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

August 31, 2016

Mr. William F. Maguire
Site Vice President
Entergy Operations, Inc.
River Bend Station
5485 U.S. Highway 61N
St. Francisville, LA 70775

SUBJECT: RIVER BEND STATION, UNIT 1 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NO. MF3675)

Dear Mr. Maguire:

By letter dated March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information pursuant to Title 10 of the *Code of Federal Regulations*, Section 50.54(f) (hereafter referred to as the 50.54(f) letter). The request was issued as part of implementing lessons learned from the accident at the Fukushima Dai-ichi nuclear power plant. Enclosure 2 to the 50.54(f) letter requested licensees to reevaluate flood-causing mechanisms using present-day methodologies and guidance. By letter dated March 12, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14073A648), Entergy Operations, Inc. (Entergy, the licensee) responded to this request for River Bend Station, Unit 1.

By letter dated September 4, 2015 (ADAMS Accession No. ML15212A727), the NRC staff sent Entergy 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 results for local intense precipitation and rivers and streams flood-causing mechanisms were not bounded by the current design-basis flood hazard. In order to complete its response to Enclosure 2 to the 50.54(f) letter, the licensee is expected to submit a focused evaluation to address the local intense precipitation reevaluated flood hazard and either (1) an integrated assessment or (2) a focused evaluation to address the rivers and streams flood-causing mechanisms, as described in Japan Lessons-Learned Division (JLD) Interim Staff Guidance (ISG) JLD-ISG-2016-01, "Guidance for Activities Related to Near Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation, Focused Evaluation and Integrated Assessment" (ADAMS Accession No. ML16162A301). This closes out the NRC's efforts associated with CAC No. MF3675.

If you have any questions, please contact me at (301) 415-2621 or e-mail at Robert.Bernardo@nrc.gov.

Sincerely,

Robert Bernardo, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No. 50-458

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

RIVER BEND STATION, UNIT 1

DOCKET NO. 50-458

1.0 INTRODUCTION

By letter dated March 12, 2012 (NRC, 2012a), the U.S. Nuclear Regulatory Commission (NRC) issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f), "Conditions of licenses" (hereafter referred to as the "50.54(f) letter"). The request was issued in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant as documented in the Near-Term Task Force (NTTF) review of insights from the Fukushima Dai-ichi accident (NRC, 2011a). Recommendation 2.1 in that document recommended that the 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, 2011b) and SECY-11-0137 (NRC, 2011c) directed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

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

If the reevaluated hazard for any flood-causing mechanism is not "bounded" by the plant's current design-basis (CDB) flood hazard, then an additional assessment of plant response is necessary, as described in the 50.54(f) letter (NRC, 2012a) and COMSECY-15-0019, "Closure Plan for the Reevaluation of Flooding Hazards at Operating Nuclear Power Plants" (NRC, 2015b). The FHRR and the responses to associated requests for additional information (RAIs) provide the flood hazard input necessary to complete this additional assessment, consistent with the process outlined in COMSECY-15-0019 (NRC, 2015b) and associated guidance documents, Japan Lessons-Learned Division (JLD) JLD-ISG-2012-01, Revision 1, "Compliance with Order EA-12-049 Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," (NRC, 2016a) and JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation; Focused Evaluation and Integrated Assessment," (NRC, 2016b).

By letter dated March 12, 2014 (Olson, 2014a), Entergy Operations, Inc. (Entergy, the licensee) provided the FHRR for River Bend Station (RBS, River Bend), Unit 1 (Entergy, 2014). The NRC

Enclosure

staff issued RAIs to the licensee by emails dated June 2, 2014 (NRC, 2014a) and April 27, 2015 (NRC, 2015a). The licensee responded to the RAIs by letters dated June 17, 2014 (Olson, 2014b); May 5, 2015 (Brumfield, 2015); and May 27, 2015 (Olson, 2015). The licensee did not identify any needed interim actions.

The reevaluated flood hazard results for local intense precipitation (LIP) and results for the rivers and streams flood-causing mechanisms are not bounded by the plant's CDB hazard. Consistent with the process outlined in COMSECY-15-0019 (NRC, 2015a) and associated guidance JLD-ISG-2016-01 (NRC, 2016b), the staff anticipates that the licensee will perform and document a focused evaluation for LIP that assesses the impact of the LIP hazard on the site and evaluates and implements any necessary programmatic, procedural, or plant modifications to address this hazard exceedance (NRC, 2015b). Additionally, for the rivers and streams flood-causing mechanism, the NRC staff anticipates that the licensee will submit either (1) an integrated assessment or (2) a focused evaluation confirming the capability of existing flood protection or implementing new flood protection consistent with the process outlined in COMSECY-15-0019 (NRC, 2015b) and associated guidance JLD-ISG-2016-01 (NRC, 2016b).

On September 4, 2015, the NRC issued an interim staff response (ISR) letter to the licensee (NRC, 2015c). The purpose of the ISR letter is to provide the flood hazard information suitable for the assessment of mitigating strategies developed in response to Order EA-12-049 (NRC, 2012b) and the additional assessments associated with NTTF Recommendation 2.1: Flooding. The ISR letter also made reference to this staff assessment, which documents the basis for the staff's conclusions in the ISR. 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 (NRC, 2015c) and discussed below, for any reevaluated flood hazards that are not bounded by the plant's CDB hazard, the licensee is expected to develop flood event duration parameters and flood-related associated effects to conduct the mitigating strategies assessment (MSA), as discussed in the latest revision to the Nuclear Energy Institute (NEI) guidance, Appendix G of NEI 12-06 (Revision 2) (NEI, 2015). Guidance document NEI 12-06 (Revision 2) (NEI, 2015) and the revised ISG (JLD-ISG-2012-01, Revision 1) (NRC, 2016a) provide an approach for the development, implementation, and maintenance of mitigating strategies for flood hazards events exceeding the design bases. Appendix G of NEI 12-06 (Revision 2) (NEI, 2015) provides guidance for conducting the MSA, which includes (1) characterizing the mitigating strategy flood hazard information (MSFHI), (2) determining if the MSFHI is bounded by diverse and flexible coping strategies (FLEX), (3) evaluating flood-hazard impacts if the MSFHI is not bounded, and (4) assessing the robustness of flood protection features. Entergy will develop the flood event duration parameters (warning time, period of inundation, and recession time) and applicable flood-associated effects, which the staff will evaluate during its review of the MSA.

2.0 REGULATORY BACKGROUND

2.1 Applicable Regulatory Requirements

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoked. As stated above, enclosure 2 to the 50.54(f) letter (NRC, 2012a) requested that licensees reevaluate the flood-causing mechanisms for their respective sites using present-day methodologies and regulatory guidance used by the NRC for the ESP and COL reviews. This section of the staff assessment describes present-day regulatory requirements that are applicable to the FHRR.

Sections 50.34(a)(1), (a)(3), (a)(4), (b)(1), (b)(2), and (b)(4), of 10 CFR, describe the required content of the preliminary and final safety analysis reports, including a discussion of the facility site with a particular emphasis on the site evaluation factors identified in 10 CFR Part 100. The licensee should provide any pertinent information identified or developed since the submittal of the preliminary safety analysis report in the final safety analysis report.

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

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

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

Present-day regulations for reactor site criteria (Subpart B to 10 CFR Part 100 for applications 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

The 50.54(f) letter requests all power reactor licensees and construction permit holders to reevaluate all external flooding-causing mechanisms at each site (NRC, 2012a). This includes current techniques, software, and methods used in present-day standard engineering practice.

2.2.1 Flood-Causing Mechanisms

Enclosure 2 of the 50.54(f) letter (NRC, 2012a) discusses flood-causing mechanisms for the licensee to address in its FHRR. Table 2.2-1 lists the flood-causing mechanisms that the licensee should consider. Table 2.2-1 also lists the corresponding Standard Review Plan (SRP) (NRC, 2007) sections and applicable ISG documents containing acceptance criteria and review procedures. The licensee should incorporate and report associated effects per JLD-ISG-2012-05,"Guidance for Performing the Integrated Assessment for External Flooding" (NRC, 2012d), in addition to the maximum water level associated with each flood-causing mechanism.

2.2.2 Associated Effects

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

- wind waves and run-up effects
- hydrodynamic loading, including debris
- effects caused by sediment deposition and erosion
- concurrent site conditions, including adverse weather conditions
- groundwater ingress
- other pertinent factors

2.2.3 Combined 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." Even if some or all of these individual flood-causing mechanisms are less severe than their worst-case occurrence, their combination may still exceed the most severe flooding effects from the worst-case occurrence of any single mechanism described in the 50.54(f) letter (See SRP Section 2.4.2, "Areas of Review" (NRC, 2007)). Attachment 1 of the 50.54(f) letter describes the "combined effect flood"[1] 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 staff will document and report the result as part of one of the hazard sections. An example of a situation where this may occur is flooding at a riverine site located where the river enters the ocean. For this site, storm surge and river flooding should be plausibly combined.

