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

October 31, 2016

Mr. Steven D. Capps
Vice President – McGuire Site
Duke Carolinas, LLC
McGuire Nuclear Station
12700 Hagers Ferry Road
Huntersville, NC 28078-8985

SUBJECT: MCGUIRE NUCLEAR STATION, UNITS 1 AND 2 – STAFF ASSESSMENT OF RESPONSE TO 10 CFR 50.54(f) INFORMATION REQUEST – FLOOD-CAUSING MECHANISM REEVALUATION (CAC NOS. MF3623 AND MF3624)

Dear Mr. Capps:

By letter dated March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information pursuant to Title 10 of the *Code of Federal Regulations*, Section 50.54(f) (hereafter referred to as the 50.54(f) letter). The request was issued as part of implementing lessons learned from the accident at the Fukushima Dai-ichi nuclear power plant. Enclosure 2 to the 50.54(f) letter requested that licensees reevaluate flood-causing mechanisms using present-day methodologies and guidance. By letter dated March 12, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14083A418), Duke Carolinas, LLC (Duke, the licensee) responded to this request for McGuire Nuclear Station, Units 1 and 2.

By letter dated September 3, 2015 (ADAMS Accession No. ML15230A161), the NRC staff sent Duke 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 several hazards were not bounded by the current design-basis flood hazard. Therefore, the NRC staff anticipates that the licensee will complete an evaluation of these unbounded flood mechanisms through a focused evaluation or an integrated assessment, as discussed in COMSECY-15-0019, "Closure Plan for the Reevaluation of Flooding Hazard for Operating Nuclear Power Plants," and Japan Lessons-Learned Division (JLD) Interim Staff Guidance (ISG) JLD-ISG-2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation; Focused Evaluation and Integrated Assessment." This closes out the NRC's efforts associated with CAC Nos. MF3623 AND MF3624.

If you have any questions, please contact me at (301) 415-3809 or e-mail at Juan.Uribe@nrc.gov.

Sincerely,

Juan Uribe, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear reactor Regulation

Docket Nos. 50-369 and 50-370

Enclosure:
Staff Assessment of Flood Hazard Reevaluation Report

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO FLOODING HAZARD REEVALUATION REPORT

NEAR-TERM TASK FORCE RECOMMENDATION 2.1

MCGUIRE NUCLEAR PLANT, UNITS 1 and 2

DOCKET NOS. 50-369 AND 50-370

## 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 NRC's Near-Term Task Force report (NRC, 2011b). Recommendation 2.1 in that document recommended that the NRC staff issue orders to all licensees to reevaluate seismic and flooding hazards for their sites against current NRC requirements and guidance. Subsequent staff requirements memoranda associated with SECY-11-0124 (NRC, 2011c) and SECY-11-0137 (NRC, 2011d) directed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

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

By letter dated March 12, 2014, Duke Energy Carolinas, LLC (Duke, the licensee) provided its FHRR for McGuire Nuclear Station (McGuire, MNS), Units 1 and 2 (Duke, 2014a). The NRC staff issued requests for additional information (RAIs) to the licensee by letter dated May 28, 2014 (NRC, 2014a), and by email dated April 9, 2015 (NRC, 2015a). The licensee responded to the RAIs by letters dated July 2, 2014 (Duke, 2014b), and June 3, 2015 (Duke, 2015). The licensee's FHRR and responses to RAIs provide the flood hazard input necessary to complete this staff assessment consistent with the process outlined in COMSECY-15-0019 (NRC, 2015b); JLD-ISG-2012-01, Revision 1 (NRC, 2016a); and JLD-ISG-2016-01, Revision 0 (NRC, 2016b).

By letter dated September 3, 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, "Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (NRC, 2012b), and the additional assessments associated with Recommendation 2.1: Flooding. The IRS 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 have been clarified as follows:

1. the NRC staff added a scenario in Table 3.1-2 for completeness under local intense precipitation (LIP),
2. the NRC staff combined the entry for storm surge and seiche to correspond to the licensee's FHRR analysis, and
3. the NRC staff added clarification footnotes to the reevaluated hazard elevations not bounded by the current design basis (CDB) table (Table 4.1-1).

However, the numerical values are presented in this staff assessment without change or alteration (when compared to the ISR letter).

As mentioned in the ISR letter and discussed below, the reevaluated flood hazard results for the LIP, rivers and streams, dam failure, and storm surge flood-causing mechanisms were not bounded by the plant's CDB hazard. Consistent with the 50.54(f) letter and as amended by the process outlined in COMSECY-15-0019 and JLD-ISG-2016-01, Revision 0 (NRC, 2015b; NRC, 2016b), the 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 rivers and streams, dam failure, and storm surge flood-causing mechanisms, the staff anticipates that the licensee will submit (1) an integrated assessment or (2) a focused evaluation that confirms the capability of existing flood protection or mitigation.

Additionally, for any reevaluated flood hazards that are not bounded by the plant's CDB hazard, the licensee is expected to develop any flood event duration (FED) and associated effects (AE) parameters currently not provided to conduct the mitigating strategies assessment (MSA) and focused evaluations or revised integrated assessments.

## 2.0 REGULATORY BACKGROUND

### 2.1 Applicable Regulatory Requirements

As stated above, Enclosure 2 to the 50.54(f) letter (NRC, 2012a) requested that the licensee reevaluate flood hazards for their 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 report, 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 a SSC must meet its functional goals.

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

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoked. The 50.54(f) letter (NRC, 2012a) requested that all power reactor licensees and construction permit holders reevaluate all external flood-causing mechanisms at each site. 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 discusses flood-causing mechanisms for the licensee to address in its 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) sections and applicable interim staff guidance (ISG) documents containing acceptance criteria and review procedures.

