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

November 30, 2017

Site Vice President
Entergy Operations, Inc.
Waterford Steam Electric Station,
Unit 3
17265 River Road
Killona, LA 70057-3093

SUBJECT: WATERFORD STEAM ELECTRIC STATION, UNIT 3 - STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NO. MF6086; EPID L-2015-JLD-0020)

Dear Sir or Madam:

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 July 21, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15204A321), Entergy Operations, Inc. (Entergy, the licensee) responded to this request for Waterford Steam Electric Station, Unit 3 (Waterford).

By letter dated April 12, 2016 (ADAMS Accession No. ML16090A313), the NRC staff sent the licensee a summary of the staff's review of the licensee's reevaluated flood-causing mechanisms. The enclosed staff assessment provides the documentation supporting the NRC staff's conclusions summarized in the letter. As stated in the letter, the reevaluated flood hazard result for the following mechanisms were not bounded by the Waterford current design basis (CDB) flood hazard: local intense precipitation, stream and rivers, failure of dams, and storm surge. The NRC staff notes that for the flood-causing mechanisms that are not bounded by the CDB the licensee has performed a flooding mitigation strategies assessment (MSA) dated November 14, 2016 (ADAMS Accession No. ML16319A089), and a flooding focused evaluation dated May 17, 2017 (ADAMS Accession No. ML17137A355). The NRC staff's assessment of the flooding MSA can be found in a letter dated February 27, 2017 (ADAMS Accession No. ML17023A282). The NRC staff will provide its assessment of the Waterford focused evaluation in a separate letter.

This closes out the NRC's efforts associated with CAC No. MF6086.

If you have any questions, please contact me at (301) 415-1132 or e-mail at Joseph.Sebrosky@nrc.gov.

Sincerely,

Joseph Sebrosky, Senior Project Manager
Beyond-Design-Basis Management Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket No. 50-382

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

WATERFORD STEAM ELECTRIC STATION, UNIT 3

DOCKET NO. 50-382

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* (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, 2011b). Recommendation 2.1 in that document recommended that the NRC staff issue orders to all licensees to reevaluate seismic and flooding 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 the NRC staff would provide a prioritization plan indicating Flood 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 July 21, 2015 (Entergy, 2015), Entergy Operations Inc. (Entergy, the licensee) provided the FHRR for Waterford Steam Electric Station Unit 3 (Waterford). The NRC staff conducted a site audit as documented in the audit report (NRC, 2017b)

On April 12, 2016, the NRC issued an interim staff response (ISR) letter to the licensee (NRC, 2016b). 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, 2012c) and the additional assessments associated with Recommendation 2.1-Flooding. The ISR letter also made reference to this staff assessment, which documents the NRC staff's basis and conclusions. The flood hazard mechanism values presented in the letter's enclosures match the values in this staff assessment without change or alteration.

As mentioned in the ISR letter, the reevaluated flood hazard results for the local intense precipitation (LIP), streams and rivers, failure of dams, and storm surge flood-causing mechanisms are not bounded by the plant's current design basis (CDB) hazard. Consistent with the 50.54(f) letter and amended by the process outlined in COMSECY-15-0019 (NRC, 2015), JLD-ISG-2016-01, Revision 0 (NRC, 2016c), the NRC staff anticipates that for LIP, the licensee will perform and document a focused evaluation to assess the impact of the LIP hazard on the site and evaluate and implement any necessary programmatic, procedural or plant modifications to address this hazard exceedance. Additionally, for the stream and rivers, dam failure, and storm surge flood-causing mechanisms, the NRC staff anticipates that the licensee will submit (a) a revised integrated assessment or (b) a focused evaluation confirming the capability of existing flood protection or implementing new flood protection consistent with the process outlines in COMSECY-15-0019 (NRC, 2015) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c).

Additionally, for any reevaluated flood hazards that are not bounded by the plant's CDB hazard, the licensee was expected to develop any flood event duration (FED) and associated effects (AE) parameters currently not provided in the FHRR to conduct the Mitigating Strategies Assessment (MSA) and focused evaluations or revised integrated assessments. By letter dated November 14, 2016, the licensee submitted the MSA (Entergy, 2016). By letter dated May 17, 2017, the licensee submitted the Focused Evaluation (Entergy, 2017). The NRC staff's assessment of the flooding MSA can be found in a letter dated February 27, 2017 (NRC, 2017a). The NRC staff will provide its assessment of the Waterford focused evaluation in a separate letter.

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 of the staff assessment describes present-day regulatory requirements that are applicable to the FHRR.

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

General Design Criterion 2 in Appendix A of 10 CFR Part 50 states that structures, systems, and components (SSCs) important to safety at nuclear power plants must be designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their intended safety functions. The design bases for these SSCs are to reflect appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area. The design bases are also to have sufficient margin to account for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

Section 50.2 of 10 CFR defines the "design bases" as the information that identifies the specific functions that an SSC of a facility must perform, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design which each licensee is required to develop and maintain. These values may be (a) restraints derived from generally accepted "state of the art" practices for achieving functional goals, or (b) requirements derived from an analysis (based on calculation, experiments, or both) of the effects of a postulated accident for which an SSC must meet its functional goals.

Section 54.3 of 10 CFR defines the "current licensing basis" (CLB) as "the set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect." This includes 10 CFR Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 52, 54, 55, 70, 72, 73, 100 and appendices thereto; orders; license conditions; exemptions; and technical specifications as well as the plant-specific design basis information as documented in the most recent updated final safety analysis report. The licensee's commitments made in docketed licensing correspondence, which remain in effect, are also considered part of the CLB.

Present-day regulations for reactor site criteria (Subpart B to 10 CFR Part 100 for site applications on or after January 10, 1997) state, in part, that the physical characteristics of the site must be evaluated and site parameters established such that potential threats from such physical characteristics will pose no undue risk to the type of facility proposed to be located at the site. Factors to be considered when evaluating sites include the nature and proximity of dams and other man-related hazards (10 CFR 100.20(b)) and the physical characteristics of the site, including the hydrology (10 CFR 100.21(d)).

2.2 Enclosure 2 to the 50.54(f) Letter

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoke. The 50.54(f) letter (NRC, 2012a) requests all power reactor licensees and construction permit holders to reevaluate the flood-causing mechanisms for their respective sites using present-day methodologies and regulatory guidance used by the NRC for the ESP and COL reviews.

2.2.1 Flood-Causing Mechanisms

Attachment 1 to Enclosure 2 of the 50.54(f) letter discusses flood-causing mechanisms for the licensee to address in 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 interim staff guidance (ISG) documents containing acceptance criteria and review procedures.

2.2.2 Associated Effects

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

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

2.2.3 Combined Effects Flood

The worst flooding at a site that may result from a reasonable combination of individual flooding mechanisms is sometimes referred to as a "combined effects flood." 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; and
- Perform an integrated assessment to: (a) evaluate the effectiveness of the CDB (i.e., flood protection and mitigation systems); (b) identify plant-specific vulnerabilities; and (c) assess the effectiveness of existing or planned systems and procedures for protecting against and mitigating consequences of flooding for the flood event duration.

If the reevaluated flood hazard is bounded by the CDB flood hazard for all flood-causing mechanisms at the site, licensees are not required to perform an integrated assessment. COMSECY-15-0019 (NRC, 2015) and JLD-ISG-2016-01, Revision 0 (NRC, 2016c) 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 hazard on their site by performing either a focused evaluation or a revised integrated assessment (NRC, 2015 and NRC, 2016a).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of the Waterford 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 Waterford FHRR, the licensee made calculation packages available to the NRC staff via an electronic reading room (ERR). The NRC staff did not rely directly on these calculation packages in its review; they were found to expand upon or clarify the information provided in the Waterford FHRR, and so they are not docketed or cited.

3.1 Site Information

The 50.54(f) letter (NRC, 2012a) included the SSCs important to safety in the scope of the hazard reevaluation. The licensee included pertinent data concerning these SSCs in the FHRR (Entergy, 2015). Based on the NRC staff's review of the FHRR, the NRC staff requested additional information. The licensee provided this additional information during an audit on March 3, 2016. This information was summarized in the NRC staff's audit report (NRC, 2017b).

Enclosure 2 (Recommendation 2.1: Flooding), "Requested Information, Hazard Reevaluation Report," Item a, describes site information to be contained in the FHRR. The NRC staff reviewed and summarized this information as follows.

3.1.1 Detailed Site Information

The FHRR (Entergy, 2015) described the site-specific information related to the flood hazard evaluation. The Waterford site is located on the west (right descending) bank of the Mississippi River near River Mile 130, approximately 25 miles upstream from New Orleans (See Figure 3.1-1). The site is over 3,000 acres with approximately 7,500 feet (ft.) of river frontage. The river frontage consists of a U. S. Army Corps of Engineers (USACE) maintained levee with a top elevation of approximately 30 ft. mean sea level (MSL) (Entergy, 2015). In the vicinity of the Waterford site (Entergy, 2015), a system of levees and hydraulic control structures interconnect the Mississippi River and its floodplain with the Atchafalaya River and its floodplain for the purposes of maintaining channel stability, navigation, and flood control as shown on Figure 3.1-2. The Mississippi and Atchafalaya Rivers both generally flow from north to south, but discharge at different locations in the Gulf of Mexico. However, to assess flooding impacts at the Waterford site, both river systems needs to be considered jointly together as one system due to the generally flat, wide, and shared flood plain of the Mississippi and Atchafalaya Rivers. Figure 3.1-3 shows the Waterford site layout and topography, including important features and locations related to flood hazards (Energy, 2015).

The following structures are identified in Figure 3.1-3: Fuel Handling Building (FHB), Dry Cooling Tower Alpha (DCT A), Dry Cooling Tower Bravo (DCT B), Wet Cooling Tower Alpha (WCT A), Wet Cooling Tower Bravo (WCT B), Reactor Auxiliary Building (RAB), Nuclear Plant Island Structure (NPIS) and Main Steam Isolation Valve Area (MSIV East and MSIV West). All SSCs important to safety are enclosed in a rectangular box-like reinforced concrete structure 380 ft. long, 267 ft. wide, and extending 64.5 ft. below grade known as the NPIS. The NPIS wall has a minimum flood protection elevation of 29.2 ft. MSL (FHRR Section 2.5.2). There are a total of seven exterior, flood-protected access doors below 29.2 ft. MSL which prevent flood waters from entering the NPIS (Entergy, 2015).

The site grade external to the NPIS ranges from approximately 14.5 ft. MSL on the south side to 17.5 ft. MSL on the north side (FHRR Section 2.1). Figure 3.1-4 shows the NPIS with perimeter annotations relevant to the licensee's reevaluation of flood hazard.

3.1.2 Design-Basis Flood Hazards

The CDB flood levels are summarized by flood-causing mechanism in Table 3.1-2.

3.1.3 Flood-Related Changes to the Licensing Basis

The licensee stated in its FHRR that there have been no significant changes to the licensing basis with respect to flooding or flood protection.

3.1.4 Changes to the Watershed and Local Area

There have been no major physical changes in the region of the river adjacent to the site, although, subsequent to Hurricane Katrina in 2005, levee repairs and improvement projects were completed.

Originally constructed to a height of 30.0 ft. MSL, FHRR Section 2.5.2 states that the NPIS minimum protection level settled by approximately 0.8 ft. from 1975 to 1978, and ongoing regional settlement has resulted in a current NPIS wall minimum protection level of 29.2 ft. MSL.

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

All area drains in each Cooling Tower area are connected by a network of drainage piping, which terminates at area drain sumps for DCT A and DCT B as shown on Figure 3.1-5. Although the DCTs are located within the NPIS they are open vertically to the atmosphere, and as a result, there is potential for precipitation to fall directly into the DCT areas. Inside DCT A and DCT B, there are sump pump motors and motor control centers (MCCs) for the ultimate heatsink (UHS) that are potentially vulnerable to flooding. The critical ponding depths for SSCs inside DCT A are 1.5 ft. (sump pump motor) and 1.7 ft. (MCC) and for DCT B they are 1.4 ft. (sump pump motor) and 1.7 ft. (MCC) (Entergy, 2015). According to the licensee (Entergy, 2015), flooding can exceed the height of the sump pump motors without directly impacting plant safety, but exceeding the height of the UHS MCCs would result in loss of the UHS. As stated in the FHRR, each cooling tower area is also provided with a diesel powered sump pump. During the design-basis probable maximum precipitation (PMP) event, the licensee assumed that one motor driven sump pump is engaged within 30 minutes of the onset of the event, and a diesel powered sump pump is engaged within 3 hours of the onset of the event.

The FHB is connected to the DCTs with the FHB considered as rain water storage capability for the DCT areas (Entergy, 2015). Water level equalization between the DCTs and FHB occurs through four 4-inch pipes installed under two door sills located at each side of the FHB. To maintain one-way flow from the DCTs into the FHB, these pipes have flappers installed. According to the licensee (Entergy, 2015), these flappers do not impede the flow of water into the FHB but two-thirds of the pipes need to remain unblocked to maintain the necessary equalization rate.

There are a combined 21 drains of various sizes (4-, 5-, and 6-inch) credited for the FHB, RAB, and Reactor buildings. There are also 14 scuppers on the RAB roof. The FHB and RAB must maintain two-thirds of their roof drainage capacity (Entergy, 2015).

The CDB for the Waterford site is due to the combined effect scenario of a probable maximum hurricane (PMH) induced probable maximum storm surge (PMSS) at the mouth of the Mississippi River coincident with a PMF and levee failure at the site. The resulting flood level is a stillwater elevation of 27.6 ft. MSL. This scenario does not include appreciable wind-generated waves due to the configuration of the flood. The CDB flood level for the DCT areas due to rainfall runoff is 1.6 ft. of ponding.

3.1.6 Additional Site Details to Assess the Flood Hazard

Additional site details include electronic copies of model input data, bathymetry, or other available data the applicant provided or discussed (AREVA, 2015). To support the audit, the licensee provided model input and output files FLO-2D (for LIP and combined effects analyses), HEC-RAS (for PMF, dam failure and combined effects analyses), ADCIRC (for PMSS analysis), ADCIRC+(Simulating Wave Nearshore) SWAN (for combined effects analysis), Sea, Lakes and Overland Surges from Hurricane (SLOSH; for PMSS analysis) and CulvertMaster (for LIP analysis). The licensee also provided other appendices and references to the NRC staff during the audit.

3.1.7 Results of Plant Walkdown Activities

The 50.54(f) letter requested that licensees plan and perform plant walkdown activities to verify that current flood protection systems 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.