2.2.4 Flood Event Duration

Flood event duration was defined in JLD-ISG-2012-05 (NRC, 2012d) as the length of time during which the flood event affects the site. It begins when conditions are met for entry into a flood procedure, or with notification of an impending flood (e.g., a flood forecast or notification of dam failure), and includes preparation for the flood. It continues during the period of inundation, and ends when water recedes from the site and the plant reaches a safe and stable state that can be maintained indefinitely. Figure 2.2-1 illustrates flood event duration.

2.2.5 Actions Following the FHRR

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

- Submit an interim action plan with the FHRR documenting actions planned or already taken to address the reevaluated hazard.

- Perform an integrated assessment subsequent to the FHRR 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.

---

[1] For the purposes of this staff assessment, the terms "combined effects" and "combined events" are synonyms.

COMSECY-15-0019 (NRC, 2015b) outlines a revised process for addressing cases in which the reevaluated flood hazard is not bounded by the plant's CDB. The revised process describes an approach in which licensees with LIP hazards exceeding their CDB flood will not be required to complete an integrated assessment, but instead will perform a focused evaluation. As part of the focused evaluation, licensee will assess the impact of the LIP hazard on their sites and then evaluate and implement any necessary programmatic, procedural, or plant modifications to address the hazard exceedance. For other flood hazard mechanisms that exceed the CDB, licensees can assess the impact of these reevaluated hazards on their site by performing either a focused evaluation or a revised integrated assessment (NRC, 2015b). The revised process is provided in the Nuclear Energy Institute's (NEI) industry guidance document NEI 16-05, "External Flooding Assessment Guidelines" (NEI, 2016), which was endorsed by the NRC via JLD-ISG-2016-01 (NRC, 2016b).

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of RBS, Unit 1. The licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews.

To provide additional information in support of the conclusions in the RBS, Unit 1 FHRR, the licensee made several calculation packages available to the staff via an electronic reading room. When the staff relied directly on any of these calculation packages in its review, they or portions thereof were docketed. Certain other calculation packages were found only to expand upon and clarify the information provided on the docket, and so are not docketed or cited. The staff's review and evaluation is provided below.

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 this pertinent data concerning the SSCs in the FHRR (Entergy, 2014). The staff reviewed and summarized this information in the sections below.

3.1.1 Detailed Site Information

The RBS, Unit 1 FHRR (Entergy, 2014) described the site-specific information related to the flood hazard reevaluation. All elevations in this staff assessment are in mean sea level (MSL). The site grade at the powerblock is elevation 95 feet (ft; 29 meters (m)) MSL (Entergy, 2014). The RBS is located near St. Francisville, Louisiana, approximately 24 miles (mi; 39 kilometers (km)) north-northwest of Baton Rouge. Figure 3.1-1 of this staff assessment shows the location of the 3,342 acre (13.5 square km (km^2)) RBS site within the Grants Bayou and West Creek drainage basin, approximately 1.5 mi (2.4 km) from the eastern bank of the Mississippi River, extending between river miles 262 and 265. The primary drainage features at the site are Grants Bayou on the east and Alligator Bayou on the west. In addition, a small channelized drainage feature (e.g., West Creek) is located to the west and to the south of the site and drains into Grants Bayou. Flow from the RBS site progresses through Grants Bayou and subsequently enters Alligator Bayou south of the site. The flow from Alligator Bayou progresses south into

Thompson Creek, which enters the Mississippi River at a location approximately 7 mi (11 km) downstream of the RBS site (Entergy, 2014).

The RBS site is situated on two terrace levels. The upper terrace—on which all buildings and safety-related equipment are located—has an average elevation of over 100.0 ft (30.5 m) MSL (Entergy, 2014). While the site grade at the powerblock is at an elevation of 95 ft (29.0 m) MSL, the FHRR reports that safety-related equipment in buildings not sealed from floodwater entry is located at elevation 98 ft (29.9 m) MSL (Entergy, 2014). The lower terrace at the RBS site includes the alluvial floodplain, which varies in width from 3,000 to 4,000 t (914 to 1,220 m), on the eastern side of the Mississippi River. The southern and southwestern portions of the RBS site include this lower terrace and have elevations of 35 to 95 ft (11 to 29 m) MSL (Entergy, 2014).

River Bend buildings containing safety-related equipment are the reactor building, control building, auxiliary building, diesel generator building, fuel building, and standby service water tower basin (Figure 3.1-2). Table 3.1-1 provides the summary of controlling reevaluated flood-causing mechanisms the licensee computed to be higher than the powerblock elevation. The NRC staff reviewed the information provided in the RBS FHRR (Entergy, 2104) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.2 Design-Basis Flood Hazards

The CDB flood levels are summarized by flood-causing mechanism in Table 3.1-2.[2] The NRC staff reviewed the information provided in the RBS FHRR (Entergy, 2014) and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter (NRC, 2012a).

3.1.3 Flood-Related Changes to the Licensing Basis

The RBS FHRR states that there have been no flood-related changes or changes to flood-protection measures beyond the flood-protection measures in place for the CDB (Entergy, 2014).

3.1.4 Changes to the Watershed and Local Area

The Mississippi River is one of the largest rivers in the United States. The river and its many tributaries, as well as their respective watersheds, have undergone many man-made and natural changes since the construction of RBS, Unit 1. However, the licensee stated in its FHRR that there have been no significant changes to the watershed area in the vicinity of the RBS site. In addition, the U.S. Army Corps of Engineers (USACE) manages the Mississippi River to maintain navigability and to implement appropriate flood control measures (Entergy, 2014).

---

[2] Entergy indicated in RAI response dated May 27, 2015 (Olson, 2015), that the CLB and CDB are equivalent. This staff assessment uses the term CDB throughout the document.

Construction of RBS, Unit 1 occurred during the late 1970s and the early 1980s (Entergy, 2008). Because the character of the Grants Bayou and West Creek watersheds is primarily rural farmland and forest, and because those characteristics have not changed significantly since license issuance for Unit 1, it can be reasonably concluded that no changes have occurred to the watersheds in this region.

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

The CLB for flood protection and flood mitigation features is described in Section 3.4 of the UFSAR. The licensee summarized this information in the FHRR by stating that flood protection is provided for safety-related systems by one of the following methods: 1) housed in Seismic Category I structures designed to withstand the flood loads; 2) located above the maximum postulated flood level; or 3) located in watertight cubicles designed to withstand external and/or internal flood loads (Entergy, 2014).

The FHRR states that the structural component of the Seismic Category I structures exposed to earth are designed using walls with a minimum thickness of 2 ft (0.6 m) for elevations below flood levels and using waterstops at construction joints below flood level (Entergy, 2014). All penetrations through exterior walls of these structures are designed to withstand the hydrostatic head of water and are made watertight. Access openings to the structures are either located above the design basis flood level or are required to be closed to prevent any adverse effect from flooding. Sumps and sump pumps control any local seepage through the walls (Entergy, 2014). The design-basis for flooding at the RBS site requires protection to a minimum elevation of 98 ft (29.9 m) MSL (Olson, 2015).

3.1.6 Additional Site Details to Assess the Flood Hazard

The licensee used surveyed topographic data of the site provided in AutoCAD format to create a Digital Terrain Model (DTM) (Entergy, 2014). Surveyed topographic data came from aerial LiDAR mapping of the site using methodology consistent with the need for first-order level of accuracy (i.e., +/- 0.1 ft (0.03 m). High resolution orthoimagery was used to determine the land use classes of the RBS site and to estimate Manning's roughness coefficient (Entergy, 2014).

3.1.7 Results of Plant Walkdown Activities

The 50.54(f) letter (NRC, 2012a) requested that licensees plan and perform plant walkdown activities to verify that current flood protection systems are available, functional, and implementable. Other parts of the 50.54(f) letter asked the licensee to report any relevant information from the results of the plant walkdown activities (NRC, 2012a).

By letter dated November 27, 2012, Entergy provided the Flooding Walkdown Report for RBS, Unit 1 (Entergy, 2012). The staff issued a staff assessment on June 20, 2014 (NRC, 2014b), which documented its review of the Flooding Walkdown Report and concluded that the licensee's implementation of the flooding walkdown methodology met the intent of the walkdown guidance.

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported in its FHRR that the reevaluated flood hazard analysis for LIP results in a stillwater surface elevation that ranges between 97.0 and 98.3 ft (29.5 and 30.0 m) MSL for Unit 1 and 79.8 ft (24.3 m) MSL for Unit 2 excavation (Entergy, 2014). This flood-causing mechanism is discussed in the licensee's CDB. The CDB probable maximum flood (PMF) elevation for LIP is a stillwater surface elevation of 96.0 ft (29.3 m) MSL for Unit 1 and 80.3 ft (24.5 m) MSL for Unit 2 excavation (Entergy, 2014).

3.2.1 Model Inputs

The licensee's LIP analysis used the FLO-2D model (FLO-2D, 2009), a two-dimensional hydrodynamic model that uses the dynamic wave momentum equation to route flood hydrographs and rainfall-runoff over unconfined flow surfaces and in channels (Entergy, 2014). Calculation inputs consisted of site topography and existing conditions data, probable maximum precipitation (PMP) hyetograph, West Creek inflow hydrograph, high resolution orthoimagery, vehicle barrier height and location, and the West Creek channel geometry (Entergy, 2014 and Olson, 2015). The FLO-2D model used a grid element size of 20 ft (6.1 m) by 20 ft (6.1 m) (Entergy, 2014).