### 2.2.2 Associated Effects

The licensee should incorporate and report associated effects per JLD-ISG-2012-05, "Guidance for Performing the Integrated Assessment for External Flooding," (NRC, 2012d) in addition to the maximum water level associated with each flood-causing mechanism. Guidance document JLD-ISG-2012-05 (NRC, 2012d), defines "flood height and associated effects" as the maximum stillwater-surface elevation plus:

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

### 2.2.3 Combined Effects Flood

The worst flooding at a site that may result from a reasonable combination of individual flooding mechanisms is sometimes referred to as a "combined effect flood" or "combined events". 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 event 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 NRC 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 elevation is not bounded by the CDB flood hazard for any flood-causing mechanisms, the 50.54(f) letter (NRC, 2012a) requests licensees and construction permit holders to:

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

If the reevaluated flood hazard is bounded by the CDB flood hazard for each flood-causing mechanism at the site, licensees are not required to perform an integrated assessment. COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b) outline a revised process for addressing cases in which the reevaluated flood hazard is not bounded by the plant's CDB. The revised process describes an approach in which licensees with LIP hazards exceeding their CDB flood will not be required to complete an integrated assessment, but instead will perform a focused evaluation that assesses 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 their 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 and NRC, 2016b).

## 3.0 TECHNICAL EVALUATION

The NRC staff reviewed the information provided for the flood hazard reevaluation of McGuire, Units 1 and 2. The licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews. To provide additional information in support of the summaries and conclusions in the FHRR, the licensee made calculation packages available to the NRC staff via an electronic reading room (ERR). When the NRC staff relied directly on any of these calculation packages in its review, they or portions thereof were docketed and cited as appropriate in the discussion below. Certain other calculation packages were found only to expand upon and clarify the information provided on the docket, and so were not docketed or cited. The NRC staff's review and evaluation is provided below.

3.1 Site Information

The 50.54(f) letter (NRC, 2012a) includes the SSCs important to safety in the scope of the hazard reevaluation. The licensee included this pertinent data concerning these SSCs in the FHRR and responses to RAIs (Duke, 2014a; Duke, 2014b; Duke, 2015). The NRC staff reviewed and summarized this information in the sections below.

3.1.1 Detailed Site Information

The licensee used mean sea level (MSL) for elevations in the FHRR which were referenced to National Geodetic Vertical Datum 1929 (NGVD29) (Duke, 2014a). All elevations in this staff assessment are in feet (ft) MSL and are rounded to the nearest 0.1 ft, unless otherwise noted.

The McGuire site is located approximately 17 miles (mi) (27.4 kilometers (km) north of Charlotte, NC and immediately east of the Cowans Ford Dam. This dam impounds the Catawba River, thus forming Lake Norman. The normal maximum pool elevation of Lake Norman is 760 ft (231.65 meters (m)) MSL (Duke, 2014a). The licensee indicated in the FHRR that the main hydrological features that influence the McGuire site are the Catawba River and a series of five reservoir developments consisting of dams, reservoirs, spillways, and powerhouses that regulate the river at McGuire and also upstream from McGuire (Duke, 2014a). The Bridgewater, Rhodhiss, Oxford, Lookout Shoals, and Cowans Ford Developments (see Figure 3.1-1), are part of Duke's Catawba-Wateree Project, a hydropower project that includes six other developments downstream of the Cowans Ford Development (Duke, 2006). The Catawba River is approximately 240 mi (386 km) long with a drainage area of approximately 4,750 $mi^2$ (12,302 $km^2$) from its headwaters to Wateree Dam where it joins with Wateree Creek to form the Wateree River, a tributary of the Santee River.

The licensee indicated in its FHRR that the site grade elevation and the minimum elevation of safety-related structures in the MNS yard (also referred to as the powerblock) in the northern section of the site is 760 ft (231.65 m) MSL. The minimum exterior doorway threshold elevation of safety-related structures is 760.5 ft (231.80 m) MSL. Table 3.1-1 provides the summary of controlling reevaluated flood-causing mechanisms, including wind setup and wave runup, the licensee computed to be higher than the powerblock elevation.

The licensee described in its FHRR that the Intake and Discharge Dike[1] continues eastward from the East Embankment until the ground surface reaches an elevation of 780 ft (237.74 m)

[1] The meaning of the terms "embankment" and "dike" are nearly identical in the present context: a bank, usually of earth, used to control or confine water. The FHRR tends to use them interchangeably, except when discussing specific features such as the east embankment and the intake and discharge dike. This staff assessment generally refers to the specific feature under discussion.

MSL northeast of the McGuire Yard. The intake and discharge dike has a crest elevation of 780 ft (237.74m) MSL, and protects the McGuire yard from flooding from the north. The intake structure, which takes cooling water from Lake Norman, is adjacent to the intake and discharge dike. The discharge structure is located immediately east of the intake structure, and discharges water back to Lake Norman through the discharge channel (see Figure 3.1-2).

The licensee stated in its FHRR that the standby nuclear service water pond (SNSWP) is a safety-related impoundment formed by damming of a small tributary immediately south of the McGuire yard. The SNSWP dam, on the west side of the SNSWP, has a crest elevation of 747 ft (227.7 m) MSL. The SNSWP dam also has a 1.5 ft (0.5 m) parapet wall for a total elevation of 748.5 ft (228.14 m) MSL. The SNSWP has a normal full pond water elevation of 740 ft (225.6 m) MSL and a surface area of 34.9 acre (0.14 $km^2$). The tailrace of the Catawba River is situated at lower elevation than McGuire, with a maximum predicted spillway flow tailwater elevation of 698.5 ft (212.90 m) MSL (see Figure 3.1-1) (Duke, 2014a).