By letter dated November 27, 2012 (Entergy, 2012), Entergy submitted the Flooding Walkdown Report for the Waterford site. On June 23, 2014 (NRC, 2014), the NRC staff issued its assessment of the Walkdown Report, which documented its review of that licensee action and concluded that the licensee's implementation of the flooding walkdown methodology met the intent of the 50.54(f) letter.

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported in FHRR Section 3.1.1.2.4 and Table 4-1 that the reevaluated flood hazard for LIP and associated site drainage is based on a stillwater-surface elevation of 20.5 ft. MSL in the Waterford yard. The licensee reported in Section 3.1.3 of its FHRR that the computed flood depths are below the NPIS flood protection level (12 to 15 ft. above site grade) and that external LIP flooding will not impact the Waterford site. Additional impacts from wind waves and runup were not considered for external LIP flooding.

A separate LIP evaluation for flooding within the NPIS resulted in a maximum ponding depth of 1.53 ft. in DCT A and 1.63 ft. DCT B (FHRR Section 3.1.3, Table 3-14, and Table 4-1). According to Section 5.1.1 of the FHRR, ponding in both DCT basins would exceed sump pump levels and potential flooding above the design-basis.

This flood-causing mechanism is discussed in the licensee's CDB for LIP flooding within the NPIS; however, no CDB exists for LIP flooding in the Waterford yard. The CDB PMF elevation for LIP within the NPIS is 1.6 ft. of ponding.

3.2.1 Background

The NRC staff issued an information needs letter requesting electronic copies of input/output files to support the audit. The licensee responded to the information needs by letter dated September 4, 2015 (AREVA, 2015), in which the licensee transmitted the files requested. The NRC staff requested additional information from the licensee on December 2, 2015. The licensee responded to the information needs January 21, 2016, by placing the requested information on the licensee's ERR. The information needs audit is summarized in the Audit Summary Report (NRC, 2017b), which is discussed in the appropriate sections below.

The NRC staff reviewed the flooding hazard from LIP and associated site drainage against the relevant regulatory criteria based on present-day methodologies and regulatory guidance.

For the purposes of this staff assessment, local watershed flooding due to LIP is referred to as external LIP flooding. The licensee also used a separate mass balance approach to evaluate LIP flooding within the NPIS and is referred to herein as internal LIP flooding.

3.2.2 External LIP Flooding (FLO-2D modeling)

To evaluate external LIP flooding at the Waterford site, the licensee followed the Hierarchical Hazard Assessment (HHA) approach as described in NUREG/CR-7046 (NRC, 2011e) by developing precipitation and flood modeling inputs and performing flood simulations. A two-dimensional hydrodynamic FLO-2D model[1] was developed to simulate flooding from an LIP event. A digital terrain model (DTM) was developed from a site topographic survey plan for the Waterford site using Light Detection and Ranging (LiDAR) data and supplemented by surveyed information. In the FHRR, Section 3.1.1.2 states that this DTM provided the necessary elevation data to identify the Waterford local watershed and develop a FLO-2D model with a 10-ft. horizontal resolution.

To simulate flow obstructions due to buildings, FLO-2D model grid elevations were manually adjusted based on a site survey to exceed the surrounding topography by at least 5 ft. The vehicle barrier system (VBS) was also simulated in FLO-2D by using levee structures elevated 4 ft. above the underlying grid elevation. The VBS encircles the Waterford site with the exception of an opening on the Northeastern end. Outflow elements were placed along the model boundary to enable outgoing flow to exit the simulation.

To simulate the LIP event, PMP values were taken from National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Reports (HMR) No. 51 (NOAA, 1978) and No. 52

[1] The FLO-2D computer code is available from FLO-2D Software, Inc., Nutrioso, AZ. For the external local intense precipitation and site drainage calculations included in the analyses in the FHRR, the licensee used the FLO-2D Professional version, Build No. 14.03.07.

(NOAA, 1982). Using HMR 52, the licensee estimated the 1-h, 1-mi^2 PMP as 19.4 inches. A 6-h, 10-mi^2 PMP of 32.0 inches was estimated using HMR 51. Sub-hourly rainfall values were computed using ratios from HMR 52 to produce 5-minute incremental rainfall. The resulting rainfall values were arranged following a front-loaded temporal distribution as used in NUREG/CR-7046 (NRC, 2011e).

Conservatively, the licensee excluded initial abstractions and infiltration. Following common practice, the licensee simulated surface roughness by using Manning's roughness coefficients based on land use categories. Values range from 0.02 to 0.20 depending on surface coverage.

To test model sensitivity, the NRC staff simulated flooding when increasing roughness coefficients from 0.02 to 0.05 for concrete and asphalt coverage. The results demonstrated low overall sensitivity, with higher roughness coefficients leading to maximum flood elevations increases of less than 0.2 ft. at critical locations. The NRC staff finds the licensee's drainage assumptions to be reasonable.

The final FLO-2D model simulation produced estimates for external LIP maximum flooding depth, water surface elevations (WSEs), and velocities. Maximum simulated WSEss at critical locations vary between 17.3 ft. MSL and 20.5 ft. MSL, with a maximum flow depth ranging from 0.5 ft. to 1.1 ft. above site grade, as documented in FHRR Table 3-1. These results indicate flood elevations in excess of the site grade; however, elevations are far below the NPIS protection level. Because all SSCs important to safety are within the NPIS walls, Waterford remains protected under an external LIP flood event.

The licensee concluded that the reevaluated hazard from flooding from external LIP and associated site drainage is not bounded by the CDB flood hazard. However, the licensee also concluded that the flood hazard from external LIP and associated site drainage alone would not inundate the site.

3.2.4 Internal LIP Flooding

To simulate LIP flooding within the NPIS, the licensee developed an Excel-based volumetric balance spreadsheet. This approach to internal LIP flooding addresses how roof runoff and direct LIP precipitation impact the NPIS interior and specifically computes flooding levels for the DCT and MSIV areas. To provide a volumetric balance approach to flooding, physical characteristics for each of the NPIS areas, connections, and drainages were assessed. While the CDB uses a similar approach, a few updates were made, including 1) using a site-specific PMP (SSPMP) rainfall input rather than an HMR-based PMP, 2) decreasing time steps to between one to five minutes rather than 30 to 60 minutes, and 3) modifying pipe flow characteristics to account for flow variations caused by flood depth variations.

The volumetric balance approach for the DCT basin and MSIV area flooding required calculation of four primary characteristics: 1) inflows, 2) storage volumes, 3) outflows, and 4) ponding depths. To account for inflows, the licensee calculated the temporal rainfall distribution and how that rainfall accumulated into direct runoff to the basins/areas and indirect overflows from surrounding building roofs based on directly and indirectly contributing areas. To address storage volumes, the NPIS interior structure was separated into multiple smaller areas for which storage area volumes and storage volume reductions were computed. Outflows from the Reactor Building and RAB roof drains and scupper drains were calculated as outflows from the NPIS system. Runoff entering these roof drains or scuppers contribute to storage reductions for these buildings and do not contribute to ponding in the DCT basins or MSIV areas. Sump pump discharges and the rating curve for flow into the FHB were calculated as DCT outflows, while MSIV area drains were evaluated for MSIV outflows. No infiltration losses were credited within the NPIS. Ponding depth was computed separately within each DCT basin and MSIV area using the volumetric balance output and depth-to-volume relationships, with incremental changes in inflow, outflow, and storage computed for each time step.

While the licensee evaluated external LIP flooding using an HMR-based PMP, the internal LIP flooding was assessed using a SSPMP approach to determine 1-h PMP and 6-h PMP values for a 1-mi^2 area. This change in rainfall input for LIP evaluation was prompted by the initial use of HMR-based PMP values causing internal LIP flooding to exceed the CDB for DCT SSCs important to safety. The licensee concluded that a refinement in the rainfall input as accomplished through a SSPMP study was in accordance with the HHA approach.

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 the World Meteorological Manual for PMP determination (WMO, 2009). While the 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.

To assess SSPMP, the licensee first identified a large number of historical PMP-type local rainfall events. Following a storm-based approach, a total of 22 events were identified and evaluated for the LIP SSPMP. Half of these storms were evaluated through previous HMR or USACE studies, while the other half were newly evaluated using the Storm Precipitation Analysis System (SPAS) computer program. After using SPAS to compute observed depth-area-duration (DAD) values for each new storm, storm transposition and maximization were applied to all 22 storms to develop adjusted DAD values. The resulting set of DAD values are compared, with the highest 1- and 6-h, 1-mi^2 rainfall values used as the LIP SSPMP. The resulting SSPMP values were ultimately based on the Thrall, TX September 1921 storm for which a 1-h, 1-mi^2 SSPMP of 15.8 inches and 6-h, 1-mi^2 SSPMP of 27.0 inches were computed. The licensee estimated sub-hourly rainfall increments using ratios taken from HMR 52. Overall, the SSPMP produced lower 1-mi^2 rainfall values than HMR 52, with the 1-h depth approximately 81 percent of the HMR values and the 6-h depth approximately 84 percent of the HMR value.

With the SSPMP hyetograph and directly contributing areas computed, FHRR Section 3.1.2.3 computes the direct rainfall volume into the DCT basins and MSIV areas for each time step. In addition, the licensee developed relationships to calculate how rainfall runoff from surrounding buildings could contribute to indirect inflow to the DCT basins and MSIV areas. Contributing areas, drainage directions, parapet heights, and roof storage capacities were all considered when developing these relationships. Outflow through the RAB and Reactor Building roof drains and scuppers were calculated using the general weir equation (weir coefficient of 3.0) and the orifice flow equation (orifice coefficient of 0.8). For each roof, the cumulative parapet storage volume was computed incrementally for each time step based on PMP inflow and drain/scupper outflow, with the results indicating that no overflow occurred from RAB Roofs A1, A2, B1, B2, and C1. However, the PMP event results in rainfall volume exceeding the Reactor Building's parapet capacity and overflowing to the DCT basins (27 percent of total overflow to each basin) and MSIV areas (12.5 percent of total overflow to each area).

In addition to the direct and indirect inflows into the DCT basins and MSIV areas, outflow calculations were also needed. Each DCT basin is hydraulically connected to two motor driven sump pump and may be serviced by an additional diesel driven sump pump. Under the CDB, Waterford credits one motor driven sump pump per DCT basin to activate 30 minutes after the PMP event onset and one diesel driven sump pump per DCT basin to activate 3 hours after the PMP event onset. Each sump pump is assumed to operate at a constant pumping rate of 300 gallons per minute (gpm) despite a pump rating of 350 gpm. For the FHRR, the licensee considered eight different sump pump scenarios.

The DCT basins are also subject to outflow via four pipes with flapper valves connected to the FHB sub-basement. Due to the flapper valve, water can enter but not exit the FHB sub-basement, meaning flow from the DCT basins to the FHB is retained within the FHB. Flow from each DCT basin to the FHB sub-basement was calculated based on the pipe capacity and head differential using CulvertMaster (Bentley, 2017), with each pipe assigned a Manning's roughness coefficient of 0.013 and length of 3 ft. Because it is not connected to an emergency diesel generator, the sump pump housed in the FHB was excluded from consideration due to an assumed loss of offsite power. In addition, the MSIV areas are subject to outflow via multiple drains for which outflow is computed based on ponding depth. (FHRR Section 3.1.2.3)

With all inflows and outflow accounted for, incremental changes to ponding depth were calculated using volume-depth relationships developed for each DCT basin and MSIV area. For the eight different DCT sump pump scenarios evaluated, the DCT Basin A maximum ponding depth ranges from 1.18 ft. to 1.53 ft., while the DCT Basin B maximum ponding depth ranges from 1.27 ft. to 1.63 ft. Assuming the same pumping procedures as credited under the CDB (1 pump per DCT basin after 30 minutes and one pump per DCT basin after 3 hours), ponding in DCT Basin A reaches 1.5 ft., while ponding in DCT Basin B reaches 1.6 ft. (FHRR Table 3-14). These values constitute the licensee's reevaluated level for internal LIP flooding.

Because these levels exceed the level of the sump pumps and would exceed the CDB, the licensee developed an Operational Decision Making Issue (ODMI) implementation action plan to ensure two sump pumps per DCT basin activate 30 minutes after the PMP event onset (FHRR Section 5.1.2). Under this revised scenario, ponding in DCT Basin A reaches 1.4 ft., while ponding in DCT Basin B reaches 1.5 ft., both of which are below the CDB and prevent impacts to SSCs important to safety (FHRR Table 3-14). The evaluations resulted in maximum flood depths of 0.69 ft. and 0.62 ft. for the MSIV East and West areas, respectively, as shown on FHRR Table 3-15, though these results do not impact the LIP design-basis.

The NRC staff requested additional justification for a 30-minute stand-by time assumption under the ODMI plan. In the cover letter for the FHRR (Entergy, 2015) the licensee states that interim actions have been taken to mitigate LIP including the development of OP-901-521, "Severe Weather and Flooding," Off-Normal Procedure to ensure two DCT sumps pumps are operating within 30 minutes after the onset of the LIP event. Procedure OP-901-521 documents warning time triggers consisting of: 1) the Waterford shift manager being notified via phone call by the St. Charles Parish EOC, 2) entry into OP-901-521, 3) monitoring of the National Weather Service's probabilistic quantitative precipitation forecast for a rainfall amount of at least 10 inches over a 24-h period, and 4) stationing of personnel at the diesel driven sump pumps to ensure the pumps are activated within 30 minutes (NRC, 2017b).

To test various evaluation assumptions, the NRC staff modified the volumetric balance spreadsheets to include HMR-based rainfall inputs (the same as used by the licensee for external LIP flooding) and assess the impacts on maximum ponding depths. For the different HMR-based DCT sump pump scenarios evaluated by staff, the DCT Basin A maximum ponding depth ranges from 1.6 ft. to 1.95 ft., while the DCT Basin B maximum ponding depth ranges from 1.7 ft. to 2.1 ft. Assuming the same pumping procedures as credited under the CDB (1 pump per DCT basin after 30 minutes and one pump per DCT basin after 3 hours), ponding in DCT Basin A reaches 1.95 ft. (an increase of 0.4 ft. compared to the SSPMP-based approach), while ponding in DCT Basin B reaches 2.1 ft. (an increase of 0.5 ft. compared to the SSPMP-based approach).

Overall, the NRC staff considered the differences between the SSPMP-based and HMR-based internal LIP flooding evaluations to be small (i.e., using HMR-based precipitation increased the maximum depth by less than 0.5 ft.). The NRC staff found the volumetric balance approach to be reasonable, and no major concerns were found with the reevaluated internal LIP flooding level.