The portion of West Creek within the site was modeled as a uniform trapezoidal channel with average depth at 10 ft (3.0 m), bottom width at 50 ft (15.2 m), and side slopes at 3:1 as verified based on the topographic site survey (Entergy, 2014 and Olson, 2014b). A grid element directly upstream of the channelized portion of West Creek was selected as the inflow grid element for the West Creek PMF within the FLO-2D model (Entergy, 2014). High resolution orthoimagery was used to determine the types of land cover at the RBS site and to estimate Manning's roughness coefficient values of 0.02 for asphalt and concrete, 0.05 for short grass, 0.10 for brush, 0.20 for short trees, and 0.40 for forest (Olson, 2015). The NRC staff performed sensitivity analyses and concurs that the Manning's roughness coefficient values were appropriately selected based on land cover in a digital orthophoto and site observations. The staff also concurs that 2-D modeling is appropriate for simulating flood elevations in the area of the RBS and finds the model input values to be consistent with present-day methodologies.

3.2.2 Digital Terrain Model and Site Drainage

Elevation data were developed from a site topographic survey and used to create a DTM (Brumfield, 2015). Surveyed data came from aerial LiDAR mapping and critical structures on site were surveyed with a vertical accuracy of +/- 0.1 ft (0.03 m). The LIP analysis assumed the onsite drainage network (including culverts and storm drains) to be completely blocked, and therefore inoperable and non-functional, during the event. For conservativism, the licensee ignored infiltration losses and abstractions within the site. Infiltration losses in the 0.36 mi^2 (0.93 km^2) contributory areas to the West Creek watershed were calculated because the watershed consists mainly of natural land cover (Entergy, 2014). The staff concurs with the drainage assumptions implemented in the analysis for both RBS and the West Creek Watershed.

3.2.3 Probable Maximum Precipitation

The licensee developed the 1-hour (h), 1-mi^2 and 6-h, 10-mi^2 PMP event distributions using Hydrometeorological Reports (HMR) 51 and 52 (HMR-51 and HMR-52) (NOAA, 1978 and 1982). This resulted in a 1-h rainfall depth of 19.4 inches (in.) (49.3 centimeter (cm)) and a 6-h PMP of 32.0 in. (81 cm). A 6-h hyetograph was constructed using 5-minute increments based on the 6-h PMP and following a front-loaded rainfall distribution (i.e., the highest intensity precipitation occurs at the beginning of the event) (Entergy, 2014). The staff verified the HMR-51 and HMR-52 computations and concludes the PMP depths are acceptable for use in the LIP flooding analysis.

3.2.4 Runoff Analyses

The licensee calculated the runoff resulting from the LIP event for the West Creek Watershed using the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) (version 3.5.0) (USACE, 2010b). Because there are no stream gages and observed flow and flood stage information was not available, the licensee used the Soil Conservation Service (SCS) method (SCS, 1986) to develop the curve number and lag time for the watershed (Entergy, 2014). The weighted curve number is conservatively based on wet antecedent conditions and the calculated weighted curve number and lag time were 87.9 and 1-h, respectively. An inflow hydrograph based on the HEC dimensionless unit hydrograph method was calculated for the 6-h LIP on West Creek and had a peak flow for the upper West Creek watershed of 2,660 cubic feet per second (cfs) (75 cubic meters per second (cms)) (Entergy, 2014). The staff verified the calculations in the HEC-HMS model, found no issues, and concurs that the curve number and lag time are appropriate.

3.2.5 Width and Area Reduction Factors

The licensee modeled rainfall on rooftops in FLO-2D by setting area and width reduction factors numerically equal to 1.0. Buildings were elevated in the grid, allowing FLO-2D to recognize them as obstructions. Grid elements completely within a building were assigned elevations 5 ft (1.5 m) higher than the surrounding elevations and water on rooftops was routed from the buildings to an adjacent site grade (Olson, 2015). The staff's sensitivity analysis determined that the licensee's use of area and width reduction factors provided flooding results similar to the results of other approaches where these factors are not implemented; therefore, the staff concludes that the width and area reductions factors, as implemented by the licensee in the FHRR, appropriately model the contribution to site flooding from rainfall on rooftops.

3.2.6 Unit 2 Excavation Area

The 31-ft (9.4-m) deep excavation for a proposed Unit 2 reactor at the RBS site for which construction was started but never finished, hereafter refer to as Unit 2 excavation, still exists at the RBS site (Entergy, 2014). The Unit 2 excavation is not credited as a flood protection feature within the CDB, but is modeled with FLO-2D in the FHRR as an area that allows for storage (Olson, 2015). While the Unit 2 excavation impacts site drainage, as well as flooding onsite, the feature is part of the current topography and plant layout. Therefore, the NRC staff concludes that the licensee's use of the Unit 2 excavation, as modeled, reflects the site's current configuration and is modeled appropriately.

3.2.7 Vehicle Barrier System

The vehicle barrier system (VBS) and the berm surrounding the Unit 2 excavation were modeled as levee structures in FLO-2D, with top elevations based on a topographic survey. The licensee identified two pedestrian openings at the northeast and southwest VBS, and a vehicle access opening at the north VBS. The pedestrian crossing along the southwestern edge was modeled as open in the LIP simulation. A portion of the VBS within the Unit 2 excavation was not modeled in FLO-2D. The licensee provided a quantitative comparison of the peak water surface elevations with and without the VBS at critical door locations (Olson, 2015).

The licensee performed sensitivity analyses to show the conservativeness of different assumptions and modeling approaches relative to the VBS (Entergy, 2014). The staff's review of these sensitivity analyses results indicate that flooding on site with the VBS is equal or higher than flooding on site without the VBS.

3.2.8 Hydraulic Model Results

The 6-h PMP hyetograph was used as input in the FLO-2D model for simulating onsite flooding from a LIP event (Entergy, 2014). In its review of the FLO-2D input and output files (Olson, 2014b) for the quantitative comparison conducted by the licensee, the staff determined that the licensee's modeling approach is reasonable. Results were presented at critical locations in terms of peak water surface elevation, maximum flow depth with respect to the ground surface elevation, maximum flow velocity, elevation at the bottom of doors, and flood height above door-bottom elevation (the difference between LIP peak elevation and elevation at the bottom of the door). The resulting maximum water surface elevation at these critical locations ranged from 97.0 to 98.3 ft (29.5 to 30 m) MSL, with corresponding flow depths ranging from approximately 0.5 to 3 ft (0.2 to 0.9 m) (Entergy, 2014). The licensee reported in its FHRR that the reevaluated flood hazard for LIP is 98.3 ft (30 m) MSL. The licensee noted that water flow through an opening in the VBS results in high maximum depths at the diesel generator building doors, and some areas are slow to drain, which the licensee attributed to the presence of the VBS (Entergy, 2014).

The staff confirmed the licensee's FLO-2D results and considers the use and implementation of this hydrodynamic model to be appropriate for meeting current regulatory guidance using present-day methods.

3.2.9 Conclusion

The staff confirmed the licensee's conclusion that the reevaluated flood hazard for LIP and associated site drainage is 98.3 ft (30 m) MSL for Unit 1 and is not bounded by the CDB flood hazard of 96 ft (29.3 m) MSL. For Unit 2 excavation the reevaluated flood hazard is 79.8 ft (24.3 m) MSL which is bounded by the CDB of 80.3 ft (24.4 m) MSL (Entergy, 2014). Therefore, the staff expects that the licensee will submit a focused evaluation for LIP for Unit 1 consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01 (NRC, 2016b).

3.3 Streams and Rivers

The licensee reported in its FHRR that the reevaluated flood hazard analysis for streams and rivers results in a stillwater-surface elevation of 59.7 ft (18.2 m) MSL for the Mississippi River PMF, 99.8 ft (30.4 m) MSL for Grants Bayou PMF, and 95.1 ft (29 m) MSL for the West Creek PMF (Entergy, 2014). The licensee did not include wind, waves, and runup in the Mississippi River PMF analysis. The West Creek PMF analysis showed insufficient fetch for wind setup and wave runup. Including wind, waves, and runup in the Grants Bayou PMF analysis results in an elevation of 100.1 ft (30.5 m) MSL (Entergy, 2014).

This flood-causing mechanism is discussed in the licensee's CDB (Entergy, 2014). The CDB PMF elevation for streams and rivers is based on a stillwater-surface elevation of 54.5 ft (16.6 m) MSL for the Mississippi River PMF, 95.3 ft (29.0 m) to 101.8 ft (31.0 m) MSL for the Grants Bayou PMF, and 94.3 ft (28.7 m) MSL for the West Creek PMF (Entergy, 2014). Wind, waves, and runup analyses were not included in the design basis for the Mississippi River, Grants Bayou, or West Creek (Entergy, 2014).