### 3.1.2 Design-Basis Flood Hazards

The CDB flood levels are summarized by flood-causing mechanism in Table 3.1-2. The staff notes that Duke indicated via an RAI response that the CLB and CDB are equivalent (Duke, 2015). The FHRR Section 1.2 describes the evaluation of the CDB of all flood causing mechanisms, as well as applicable combined and associated events. The CDB flood hazards were established on the Updated Final Safety Analysis Report (UFSAR), Revision 16 and Revision 17 (Duke, 2014a). The NRC staff reviewed the information provided and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

### 3.1.3 Flood-Related Changes to the Licensing Basis

The licensee stated in FHRR Section 1.3 that MNS has not made any licensing basis flood-related or flood protection changes. The licensee identified certain interim actions in FHRR Section 4 and stated that interim actions and procedures exist to ensure that the plant will be safe during a flood event, and that these interim actions and procedures will be reevaluated and updated as determined by a focused evaluation and/or an additional assessment. The NRC staff reviewed the information provided in the FHRR and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

### 3.1.4 Changes to the Watershed and Local Area

The licensee stated in FHRR Section 1.4 that the majority of the watershed of the Catawba River is comprised of protected forest land. There has been construction related to housing and support facilities, but the overall percentage of land use has not significantly changed since the construction of the Catawba-Wateree developments and McGuire in 1960s (Duke, 2014a). There has not been a significant change in land use around Lake Norman since its dams were constructed in 1963 (Duke, 2014a). The FHRR also stated that changes at the McGuire site have been captured and represented in the modeling process of the reevaluation for LIP and dam failure inundation at the plant site. These features, such as updated drainage, utility trenches, and building configurations, were obtained using aerial and ground surveys as recent as 2013 (Duke, 2014a).

3.1.5 Current Licensing Basis Flood Protection and Pertinent Flood Mitigation Features

Section 1.5 in the FHRR stated that there are no planned or newly installed flood protection systems or flood mitigation measures identified as a result of the flood walkdown process (Duke, 2014a). The NRC staff reviewed the information provided in the FHRR and determined that sufficient information was provided to be responsive to Enclosure 2 of the 50.54(f) letter.

3.1.6 Additional Site Details to Assess the Flood Hazard

To facilitate the review and analysis performed for the LIP and reservoir flooding, several documents and files have been provided by the licensee pertaining to the LIP, reservoir, and dam failure flooding. Among them include calculation packages, input and output files for modeling, and geographic information system support files (Duke, 2014b).

3.1.7 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 (NRC, 2012a).

By letter dated November 27, 2012 (Duke, 2012b), Duke provided the flood walkdown report for McGuire, Units 1 and 2. The NRC staff issued a staff assessment report on June 10, 2014 (NRC, 2014b), to document its review of the walkdown report, which concluded that the licensee's implementation of the flooding walkdown methodology met the intent of the walkdown guidance.

3.2 Local Intense Precipitation and Associated Site Drainage

The licensee reported in its FHRR that the reevaluated flood hazard for LIP results in a maximum stillwater-surface elevation of 761.1 ft (232 m) MSL within the McGuire plant area (near the auxiliary building) and a reevaluated elevation of 746.8 ft (227.62 m) MSL (including wind effects) at the SNSWP. This flood-causing mechanism is discussed in the licensee's CDB. The CDB flood elevation for LIP is reported as a stillwater-surface elevation of 760.4 ft (231.77 m) MSL in the McGuire plant area and 746.9 ft (227.7 m) MSL at the SNSWP (Duke, 2014a).

For LIP, two separate analyses were performed, one for the McGuire plant area as outlined in Figure 3.2-1, and a second pertaining to the flooding of the SNSWP, located southeast of the plant, as shown in Figure 3.2-2. The same analysis of on-site probable maximum precipitation (PMP) applies to both (Duke, 2014a).

3.2.1 LIP Flooding in McGuire Plant Area

The licensee's reevaluation for LIP for the McGuire plant area is based on a 1-hour (h) point PMP rainfall scenario (1-mi$^2$ (2.6 km$^2$)) at 18.8 inches (in) (47 cm/h, obtained from

Hydrometeorological Report No. 52 (HMR-52) (NOAA, 1982), with a front-peak-loaded precipitation distribution at the 5-minute (min) intervals, modeled in 5-min increments. This PMP scenario is based on guidance for assessing on-site flooding from NRC NUREG/CR-7046 (NRC, 2011e) and is appropriate for use in the assessment of the McGuire LIP determination and effects.

3.2.1.1 Runoff Analysis

Depending on the roof material, the licensee's flow routing uses appropriate Manning's n values ranging from 0.010 and 0.011 for tent and steel, respectively, and up to 0.016 to 0.030 for concrete and asphalt surfaces, respectively (Duke, 2014a). The licensee used conceptual weirs with appropriate elevation and lengths to model overflow of gutters and parapets with a discharge coefficient of around 2.6 with a modular limit of 0.9 (Duke, 2014a).

Within the two-dimensional (2-D) zone, the buildings' roofs were represented by polygons and act as one-dimensional (1-D) sub-catchments using roof runoff and routing results modeled using the Storm Water Management Model (Duke, 2014b). The licensee treated overflow from roof parapets as weir flow and flow through roof scuppers was treated as sluice flow. The licensee included LIP-related flood protection features at the site, such as building roof drains, surface collection, subsurface storm drainage, and configured topography to help remove or route rain water away from pertinent safety structures (Duke, 2014b).