The NRC staff also tested the sensitivity of the selected pipe orifice coefficient. When decreasing the orifice coefficient to the lower end of the reasonable range, only a minor increase in ponding depth was found.

Subsequent to the submittal of the FHRR, the licensee submitted its MSA report (Entergy, 2016) describing revised procedures to activate two sump pumps within 30 minutes after the onset of the LIP event to maintain the ponding levels below the CDB which is based on the height of the MCCs. By letter dated February 27, 2017, the NRC staff issued its staff assessment for the MSA documenting its review and conclusions (NRC, 2017a).

3.2.6 Conclusion

The NRC staff confirmed the licensee's conclusion that the flood hazard from external LIP and associated site drainage alone would not inundate the site. Therefore, external LIP and associated site drainage does not need to be analyzed in a focused evaluation or revised integrated assessment. However, the NRC staff confirmed the licensee's conclusion that the reevaluated hazard from internal LIP and associated site drainage is not bounded by the CDB flood hazard. By letter dated May 17, 2017, the licensee submitted a focused evaluation for internal LIP and associated site drainage for the Waterford site (Entergy, 2017). The NRC staff's review and conclusion of the focused evaluation will be documented in a separate staff assessment.

3.3 Streams and Rivers

The licensee reported in the FHRR that the reevaluated flood hazard (FHRR Section 3.2.3 and Table 4-1) for streams and rivers is based on a stillwater-surface elevation of 20.0 ft. MSL at Waterford and 29.9 ft. MSL in the Mississippi River. Effects from wind waves and runup were not considered for flooding in streams and rivers since this hazard is bounded by the combined effect flood resulting from storm surge coincident with levee failure.

This flood-causing mechanism is discussed in the licensee's CDB. The CDB PMF elevation for streams and rivers is based on a stillwater-surface elevation of 27.0 ft. MSL in the Mississippi River, though no flood level is reported at the Waterford site. Effects from wind waves and runup were not considered in the CDB.

At the request of the NRC staff (NRC, 2015a and 2015b), the licensee provided electronic copies of input/output files (AREVA, 2015) and additional supporting information through the licensee's ERR. The information needs audit is summarized in the Audit Summary Report (NRC, 2017b), which is discussed in the appropriate sections below.

The NRC staff reviewed the flooding hazard from streams and rivers against the relevant regulatory criteria based on present-day methodologies and regulatory guidance.

The licensee estimated the PMF by using USACE Project Design Flood (PDF) information, which is used for the flood protection program within the lower Mississippi Valley. Citing Chow et al. (1964), the licensee assumed the PDF is equivalent to 40 percent of the PMF (i.e., 2.5 conversion factor). To avoid the influence of flow diversions through flood control structures, the licensee measured the PDF at a point just upstream of the Old River Control structure (ORCS), a hydraulic structure which diverts flow from the Mississippi River to the Atchafalaya River. The PDF for the Mississippi River at this location is 2,720,000 cubic feet per second (cfs), while the combined PDF for the Atchafalaya River is 350,000 cfs. This corresponds to a Mississippi River PMF of 6,800,000 cfs and Atchafalaya River PMF of 875,000 cfs, with a combined PMF peak flow of 7,675,000 cfs for the Mississippi-Atchafalaya River system. For comparison, the estimated PMF is approximately three times higher than the highest recorded flow upstream of the ORCS (2,300,000 cfs in May 2011). The NRC staff considers the licensee's approach to estimating PMF flow rates using USACE-produced PDF values and a conversion factor of 2.5 to be appropriate and consistent with methodology used for other nuclear power plants on the Lower Mississippi River (NRC, 2017b).

To simulate flood elevations along the Mississippi River and Atchafalaya floodplain, the licensee developed a Hydrologic Engineering Center - River Analysis System (HEC-RAS) steady flow hydraulic model (USACE, 2010). The HEC-RAS model was constructed to simulate a split river system consisting of two river reaches connected via overtopping of the Mississippi River right descending levee. The eastern reach includes the Mississippi River and its left descending levee, while the western reach includes the right descending bank, consisting of the Atchafalaya River, Atchafalaya River floodplain, and the Waterford site. The NRC staff finds the licensee's application of HEC-RAS model to be appropriate and in accordance with current regulatory guidance.

To better understand the licensee's HEC-RAS modeling assumptions, the NRC staff issued an information need related to the use of a steady-state model (NRC, 2017b). The licensee provided an explanation and the NRC staff conducted a sensitivity study which resolved the NRC staff's concern (NRC, 2017b). The NRC staff's model sensitivity results showed that the flood WSE could be about 1.4 ft. higher than the licensee's results in the Mississippi River; however, the elevation in the floodplain was largely insensitive. Though a higher maximum WSE in the Mississippi River can occur, additional sensitivity analysis on levee failure simulations with FLO-2D shows that the Waterford site will experience the worst flooding when water levels are highest in the floodplain (rather than in the Mississippi River). As a result, the NRC staff finds the licensee's use of a steady-state modeling assumption to be reasonable for predicting maximum flooding elevations but not the timing of the flood event.

The licensee modeled two ineffective flow areas to the east of the Mississippi River left descending levee. To better understand the licensee's HEC-RAS modeling arrangement, NRC staff issued an information need related to ineffective flow areas (NRC, 2017b). The NRC staff conducted a model test to evaluate the impact of the removal of the ineffective flow areas and found the resultant flood WSEs to not be significantly altered by this change. Based on the licensee response and the NRC staff's sensitivity results, the NRC staff finds the licensee's use of ineffective flow areas to be reasonable.

The HEC-RAS model stretches approximately 320 miles from Mississippi River Mile 320 (approximately 5 miles upstream of the ORCS) to Mile 0. Over this stretch of river, USACE published records indicate that the levee top elevations descend from about 75 ft. MSL to 17.4 ft. MSL. The licensee validated these elevations using LiDAR data. The model was constructed to allow split flow between the reaches via levee overtopping of a simulated lateral structure. Flow over the levees was computed using a weir coefficient of 2.6, which is at the lower end for typical broad-crested weirs.

To better understand the licensee's HEC-RAS modeling assumptions, the NRC staff issued an information need related to the weir coefficient used to simulate levee overflow via lateral structures (NRC, 2017b). The NRC staff performed a sensitivity run using a steady-state model with reduction of the lateral weir coefficient to 0.5 exhibited only minor model instability (variation in max flooding elevation depending on upstream flow distribution). The worst-case scenario evaluated produced a max WSE of 30.5 ft. MSL (+0.6 ft.) compared to licensee's analysis) in the Mississippi River; however, the elevation in the floodplain was largely insensitive (varies by only a few tenths of a foot). Though a higher maximum WSE in the Mississippi River can occur, additional sensitivity analysis on levee failure simulations with FLO-2D shows that the Waterford site will experience the worst flooding when water levels are highest in the floodplain (rather than in the Mississippi River). The NRC staff determined that the licensee's response was reasonable. As a result, the NRC staff finds the licensee's selection of levee weir coefficient to be reasonable.

The licensee established a normal depth energy slope as both an upstream and downstream boundary condition in the HEC-RAS model. An average energy slope of 0.00004 was estimated using USACE water surface profiles for a 2008 flood and the 100-year flood on the Mississippi River. The licensee performed sensitivity analysis on the downstream normal depth energy slope value and found that peak WSEs were not very sensitive to the value used. As a result, the NRC staff finds the licensee's selection of normal depth energy slope values to be reasonable.

At the HEC-RAS upstream boundary, flow entering the river system is gradually split over the right descending levee using the HEC-RAS flow optimization tool feature. Cross sections were constructed at locations where elevations or floodplain geometry changes were noted. Due to the generally flat terrain of the Mississippi and Atchafalaya River flood plains, relatively few representative cross sections were included in the model, with just 15 cross sections calculated from bathymetric and Digital Elevation Model (DEM) data and intermediate cross sections interpolated within HEC-RAS. Since flow conveyance in the Atchafalaya River is expected to be minimal during a PMF event, the licensee did not capture the river channel in the cross section data, instead representing the area using the broad floodplain cross sections.

To calibrate the HEC-RAS model, the licensee used flow and stage data from the historical 2011 Mississippi River flood of record, which nearly reached the PDF flow at the Waterford site. Data were obtained from Reserve, LA, located approximately 9 miles upstream of the Waterford site. Calibration results indicated that the HEC-RAS model predicted higher peak WSE by approximately 0.9 ft. at Reserve, LA when using the 2011 flood data. Model verification was performed using data for a simulated PDF flood event and demonstrated that the HEC-RAS model predicted a peak WSE at the Waterford site within 0.5 ft. of the USACE's predicted elevation. The licensee concluded that the calibration and verification results demonstrated appropriate model conservativeness.

The licensee performed a steady-state HEC-RAS simulation by splitting the peak PMF at the upstream model boundary, with 6,800,000 cfs in the Mississippi River reach and 875,000 cfs in the Atchafalaya River reach. Using the calibrated model, the peak PMF flow rate at the

Waterford site was calculated as 1,800,000 cfs in the Mississippi River and 5,875,000 cfs in the Atchafalaya River reach. The results indicate a peak WSE of 29.9 ft. MSL in the Mississippi River at the Waterford site and 18.6 ft. North American Vertical Datum of 1988 (NAVD88) (20.0 ft. MSL) in the Atchafalaya River near the Waterford site.

To better understand the reasonableness of the licensee's upstream PMF flow distribution between the Mississippi and Atchafalaya rivers, the NRC staff conducted various sensitivity analyses by selecting multiple combinations of flow through the two river reaches. Despite some model instability, the results indicate that the peak WSE in the Atchafalaya River near the Waterford site is generally within 0.1 ft. of the licensee's results. As a result, the NRC staff finds the licensee's selected upstream PMF flow distribution to be reasonable.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard from flooding from streams and rivers is not bounded by the CDB flood hazard. By letter dated May 17, 2017, the licensee submitted a focused evaluation for flooding from streams and rivers (Entergy, 2017). The NRC staff's review and conclusion of the focused evaluation will be documented in a separate staff assessment.

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in its FHRR that the reevaluated flood hazard for failure of dams and onsite water control or storage structures is based on a stillwater-surface elevation of 20.6 ft. MSL at the Waterford site and 29.9 ft. MSL in the Mississippi River. When considering the combined effects associated with a Mississippi River levee failure, a maximum stillwater-surface elevation of 22.8 ft. MSL at the Waterford site was found. The combined effects scenario including wind waves and runup results in an elevation of 27.7 ft. MSL. This flood-causing mechanism is discussed in the licensee's CDB, but no PMF elevation was reported for the Waterford site.

At the request of the NRC staff (NRC, 2015a and 2015b), the licensee provided electronic copies of input/output files (AREVA, 2015) and additional information in the ERR. The Information Needs Audit is summarized in the Audit Summary Report (NRC, 2017b), which is discussed in the appropriate sections below. The NRC staff reviewed the flooding hazard from streams and rivers against the relevant regulatory criteria based on present-day methodologies and regulatory guidance.

To address the flood hazard due to upstream dam failure, the licensee considered impacts resulting from hydrologic, seismic, and sunny day failure events and concluded that a hydrologic (PMF) failure scenario would bound. Due to the significant size of the Mississippi River drainage area, the licensee concluded that the flooding from dam failures occurring in the more upstream sub-watersheds would be sufficiently attenuated to prevent any noticeable impact at the Waterford site. Consequently, the licensee performed a screening assessment to identify upstream dams which could contribute to flooding impacts at the Waterford site. Per the NRC's Dam Failure ISG (NRC, 2013b), the licensee adopted a hypothetical dam approach in which characteristics of multiple upstream dams were represented as a single, hypothetical dam subject to failure. Following the ISG, the licensee assigned the hypothetical dam with a location equivalent to the most downstream major dam within the watershed, a storage volume equivalent to the cumulative storage volume of all major dams, and a height equivalent to the tallest major dam.

To obtain data related to dams within the Lower Mississippi Region and Arkansas-White-Red Region watersheds, the licensee used the "Major Dams of the United States" map layer (DOI, 2014), which is housed by the U.S. Geological Survey (USGS) based on data from the USACE's National Inventory of Dams (USACE, 2013). All major dams within the Lower Mississippi Region and Arkansas-White-Region watersheds upstream of the Waterford site were accounted for in the hypothetical dam evaluation. Dams deemed as inconsequential (i.e., "dams whose failure poses no danger to life and property, or dams whose failure would only cause damage to property of the dam owner") were excluded from consideration.

The licensee's evaluation identified 115 major dams in the Lower Mississippi Region watershed and 777 major dams in the Arkansas-White-Red Region watershed. Based on the tallest major dam and total storage volume of all major dams within each region, a single hypothetical dam was considered for each region.

To estimate the peak breach outflow for each hypothetical dam, the licensee compared estimates from multiple regression equations (Froehlich, 1995; MacDonald, 1984; Costa, 1985) and used the most conservative (i.e., highest breach flow) result. The peak breach flow estimates for the three regression methods were based on the total storage volume and maximum height of each hypothetical dam. The licensee accounted for potential peak flow attenuation along the river and floodplain using the United States Bureau of Reclamation (USBR) attenuation method (USBR, 1982), which estimates the attenuated peak flow based on the peak breach flow and the distance (stream length) over which attenuation occurs.

Using the hypothetical dam characteristics, the peak breach flow was estimated as 5,510,000 cfs for the Lower Mississippi Region and 11,300,000 cfs for the Arkansas-White-Red Region. The licensee identified the distance between the Waterford site and the closest major dam upstream of the Waterford site in the Lower Mississippi River Region and Arkansas-White-Red Region watersheds as being 129 river miles and 252 river miles, respectively. After attenuation, the peak breach flows were estimated as 280,000 cfs and 34,000 cfs, respectively.

To better understand the reasonableness of the licensee's estimate for dam failure peak flow attenuation, the NRC staff requested an information need to seek further justification for using the USBR attenuation method (NRC, 2017b). Despite the peak attenuated flow being only 5.1 percent and 0.3 percent of the regression-based peak flow, the licensee considers the attenuation estimates to be appropriate. The relatively long distance between the upstream hypothetical dam and the Waterford site, the wide, flat nature of the floodplains, and lower, less conservative attenuation estimates found using other methodologies were cited as justification for using the USBR method. As a result, the NRC staff finds the licensee's use of the USBR dam failure flow attenuation method to be reasonable.