3.3.1 Streams and Rivers - PMF Evaluation

The PMF reevaluated flooding evaluation for RBS is separated into three analyses: (1) West Creek Watershed PMF, (2) Grants Bayou PMF, and (3) Lower Mississippi River PMF (Entergy, 2014). The separate analyses are described in the subsections below. The Lower Mississippi River PMF model includes Alligator Bayou (Entergy, 2014 and Olson 2014b). The other two watersheds/bayous that are indirectly affected by the Mississippi River are modeled separately, each with its own PMP and PMF determination, and are discussed together in the subsections that follow.

3.3.2 Grants Bayou and West Creek - PMP

The licensee used HMR-51 and HMR-52 (NOAA, 1978 and 1982) to develop the PMP for evaluating the PMF on both the 0.9-mi^2 (2-km^2) West Creek watershed and the 8.4-mi^2 (21.8-km^2) Grants Bayou watershed. The computer program "HEC-HMR52" (USACE, 1987) was used to calculate the maximum rainfall depths and hyetographs for each of the watersheds using selected inputs (Entergy, 2014). The staff verified the HMR-51 and HMR-52 computations and concludes the PMP depths in each watershed are correct.

3.3.3 Grants Bayou and West Creek - Hydrologic Parameters

Because the watersheds do not contain stream gages and because observed flood flow and flood stage information is not available, the SCS (1986) method was used by the licensee to develop the curve number and lag time for West Creek and Grants Bayou watersheds. SCS method Antecedent Runoff Condition III (ARCIII) (i.e., wet conditions) curve numbers were used for a more conservative estimation of runoff (Entergy, 2014). The licensee divided Grants Bayou into two watersheds: Grants Bayou above the confluence with West Creek (GBAWC) and Grants Bayou below the confluence with West Creek (GBBWC). The calculated ARCIII curve numbers for GBAWC, GBBWC, and West Creek are 88.3, 88.0, and 88.9, respectively. The lag times for the watersheds are 2.2, 2.5, and 1.2 hours, respectively (Entergy, 2014).

The staff reviewed and agreed with the conservatism associated with the use of ARCIII conditions as they provide higher levels of runoff, and therefore, the staff concluded that the selected curve numbers and lag times for each watershed are reasonable.

3.3.4 Grants Bayou and West Creek - Unit Hydrographs

Basin models were set up in HEC-HMS (version 3.5.0) (USACE, 2010b) consisting of West Creek, GBBWC, and GBAWC watersheds by the licensee (Entergy, 2014 and Olson, 2014b). All-season PMP simulations were performed to determine the PMF. The input hyetograph was constructed, per NUREG/CR-7046 (NRC, 2011d), using an antecedent storm consisting of 40 percent of the PMP depths during the first 72-h period, followed by a dry 72-h period, and lastly a full 72-h PMP storm (Entergy, 2014). Unit hydrographs for each watershed were derived based on the SCS dimensionless unit hydrograph and methodology contained in the United States Department of Agriculture (USDA) National Engineering Handbook (USDA, 2004). The unit hydrographs were verified in HEC-HMS and then adjusted for non-linearity by increasing the peak discharge by one fifth and decreasing the time-to-peak by one third in accordance with NUREG/CR-7046 (NRC, 2011d). The staff reviewed the hydrographs and agrees that the assumptions and parameters implemented in the development of the unit hydrographs are consistent with present-day methodologies.

3.3.5 Grants Bayou and West Creek - Hydraulic Model

The licensee used the one-dimensional Hydrologic Engineering Center - River Analysis System (HEC-RAS) computer model (USACE, 2010a) to analyze the peak water surface elevations resulting from the PMF in each watershed (Entergy, 2014 and Olson, 2015). Inputs at the upstream boundary conditions include PMF hydrographs for the respective watershed. Downstream boundary conditions are set at the PMF elevations of the streams into which the model streams discharge. The downstream boundary condition for Grants Bayou is the PMF elevation of the Mississippi River. The downstream boundary condition for West Creek in the FHRR is the maximum water surface elevation at Grants Bayou where it converges with West Creek (Entergy, 2014 and Olson, 2015).

The licensee developed cross section geometries for Grants Bayou and West Creek based on digital elevation model data from the USACE (2001), supplemented with DTM points from a site survey (Entergy, 2014). The Unit 2 excavation is treated as a “storage area” in HEC-RAS, with the divide between West Creek and the Unit 2 excavation modeled using a lateral structure. The Manning’s roughness coefficient values in the model are based on channel type and floodplain land cover through evaluation of high-resolution orthoimagery and include 0.05 for natural channels, 0.02 for concrete-lined channels, 0.05 for open areas and grass or lightly vegetated channel banks, and 0.12 for forested banks or forested floodplains. Culverts on West Creek are assumed to be completely blocked by debris (Entergy, 2014). The staff agrees with the assumptions and parameters used in the development of the hydraulic model in HEC-RAS.

3.3.6 Grants Bayou and West Creek - Bridges

The Louisiana State Highway 10 Bridge over Grants Bayou is assumed to be 50 percent blocked. All flow under other bridges downstream of the RBS on Grants Bayou is assumed to be completely blocked. Flow over these bridges is modeled with inline structures in HEC-RAS (Entergy, 2014). No upstream bridges are modeled because they are likely to cause backwater effects upstream of RBS and reduce the PMF flowrates downstream (Olson, 2015). The NRC staff reviewed these assumptions and agrees with the licensee that the assumptions in HEC-RAS for modeling bridges was reasonable for the purposes of the 50.54(f) letter response.

3.3.7 Grants Bayou and West Creek - Baseflow

The licensee determined baseflow in West Creek and Grants Bayou watersheds to be negligible in comparison to the peak PMF flow rates; thus, baseflow is not considered in the model (Entergy, 2014). The licensee conducted sensitivity analyses using the baseflow of a nearby watershed because there are no gages in either West Creek or Grants Bayou watersheds and demonstrated that inclusion of these baseflow values has no impact on the water surface elevations on site during the PMF (Olson, 2015). Therefore, the staff agrees that baseflows in West Creek and Grants Bayou are negligible.

3.3.8 Mississippi River – PMF and Flood Control Structures

The licensee estimated the magnitude of the PMF for the Lower Mississippi River Basin based on the USACE Project Design Flood (PDF) (Entergy, 2014). The PDF is assumed equivalent to approximately 40 percent of the PMF (Chow et al., 1964). Two flood control structures upstream of the RBS, Old River Control Structures (ORCS) and the Morganza Control Structure (MCS), divert water from the Mississippi River into respective floodways. These structures divert approximately 1.22 million cfs (34,500 cms) from the Mississippi River during both the PMF and PDF. Together, taking into account the diversions of flow, the resulting PMF for the Mississippi River at RBS is approximately 5,580,000 cfs (158,000 cms) (Entergy, 2014). The staff verified the amount of flow diverted from the Mississippi and found the calculated flow to be correct.

3.3.9 Mississippi River – Hydraulic Model

The licensee used the HEC-RAS version 4.1.0 (USACE, 2010a) computer model to simulate the PMF peak water surface elevation. Cross sections were developed from bathymetric data obtained from USACE, as well as a digital elevation model from the United States Geological Survey (USGS) (Entergy, 2014). Because stage data exist for the Mississippi River, the HEC-RAS model was calibrated for the Mississippi River flood in 2011 until a target elevation difference of 0.5 ft (0.2 m) or lower was reached. The licensee adjusted the Manning's roughness coefficients until the model provided a peak water surface elevation in agreement with the calibrated peak water surface elevation of the 2011 flood. The model was then verified within 1 ft (0.3 m) of the USACE elevation at RBS using the Mississippi River PDF of 1,500,000 cfs (42,500 cms) at the USACE Baton Rouge gage. After the model was calibrated and verified, the licensee modeled a steady-state flow condition to determine the PMF peak water surface elevation of the Mississippi River. Structures including ORCS and MCS were not modeled (Entergy, 2014). The Manning's roughness coefficient values used for calibration are consistent with those associated for large flood stages for river channels as recommended by Chow (1959). The NRC staff reviewed and agreed with the Manning's coefficient values used for calibration, as well as the results obtained from the model as calibrated and verified by the licensee.

3.3.10 Coincident Wind and Wave Activity

The licensee evaluated the effect on water surface elevations for a combined effect of PMF and wind-generated waves per NUREG/CR-7064 (NRC, 2011d). Alternative 1 (i.e., mean monthly base flow, median soil moisture, antecedent or subsequent rain, PMP, and waves induced by 2-year wind speed applied along the critical direction) was used in the analyses, because snowpack is negligible at RBS (Entergy, 2014).

Coastal Engineering Design and Analysis System (CEDAS) version 4.03, a comprehensive collection of coastal engineering design and analysis software developed by the U.S. Army Corps of Engineer Waterways Experiment Station (Veri-Tech, 2014), was used to calculate the wave height and period, wind setup, and wave runup on the Grants Bayou. The wave height and period in Grants Bayou are 1.3 ft (0.4 m) and 1.7 seconds, respectively (Entergy, 2014). The wind setup across Grants Bayou is 0.1 ft (0.03 m), and the wave runup on Grants Bayou is 0.2 ft (0.06 m). The PMF elevation on Grants Bayou near RBS was calculated by adding the predicted wind setup and wave runup on Grants Bayou to the PMF stillwater elevation at Grants Bayou to get an elevation of 100.1 ft (30.5 m) MSL. The licensee did not include wind, waves, and runup in the Mississippi River PMF analysis. The West Creek PMF analysis showed insufficient fetch for wind setup and wave runup. The staff finds the methods to estimate wind-generated wave heights to be appropriate and the results reasonable for West Creek and Grants Bayou.

