Reevaluated hazard mechanisms bounded by the CDB are not included in the table.

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

Table 4.2-1. Flood Event Duration Parameters for Flood-Causing Mechanisms Not Bounded by the Palisades 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	See Note 1	0.2 h to 0.5 h at critical locations	Typically 6 h; up to 25 h at some critical locations.
Storm Surge (H.4 Combined Flood Event)	Not provided	Not provided	25 h (NRC, 2016c)

Note 1: The licensee has the option to use NEI guideline 15-05 (NEI, 2015a) to estimate the warning time for LIP events.

Note 2: Provided LIP flood event duration parameters are given in FHRR Table 4-2 and the FHRR audit report (NRC, 2016c). Storm surge (H.4 Combined Flood Event) flood event duration parameters are given as “not evaluated” in FHRR Table 4-4 but provided in the FHRR audit report (response to information need #9) as about 25 h.

Note 3: NRC staff will evaluate the flood event duration parameters that were not provided in the FHRR as part of the future additional assessment.

Table 4.3-1. Associated Effects Parameters not Directly Associated with Total Water Surface Elevation for Flood-Causing Mechanisms not Bounded by the Palisades CDB

	Flooding Mechanism	
Associated Effects Factor	**Local Intense Precipitation**	**Storm Surge (H.4 Combined Flood Event)**
Breaking wave load at circulation water pipes applied at 594.5 ft. NGVD29	Not applicable	4,460 pounds per linear foot of pipe
Breaking wave load at circulation water pipes applied at saddles (applied at 593.9 ft. NGVD29)	Not applicable	1,770 pounds applied at 593.9 ft. NGVD29
Hydrodynamic drag load on circulation pipes applied at 593.0 ft. NGVD29	Not applicable	244 pounds per linear foot of pipe
Vertical uplift load on circulation water pipes applied at 3.3 ft. from lakeward edge of pipe	Not applicable	2,120 pounds per linear foot of pipe applied
Debris loading on circulation water pipes applied at 593.9 ft. NGVD29	Not applicable	24,640 pounds
Hydrodynamic and Debris loadings shoreward of circulation water pipes	Not applicable	Minimal
Sediment loading	Minimal	Not provided
Concurrent conditions	Not provided,	Wind-wave effects associated with the PMWS
Groundwater effects	Minimal	Groundwater minimally affected.
Other pertinent factors (e.g., waterborne projectiles)	Not provided	Not provided.

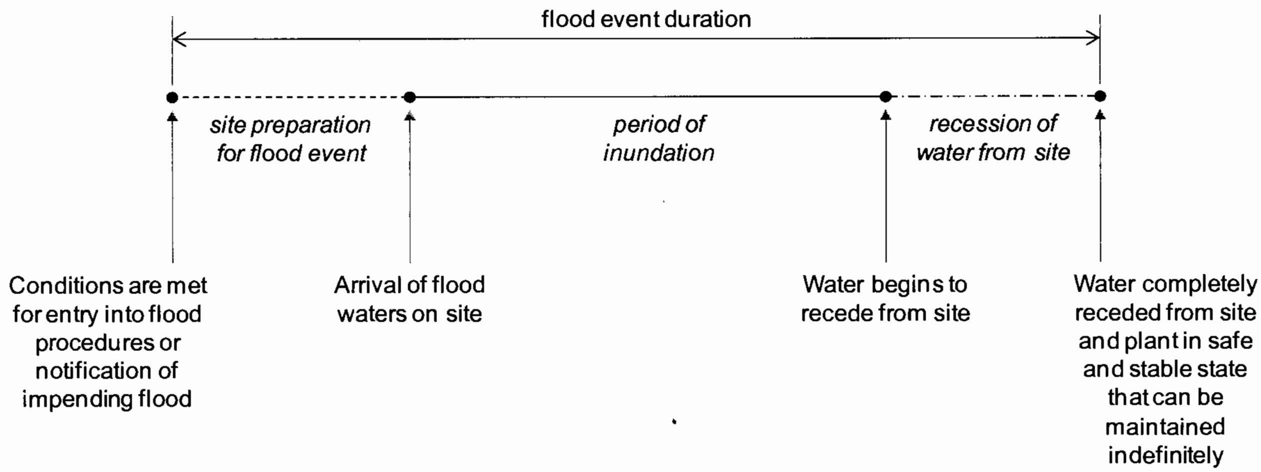

Figure 2.2-1 Flood Event Duration (NRC, 2012c)