Using the HEC-RAS model developed for the PMF evaluation (see Section 3.3 of this staff assessment), the licensee modified the model's upstream boundary input to include the attenuated dam failure peak breach flows in addition to the PMF flows. When attempting to apportion these additional flows to the model, the licensee observed model instabilities in the Mississippi River reach in which increases in upstream flow resulted in decreases in WSE. Such instabilities were confirmed by NRC staff, and the licensee added the entire peak attenuated dam failure flow (314,000 cfs) to the model's Atchafalaya River reach, which results in a more conservative WSE at the Waterford site.

The licensee performed a steady-state HEC-RAS simulation by splitting the peak PMF at the upstream model boundary, with 6,800,000 cfs in the Mississippi River reach and 1,189,000 cfs in the Atchafalaya River reach. Using the calibrated model, the licensee computed a dam failure PMF peak WSE of 29.9 ft. MSL in the Mississippi River at the Waterford site and 20.6 ft. MSL in the Atchafalaya River near the Waterford site.

To better understand the reasonableness of the licensee's PMF plus upstream dam failure flow distribution, NRC staff issued an information need (NRC, 2017b) and conducted various sensitivity analyses by selecting multiple combinations of flow through the two river reaches. Based on the licensee's response and NRC staff's sensitivity test results, NRC staff finds the licensee's selected PMF plus upstream dam failure estimation to be reasonable.

3.4.1 Combined Effects Flooding (Levee Failure)

Following NUREG/CR-7046 (NRC, 2011e), the licensee considered multiple combined effects flood scenarios as a part of its FHRR evaluation. Combined Effects Scenario H.1 – Floods caused by precipitation events applies directly to the PMF plus upstream dam failure event. Since PMF plus upstream dam failure flooding bounds seismic dam failure flooding, Combined Effects Scenario H.2 – Floods caused by seismic dam failures was screened out. Details of Combined Effects Scenario H.2 are included in FHRR Section 3.9; however, the NRC staff did not conduct a detailed review of the seismic dam failure flooding hazard. A detailed evaluation of the licensee's controlling Combined Effects Scenario H.3-Flood along the shores of open bodies of water is discussed in Section 3.5 of this staff assessment.

For the licensee's Combined Effects Scenario H.1, the PMF plus upstream dam failure event was combined with wave effects produced by the 2-year wind speed applied along the critical direction. To simulate the effect of a postulated failure of the Mississippi River right-descending levee in association with Combined Effects Scenario H.1, the licensee used a two-dimensional FLO-2D model, Build No. 14.03.07 (FLO-2D, 2009). This model construction was similar to the LIP-based FLO-2D model but expanded to include additional coverage for areas adjacent to the levee both upstream and downstream of the Waterford site over a length of approximately one mile.

The levee was represented within the FLO-2D model using the model's levee feature and was assigned a top elevation of 30 ft. MSL, a prescribed failure elevation of 29.9 ft. MSL, a bottom failure elevation of 17.4 ft. MSL, a levee breach width of 500 ft., a horizontal failure rate of 5,000 ft. per hour, a vertical failure rate of 125 ft. per hour, and a failure response delay of 1 hour.

The Mississippi River and Atchafalaya floodplain maximum WSEs estimated with HEC-RAS were input to FLO-2D using Outflow grid elements. To simulate the postulated levee failure while ensuring appropriate river and floodplain water levels, the licensee assigned the Outflow grid elements with WSEs equivalent to the HEC-RAS results.

A total of six grid elements were identified for monitoring locations of interest on the Northwest corner, Northeast side, East side, Southeast side, and Northwest side of the NPIS, as well as the Southeast side of the Independent Spent Fuel Storage Installation. The results indicate that maximum WSEs reach approximately 23.4 ft. MSL on the northern NPIS, 22.8 ft. MSL on the eastern NPIS, and 23.2 ft. MSL on the western NPIS. These water levels correspond to maximum flow depths of approximately 6.3 ft. on the northern NPIS, 5.5 ft. on the eastern NPIS, and 6.2 ft. on the western NPIS. Maximum velocities reach approximately 2.6 ft./s on the northern NPIS, 3.1 ft./s on the eastern NPIS, and 2.4 ft./s on the western NPIS.

The licensee adjusted the time-stage relationships at the boundaries of the FLO-2D model for the levee breach analysis in order to maintain model stability during the initial simulation period. In order to determine the impacts of these adjustments, the NRC staff conducted model tests. The NRC staff determined that the licensee's adjustments were not significant in the determination of the flood hazard levels associated with levee breach flooding.

Following NUREG/CR-7046 (NRC, 2011e), the licensee computed the significant wave height and maximum wave height based on the 2-year annual recurrence interval wind speed and the effective fetch length. The maximum reflected/standing wave crest elevation was computed using the Sainflou equation (Sainflou, 1928) and determined to be 27.7 ft. MSL. The licensee also reported hydrostatic, hydrodynamic, and debris impact loads as a result of Combined Effects Scenario H.1.

The licensee's Combined Effects Scenario H.1 evaluation's results are equivalent to those for the Controlling Combined Effects Scenario H.3, which is discussed in Section 3.5 of this staff assessment. Therefore the NRC staff finds the licensee's methodology and assumptions to be reasonable.

3.4.2 Conclusion

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard from flooding from failure of dams and onsite water control or storage structures is not bounded by the CDB flood hazard. By letter dated May 17, 2017, the licensee submitted a focused evaluation for flooding from failure of dams and onsite water control or storage structures (Entergy, 2017). The NRC staff's review and conclusion of the focused evaluation will be documented in a separate staff assessment.

3.5 Storm Surge

The licensee reported in the FHRR that the reevaluated flood hazard for storm surge is based on a stillwater-surface elevation of 26.0 ft. MSL, 26.9 ft. MSL for significant wave crest elevation, and 31.8 ft. MSL for maximum wave crest elevation. This flood-causing mechanism is described in the licensee's CDB. The CDB hazard for site flooding due to the combined effect scenario of a PMH-induced PMSS at the mouth of the Mississippi River coincident with a PMF and levee failure at the Waterford site is 27.6 ft. MSL.

The licensee's storm surge evaluation was based on a review of historical storm and storm surge data, development of PMH parameters, selection of storm surge and wave modeling tools, configuration of those models, and the estimation of the surge and wave effects within the Mississippi River watershed near to and at the Waterford site. The licensee used the SLOSH (NOAA, 1992) model and the Advanced CIRCulation (ADCIRC) (Luettich and Westerink, 2004) model to estimate surge elevations. The licensee used the SLOSH model to provide input to the parameter combination sensitivity analysis. The licensee then used the ADCIRC model to determine storm surge sensitivity to model parameters and to simulate storm surge elevations. The licensee used ADCIRC+SWAN (Dietrich et al., 2012) to estimate nearshore wind-wave transformation. The licensee also used the modeling tools to evaluate combined effect hazards and identify the controlling combined effect flood scenario.

3.5.1 Historical Storm Surge Data

The licensee reviewed the major hurricane tracks from 1880 to 2013 and observed tide levels as discussed in the Waterford FHRR (Entergy, 2015). The licensee provided the details of the site and region-specific meteorological and climatological study, and estimations of the ranges of PMH parameters. The NRC staff reviewed SURGEDAT database (SURGEDAT, n.d.) and found the track and category of the top ten storms surges identified by the licensee, which are consistent with those identified by Needham and Keim (2012).

3.5.2 Antecedent Water Levels (AWLs)

The licensee calculated the AWLs using recorded monthly maximum tide elevations from NOAA tidal gage stations at Grand Isle, Dauphin Island, and Eugene Island (locations shown in Figure 3.5-4) to estimate a 10-percent exceedance high tide of 4.1 ft. MSL.

Based on the 10-percent exceedance high tide and the expected 30-year sea level rise, NRC staff verified the licensee's calculation of the AWL. The licensee's value of 4.3 ft. MSL was found to be slightly higher than staff's value of 3.8 ft. MSL. Thus, the NRC staff concludes that the licensee used a reasonable AWL for its surge analysis.

3.5.3 Storm Surge and Wave Models

The licensee applied two-dimensional hydrodynamic computer software programs to simulate the storm surge: 1) the SLOSH Model (NOAA, 1992), and 2) the ADCIRC Model (Luettich and Westerink, 2004). The licensee used the SLOSH model to provide input to the parameter combination sensitivity analysis and the ADCIRC model to determine storm surge sensitivity to model parameters and to simulate storm surge elevations. The licensee applied the SWAN wave model to estimate wind-generated waves. The SWAN model was coupled to the ADCIRC model within the SWAN+ADCIRC model (Dietrich et al., 2012). Although, the FHRR does not describe ADCIRC model performance near the Waterford site or validation to measured waves, the comparisons provided in the FHRR of high water levels between model simulation and observation present a reasonable validation of the ADCIRC model at select locations. The licensee stated that relocating severe historical storms was conservative enough and therefore, an uncertainty factor was not needed. The NRC staff found the licensee's justification for not adding an uncertainty factor was reasonable.

3.5.4 Storm Surge Water Levels

The licensee performed SLOSH model parameter combination sensitivity simulations as a first level screening step and extracted the storm surge elevations near the Waterford site. The licensee completed model sensitivity simulations using the ADCIRC model as a second level screening step and further evaluated the storms identified as producing large surges using the SLOSH model screening/sensitivity analysis. The licensee applied the ADCIRC grid developed by FEMA for the southeast Louisiana FEMA Flood Insurance Study (FEMA, 2008); the resulting models provided the final PMSS elevations. Based on sensitivity analyses performed, the licensee concluded that the controlling combined effect flood methodology is conservative.

The ADCIRC results show that the PMSS is a slow moving, north tracking storm making landfall east of Eugene Island. The licensee incorporated offshore and inland post-landfall intensity decay as part of the ADCIRC simulation and AWL adjustments to the ADCIRC results. This stillwater PMSS was developed without the combination of storm surge and river flood conditions. After identifying the PMH conditions that contributed to the maximum surge, the licensee considered combined events that included surge. The licensee identified the controlling combined effect flood as one that includes the PMH combined with the 25-year river flood, 10-percent exceedance high tide, levee failure and wind-wave activity. The licensee reported that this combination of events resulted in a stillwater elevation of 26.0 ft. MSL at the NPIS on the Waterford site.

The FHRR calculates and applies the significant wave crest and maximum reflected/standing wave crest for the Controlling Combined Effect Flood Scenario to quantify the total water levels caused by the PMH forcing. The licensee used a combination of SWAN+ADCIRC, FLO-2D and the Sainflou formula (USACE, 2015) to evaluate this scenario. Related to overtopping of the Mississippi River levee near the site, the FHRR investigated the levee breach scenario with a FLO-2D model. The FHRR analysis that included a levee breach near the Waterford site applied the FLO-2D model with SWAN+ADCIRC model input data for the PMSS boundary conditions (elevation of water at breach). During the audit, the licensee provided the basis for the formulation combination of events for this analysis (NRC, 2017b). The licensee found that the significant wave crest elevation of 26.9 ft. MSL, and a maximum wave crest elevation of 31.8 ft. MSL at the NPIS. The licensee also reported an estimate of NPIS wall overtopping flow rate of 0.1 ft.^{3}/s as a result of these wave conditions. The licensee estimated that controlling combined event storm will cause flooding from maximum wave height for a period of about 5.3 hours (Entergy, 2015).

During the audit, the licensee provided additional detail supporting their determination of the controlling storm condition which was based on the criteria of maximizing stillwater elevation at the Waterford site (NRC, 2017b).

3.5.5 NRC Independent Model Evaluation

The NRC staff evaluated the hurricane surge by conducting an independent modeling study, which applied the ADCIRC hydrodynamic model mesh from the FEMA Region 6 Coastal Storm Surge Study for Louisiana (FEMA, 2008). The independent simulations applied time-varying, two-dimensional wind and pressure fields for tropical storms with varying parameters. NRC staff developed the tropical storm parameter combinations to produce the Probable Maximum Intensity (PMI) storm conditions at the Waterford site. The site location created a complex storm surge response at the site, which required examination of many storm track angles and landfall locations.

The results from the independent simulations with the PMI forcing allow comparison of the licensee's reevaluated combined events analysis that includes the PMSS and the effects of waves and river flow. The NRC staff compared the independent model results with those reported in the FHRR for locations near the main WSES infrastructure and a location along the Mississippi River.

The NRC staff's independent simulations applied linear superposition to add the tide and sea level rise effect to the modeled storm surge value. The independent simulations provide suitable PMI storm forcing given historical data and meteorological forcing in the WSES region. The multiple results with storms featuring different angles and landfall locations shows the sensitivity of the final model results to these parameters.

The stillwater levels for the NRC staff independent simulations compare well with the FHRR stillwater level; both the FHRR and NRC stillwater values are below the CDB. The FHRR licensee's CDB. The licensee provided no CDB maximum flood elevation for seiche in the FHRR.

The licensee stated the potential flood hazard due to seiche activity was negligible based on the site's riverine setting and elevation. The license stated that the Mississippi River is not closed or semi-enclosed, and due to other channel geometry considerations, is not conducive to seiche formation. The licensee also stated that the any oscillations within the Mississippi River near the site would be effectively attenuated due to geometric considerations. Therefore, the licensee concluded that flood hazards from seiche would have minimal to no effect on flooding at the Waterford site.

The NRC staff accept the licensee's description of the factors controlling the formation of seiche and the lack on the necessary conditions to pose a significant seiche formation potential near the Waterford site.

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

3.7 Tsunami

The licensee reported in its FHRR that the reevaluated hazard for tsunami does not inundate the plant site, but did not report a PMF elevation. This flood-causing mechanism is discussed in the licensee's CDB, but no probable maximum flood elevation was reported.

The licensee considered both the Mississippi River and the Gulf of Mexico in its reevaluation of tsunami flooding of the Waterford site. The licensee stated that Waterford site is located 35 river miles upstream of New Orleans and 130 river miles upstream of the Head of Passes. The licensee stated in its FHRR that the Waterford site is 60 miles north of the Gulf of Mexico, but that considering the topography between the site and the Gulf of Mexico does not preclude the hydraulic connectivity between these locations during extreme flooding conditions.

The licensee considered the tsunamigenic potential on the Mississippi River in the vicinity of the Waterford site. The licensee concluded that "the potential for a subaerial landslide causing a tsunami is limited" near the Waterford site due to the flat topography of the area. The licensee further stated that the spillway structure on the opposite side of the Mississippi River from the Waterford site would be the first to overtop in the event of a riverine-generated tsunami.