3.3.11 Conclusion

The results of the reevaluation of the peak resultant water surface elevation on the local streams near RBS are 99.8 ft (30.4 m) MSL at Grants Bayou and 95.1 ft (29 m) MSL at West Creek. The stillwater reevaluated peak calculated PMF stage is 59.7 ft (18.2 m) MSL at the Mississippi River (Entergy, 2014). The probable maximum stillwater elevation with wind setup and wave runup on Grants Bayou is 100.1 ft (30.5 m) MSL. Wind setup and wave runup was not calculated for West Creek or the Mississippi River PMF. The results indicate the West Creek PMF elevation is not bounded by the CDB elevation of 94.3 ft (28.7 m) MSL and the Mississippi River PMF is not bounded by the CDB of 54.5 ft (16.6 m) MSL (Entergy, 2014) while the Grants Bayou reevaluated hazard is bounded by the maximum CDB of 101.8 ft (31 m) MSL.

The NRC staff confirmed the licensee's conclusion that the reevaluated hazard from flooding from rivers and streams for West Creek and the Mississippi River are not bounded by the CDB flood hazard. Therefore, the NRC staff expects that the licensee will submit a focused evaluation for these hazards, confirming the capability of flood protection and available physical margin, or a revised integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01 (NRC, 2016b).

3.4 Failure of Dams and Onsite Water Control/Storage Structures

The licensee reported in its FHRR that the reevaluated flood hazard analysis for failure of dams and onsite water control or storage structures results in a Mississippi River stillwater-surface elevation of 64.4 ft (19.6 m) MSL. Including wind, waves, and runup, this results in an elevation of 74.1 ft (22.6 m) MSL (Entergy, 2014). This flood-causing mechanism is discussed in the licensee's CDB and no impact to the site was identified (Entergy, 2014).

No dams exist on the Mississippi River within 100 river miles upstream of the RBS site (USACE, 2013). Furthermore, there are no dams or levees within either the West Creek watershed or the Grants Bayou watershed (Entergy, 2014) nor are there onsite dams, levees, water control, or water storage structures that could fail at the RBS site (Entergy, 2014). The licensee used methodology adopted from NRC guidance (NRC, 2013b), which evaluates dam failure from the perspective of a single hypothetical dam having the combined total storage volume of all major dams upstream of RBS within the Lower Mississippi River watershed. The licensee estimated the magnitude of the PMF based on the USACE Project Design Flood (PDF) (Entergy, 2014). The PDF is assumed equivalent to approximately 40 percent of the PMF (Chow et al., 1964). The total flow at RBS with combined dam failure under PMF conditions is 11,100,000 cfs (314,000 cms) (Entergy, 2014).

The licensee located the hypothetical dam immediately upstream of the RBS site (Entergy, 2014). The height of the hypothetical dam was determined from the maximum height among the set of individual dam heights. The hypothetical storage and dam height were 24,413,000 ft (30.1 million cubic meters) and 243 ft (74.1 m), respectively (Entergy, 2014). The licensee estimated the peak breach outflow using three different equations: the Froehlich (Froehlich, 1995), U.S. Bureau of Reclamation (USBR, 1982), and the Natural Resource Conservation Service (NRCS, 1985) equations. The Froehlich equation, based on the reservoir size (i.e., storage) and the height of water in the reservoir at the time of failure, provided the maximum peak breach outflow of 5,510,000 cfs (156,000 cms).

The results of the wind and wave activity coincident with the PMF flooding indicate that water levels would be more than 20 ft (6.1 m) below the RBS site grade for flooding on the Mississippi River. The wind setup across the Mississippi River is 4.0 ft (1.2 m), and the wave runup on the Mississippi River is 5.7 ft (1.74 m) (Entergy, 2014). These results indicate that wind and wave activity do not pose a flooding threat to the safety of the SSC facilities at the RBS site.

The NRC staff reviewed all assumptions and calculations used in the licensee's analysis of dam failure, and finds the analysis to be reasonable in response to the 50.54(f) letter. Fort the RBS site, there are no dams within 100 miles upstream of the site. When a hypothetical dam failure approach was used to determine if dams farther upstream could impact the site, the result was a water surface elevation well below site grade. Therefore, the NRC staff agrees with the licensee's conclusion that the reevaluated flood hazard for failure of dams and onsite water control or storage structures is bounded by the CDB. Consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01 (NRC 2016b), flooding from failure of dams or onsite water control or storage structures does not need to be analyzed in a focused evaluation or a revised integrated assessment.

3.5 Storm Surge

The licensee reported in its FHRR that the reevaluated hazard for storm surge is negligible due to the RBS location. This flood-causing mechanism is discussed in the CDB as not having an impact on the site (Entergy, 2014).

The RBS is located inland approximately 2 mi (3.2 km) from the east bank of the Mississippi River near River Mile 262 and 70 mi (113 km) from the Gulf of Mexico coastline. As such, regional storm surge waves propagating from Gulf of Mexico coastal waters upstream to RBS would dissipate due the river distance from the coast and the meandering nature of the river (Entergy, 2014). Also, there are no adjacent cooling ponds or reservoirs that could result in a storm surge that would impact the RBS site (Entergy, 2014). Therefore, the licensee did not perform an analysis to determine flooding elevations resulting from storm surge because storm surge is not likely to affect the site.

The NRC staff confirmed the topography of the site and the RBS site location relative to the bank of the Mississippi River and the Gulf of Mexico coastline. In addition, the Mississippi River in the RBS area is narrow (approximately 0.5 mi (0.8 km)) and, therefore, fetch is limited. As a result, the staff agrees with the licensee's conclusion that the distance from the Gulf of Mexico and the geometry of the Mississippi River makes it unlikely that storm surge propagating upstream would reach the RBS site. The staff also agrees that a storm surge from onsite features or structures is unlikely.

The NRC staff confirms the licensee's conclusion that the reevaluated hazard for flooding from storm surge is bounded by the CDB. Therefore, flooding from storm surge does not need to be analyzed in a focused evaluation or a revised integrated assessment, as discussed in COMSECY-15-0019 (NRC, 2015b) and associated guidance JLD-ISG-2016-01 (NRC 2016b).

3.6 Seiche

The licensee reported in its FHRR that the reevaluated hazard for seiche is negligible because of the RBS site's riverine setting and elevation (Entergy, 2014). This flood-causing mechanism is discussed in the licensee's CDB, and does not impact the site (Entergy, 2014).

A seiche is an oscillation of a water surface in an enclosed or semi-enclosed water body, initiated by an external source such as a wind storm, tsunami, or landslide that gradually decays over time. The Mississippi River is not an enclosed or semi-enclosed water body. In addition, the Mississippi River in the RBS area is narrow (approximately 0.5 mi (0.8 km)) and meandering, which limits the development of seiche (Entergy, 2014). Therefore, the licensee did not perform an analysis to determine a reevaluated flooding elevation because seiche is not likely to affect the site.

The NRC staff examined the location of the RBS site and confirms that the location (not being near a large water body), along with the geometry of the Mississippi River, limits the development of any seiche near the RBS site. The staff agrees with the licensee's conclusion that the reevaluated hazard for flooding from seiche could not impact the RBS site. Therefore, flooding from seiche does not need to be analyzed in a focused evaluation or a revised integrated assessment, as discussed in COMSECY-15-0019 (NRC, 2015b) and associated guidance JLD-ISG-2016-01 (NRC 2016b).

3.7 Tsunami

The licensee reported in its FHRR that the reevaluated hazard for tsunami is negligible because of the RBS site's riverine setting and elevation (Entergy, 2014). This flood-causing mechanism is discussed in the CDB and does not impact the site (Entergy, 2014).

As stated in its FHRR (Entergy, 2014), the licensee followed the Hierarchal Hazard Assessment (HHA) described in NUREG/CR-6966, "Tsunami Hazard Assessment at Nuclear Power Plant Site in the United States of America" (NRC, 2009), and JLD-ISG-2012-06 (NRC, 2013a) in the tsunami reevaluated flood hazard analysis. The license performed a regional survey using the Global Historical Tsunami Database maintained by NOAA to determine the history of tsunamis and potential tsunami-generating sources. Based on the regional seismicity information, the required level of seismic activity (magnitude and location) for the development of a tsunami was essentially absent for the RBS site. In addition, the likelihood of tsunamis caused by subaerial or subaqueous landslides impacting the site is negligible given the elevation of the site, which is approximately 37 ft (11.3 m) higher than the Mississippi River. Lastly, the site is not subject to oceanic tsunamis due to its location far inland from the Gulf of Mexico. Therefore, the licensee did not perform an analysis to determine flooding elevations from tsunamis because tsunamis are not likely to affect the site (Entergy, 2014).