In Section 1.2 of its FHRR, the licensee stated that McGuire is protected from LIP with a system of roof drains, a surface collection system, and ditches connected to nearby natural channels. The buried storm drainage system is designed to remove rainfall of up to 4 in/h (10.2 cm/h) with additional precipitation ponding in the plant yard or overflowing the plant yard perimeter by sheet flow (Duke, 2014a).

The licensee performed a LIP analysis to account for the backwater effects of any flooding that occurs as a result of the SNSWP located to the southeast of the McGuire site (see Figure 3.2-2). The SNSWP is used as a cooling water reserve in the event that the McGuire must shut down. The total delineated watershed area depicted in Figure 3.2-2 is 155.6 acres or 0.2431 $mi^2$ (0.63 $km^2$). The analysis of the watershed area includes modeling runoff and pond storage. The pond uses a spillway to control water level and storage. The licensee modeled the watershed runoff using the Soil Conservation Service (SCS) method (SCS, 1986) with a curve number (CN) of 98, which is indicative of all rainfall effectively being managed as runoff with no losses (Duke, 2014b).

The licensee accomplished routing throughout the watershed using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center' - Hydrologic Modeling System (HEC-HMS), Version 3.5 model (USACE, 2010b), paired with a spillway rating curve and a storage and elevation relationship curve for the pond, with a normal pond water starting elevation and a conservative time of concentration of 6 min (Duke, 2014a). To determine pond surface water elevations, the licensee used conservative scenarios to reduce the spillway capacity by assuming the pond spillway as blocked were used.

The NRC staff reviewed the runoff analysis assumptions and results. The NRC staff concurs that the licensee's assumptions are conservative and the analysis is adequate for assessing the runoff for the site.

3.2.1.2 Hydraulic Modeling

The licensee modeled the precipitation and subsequent overland runoff using the combined 1-D and 2-D code, Innovyze Infoworks Integrated Catchment Model (ICM) (Version 3.0 software 2012 (Innovyze, 2012). This model uses a representation of the site's topography with a user defined mesh for which the equations of fluid flow and, subsequently depth, are calculated. The mesh model is based on a triangulated network of irregular-sized surfaces or triangulated irregular network based on topography data retrieved using a light detection and ranging (LiDAR) survey and aerial photography obtained in 2013, supplemented by information from building plans (Duke, 2014a).

The licensee determined the 2-D model's extent by security barriers, the intake and discharge dike, and ground surface sloped away from the site (see Figure 3.1-2) (Duke, 2015). On the north and northwest sides of the site, the intake and discharge dike serves as the boundary. On the east and northeast sides of the site, the security barriers serve as the model boundary. On the south and west sides of the site, the boundary of the model corresponds to where the ground surfaces sloped away from the site (Duke, 2015).

The NRC staff noted that the licensee modeled the hydrodynamic model boundary condition as a critical condition, allowing water to leave the 2-D zone using a broad crested weir equation without energy loss (Duke, 2014b). The licensee explained how it modeled site boundaries by using the critical flow boundary since water exceeds the ground level of the grid element when flow is exiting the model. The NRC staff determined that the use of a broad crested weir equation to determine flow at these boundaries without energy loss is appropriate and conservative. Additional conservatism was used in the treatment of modeling the security barriers as a continuous structure with no gaps. This is appropriate as it acts to contain more rainfall volume within the model and on the site. Since the barriers are at the boundary of a downslope away from the site, there is no potential for drainage towards the site from the other side of the barriers (Duke, 2014b).

The licensee's 2-D mesh generated for the on-site flow and depth modeling is a triangular non-configured grid used to calculate the flow magnitude and direction, as well as the corresponding depth (Duke, 2015). The grid is boundary-fitted containing many of the larger buildings allowing for flow up to and along the buildings' exterior walls. Some buildings and structures are not included in the mesh; for example, the mesh in the vicinity of the dry cask storage yard does not capture the vertical cylindrical structures or the adjacent structures in the yard, and there are a few other similar areas throughout the site indicative of the same simplification. Based on its review of the model provided by the licensee, the NRC staff determined that these buildings were not judged to be critical to include in mesh as flow obstructions to evaluate site inundation.

The licensee identified a group of 21 locations of interest for monitoring near the auxiliary building, fuel building, equipment staging building, diesel generator building, turbine building, waste solidification building, dry cask storage yard, and standby shutdown facility. The licensee's selection of the 21 points was based on the potential for water intrusion into safety-related buildings. The highest reevaluated flood level at any of these locations is 761.1 ft (232 m) MSL (Duke, 2014a).

The NRC staff reviewed and agrees with the assumptions and inputs, and with the boundaries as described by the licensee in the hydraulic model. The NRC staff also concludes that the maximum flood levels identified at or near the safety-related structures are conservative and acceptable for the focused evaluation.

3.2.2 LIP Flooding at McGuire SNSWP

The licensee used a 1-h LIP storm totaling 18.8 in (47.8 cm/h) for the contributing drainage area of 155.6 acres (0.63 $km^2$) (refer to Figure 3.2-2) and using a front-peak-loaded precipitation distribution at the 5-min intervals, modeled in 5-min increments (Duke, 2014a). The licensee used the SCS CN method to assess the hydrological response of the watershed. The licensee also used the recommended minimum lag time in the HEC-HMS model for routing the watershed response (Duke, 2014a).