The licensee also considered the sources in the Gulf of Mexico by performing a regional survey of sources using the NGDC Tsunami Event Database (NOAA, n.d.), a literature search of far- and near-field sources, and USGS Tsunami Potential Gulf of Mexico report (USGS, 2009). The licensee reported that a USGS modeling study suggested that a maximum 26 ft. tsunami could occur along the coast of Texas, but did not include an estimate for the coast of Louisiana. The licensee compared an USGS estimated tsunami elevation at the Gulf Coast to the Waterford site grade and to the SSC external flooding protection elevation and concluded that the estimated tsunami elevation was lower than Waterford site grade by over 1 ft. and lower than the SSC external flooding protection elevation by about 16 ft. when tsunami propagation path from the Gulf Coast is considered to be overland rather than along the course of the Mississippi River.

The licensee considered a riverine tsunami flow path from the Gulf Coast to the site. The license stated that the river depth and its mild bottom slope do not support the propagation of a tsunami for the 130 river mile long reach of the Mississippi River between the Gulf of Mexico and the Waterford site. The licensee found no historical instances of propagation at such long distances. The licensee also noted that levees in the vicinity of the Waterford site would inhibit tsunami-related flow from the river toward the Waterford site for tsunami elevations up to the levee crest (30 ft. MSL). In summary, the licensee concluded that a tsunami is not expected to be a significant contributor to flooding at the Waterford site.

The NRC staff review of historical tsunami data (NOAA, n.d.) identified possible tsunamis with the potential to affect the Gulf Coast near the Waterford site but noted that no tsunami runup heights were available. Based on the review of the historical observations the NRC staff concluded that the tsunamis in the region are relatively rare and coastline runup heights would be 3 ft. or less. The NRC staff also confirmed that of the tsunamigenic sources, including subaerial and submarine landslides, volcanic activity, near-field intra-plate earthquakes and inter-plate earthquakes, and seismic seiches, submarine landslides in the Gulf of Mexico should be considered as potential PMT sources at the Waterford site. The NRC staff considered the landslide sources and characterized the maximum credible landslide parameter for each source based on examination of relevant literature. Of the submarine landslide scenarios the NRC staff concluded that the postulated Mississippi Canyon Landslide (MCL) should be further examined as part of the staff's review. The NRC staff independently evaluated the PMT using the numerical models, which yielded maximum WSEs of about 48 ft. MSL near the Mississippi River mouth for the numerical simulation of the MCL. The NRC staff predicted PMT water levels in the Mississippi River channel adjacent to the Waterford site were about 11 ft. MSL. The NRC staff considers this scenario to be the worse-case scenario and the WSE from this scenario is below the Waterford site grade.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for flooding from a tsunami does not inundate the Waterford site. Therefore, the NRC staff determined that flooding from a 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 its FHRR that the reevaluated flood hazard for ice-induced flooding is negligible. This flood-causing mechanism is discussed in the licensee's CDB, but no flood elevation was reported.

The licensee described two mechanisms by which ice jams and ice dams could lead to flooding of a site: collapse of an upstream ice jam creating a flood wave and formation of a downstream ice jam causing a backwater flood. The licensee reviewed historical ice effects in the Mississippi River and examined historical records of water temperature in the vicinity of the Waterford site. The licensee searched the USACE Ice Jam Database (USACE, n.d.) and found that there have not been any recorded ice jams near the Waterford site. The licensee reported that the annual minimum water temperatures ranged from 36 to 48 °F at Baton Rouge and above 33 °F at Natchez. In its FHRR, the licensee determined that the reevaluated hazard for ice-induced flooding would not inundate the plant site based on its review of historical records for ice jam, ice dams, and Mississippi River water temperatures.

The NRC staff searched the USACE Ice Jam Database (USACE, n.d.) for the state of Louisiana and found no instances of ice jams. The NRC staff examined the graph of Mississippi River water temperatures recorded at Baton Rouge, LA (USGS Station 0737400 within USGS HUC 08070100), for the period October, 2007 to June, 2017 (USGS, n.d.). The NRC staff concluded that the lowest water temperatures reported for this period were about 37 °F and the annual low temperatures were typically above 41 °F. The NRC staff determined that the licensee reevaluated the potential for ice-induced flooding at the Waterford site using present-day guidance and methodology.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard for ice-induced flooding is bounded by the CDB flood hazard at the Waterford site. Therefore, the NRC staff determined that ice-induced flooding effects does not need to be analyzed in a focused evaluation or a revised integrated assessment for the Waterford site.

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. This flood-causing mechanism is discussed in the licensee's CDB, but no maximum flood elevation was reported.

The licensee stated in FHRR Section 3.8 that historical records and hydro-geomorphological data were used to reevaluate the potential for flooding due to channel migrations or diversions of the Mississippi River. The licensee also evaluated current channel protection and stabilization measures to mitigate channel diversion of the river. The licensee described the historical evidence of the migration of the river channel but noted that none were prevalent near the site. The licensee noted the soil types near the site were more resistant to erosion near the site than in other river locations. The licensee noted the effort by the USACE to maintain navigability on the Lower Mississippi River (including the segment near the Waterford site). Part of the USACE management of this river segment is to maintain the stability of the channel that includes the Waterford Revetment completed between 1973 and 1991. The licensee identified major floodways and diversion structures that could affect the flood hazard near the Waterford site. The licensee evaluated whether the failure of the diversion structures would plausibly lead to increased flooding to the site. The licensee determined these floodways and diversion structures only divert flow away from the site during periods of flooding and failure of these diversion structures would only result in flow toward the Atchafalaya River and flow attenuation in the Mississippi River, as described in the USACE information paper on the Mississippi River floodways (USACE, 2007).

The NRC staff reviewed the USACE information paper on the Mississippi River floodways (USACE, 2007) and agrees with the licensee's conclusions drawn from it with respect to the general observation that the flow diversions during operation, overtopping, or failure would distribute flow away from the Waterford site.

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

4.0 REEVALUATED FLOOD HEIGHT, EVENT DURATION AND ASSOCIATED EFFECTS 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, flooding from streams and rivers, failure of dams and onsite water control/storage structures, and storm surge are the flood-causing mechanisms not bounded by the CDB.

By letter dated May 17, 2017, the licensee submitted the MSA (Entergy, 2016). By letter dated February 27, 2017, the NRC staff issued its staff assessment for the MSA documenting its review and conclusions (NRC, 2017a). By letter dated November 14, 2016, the licensee submitted a focused evaluation (Entergy, 2017). The NRC staff's review of the information provided in the focused evaluation will be documented in a separate staff assessment.

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided by in Entergy's 50.54(f) response (Entergy, 2015; NRC, 2017a; 2017b) regarding the FED parameters needed to perform the additional assessments of plant response for flood-causing mechanisms not bounded by the CDB. The FED parameters provided in the FHRR for the four flood-causing mechanisms not bounded by the CDB are summarized in Table 4.2-1. During the audit, the licensee discussed the provision of FED parameters (NRC, 2017b). By letter dated November 14, 2016, the licensee submitted the MSA (Entergy, 2016b), which included the FED parameters for the four controlling scenarios. The NRC staff's review and conclusions regarding the FED parameters provided in the MSA are documented in a separate staff assessment that was issued on February 27, 2017 (NRC, 2017a). In its MSA staff assessment, the NRC staff concluded that the FED has no effect on the mitigating strategies and is bounded by the FLEX design-basis. The licensee submitted a focused evaluation by letter dated May 17, 2017 (Entergy, 2017a). The NRC staff review and conclusions for the information provided in the focused evaluation, including any variation of the FED parameters from those in the MSA submittal, will be documented in a separate staff assessment.

4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided by in Entergy's 50.54(f) response (Entergy, 2015) regarding the AE parameters needed to perform the additional assessments of plant response for flood hazards not bounded by the CDB. The licensee also presented the AE parameters associated with the four, unbounded flood-causing mechanisms directly related to maximum total water height, such as wave and runup, in the MSA (Entergy, 2016). The AE parameters are presented in Table 4.1-1. The AE parameters not directly associated with total wave height are listed in Table 4.3-1 based on information provided in the FHRR and MSA (Entergy, 2015; Entergy, 2016).

For the four controlling scenarios the licensee summarized the evaluation of AE parameters in the FHRR and the MSA (Entergy, 2015; Entergy, 2016). In its FHRR, the licensee provided an evaluation of sediment loading, sediment erosion/deposition, groundwater ingress, or concurrent conditions associated with these flood-causing mechanisms. For AE parameters noted as minimal or not applicable, the NRC staff confirms the licensee's AE parameter results are reasonable for use in additional assessments as discussed in NEI-12-06, Revision 2, Appendix G (NEI, 2015b), and outlined in COMSECY-15-0019 (NRC, 2015a), JLD-ISG-2012-05 (NRC, 2012d), JLD-ISG-2012-01, Revision 1 (NRC, 2016a), and JLD-ISG-2016-01, Revision 0 (NRC, 2016c).

By letter dated November 14, 2016, the licensee submitted the MSA (Entergy, 2016b), which included these AE parameters for the four controlling scenarios. The NRC staff's review and conclusions regarding the AE parameters provided in the MSA are documented in a separate staff assessment issued on February 27, 2017 (NRC, 2017a). In its MSA staff assessment, the NRC staff concluded that debris hazards are not credible at the Waterford site. The NRC staff also concluded that deposition and erosion is considered minimal, hydrodynamic and debris loading is bounded by the missile requirements, and the hydrodynamic and debris impact loads are bounded by the FLEX design-basis. The licensee submitted a focused evaluation by letter dated May 17, 2017 (Entergy, 2017a). The NRC staff review and conclusions regarding the information provided in the focused evaluation, including any AE parameters, will be documented in a separate staff assessment.

4.4 Conclusion

Based upon the preceding analysis, 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 was expected to develop 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, 2016c). The NRC staff review and conclusions for the FED and AE parameters provided in the MSA and focused evaluation (Entergy, 2016; Entergy, 2017) are documented separately from this staff assessment.

5.0 CONCLUSION

The NRC staff reviewed the information provided for the reevaluated flood-causing mechanisms of the Waterford site. Based on the 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 (1) the reevaluated flood hazard results for LIP, stream and rivers, failure of dams, and storm surge are not bounded by the CDB flood hazard, (2) additional assessments of plant response would need to be performed for LIP, and for flooding from stream and rivers, failure of dams, and storm surge, and (3) the reevaluated flood-causing mechanism information is appropriate input to the additional assessments of plant response, as described in 50.54(f) letter and COMSECY-15-0019, and associated guidance. The NRC staff has no additional information needs at this time with respect to the Entergy's 50.54(f) response.

6.0 REFERENCES

Notes: ADAMS Accession No. refers to documents available through NRC's Agencywide Documents Access and Management System (ADAMS). Publicly-available ADAMS documents may be accessed through http://www.nrc.gov/reading-rm/adams.html.

U.S. Nuclear Regulatory Commission Documents and Publications

NRC (U.S. Nuclear Regulatory Commission), 2007, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition", NUREG-0800, [available online at http://www.nrc.gov/reading-rm/basic-ref/srp-review-standards.html.]

NRC, 2011a, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," Commission Paper SECY-11-0093, July 12, 2011, ADAMS Accession No. ML11186A950.

NRC, 2011b, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," Enclosure to Commission Paper SECY-11-0093, July 12, 2011, ADAMS Accession No. ML111861807.

NRC (U.S. Nuclear Regulatory Commission), 2011c, "Recommended Actions to be Taken Without Delay from the Near-Term Task Force Report," Commission Paper SECY-11-0124, September 9, 2011, ADAMS Accession No. ML11245A158.

NRC, 2011d, "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned," Commission Paper SECY-11-0137, October 3, 2011, ADAMS Accession No. ML11272A111.

NRC, 2011e, "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United State of America," NUREG/CR-7046, November 2011, ADAMS Accession No. ML11321A195.

NRC, 2012a, letter from Eric. J. Leeds, Director, Office of Nuclear Reactor Regulation and Michael R. Johnson, Director, Office of New Reactors, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding the Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," March 12, 2012, ADAMS Accession No. ML12053A340.

NRC, 2012b, letter from Eric. J. Leeds, Director, Office of Nuclear Reactor Regulation, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, "Issuance of Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," Order EA-12-049, March 12, 2012, ADAMS Accession No. ML12054A736.

NRC, 2012c, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, "Prioritization of Response Due Dates for Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Flooding Hazard Reevaluations for Recommendations 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," May 11, 2012, ADAMS Accession No. ML12097A510.

NRC, 2012d, “Guidance for Performing the Integrated Assessment for External Flooding,” Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2012-05, Revision 0, November 30, 2012, ADAMS Accession No. ML12311A214.

NRC, 2013a, “Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment,” Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2012-06, Revision 0, January 4, 2013, ADAMS Accession No. ML12314A412.

NRC, 2013b, “Guidance For Assessment of Flooding Hazards Due to Dam Failure,” Japan Lessons-Learned Project Directorate, Interim Staff Guidance JLD-ISG-2013-01, Revision 0, July 29, 2013, ADAMS Accession No. ML13151A153.

NRC, 2014, “Staff assessment of the flooding walkdown report near-term task force recommendation 2.3 related to the Fukushima Dai-Ichi Nuclear Power Plant accident, Entergy Operation, Inc., Waterford Steam Electric Station, Unit 3, Docket No. 50-382,” ADAMS Accession No. ML14135A349.

NRC, 2015, “Mitigating Strategies and Flood Hazard Reevaluation Action Plan,” Commission Paper COMSECY-15-0019, June 30, 2015, ADAMS Accession No. ML15153A104 (Package, two documents, (Publicly available): ML15153A105, “Closure Plan for the Reevaluation of Flooding Hazards for Operating Nuclear Power Plants” [cover letter] (Publicly available) and ML15153A110, “Enclosure 1 – Mitigating Strategies and Flooding Hazard Re-Evaluation Action Plan” [Publicly available]).

NRC, 2016a, “Compliance with Order EA-12-049 Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events”, Interim Staff Guidance JLD-ISG-2012-01, Revision 1 and Comment Resolution, January 22, 2016, ADAMS Accession No. ML15357A142.

NRC, 2016b, “Waterford Steam Electric Station, Unit 3 - Interim Staff Response to Reevaluated Flood Hazards Submitted in Response to 10 CFR 50.54(f) Information Request - Flood-causing Mechanism Reevaluation (CAC No. MF7125),” April 21, 2016, ADAMS Accession No. ML16090A327.

NRC, 2016c, “Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation; Focused Evaluation and Integrated Assessment,” Interim Staff Guidance JLD-ISG-2016-01, Revision 0, July 11, 2016, ADAMS Accession No. ML16162A301.