The NRC staff confirmed the location of the RBS site in relation to the bank of the Mississippi River and the Gulf of Mexico coastline. A staff review of the potential tsunami-generating sources concluded that only submarine landslides have the potential to generate large tsunamis in the region. The staff identified the historic submarine Mississippi Canyon Landslide, located off the coast of Louisiana, as the primary candidate source zone for a probable maximum tsunami (PMT) for the coastal region near the mouth of the Mississippi River (ten Brink et al., 2008).

The NRC staff performed a detailed two-dimensional analysis of the Mississippi Canyon source to independently determine the tsunami's potential to impact the RBS site. Using COULWAVE (Cornell University Long and Intermediate Wave Modeling Package) tsunami numerical model (Lynett and Liu, 2002), the staff relied on highly-conservative input parameters for the analysis. Based on the staff's independent numerical analysis, the estimated PMT water level at the mouth of the Mississippi River is approximately 49 ft (14.9 m) MSL, which is 262 river miles south of the RBS site. As the maximum tsunami water level associated with the PMT is below the designed plant grade elevation of 95 ft (29.0 m) MSL, the staff confirmed the licensee's conclusion that the RBS site could not be flooded by a tsunami originating off the coast of Louisiana.

The staff agrees with the licensee's conclusion that the reevaluated hazard for flooding from a tsunami will not inundate the RBS site and this hazard mechanism is bounded by the CDB. Therefore, flooding from tsunami hazard does not need to be analyzed in a focused evaluation or a revised integrated assessment as discussed in COMSECY-15-0019 (NRC, 2015b) and associated guidance JLD-ISG-2016-01 (NRC 2016b).

3.8 Ice-Induced Flooding

The licensee reported in its FHRR that the reevaluated hazard for ice-induced flooding is negligible. This flood-causing mechanism is discussed in the licensee's CDB and was determined to not have an impact on the site (Entergy, 2014).

The licensee reported in its FHRR (Entergy, 2014) that the reevaluated hazard analysis followed the HHA approach described in NUREG/CR-7046, "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America" (NRC, 2011d). The licensee provided a review of historical water temperature records of the Mississippi River from USGS stream gauges at Vicksburg, Mississippi (1973-1999) and Baton Rouge, Louisiana (2007-2013), and water temperature records from the USACE for Natchez, Mississippi (2000-2013) (Entergy, 2014). The licensee found that all reported water temperature records were above freezing at these locations. In addition, the Mississippi River near the site is heavily navigated and maintained by the USACE, and this active management and water traffic further reduces the potential for the formation of ice jams. Lastly, in the unlikely event that ice formation does occur on the Mississippi River in the vicinity of the RBS site, the site would not be inundated because the site is approximately 37 ft (11.3 m) above the river flood control levee system and any overtopping would be diverted away for the plant to a large floodplain to the west of the plant (Entergy, 2014). Therefore, the licensee concluded that the potential for impact from ice-induced flooding at the RBS site is negligible.

The NRC staff independently reviewed daily air temperature data for the Baton Rouge area from National Climate Data Center gage ID GSOD 72232013970, covering the time period from 1948 to 2014 (NOAA, 2016). The data indicated that the longest period of sustained sub-freezing air temperatures was two days, which would be an insufficient amount of time for any significant ice jam to form. To confirm this, the staff independently searched the USACE Cold Regions Research and Engineering Laboratory Ice Jam Database for current and historical ice jams near the RBS site and found no current or historical ice jams in the vicinity of the RBS site (USACE, 2012).

The NRC staff agrees with the licensee's conclusion that the reevaluated hazard for ice-induced flooding results in no impact to the site because ice jams would not occur in the Mississippi River in the vicinity of the RBS site. Therefore, this hazard mechanism is bounded by the CDB. As a result, ice-induced flooding does not need to be analyzed in a focused evaluation or a revised integrated assessment as discussed in COMSECY-15-0019 (NRC, 2015b) and associated guidance JLD-ISG-2016-01 (NRC 2016b).

3.9 Channel Migrations or Diversions

The licensee reported in its FHRR that the reevaluated hazard for channel migrations or diversions is negligible for the RBS site. This flood-causing mechanism is discussed in the licensee's CDB and does not impact the site (Entergy, 2014).

The licensee used the HHA approach described in NUREG/CR-7046 (NRC, 2011d) and reviewed historical records and hydro-geomorphological data to assess whether the Mississippi River has a tendency to meander toward the RBS site (Entergy, 2014). The licensee also evaluated present-day channel protection and stabilization measures in place to mitigate channel diversion of the Mississippi River (Entergy, 2014). The licensee reported in its FHRR that any flooding hazard due to channel migrations or diversions would not be an issue at RBS, Unit 1, because the river flow and geometry of the Mississippi River are controlled by USACE navigable structures and the channel is kept in place through an extensive program that includes channel stabilization and protection, revetment, dredging, and levee and dike maintenance (Entergy, 2014). The licensee concluded that even though there is a history of meandering on the Mississippi River, the potential for river channel migration to impact the site is negligible for the reasons discussed above (Entergy, 2014).

The NRC staff independently reviewed historical records of Mississippi River meander from the period of record from 1765 to 1944 (Fisk, 1944). The eastern boundary of the river in 1765 was approximately 0.25 mi (0.40 km) closer to the RBS site than the current boundary of the river. Other meander during this period occurred either on the western boundary of the river (i.e., away from the RBS site) or within 0.25 mi (0.40 km) of the present eastern boundary of the river. Geological records of river meander prior to 1765 indicate that the Mississippi River migration occurred mainly on the west shore, opposite the RBS site (Fisk, 1944). Due to heavy navigation, the Mississippi River is actively maintained by the USACE New Orleans District. The USACE maintains revetments and flood controls structures that have been constructed to minimize the risk of channel diversions, bank erosion, and instability. Since the construction of revetments and levees, the Mississippi River has not exhibited a tendency to meander towards or away from the site.

The NRC staff's review confirms the licensee's conclusion that the reevaluated hazard for flooding from channel migrations or diversions is negligible and would not impact the site, and therefore is bounded by the CDB. As a result, flooding from channel migrations or diversions does not need to be analyzed in a focused evaluation or a revised integrated assessment as discussed in COMSECY-15-0019 (NRC, 2015b) and associated guidance JLD-ISG-2016-01 (NRC 2016b).

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

4.1 Reevaluated Flood Height for Hazards Not Bounded by the CDB

Section 3 of this staff assessment documents the staff's review of the licensee's flood hazard water height results. Table 4.1-1 contains the maximum results, including waves and runup, for flood mechanisms not bounded by the CDB, which is presented in Table 3.1-3. The staff agrees with the licensee's conclusion that LIP and streams and rivers are the only hazard mechanisms not bounded by the CDB.

Consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01 (NRC, 2016b), the NRC staff anticipates the licensee will submit a focused evaluation for LIP and associated site drainage. For the rivers and streams flood-causing mechanism, the NRC staff anticipates the licensee will perform additional assessments of plant response, either through a focused evaluation or an integrated assessment, as discussed in COMSECY-15-0019 (NRC, 2015b) and associated guidance JLD-ISG-2016-01 (NRC, 2016b).

4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The staff reviewed information provided in Entergy's 50.54(f) responses (Entergy, 2014; Olson, 2014a; Olson, 2014b; Olson 2015; and Brumfield, 2015) regarding the flood event duration (FED) parameters needed to perform the additional assessments of plant response for flood hazards not bounded by the CDB. The FED parameters for the flood-causing mechanisms not bounded by the CDB are summarized in Table 4.2-1.

The licensee did not provide FED parameters for LIP or streams and rivers. The licensee is expected to develop FED parameters for these flood-causing mechanisms to conduct the MSA as discussed in NEI 12-06 (Revision 2), Appendix G (NEI, 2015), and outlined in COMSECY-15-0019 (NRC, 2015b) and associated guidance JLD-ISG-2012-01, Revision 1 (NRC, 2016a).

4.3 Associated Effects for Hazards Not Bounded by the CDB

The staff reviewed information provided in Entergy's 50.54(f) response (Entergy, 2014; Olson, 2014a; Olson, 2014b; Olson, 2015; and Brumfield, 2015) regarding associated effects (AE) parameters needed to perform future additional assessments of plant response for flood hazards not bounded by the CDB. The AE parameters directly related to maximum total water height, such as waves and runup, are presented in Table 4.1-1. The AE parameters not directly associated with total water height are listed in Table 4.3-1. The AE parameters not submitted as part of the FHRR are noted as "not provided" in this table. The NRC staff will review these AE parameters as part of future additional assessments of plant response, if applicable to the assessment and hazard mechanism.

4.4 Conclusion

Based upon the preceding analysis, NRC staff confirms that the reevaluated flood hazard information defined in the Section 4.1 is appropriate input to the additional assessments of plant response as described in the 50.54(f) letter (NRC, 2012a), COMSECY-15-0019 (NRC, 2015b), JLD-ISG-2012-01, Revision 1 (NRC, 2016a), and JLD-ISG-2016-01 (NRC, 2016b).