The licensee made several assumptions in the modeling of the LIP flooding for the SNSWP in accordance with the guidelines provided by NUREG/CR-7046 (NRC, 2011e). These assumptions, as discussed in the FHRR and shown from the model input/output files (Duke, 2014a; Duke, 2014b), are:

- All site drainage structures used to route water away from the pond are assumed to be non-functional.
- Runoff losses are minimized with the use of a CN of 98, which maximizes runoff and contribution of water routed to the pond.
- The minimum value for time of concentration is used for basin. This advances the runoff to the pond quickly.
- Available storage in the pond is minimized by assuming a normal full pool elevation as an initial condition.
- Spillway obstruction occurs at the beginning of the rainfall event with a 20 percent reduction in spillway capacity for all flows.

The licensee used a storage-discharge relationship for the SNSWP to model flood elevations for inflows to the pond. Along with the prescribed assumption of a 20 percent reduction in spillway capacity, the licensee performed sensitivity studies for various scenarios representing further reductions in spillway capacity by 25, 50, 75, and 100 percent. The most conservative case of no spillway discharge results in a peak pond elevation of 745.9 ft (227.4 m) MSL.

With this stillwater elevation, the licensee estimated the wind wave run-up height using the method from the Shore Protection Manual (USACE, 1984) with a 2-year wind speed of 40 mi/h (64.3 km/h) and a maximum fetch length at Lake Norman of 1,998 ft (609 m) (Duke, 2014a). With the effects of wind driven wave run-up of 0.9 ft (0.27 m), the reevaluated water surface elevation in the pond is 746.8 ft (227.62 m) MSL.

The staff reviewed the assumptions and results of the LIP flood modeling at the SNSWP area and concluded that a CN value of 98 was conservatively used to assess the hydrological response of the watershed, and that the minimum lag time and spillway reduction capacity rate used in the model are reasonable and conservative. Therefore, the staff concurs that the licensee's assumptions are conservative and the analysis is adequate for assessing the LIP flood hazard at the SNSWP.

3.2.3 LIP Conclusion

The NRC staff confirmed that the licensee's reevaluation of the hazard from LIP used present-day methodologies and regulatory guidance. The NRC staff also confirmed the licensee's conclusion that the reevaluated flood hazard for LIP was 761.1 ft (232 m) MSL, which is not bounded by the CDB of 760.4 ft (231.77 m) MSL for the MNS plant area and that the reevaluated flood hazard for the SNSWP is 746.8 ft (227.62 m) MSL, which is bounded by the CBD of 746.9 ft (227.7 m) MSL. Therefore, the NRC staff expects that the licensee will submit a focused evaluation for the LIP flood at the MNS plant area consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b).

3.3 Streams and Rivers

The licensee reported in its FHRR that the reevaluated hazard for streams and rivers, results in a stillwater-surface elevation of 777.9 ft (237.1 m) MSL (Duke, 2014a). Wind waves and run-up are discussed in connection with dam failure flooding in Section 3.4, because flood levels from dam failure are greater than those from stream and river flooding. This flood-causing mechanism is discussed in the licensee's CDB. The CDB probable maximum flood (PMF) elevation for streams and rivers is based on a stillwater-surface elevation at the upstream of the Cowans Ford Dam of 767.9 ft (234.1 m) MSL, and results in a CDB PMF elevation, including wind waves and run-up of 773.0 ft (235.61 m) MSL (Duke, 2014a).

3.3.1 PMP Evaluation

The licensee obtained PMP estimates using Hydrometeorological Report No. 51 (HMR-51) (NOAA, 1978) and HMR-52 (NOAA, 1982). The licensee used elliptical-shaped isohyetal patterns to maximize the PMP rainfall over each Catawba-Wateree Development's basin by systematically assessing hydrological response for various positions of the storm over the basin. The licensee set up the bounding PMP scenario based on a 216-h rainfall event consisting of three 72-h precipitation sub-events including the 40 percent PMP, 72-h of zero rainfall, and the HMR-51 PMP. The PMP event estimated was 33.25 in (84.5 cm). The NRC staff reviewed the development of the PMP inputs, and agrees that the postulated PMP scenario is reasonable for purposes of the 50.54(f) letter as they followed the guidelines provided by NUREG/CR-7046 (NRC, 2011e).

3.3.2 Hydrologic and Hydraulic Assessment

The licensee's evaluation of the PMF is based on a 1992 Federal Energy Regulatory Commission (FERC) study performed by Law Environmental (Duke, 2014a)). This study was performed as part of FERC compliance activities. The FERC study evaluated a PMF for each of the Duke Catawba-Wateree Developments (from upstream to downstream with a domino-type failure) to determine the maximum hydrologic and hydraulic scenarios for each dam and reservoir (Law Environmental, 1992). The PMF evaluations were performed using the HEC-1 (USACE, 1990) to develop rainfall-runoff hydrographs for the tributary watersheds and the National Weather Service's (NWS's) DAMBRK model (NWS, 1991) to route the PMF along the Catawba River (Law Environmental, 1992).

For the PMF reevaluation, the licensee used the modern-day routing model, Hydrologic Engineering Center - River Analysis System (HEC-RAS) Version 4.1 (USACE, 2010a). The licensee evaluated the flooding in streams and rivers by simulating the passage of the PMF through each Duke dam and reservoir in the Catawba-Wateree Basin using the HEC-RAS model and is referred to herein as the 2013 Catawba River Model (Duke, 2014a). Figure 3.3-1 depicts the history of the hydrologic and hydraulic model development and use.