NRC, 2017a, letter from Robert Bernardo to Site Vice President, Entergy Operations, Inc., Waterford Steam Electric Station Unit 3 dated February 27, 2017 “Waterford Steam Electric Station, Unit 3 – Flood Hazard Mitigation Strategies Assessment”, Enclosure “Staff Assessment Related to the Waterford Steam Electric Station, Unit 3 As A Result of the Reevaluated Flooding Hazards Report Near-Term Task Force Recommendation 2.1-Flooding CAC No. MF7989,” ADAMS Accession No. ML17023A282.

NRC, 2017b, “Waterford Steam Electric Station, Unit 3, Information needs – Audit/Post Audit Summary Report related to the Fukushima Lessons Learned Flood Hazard Reevaluation Report,” dated November 8, 2017, ADAMS Accession No. ML16181A251.

Codes and Standards

ANSI/ANS (American National Standards Institute/American Nuclear Society), 1992, ANSI/ANS-2.8-1992, "Determining Design Basis Flooding at Power Reactor Sites," American Nuclear Society, LaGrange Park, IL, July 1992.

American Society of Civil Engineers (ASCE), 2010, ASCE 7-10, Minimum Design Loads for Buildings and Other Structures, Reston.

Other References

AREVA, 2015, Letter from Cynthia Fasano dated September 4, 2015, Transmitting input/output files for Flood Hazard Re-Evaluation for Waterford Steam Electric Station. ADAMS Accession No. ML17208A033.

Bentley, 2017, "CulvertMaster – Culvert Hydraulic Analysis and Design Software," https://www.bentley.com/en/products/product-line/hydraulics-and-hydrology-software/culvertmaster

Chow, V. T., D. R. Maidment, and L. W. Mays, 1964, "Applied Hydrology", McGraw-Hill, New York.

Dietrich, J.C., S. Tanaka, J.J. Westerink, C.N. Dawson, R.A. Luettich Jr., M. Zijlema, L.H. Holthuijsen, J.M. Smith, L.G. Westerink, and H.J. Westerink. 2012, Performance of the Unstructured-Mesh, SWAN+ADCIRC Model in Computing Hurricane Waves and Surge, Journal of Scientific Computation, 52:468-497.

Entergy, 2012, "Flooding Walkdown Report - Entergy's Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Flooding Aspects of Recommendation 2.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident, Waterford Steam Electric Station, Unit 3 (Waterford 3), Docket No. 50-382, License No. NPF-38, 2012," ADAMS Accession No. ML12333A147.

Entergy, 2015, "Waterford Steam Electric Station Unit 3 Flood Hazard Reevaluation Report," ADAMS Accession No. ML15204A321.

Entergy, 2016a, "Waterford Steam Electric Station, Unit 3, Revision 309 to Final Safety Analysis Report, Chapter 2, Site Characteristics 2.4," August 28, 2016, ADAMS Accession No. ML16256A152.

Entergy, 2016b, "Mitigating Strategies Assessment (MSA) Report for Flooding Hazard Waterford Steam Electric Plant, Unit 3 (Waterford 3)," November 14, 2016. ADAMS Accession No. ML16319A089.

Entergy, 2017, "Focused Evaluation of External Flooding for Waterford Steam Electric Station, Units 3 (Waterford 3)," May 17, 2017. ADAMS Accession No. ML17137A355.

FEMA, 2008, Flood Insurance Study: Southeastern Parishes, Louisiana, Intermediate Submission 2: Offshore Water Levels and Waves, Federal Emergency Management Agency and US Army Corps of Engineers, New Orleans District. Available on the web at: http://www3.nd.edu/~coast/reports_papers/SELA_2007_IDS_2_FinalDraft/Text%20SELA%202

007%20IDS%202%20FINAL%20072808.pdf. Licensee accessed in September 2014. Last updated in July 2008.

FLO-2D Software Inc., 2009, *FLO-2D® v.2009 Reference Manual*, FLO-2D Software, Inc., Nutrioso, AZ.

Luettich, R.A. Jr., Westerink, J.J., 2004, Formulation and Numerical Implementation of the 2D/3D ADCIRC Finite Element Model Version 44.XX. http://adcirc.org/adcirc_theory_2004_12_08.pdf

Needham, H. F., and B. D. Keim, 2012, A Storm Surge database for the US Gulf Coast, International Journal of Climatology, 32: 2108-2123, November 2011.
NOAA (National Oceanic and Atmospheric Administration), 1956, "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1000 Square Miles and Duration of 6, 12, and 48 Hours," NOAA Hydrometeorological Report No. 33, June 1956.

NOAA (National Oceanic and Atmospheric Administration), n.d., "Global Historical Tsunami Database" (Web site), https://www.ngdc.noaa.gov/hazard/tsu_db.shtml.

NOAA, 1978, "Probable Maximum Precipitation Estimates, United States, East of the 105th Meridian," NOAA Hydrometeorological Report No. 51, June 1978.

NOAA, 1980, "Seasonal Variation of 10-Square-Mile Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," NOAA Hydrometeorological Report No. 53, August 1980.

NOAA, 1982, "Application of Probable Maximum Precipitation Estimates, United States, East of the 105th Meridian," NOAA Hydrometeorological Report No. 52, August 1982.

NOAA, 1992, "SLOSH: Sea, Lake, and Overland Surges from Hurricanes", NOAA Technical Report NWS 48, Available at http://slosh.nws.noaa.gov/sloshPub/pubs/SLOSH_TR48.pdf.

Sainflou, 1928. "Essay on Vertical Breakwaters," Annales des Ponts et Chaussees, Paris (Translated by Clarence R. Hatch, Western Reserve University, Cleveland, OH), 1928.

SURGEDAT, n.d., SURGEDAT - The World's Storm Surge Data Center. Maps of the Top 10 Gulf Coast Storm Surges, Available on the Web at: http://surge.srcc.lsu.edu/historical_maps.html, Licensee accessed August 2014, NRC accessed July 7, 2017

USACE (U.S. Army Corps of Engineers), n.d., "Ice Jam Database," U.S. Army Corps of Engineers, Cold Region Research and Engineering Laboratory (CRREL), available online at http://icejams.crrel.usace.army.mil/. Staff accessed on June 7, 2017.

USACE, 2007, "The Mississippi River and Tributaries Project: Floodways," Information Paper.

USACE, 2008, "Coastal Engineering Manual," Engineer Manual 1110-2-1100, available online at http://www.publications.usace.army.mil/USACEPublications/EngineerManuals.

USACE, 2010, "River Analysis System (HEC-RAS), Version 4.1.0," Hydrologic Engineering Center, U.S. Army Corps of Engineers, January 2010.

USACE, 2013, "National Inventory of Dams," available online at http://nid.usace.army.mil.

USACE, 2015, Engineering and Design: Coastal Engineering Manual (EM 1110-2-1100). US Army Corps of Engineers, Washington, DC.

USGS (U.S. Geological Survey), n-d. "National Water Information System, USGS 0737400 Mississippi River at Baton Rouge, LA," Staff accessed on June 7, 2017. https://nwis.waterdata.usgs.gov/usa/nwis/uv/?cb_00010=on&format=gif_default&site_no=07374000&period=&begin_date=2010-05-31&end_date=2017-06-07

USGS, 2009, Regional Assessment of Tsunami Potential in the Gulf of Mexico: U.S. Geological Survey Administration Report.

USBR, 1982, "Guidelines for defining inundated areas downstream from Bureau of Reclamation dams," Reclamation Planning Instruction No. 82-11, U.S. Bureau of Reclamation, June 15, 1982.

WMO (World Meteorological Organization), 2009. Manual for Estimation of Probable Maximum Precipitation, Operational Hydrology Report No 1045, WMO, Geneva, 2009.

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

Table 3.1-2. Current Design Basis Flood Hazards

Flooding Mechanism	Stillwater Elevation	Associated Effects, ft	CDB Flood (CDB) Elevation	Reference
Local Intense Precipitation				
Nuclear Plant Island Structure Internal Ponding Depth at Dry Cooling Tower	1.6 ft. depth	Minimal	1.6 ft. depth	FHRR Sections 2.2, 2.3.1, & Table 4-1
Streams and Rivers				
PMF on Mississippi River	27.0 ft. MSL	Not applicable	27.0 ft. MSL	FHRR Section 2.3.1 & Table 4-1
Combined Event: PMF on Mississippi River and PMH coincident with a levee failure at the Mississippi River	27.6.ft. MSL	Not applicable	27.6 ft. MSL	FHRR Sections 2.2, 2.3.1 & Table 4-1
Failure of Dams and Onsite Water Control/Storage Structures				
Probable Upstream Dam Failures – Seismically Induced	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Section 2.3.1 & Table 4-1
Storm Surge				
Probable Maximum Storm Surge from Gulf of Mexico	18.1 ft. MSL	5.6 ft.	23.7 ft. MSL	FHRR Section 2.3.1 & Table 4-1, FSAR Section 2.4 (Entergy, 2016a)
Seiche	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Section 2.3.1 & Table 4-1
Tsunami	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Section 2.3.1 & Table 4-1
Ice-Induced	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Section 2.3.1 & Table 4-1
Channel Migrations or Diversions				
Cooling Water Canals	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Section 2.3.1 & Table 4-1

Note 1: Reported values are rounded to the nearest one-tenth of a foot.
Note 2: For flooding hazards within the NPIS, the licensee reported some flooding hazard levels in terms of ponding depth rather than WSE. The NRC staff accepted the licensee's convention and present this information in terms of ponding depth, where applicable.

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

Flood-Causing Mechanism	Stillwater Elevation	Waves/Runup	Reevaluated Flood Hazard	Reference
Local Intense Precipitation Waterford Steam Electric Station Yard (Outside of Nuclear Plant Island Structure)	20.5 ft. MSL	Minimal	20.5 ft. MSL	FHRR Section 3.1.1.2.4 & Table 4-1
Local Intense Precipitation in Dry Cooling Tower Basins (Ponding)	1.6 ft. Depth	Minimal	1.6 ft Depth	FHRR Section 3.1.3 & Table 4-1
Streams and Rivers Probable Maximum Flood on Mississippi River	29.9 ft. MSL	Not applicable	29.9 ft. MSL	FHRR Section 3.2.3 & Table 4-1
Failure of Dams and Onsite Water Control/Storage Structures Probable Maximum Flood + Hypothetical Dam Break within the Mississippi River	29.9 ft. MSL	Not applicable	29.9 ft. MSL	FHRR Section 3.3.2 & Table 4-1
Probable Maximum Flood + Hypothetical Dam Break at WSE Site	20.6 ft. MSL	Not applicable	20.6 ft. MSL	FHRR Section 3.3.2 & Table 4-1
Probable Maximum Flood + Hypothetical Dam Break within the Mississippi River and Levee Failure (Scenario H.1 at East NPIS)	22.8 ft. MSL	4.9 ft.	27.7 ft. MSL	FHRR Section 3.9.3.1 & Tables 3-30 & 3-31

Probable Maximum Flood + SSE Seismic Dam Failure, Levee Failure, and Induced Wind Waves (Scenario H.2 for Northwest NPIS)	20.8 ft. MSL	Not applicable	20.8 ft. MSL	FHRR Section 3.9.3.2 & Table 3-31
Probable Maximum Flood + SSE Seismic Dam Failure, Levee Failure, and Induced Wind Waves (Scenario H.2 for East NPIS)	18.9 ft. MSL	1.9 ft.	20.8 ft. MSL	FHRR Section 3.9.3.2 & Table 3-31
Storm Surge Probable Maximum Storm Surge from Gulf of Mexico at Waterford	 21.6 ft. MSL	 Not applicable	 21.6 ft. MSL	 FHRR Section 3.4.5 & Table 4-1
Combined Event H.3 (Alternative 3): 25-Year Flood in the Mississippi River, Probable Maximum Storm Surge Including Antecedent Water Level, Levee Failure, and Coincident Wind-Generated Waves at Site	26.0 ft. MSL	5.8 ft.	31.8 ft. MSL	FHRR Sections 3.9.3.3 & 3.9.4 & Table 4-1

Note 1: The licensee is expected to develop flood event duration parameters and applicable flood associated effects to conduct the MSA. The NRC staff will evaluate the flood event duration parameters (including warning time and period of inundation) and flood associated effects during its review of the MSA.
Note 2: Reevaluated hazard mechanisms bounded by the CDB (see Table 1) are not included in this table.
Note 3: Reported values are rounded to the nearest one-tenth of a foot.
Note 4: For flooding hazards within the NPIS, the licensee reported some flooding hazard levels in terms of ponding depth rather than WSE. The NRC staff accepted the licensee's convention and present this information in terms of ponding depth, where applicable.

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

Flood-Causing Mechanism	Time Available for Preparation for Flood Event	Duration of Inundation of Site	Time for Water to Recede from Site
Local Intense Precipitation inside of NPIS	Not Applicable[1]	Not Applicable[1]	Not Applicable[1]
PMF on the Mississippi River	Not Applicable[1]	Not Applicable[1]	Not Applicable[1]
PMF + Hypothetical Dam Break within Mississippi River and Levee Failure – Scenario H.1 at East of NPIS	Not Applicable[1]	Not Applicable[1]	Not Applicable[1]
Combined Event H.3 (Alternative 3): 25-Year Flood in the Mississippi River, PMSS Including Antecedent Water Level, Levee Failure, and Coincident Wind-Generated Waves at Site	Not Applicable[1]	Not Applicable[1]	Not Applicable[1]
Storm Surge: PMSS	Not Provided	overtopping period is about 5.3 hours (MSA Section 2)	Not Provided

Note 1: MSA Tables 1, 2, 3 and 4 (Entergy, 2016b) information related to the FLEX design basis flood hazard.

Note 2: The licensee found that under the Combined Event H.3 (Alternative 3), the eastern wall of the NPIS was overtopping by waves which generated a flood flow into the NPIS at a very low rate which was bounded by the level of ponding resulting from the LIP event inside the NPIS. The duration of the H.3 overtopping was estimated to be about 5.3 hours (Entergy, 2016b Table 4 Note 2).