The licensee is expected to develop FED parameters and applicable flood AE to conduct the MSA as discussed in NEI 12-06 (Revision 2), Appendix G (NEI, 2015). The staff will evaluate the FED parameters (including warning time, period of inundation, and recession time) and flood-related AE marked as "not provided" in Tables 4.2-1 and 4.3-1 during its review of the MSA.

5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms for RBS, Unit 1. Based on its review of available information provided in Entergy's 50.54(f) response (Entergy, 2014; Olson, 2014a; Olson, 2015b; Olson, 2015; and Brumfield, 2015), the 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 confirms 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, staff confirms the licensee's conclusions that (a) the reevaluated flood hazard results for LIP and streams and rivers (West Creek PMF and Mississippi River PMF) are not bounded by the CDB flood hazard; (b) additional assessments of plant response will be performed for the LIP and the rivers and streams flood-causing mechanisms; and (c) the reevaluated flood-causing mechanism information is appropriate input to additional assessments of plant response, as described in the 50.54(f) letter, COMSECY-15-0019 (NRC, 2015b), JLD-ISG-2012-01, Revision 1 (NRC, 2016a), and JLD-ISG-2016-01 (NRC, 2016b).

6.0 REFERENCES

Note: ADAMS Accession Nos. refers to documents available through NRC's Agencywide Documents Access and Management System. 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, 2007. ADAMS stores the Standard Review Plan as multiple ADAMS documents, which are accessed through NRC's public web site at http://www.nrc.gov/reading-rm/basic-ref/srp-review-standards.html.

NRC, 2009, "Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America, Final Report", NUREG/CR-6966, March 2009, ADAMS Accession No. ML091590193.

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, "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, 2011c, "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, 2011d, "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, 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. ML12056A046.

NRC, 2012b, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation and Michael R. Johnson, Office of New Reactors, 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 Recommendation 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, 2014a, "NRR E-mail Capture – Request for Additional Information: River Bend Station – Flooding Hazard Reevaluation Report (TAC No. MF3675)," June 2, 2014, ADAMS Accession No. ML14153A392.

NRC, 2014b, "Staff Assessment of Flooding Walkdown Report Near-Term Task Force Recommendation 2.3 Related to the Fukushima Dai-Ichi Nuclear Power Plant Accident Entergy Operations, Inc. River Bend Station Unit 1, Docket No. 50-458," June 20, 2014, ADAMS Accession No. ML14148A150.

NRC, 2015a, "NRR Email Capture - Request for Additional Information: River Bend Station – Flooding Hazard Reevaluation Report (TAC No. MF3675)," April 27, 2015, ADAMS Accession No. ML16167A325.

NRC, 2015b, "Closure Plan for Flooding Hazard for Operating Nuclear Power Plants," Commission Paper COMSECY-15-0019, June 30, 2015, ADAMS Accession No. ML15153A104.

NRC, 2015c, "River Bend Station, Unit 1 – Interim Staff Response to Reevaluated Flood Hazards Submitted in Response to 10 CFR 50.54(f) Information Request – Flood-Causing Mechanism Reevaluation (TAC No. MF3675)," September 4, 2015, ADAMS Accession No. ML15230A010.

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," Japan Lessons-Learned Directorate, Interim Staff Guidance JLD-ISG-2012-01, Revision 1 and Comment Resolution, January 22, 2016, ADAMS Accession No. ML15357A142.

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

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.

Other References

Brumfield, N.T., 2015, "Response to Additional Information on River Bend Station Recommendation 2.1 Flood Hazard Reevaluation River Bend Station – Unit 1 Docket No. 50-458 Licensee No. NPF-47," May 5, 2015, ADAMS Accession No. ML15155A602.

Chow, V.T., 1959, "Table 5-6: Values of the Roughness Coefficient n," *Open-Channel Hydraulics*, McGraw-Hill, New York.

Chow, et al, 1964, "*Applied Hydrology*," Ven Te Chow, David R. Maidment, and Larry W. Mays, McGraw-Hill, New York, 1964.

Entergy (Entergy Nuclear Operations, Inc.), 2008, "Application for Combined License for River Bend Unit 3; Part 2—Final Safety Analysis Report," Revision 0, Jackson, MS, September 25, 2008, ADAMS Accession No. ML082830262.

Entergy (Entergy Nuclear Operations, Inc.), 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 Da-ichi Accident, River Bend Station - Unit 1 Docket No. 50-458 License No. NPF-47," November 27, 2012, ADAMS Accession No. ML123400067.

Entergy (Entergy Nuclear Operations, Inc.), 2014. "Entergy Fleet Fukushima Program Flood Hazard Reevaluation Report for River Bend Station." March 12, 2014, ADAMS Accession No. ML14073A649.

Fisk, H.N., 1944, "*Geological Investigation of the Alluvial Valley of the Lower Mississippi River*," Ancient Courses, Mississippi River Meander Belt: Cape Girardeau, Missouri, to Donaldsville, Louisiana, Sheet 14 of 15, prepared by U.S. Army Corps of Engineers, Vicksburg, MS, prepared for Mississippi River Commission, Vicksburg, MS, December 1, 1944. Available on-line at http://lmvmapping.erdc.usace.army.mil

Froehlich, 1995. Peak Outflow from Breached Embankment Dam. Froehlich, D.C. 1995. Journal of Water Resources Planning and Management, vol. 121, no. 1, p. 90-97.

FLO-2D (FLO-2D Software Inc.), 2009, FLO-2D®, 2009 Reference Manual, FLO-2D Software, Inc., Nutrioso, Arizona FLO-2D, 2009, FLO-2D Professional version, Build No. 13.07.05.

Lynett, P., and Liu, P.L.F., 2002, "A numerical study of submarine-landslide-generated waves and run-up: Proceedings of the Royal Society of London," A, v. 458, p. 2885-2910.

NEI (Nuclear Energy Institute), 2015, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," NEI 12-06 Revision 2, December 2015, ADAMS Accession No. ML16005A625.

NEI, 2016, "External Flooding Assessment Guidelines," NEI 16-05, Revision 1, June 2016, ADAMS Accession No. ML16165A176.

NOAA (National Oceanic and Atmospheric Administration), 1978, "Probable Maximum Precipitation Estimates, United States, East of the 105th Meridian," NOAA Hydrometeorological Report No. 51, June 1978.

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

NOAA, 2016, National Centers for Environmental Information, Climate Data Online, Database available online at https://www.ncdc.noaa.gov/cdo-web/, June 2016.

NRCS (Natural Resource Conservation Service), 1985, "Simplified Dam Breach Routing Procedure," Technical Release No. 66, U.S. Department of Agriculture, Washington, D.C., September 30, 1985.

Olson, E.W., 2014a, "Response to Request for Information Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident River Bend Station – Unit 1 Docket No. 50-458 License No. NPF-47," March 12, 2014, ADAMS Accession No. ML14073A648.

Olson, E.W., 2014b, "River Bend Station, Unit 1 - Response to Request for Additional Information on River bend Station Recommendation 2.1 Flood Hazard Reevaluation," June 17, 2014, ADAMS Accession No. ML14178A024.

Olson E.W., 2015, "River Bend Station, Unit 1 - Response to Request for Additional Information on River bend Station Recommendation 2.1 Flood Hazard Reevaluation," May 27, 2015, ADAMS Accession No. ML15162A272.

SCS (Soil Conservation Service), 1986, "Urban Hydrology for Small Watersheds," Technical Release 55, Soil Conservation Service, U.S. Department of Agriculture, June 1986.

ten-Brink, U.S., Twichell, D.C., Geist, E.L., Chaytor, J., Locat, J., Lee, H., Buczkowski, B., Barkan, R., Solow, A.R., Andrews, B.D., Parsons, T., Lynett, P., Lin, J., and Sansoucy, M., 2008, "Evaluation of Tsunami Sources with the Potential to Impact the U.S. Atlantic and Gulf Coasts: An Updated Report to the Nuclear Regulatory Commission," 302 p. (U.S. Geological Survey Administrative Report).

USACE (U.S. Army Corps of Engineers), 1987, "HMR52 Probable Maximum Storm (Eastern United States): User's Manual," Hydrologic Engineering Center, U.S. Army Corps of Engineers, April 1987, available online at http://www.hec.usace.army.mil/publications/ComputerProgramDocumentation/HMR52_UsersManual_(CPD-46).pdf.

USACE, 2001, “Digital Elevation Model (USGS DEM), Louisiana FEMA Project—Phase 1: Point Coupee.”

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

USACE, 2010b, “Hydrologic Modeling System (HEC-HMS), Version 3.5.0,” Hydrologic Engineering Center, U.S. Army Corps of Engineers, August 2010.

USACE, 2012, “Ice Jam Database,” U.S. Army Corps of Engineers, Cold Region Research and Engineering Laboratory, available online at http://icejams.crrel.usace.army.mil/.

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

USBR (U.S. Bureau of Reclamation), 1982, “Guidelines for Defining Inundated Areas Downstream from Bureau of Reclamation Dams,” Reclamation Planning Instruction No. 82-11, Washington, D.C., June 15, 1982.