As discussed in its FHRR, the licensee used the SCS method (SCS, 1986) to develop CNs for the watershed (Duke, 2014a). The licensee performed a regional analysis using gaged stations within and outside of the basin to develop SCS dimensionless unit hydrographs. The licensee used the HEC-1 model to assess the hydrological response of the basin. The licensee also used average lag-time parameters for the unit hydrographs to adjust the response of the runoff. The licensee performed calibration of the HEC-1 model using several storm events (1972 to 1985) and verified with Hurricane Hugo and with the 1916 and 1940 storm events (Duke, 2014a).

3.3.2.1 Calibration and Validation

As discussed in the FHRR, the HEC-1 and DAMBRK models were calibrated using an analysis of observations at rainfall and runoff gage stations located within and outside of the basin over 44 storms occurring between 1972 and 1985 (Duke, 2014a). The SCS CN method was used for abstraction of runoff. The licensee adjusted lag-time parameters for each subbasin to improve performance of the unit-hydrograph for predicting runoff. The licensee considered a correlation between the average lag-time parameter and physical characteristics of the basin for the region and used the correlation for determining lag-times for the Cowans Ford and Wylie subbasins. Some of the better predictions for peak discharge and timing are within 10 percent and 1-h of the observed, respectively.

The performance of HEC-1, DAMBRK, and the HEC-RAS models were validated with three storm events from the FERC study (Duke, 2014a). The licensee accounted for actual conditions specific to the absence of dams within the basin during the 1916 and 1940 time period (Duke, 2015). The licensee used a 'run-of-river' condition in the HEC-RAS modeling of the rainfall event response to account for the missing dams to correctly perform simulation and modeling comparisons. The licensee modified dam discharge parameters to reflect physical site parameters that existed at the time of the 1916 and 1940 events in order to replicate "as-existed" conditions. The licensee found the result to be an adequate representation of the basin runoff response and thus decided no adjustment of the unit hydrographs were necessary to simulate the PMF events. Validation results for the Hurricane Hugo event and the 1916 and 1940 storm events are reported to match very well with observations (Duke, 2014b).

The NRC staff reviewed the calibration and validation of the models used in the hydrologic and hydraulic assessment in the PMF analysis. The NRC staff agrees with the calibration used by the licensee and concurs that the validation results of the HEC-1 and HEC-RAS model for predicting reservoir levels indicate the two models are adequate for assessing water effects of the PMF.

3.3.2.2 Model Assumptions and Input

The licensee's modeling assessment incorporates the area bounded by the headwaters of Lake James through the Catawba River tailwater below Wylie Dam (Duke, 2014a). The licensee modeled approximately 165 mi (266 km) of the Catawba River, which includes the five upstream drainage areas, reservoirs and dams, and the immediate Cowans Ford Dam areas, including the upstream reservoir adjoining the intake and discharge dike and downstream Catawba River adjoining the SNSWP dam. To account for hydraulic backwater effects, the model extends downstream of McGuire to include Mountain Island and Wylie Dams.

For the HEC-1 model, the licensee used CN values based on Antecedent Moisture Conditions (AMC) II (Duke, 2014b). The licensee used an area-weighting of hydrologic soil groups and land use patterns for each sub-basin to determine a composite CN for each of the sub-basins. The licensee used an AMC II condition for calibration and validation. The rainfall events of 1916 and 1940 indicate average antecedent conditions which are consistent with ranges between AMC I and II for the 1940 event and AMC II and III for the 1916 event. The licensee asserted that the use of the SCS dimensionless unit hydrograph method along with a regional correlative analysis for obtaining lag-time parameters using basin characteristics is appropriate for assessing the hydrological response of the basin. In addition, this method yields more conservative results as compared to other synthetic methods. Since the 1916 and 1940 verification storms are roughly 60 and 40 percent of the calculated PMP event, the licensee chose not to adjust the unit hydrograph's response to account for non-linearity response associated with larger storms (Duke, 2015).

The licensee applied the HEC-RAS model based on the existing DAMBRK model. To maintain consistency with the 1992 DAMBRK model, the licensee combined select inflow hydrographs and added additional tributary inflows (Duke, 2014a). The licensee applied area proration to the sub-basin inflow hydrographs to distribute the flow within the modeled tributary reaches in the 2013 Catawba River Model, conserving the total inflow hydrograph for each respective subbasin. The licensee made time adjustments to individual inflow hydrographs so that the superposition of the routed hydrograph reasonably matched the FERC approved 1992 PMF hydrographs for the Cowans Ford and Wylie subbasins. The licensee extracted river and tributary reach cross sections, bank lines, flow paths, and mainstream and tributary junction from a geo-referenced digital terrain model and imported into HEC-RAS. The licensee used Manning's n values of 0.13 and 0.025 for the main channel and overbank regions, respectively (Duke, 2014a). The licensee handled the effect of bridges within the HEC-RAS model by using cross-section data obtained from LiDAR to define the section at each bridge and standard industry values of 0.3 and 0.5 for contraction and used expansion coefficients respectively to define the effect of the abrupt changes in the cross sections (Duke, 2015).

The licensee developed several scenarios, as discussed in its FHRR (Duke, 2014a), for investigating the effects of the PMF. The assumptions and details associated with the scenario resulting in the most significant consequences for PMF effects were:

- Setting starting reservoir elevations at the FERC operating license established reservoir target elevations, which are below normal full pond elevations.
- A 25-percent reduction of turbine discharge capacity (1 of 4 units) at Cowans Ford Dam.
- A 5-percent reduction in the spillway discharge capacity at Oxford, Cowans Ford, and Wylie Dams.
- Oxford Dam spillway gates are assumed in their full open position with top of gate elevation at 961.0 ft (293 m) MSL.