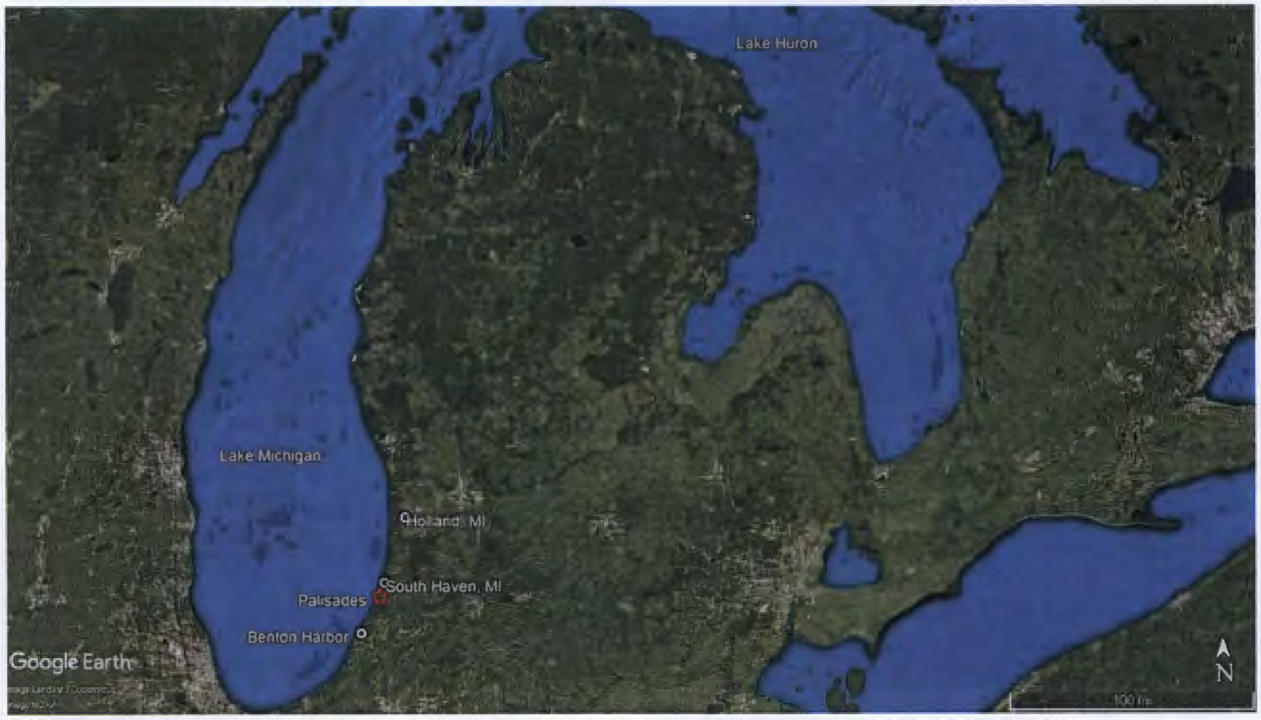

Figure 3.1-1 Regional map; approximate west-east extent of figure is 500 miles; Palisades site is shown as red star symbol.