Table 4.3-1. Associated Effects for Flood-Causing Mechanisms Not Bounded by the CDB (Sources: FHRR (Entergy, 2015) and MSA (Entergy, 2016))

	Flooding Mechanism			
Associated Effects Factor	**Local Intense Precipitation Inside the NPIS**	**PMF on the Mississippi River**	**PMF + Hypothetical Dam Break within Mississippi River and Levee Failure – Scenario H.1 at East of NPIS**	**25-Year Flood in the Mississippi River, PMSS Including Antecedent Water Level, Levee Failure, and Coincident Wind-Generated Waves at Site**
Hydrodynamic loading at Plant Grade	Not Applicable	Not Applicable)	70 lb/ft.^{2}, "relatively low"	Not Applicable
Debris loading at plant grade	Not Applicable	Not Applicable	4900 lb/ft.^{2}, "relatively low"	Not Applicable
Sediment loading at plant grade	minimal	None identified	Minimal	Not applicable
Sediment deposition and erosion	minimal	Not Applicable	Not Applicable	Not Applicable
Concurrent Conditions, including adverse weather	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Groundwater ingress	Not Applicable	Not Applicable	Not Applicable	Not Applicable)
Other pertinent factors (e.g., waterborne projectiles)	Not Applicable	Not Applicable	Not Applicable	Not Applicable

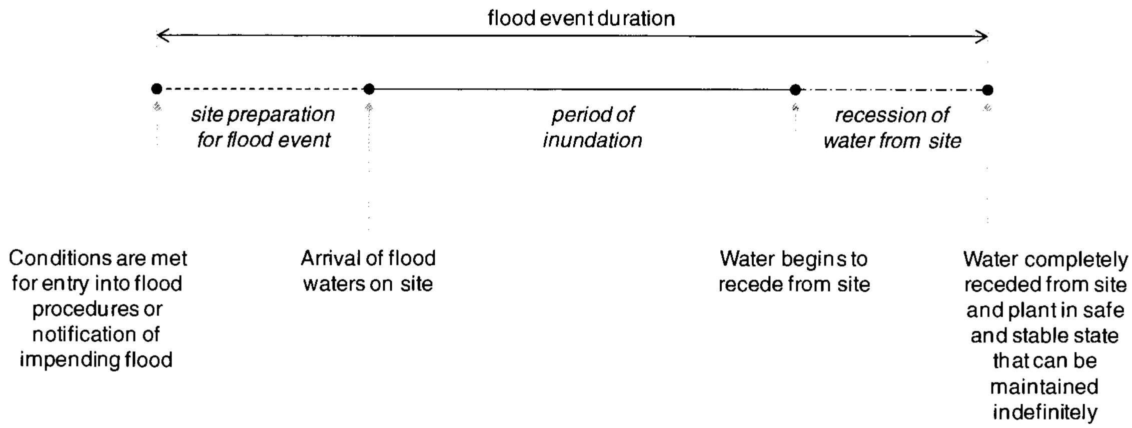


Figure 2.2-1 Flood Event Duration (NRC, 2012c)

Figure 3.1-1 Site Location Map (adapted from FHRR Figure 2-1)

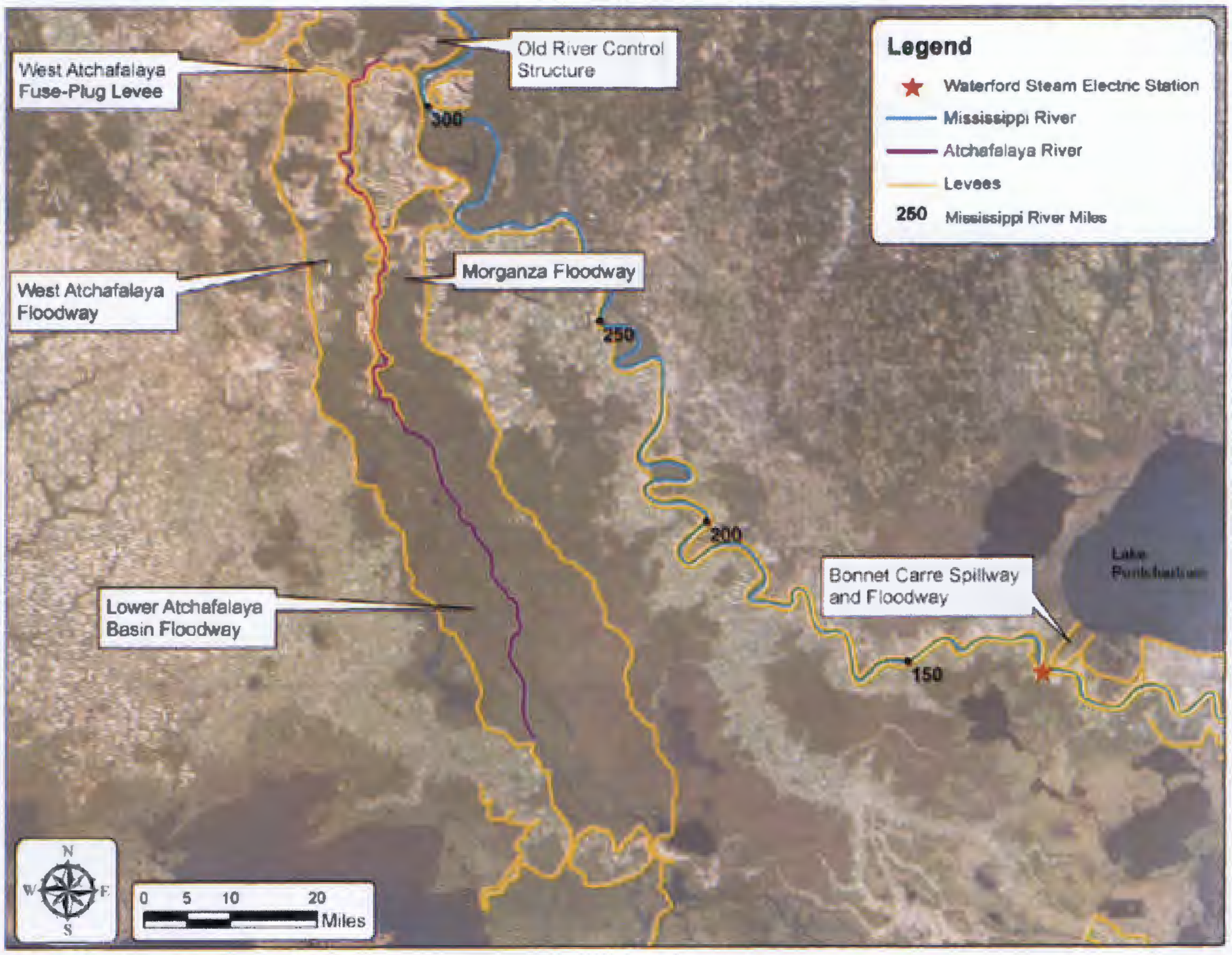


Figure 3.1-2. Hydraulic Control Structures in the Lower Mississippi River Basin (FHRR 3-23)

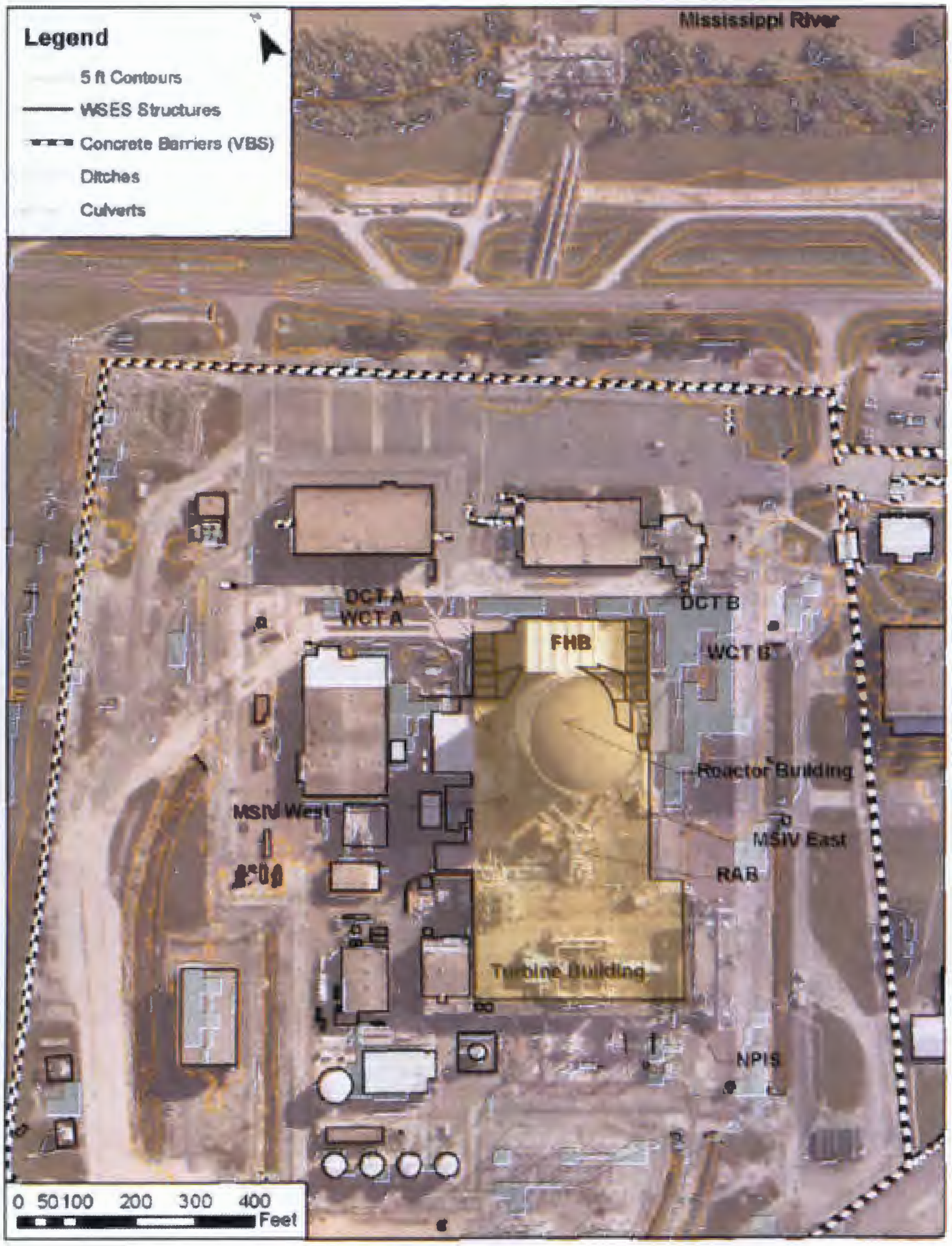
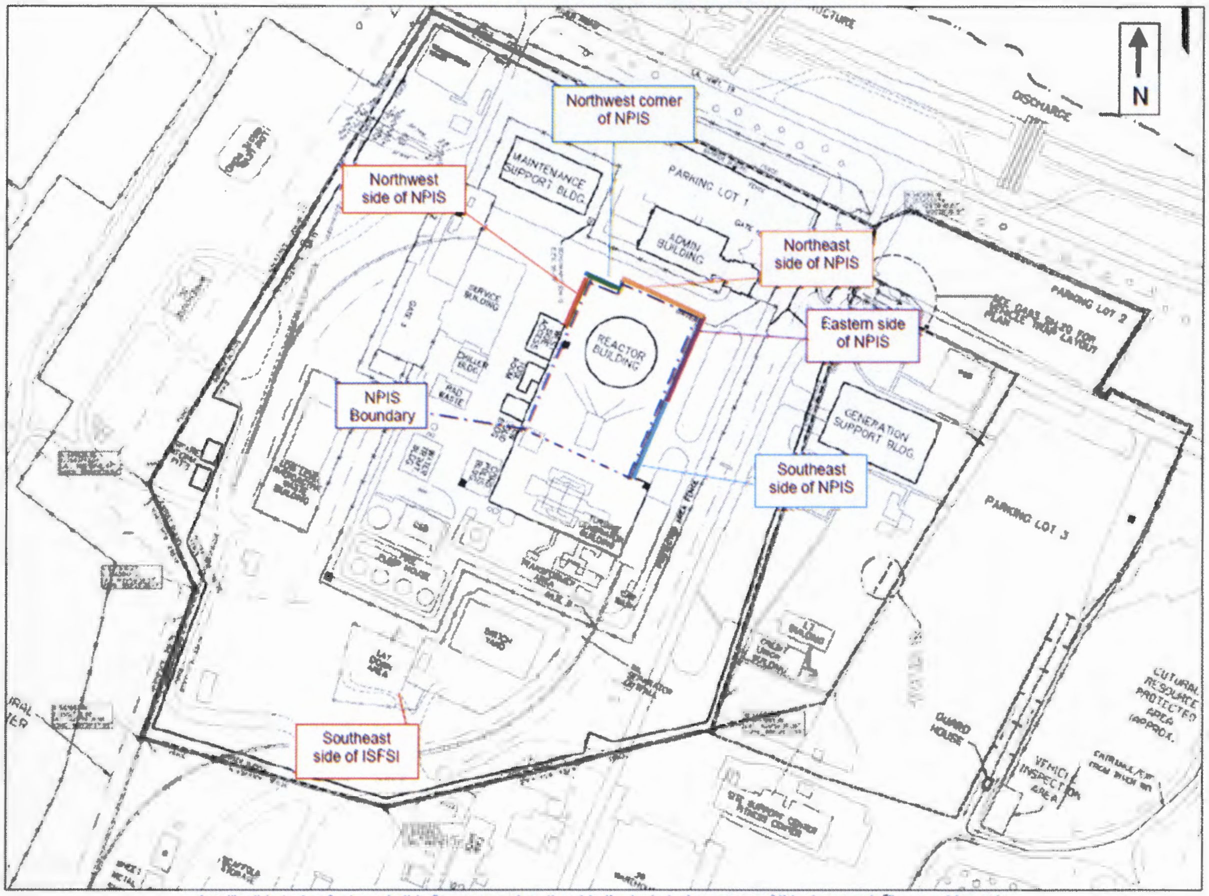


Figure 3.1-3. Site Topography and Layout (FHRR Figure 2-2)

Figure 11: Selected Locations at WSES for Reporting Results



Any illegible text or features in this figure are not pertinent to the technical purposes of this document. Figure not to scale

Figure 3.1-4. Selected NPIS Perimeter Locations at Waterford NPIS for Reporting Flood Hazards.