The NRC staff reviewed the inputs and assumptions used in the PMF modeling, and considers the use of an AMC II condition for the reevaluated PMF to be appropriate and conservative given that the PMP scenario uses a 40 percent PMP event three days prior to the 100 percent PMP event. The NRC staff also considers the Manning's n vales to be appropriate and the assumptions for the most significant scenario are reasonable.

3.3.2.3 Sensitivity Analyses

The licensee's FHRR stated that the FERC study conducted sensitivity runs for the 1992 model (Duke, 2014a). These sensitivity runs indicated that modeling of the more conservative AMC III conditions (i.e., saturated soil) yields discharge values that are generally 21 percent higher than the AMC II (i.e., average soil moisture) values, resulting in a peak reservoir elevation increase of up to 2.5 ft (Law Environmental, 1992).

The licensee performed several runs for the 2013 Cowans Ford PMF to determine AMC sensitivity along with the resulting impacts at the McGuire site (Duke, 2015). The results showed the peak reservoir elevations during a simulated PMF event was sensitive to the selection of CN value and indicated that selection of different AMC conditions for sub-basins can result in overtopping of upstream dams and failure of Cowans Ford Dam. The licensee provided justification for use of the AMC II condition for the reevaluated PMF and reported that the calibration and verification results of the HEC-1 model indicated good performance when using AMC II conditions for the storm events modeled (Duke, 2015). The licensee noted that the use of an AMC II condition is appropriate since the PMP event for the reevaluation includes a 40 percent PMP event occurring three days prior to the onset of the 72-h 100 percent PMP.

The licensee reported that sensitivity studies performed on the DAMBRK routing for adjustments in Manning's n values indicated that the routing is not sensitive to about 20 percent changes in Manning's n values (Duke, 2014f). Sensitivity studies performed by the NRC staff for a 20 percent decrease and increase in Manning's n values on the Catawba River in the HEC-RAS routing model indicates only a 0.20 ft (0.061 m) increase and 0.25 ft (0.762 m) decrease in water surface elevation at Lake Norman. This confirms that the model is relatively insensitive to changes in Manning's n values.

The NRC staff reviewed the sensitivity analyses used in the development of the hydrologic and hydraulic models. The NRC staff agrees with the licensee's PMF evaluation that the 40 percent PMP antecedent event used in conjunction with the AMC II condition is appropriate for conservatively assessing the effect of the PMF and the model is not sensitive to changes in Manning's n values. Therefore, the PMF modeling is reasonable for the purposes of the 50.54(f) letter.

### 3.3.3 Evaluation of Wind Wave and Runup Effects

The licensee evaluated the effect of wind for a special case for PMF which was dam failure, as described in Section 3.4. The licensee also evaluated resulting wave spill over onto the McGuire site with the ICM 2-D model (Innovyze, 2012), which resulted in depths of water lower than that associated with the modeled LIP inundation depths (Duke, 2014a).

### 3.3.4 Streams and Rivers Flooding Conclusions

Based on the review of the licensee's information provided for the PMF analysis, the NRC staff agrees with the licensee's reevaluated still-water PMF flood elevation at the upstream of the Cowans Ford Dam to be 777.9 ft (237.10 m) MSL. The NRC staff also confirms the licensee's conclusion that the PMF reevaluated hazard for this scenario is not bounded by the corresponding CDB flood level which is 767.9 ft (234.1 m) MSL. Therefore, the NRC staff expects that the licensee will submit a focused evaluation for this hazard 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, Revision 0 (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, is based on a stillwater-surface elevation of 778.5 ft (237.29 m) MSL. The licensee evaluated wind wave runup which resulted in a height of 0.04 ft (0.012 m) (Duke, 2014a). The NRC staff considers this to be a minimal impact on the reevaluated flood elevation. This flood-causing mechanism is discussed in the licensee's CDB. The CDB maximum flood elevations for the combined event of upstream dam failure with PMF is 762.6 ft (232.44 m) MSL without wind effects, and 767.7 ft (234 m) MSL with wind effects (Duke, 2014a).

### 3.4.1 Methodology

The licensee's reevaluation of dam failure used a PMF that was based on the same 1992 FERC study performed by Law Environmental (Law Environmental, 1992), and PMP input that was used for the reevaluation of streams and rivers, as discussed in Section 3.3.1. The licensee used the guidelines provided by NRC interim staff guidance (NRC, 2011e) to postulate a plausible dam failure scenario which is based on the combination of dam failure of the Duke Developments for fair-weather piping failure (sunny day failure), with half PMF with upstream seismic failure scenario, and PMF with dam failure (Duke, 2014a). In each case, if overtopping of a dam does not occur, the flood is routed through the development that has water releasing facilities, such as hydroelectric turbines and spillways. The licensee reevaluated the combined dam failure scenarios by simulating the passage of the PMF and dam failure floods through each Duke Dam and reservoir in the Catawba-Wateree Basin using the HEC-RAS model. For developments that incur overtopping, breach parameters were assigned and sensitivity scenarios are used to establish the most conservative effects of the flood at the McGuire site. The Cowans Ford subbasin PMF with dam failure was considered to be the bounding case for the McGuire (Duke, 2014a).