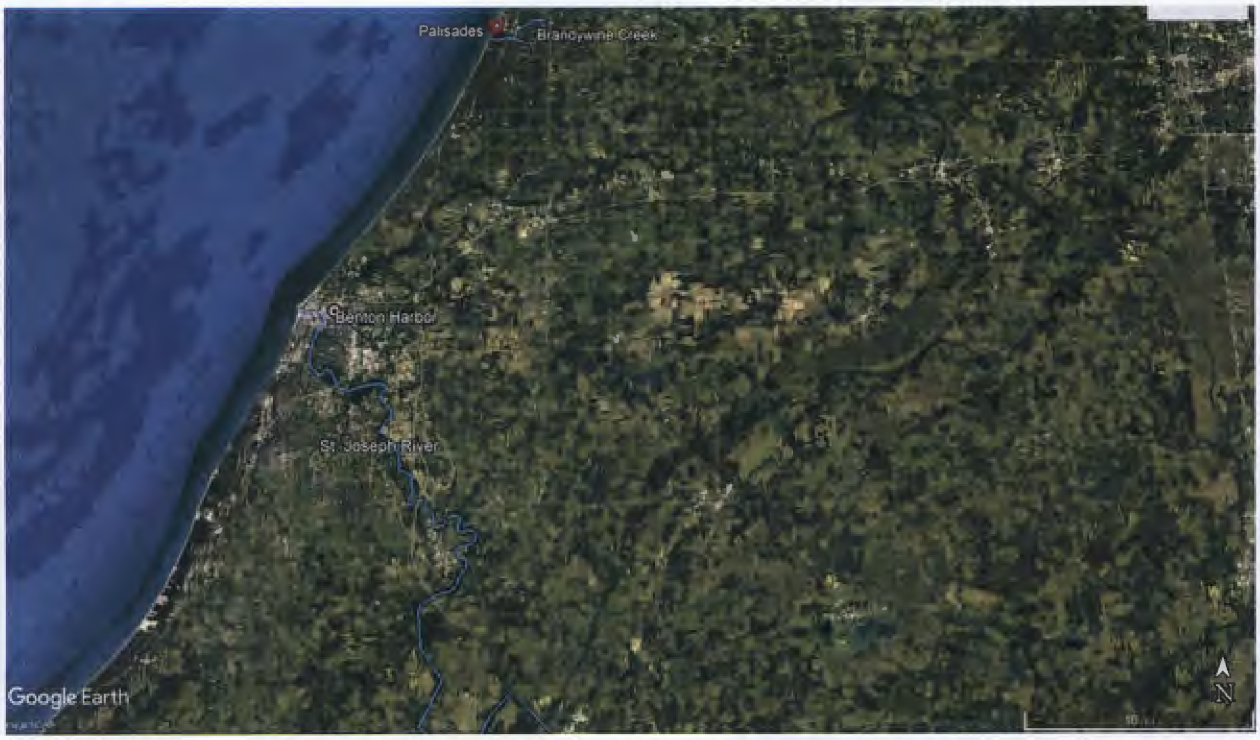

Figure 3.1-2 Local map; Palisades site is shown as red star symbol; Lake Michigan is water body shown on left portion of figure; approximate courses of Brandywine Creek and St. Joseph River are shown as blue lines.

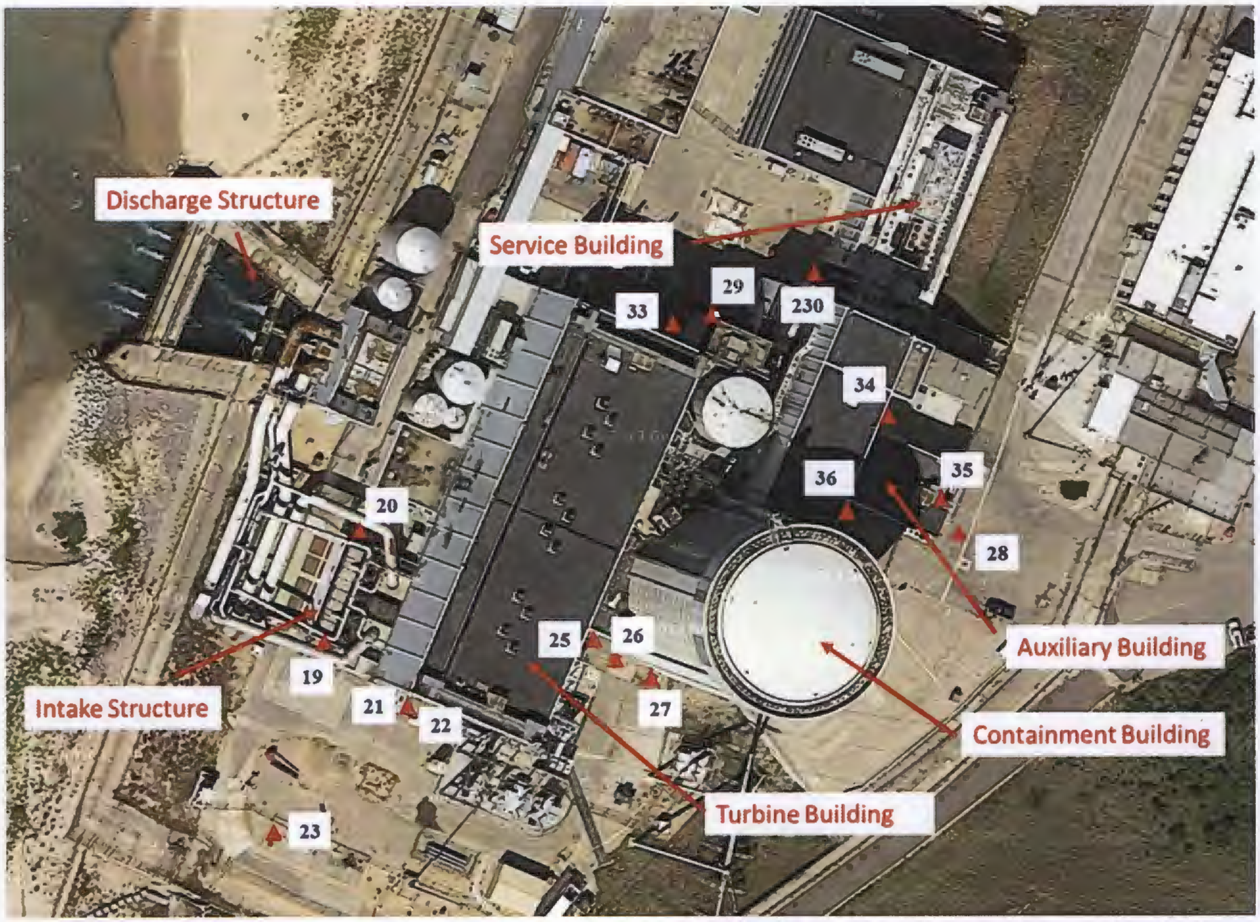

Figure 3.2-1. Map showing the key structures and identification numbers for the critical locations at safety-related structures of Palisades Nuclear Plant (Adapted from FHRR Figure 3.2-1). Locations are identified by numbers consistent with Table 3.2-1.

SUBJECT: PALISADES NUCLEAR PLANT – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NO. MF6128: EPID L-2015-JLD-0003) DATED February 14, 2018

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