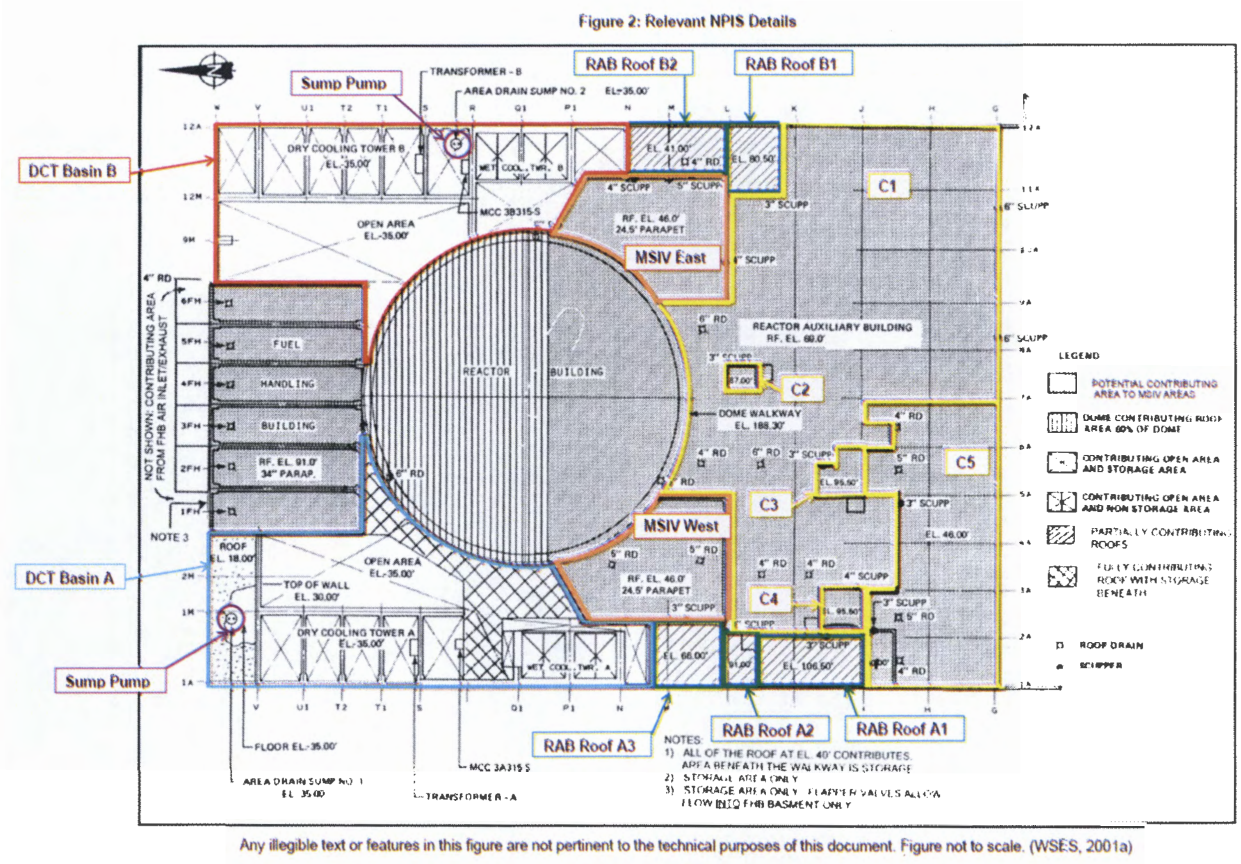


Figure 3.1-5. Layout of areas within the NPIS and location of Sump Pumps.

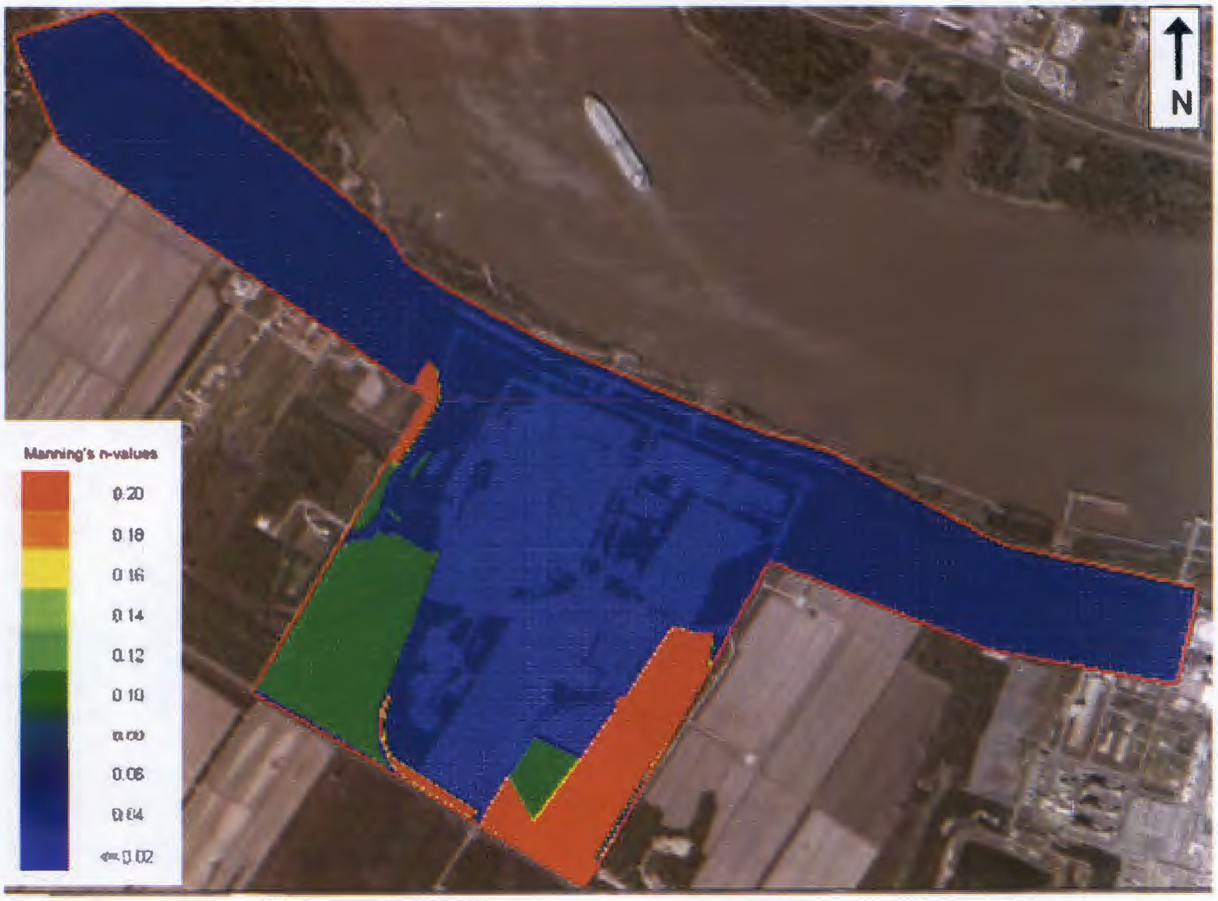


Figure 3.4-1. Combined Effects FLO-2D model domain and Manning's Roughness Coefficient Rendering.

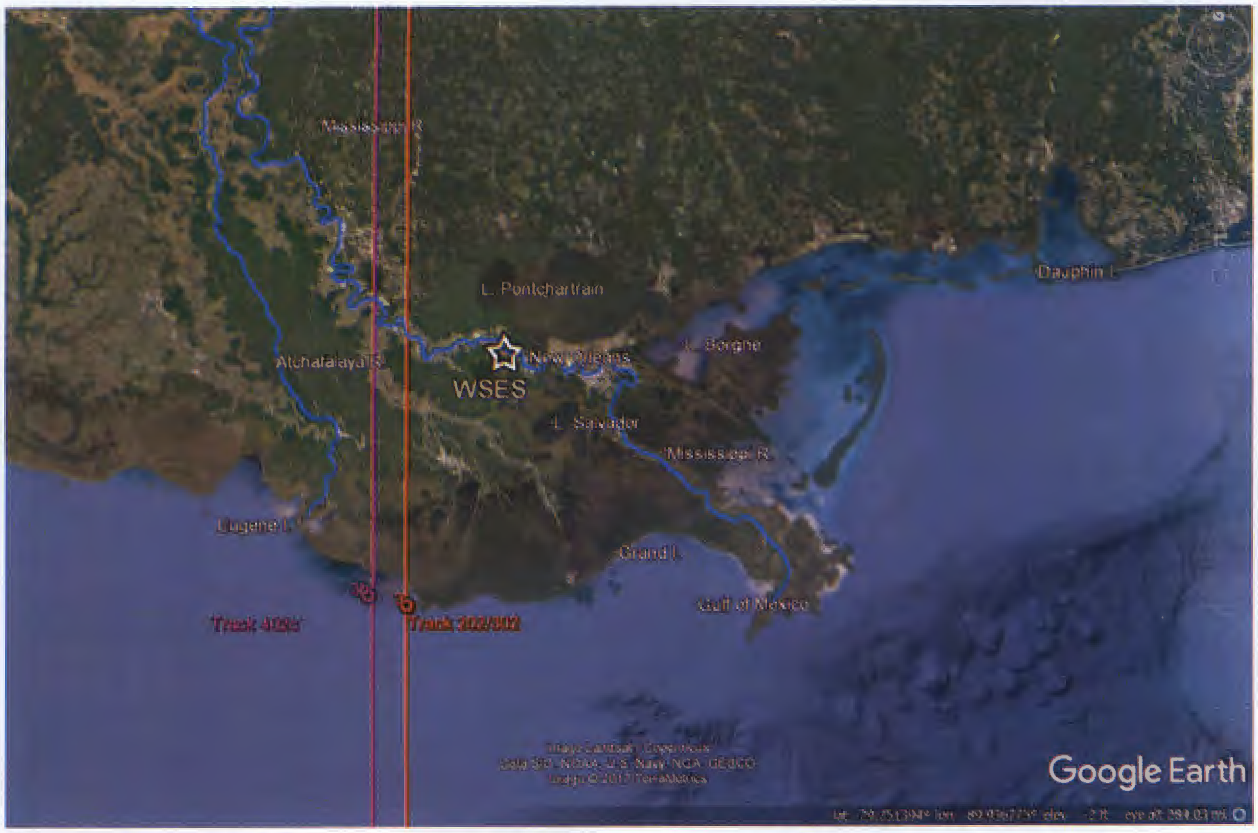


Figure 3.5-4. Locations of Waterford, Water bodies, northward 202/302 and 402c Storm Tracks west of WSES and track landfall locations 3 and 3b.

Figure 1.5-5. Waterford Station Locations for Independent Analysis Water Levels.

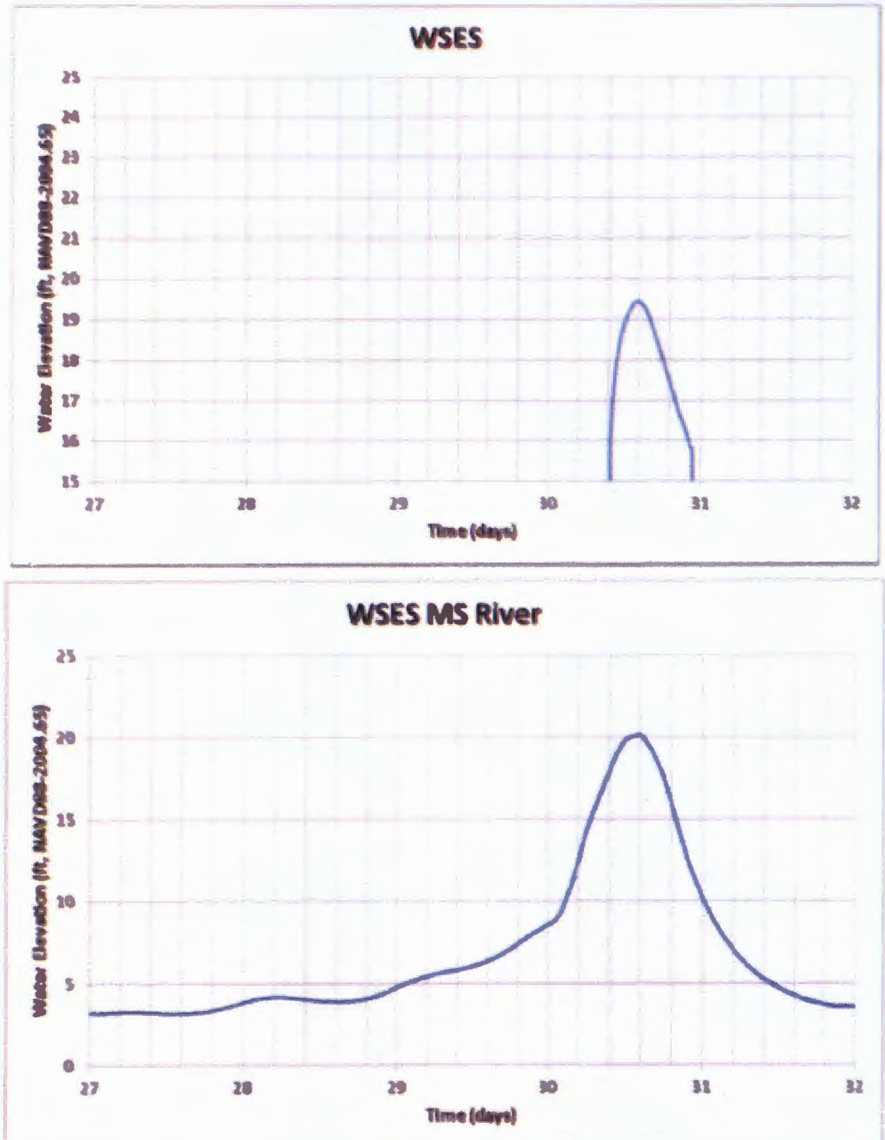


Figure 3.5-3. Water Level Time Series Plots - Storm 302 at Waterford (WSES) (top panel) and at Mississippi River near the Waterford (bottom panel) (Source: FHRR Figure 3-61). Note the WSE are relative to the NAVD88; 1.4 ft. should be added to make these relative to mean sea level.

WATERFORD STEAM ELECTRIC STATION, UNIT 3 - STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION NOVEMBER 30, 2017

DISTRIBUTION:

PUBLIC
PBMB R/F
JSebrosky, NRR
RidsNroDsea Resource
JGiacinto, NRO
NRORidsNrrPmWaterford
MShams, NRR
BHarvey, NRO
CCook, NRO
JThompson, NRO
RidsNrrDorlLpl4
RidsNrrDlp Resource

ADAMS Accession No.: ML17311B351 *via email

OFFICE	NRR/DLP/PBMB/PM	NRR/DLP/PBMB/LA	NRO/DSEA/RHM1/TR
NAME	JSebrosky	SLent	LHibler*
DATE	11/8/17	11/8/17	9/18/17
OFFICE	NRO/DSEA/RHM1/BC	NRR/DLP/PBMB/BC	NRR/DLP/PBMB/PM
NAME	CCook*	MShams	JSebrosky
DATE	9/26/17	11/21/17	11/30/17

OFFICIAL RECORD COPY