USDA (U.S. Department of Agriculture), 2004, “Chapter 10 Estimation of Direct Runoff from Storm Rainfall,” Part 630 Hydrology, National Engineering Handbook, Natural Resource Conservation Service, Washington, D.C., July 2004.

Veri-Tech, Inc., 2014, “Coastal Engineering Design and Analysis System” (CEDAS) computer code, Version 4.03, Summit, MS. Available (at cost) on-line at http://veritechinc.com/products/cedas/index.php

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

Notes:
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 3.1-1. Summary of Controlling Flood-Causing Mechanisms

Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation 95.0 ft (29.0 m) MSL[1]	ELEVATION ft (m) MSL
Local Intense Precipitation and Associated Drainage	98.3 ft (30 m)
Streams and Rivers: West Creek[2]	95.1 ft (29 m)

Source: Entergy, 2014
Notes:
[1]Flood height and associated effects as defined in JLD-ISG-2012-05 (NRC, 2012d).
[2]The reevaluated hazard for Grants Bayou for this flood-causing mechanism, is 100.1 ft (30.5 m) MSL. The elevation of 100.1 ft (30.5 m) MSL is below the associated CDB of 101.8 ft (31.0 m) MSL for Grants Bayou and so is omitted here.

Table 3.1-2. Current Design-Basis Flood Hazards

Flooding Mechanism	Stillwater Elevation MSL	Associated Effects	Current Design Basis Flood (CDB) Elevation MSL	Reference
Local Intense Precipitation				
Unit 1	96.0 ft MSL	Not applicable	96.0 ft MSL	FHRR Table 4.1-1
Unit 2 Excavation	80.3 ft MSL	Not applicable	80.3 ft MSL	FHRR Table 4.1-1
Streams and Rivers				
West Creek	94.3 ft MSL	Not applicable	94.3 ft MSL	FHRR Table 4.1-1
Mississippi River	54.5 ft MSL	Not applicable	54.5 ft MSL	FHRR Table 4.1-1
Grants Bayou:	101.8 ft MSL	Not applicable	101.8 ft MSL	FHRR Table 4.1-1
Failure of Dams and Onsite Water Control/Storage Structures	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Table 4.1-1
Storm Surge	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Table 4.1-1
Seiche	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Table 4.1-1
Tsunami	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Table 4.1-1
Ice-Induced	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Table 4.1-1
Channel Migrations or Diversions	No impact on the site identified	No impact on the site identified	No impact on the site identified	FHRR Table 4.1-1

Source: NRC, 2015c
Notes:
Reported values are rounded to the nearest one-tenth of a foot.

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

Mechanism	Stillwater Elevation	Waves/Runup	Reevaluated Hazard Elevation	Reference
Local Intense Precipitation				
Unit 1	98.3 ft MSL	Minimal	98.3 ft MSL	FHRR Tables 4.1-1, 4.1-2 & 4.1-3
Streams and Rivers				
West Creek	95.1 ft MSL	Not applicable	95.1 ft MSL	FHRR Table 4.1-4
Mississippi River	59.7 ft MSL	Not applicable	59.7 ft MSL	FHRR Table 4.1-4

Source: NRC, 2015c
Notes:
Reevaluated hazard mechanisms bounded by the CDB are not included in this table.
Reported values are rounded to the nearest one-tenth of a foot

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

Flood-Causing Mechanism	Time Available for Preparation for Flood Event	Duration of Inundation of Site	Time for Water to Recede from Site
Local Intense Precipitation and Associated Drainage	Not Provided[1]	Not Provided	Not Provided
Streams and Rivers: West Creek and Mississippi River PMF	Not Provided[2]	Not Provided	Not Provided

Source: Entergy, 2014, Olson 2015
Notes:
[1] The staff will evaluate flood event duration parameters that were not provided in the FHRR as part of future additional assessments.
[2] The licensee did provide warning time (also known as lag time) for the West Creek PMF only which was 1.2 h.

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

	Flooding Mechanism		
Associated Effects Factor	**Local Intense Precipitation[1]**	**Streams and Rivers: West Creek PMF[2]**	**Streams and Rivers: Mississippi River PMF**
Hydrodynamic loading at plant grade	Not Provided: The licensee did not evaluate hydrodynamic loading due to low velocities.	Hydrodynamic loading was not evaluated for West Creek streams and rivers simulation due to lack of inundation around plant structures.	Not Provided
Debris loading at plant grade	Due to limited debris sources inside the protected area during a LIP event, debris loading was not considered at the site.	Debris loading at plant grade was not evaluated due to absence of inundation around plant structures.	Not Provided
Sediment loading at plant grade	Not provided	Not provided	Not Provided
Sediment deposition and erosion	Not provided	Not provided	Not Provided
Concurrent conditions, including adverse weather	No antecedent storm or other condition was modeled in conjunction with the LIP event; Unit 2 excavation was assumed dry as an initial condition.	An antecedent 40 percent PMP was used for the West Creek watershed PMP analysis.	Not Provided
Groundwater ingress	Groundwater ingress was not evaluated due to the minimal depth and duration of the event. The Unit 2 excavation water level 79.8 ft (24.3 m) MSL is well below the Unit 1 site grade.	Not provided	Not Provided
Other pertinent factors (e.g., waterborne projectiles)	Plant mode of operations were considered to be at normal for modeling purposes.	Plant mode of operations were considered to be at normal for modeling purposes.	Not Provided

Source: Entergy, 2014 and Olson, 2015.
Notes:
[1] NRC RAI Item No. 15 requested FED and AE information. In response, the licensee agreed to provide specific flood durations for LIP in future assessments, specific to RBS exterior entrances. The velocities and depths associated with these LIP durations will support the presentation of AE. No additional response was provided relative to AE.
[2] In response to NRC RAI Item No. 15, the licensee agreed to provide evaluation of impacts and associated protection and mitigation measures for the West Creek PMF scenario in future assessments.

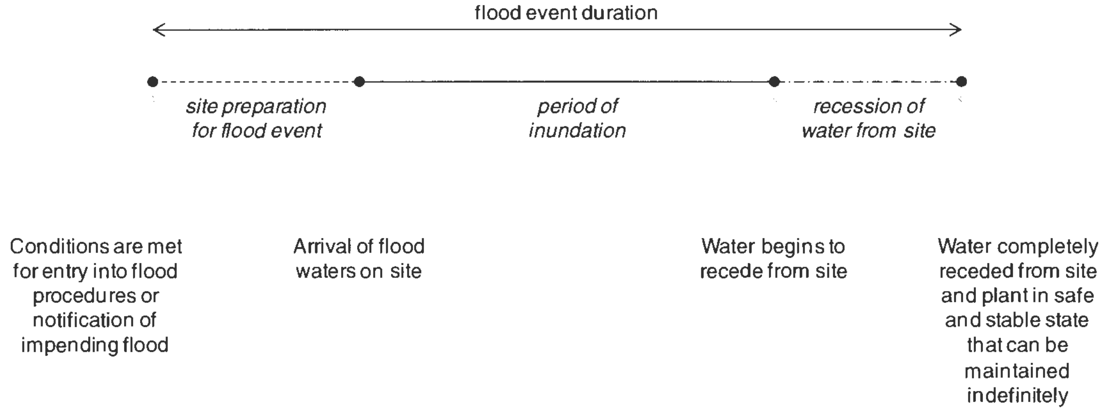

Figure 2.2-1 Flood Event Duration (NRC, 2012d)

Figure 3.1-1. Site Location Map showing Delineation of Grants Bayou and West Creek Watersheds (Adapted from Entergy, 2014)

Figure 3.1-2. RBS Building Map with SSCs (Adapted from Entergy, 2014)

If you have any questions, please contact me at (301) 415-2621 or e-mail at Robert.Bernardo@nrc.gov.

Sincerely,

/RA/

Robert Bernardo, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No. 50-458

Enclosure:
Staff Assessment of Flood Hazard
Reevaluation Report

cc w/encl: Distribution via Listserv

DISTRIBUTION:

PUBLIC	JLD R/F	RidsNRRJLD Resource
RBernardo, NRR	MShams, NRR	MFranovich, NRR
GBowman, NRR	YCheng, NRO	RidsNrrPMRiverBend
RidsNrrDorllpl4-2Resource	RidsNrrDorl Resource	Resource RidsRgn4MailCenter
RidsOpaMail Resource	RidsNrrLASLent	RidsOgcMailCenter Resource
ACampbell,NRO	SBreithaupt, NRO	MBensi, NRO
MMcBride, NRO	RidsNroDsea Resource	RidsNrrJLD Resource
MWillingham, NRO	CCook, NRO	RidsAcrsAcnw_MailCtr Resource
ARivera-Varona, NRO		

ADAMS Accession No.: ML16204A207 ***via email**

OFFICE	NRR/JLD/JHMB/PM	NRR/JLD/LA	NRO/DSEA/RHM2/BC
NAME	RBernardo	SLent	CCook
DATE	7/22/2016	7/27/2016	8/ /2016
OFFICE	NRR/JLD/JHMB/BC(A)	NRR/JLD/JHMB/PM	
NAME	GBowman	RBernardo	
DATE	8/7/2016	08/31/2016	

OFFICIAL RECORD COPY