As discussed in its FHRR, the licensee used a screening process to determine the relative significance of the volume associated with small dams, as compared to the Duke Dams listed in the National Inventory of Dams, and ascertain the importance of the inclusion of these dam volumes in the subsequent fair-weather and PMF with dam failure analyses (Duke, 2014a). Of the 130 upstream dams, the licensee identified 10 major dams to be use in the dam failure analysis. The licensee calculated cumulative volumes of selected small dams to estimate the maximum possible increase in reservoir water surface elevations assuming the entire volume of all small dams instantaneously added to each reservoir during the FERC-approved Cowans Ford PMF (Duke, 2014a). The licensee stated that the rationale for using the FERC PMF for assessing the effect cumulative volumes of the small dams is based on the fact that this cumulative volume contribution associated with the small dams is significantly smaller than that associated with Lake Norman (Duke, 2015). The licensee estimated that the hypothetical instantaneous failure of all the small dam storage volumes being instantaneously added to Lake Norman would raise the lake level from 760 ft (231.6 m) MSL to 761 ft (231.95 m) MSL, approximately 14 ft (4.27 m) below the Cowans Ford Dam crest elevation (Duke, 2014a). The licensee determined that these small dams could be removed from consideration in determining the further dam failure flood hazard reevaluation.

The licensee performed sensitivity runs related to Manning's n values, the number of upstream dams involved in the cascading failure, the breach size, and failure time to provide a range of reservoir elevations near the upstream east embankment and near the SNSWP dam. Based on these models runs, the licensee selected nine scenarios for combined effect of PMF with dam failure for Cowans Ford Dam. The scenario that provided the most severe flood elevations at McGuire included: 1) the Cowans Ford Dam PMF, overtopping failures of Oxford Dam and Lookout Shoals Dam; 2) failure of the three Cowans Ford Dam structures (east spillway bulkhead and embankment, west rim dike, and hicks crossroads dike) simultaneously; and 3) the cascading failures of Mountain Island and Wylie Dams (Duke, 2015).

The licensee developed overtopping and piping failure breach parameters for selected Duke Developments using regression methodologies for earth embankments. The licensee tried several regression-based bam breach parameter equations, and then chose to use the Froehlich regression equation (Froehlich, 1995) for modeling due to the breach geometry being in close agreement with specific physical site constraints. The licensee used earth dam breach parameters in the HEC-RAS model Version 4.1 (USACE, 2010a). The licensee also considered overtopping failures at Rhodhiss, Oxford, and Lookout Shoals Developments using existing FERC dam structure stability analyses (Duke, 2014a).

The licensee used results from the PMF analysis without dam failure to determine the significant flood event to be used in the final dam failure scenarios (Duke, 2014a). The PMF evaluation criteria included water surface elevation adjoining the McGuire, upstream reservoir storage capacity, and any upstream dam overtopping during the non-failure simulation of the PMF. The licensee considered numerous model runs with varying breach parameters and breach locations at Mountain Island Dam since the SNSWP Dam is impacted by releases from Cowans Ford Dam that discharge into Mountain Island Lake. The licensee used the HEC-RAS model to simulate an unsteady flow due to dam failure based on 1-h time increments for inflow hydrographs, computation intervals of 1-min, and a total simulation time of 11 days (Duke, 2014a).

3.4.2 Dam Failure Elevation Results

The bounding dam failure scenario postulated by the licensee included the Cowans Ford subbasin PMF, overtopping failures of Oxford Dam, Lookout Shoals Dam, and the three Cowans Ford Dam structures (i.e., east spillway bulkhead and embankment, West Rim Dike, and Hicks Crossroads Dike), and the cascading failures of Mountain Island and Wylie Dams (Duke, 2014a). The licensee's HEC-RAS simulation results indicated the following:

- A peak water surface elevation of 778.5 ft (237.29 m) MSL at Lake Norman produces:
    - Approximately 1.5 ft (0.46 m) of freeboard at the Intake and discharge dike and the east embankment, which is between the dike and the concrete section of Cowans Ford dam.
    - Approximately 3.5 ft (1.07 m) overtopping of the 775 ft (236.22 m) MSL elevation section of Cowans Ford dam for approximately 9 h, resulting in increased tailwater overflow onto McGuire.

- A peak water surface elevation of 736.8 ft (224.58 m) MSL was modeled at the downstream of the SNSWP dam, which represents an inundation depth of approximately 46.8 ft (14.26 m), resulting in approximately 11 ft (3.35 m) to 12 ft (3.65 m) of freeboard to the top of the SNSWP dam at 748.5 ft (228.1 m) MSL.

The licensee stated in its FHRR that the maximum water surface elevation of 778.5 ft (237.29 m) MSL causes breaching of the section to the east of the concrete section of Cowans Ford Dam adjoining the intake and discharge dike at the transition section of the crest elevation from 775 ft (236.22 m) MSL to 780 ft (237.74 m) MSL (Duke, 2014a). This overtopping event causes flood waters to enter the McGuire yard (powerblock area) at this transition. Breaching also occurs on the west embankment of the Cowans Ford Dam and the flood waters flow to the tailrace. A third breach occurs at the Hicks Crossroad dike (Duke, 2014a). The licensee incorporated these serial breaches in their modeling for the reevaluation of this flood hazards (Duke, 2015).

The licensee evaluated the overtopping effects with the Innovyze Infoworks ICM, Version 3.0 software 2012 (Innovyze, 2012) model. The licensee adjusted boundary conditions to account for the specific flooding scenario (Duke, 2014g). The licensee used an inflow boundary condition on the north-western section of the model to simulate the inflow of water onto the site, and subsequently model the flow and depth on site to account for the inflow of flooding water resulting from the dam failure (Duke, 2014g).

The licensee's ICM model uses the dam failure flood hydrograph with overtopping of the eastern section of the East Embankment upon which wind effects are later added and denoted as the combined effect. The results of the combined effect in some cases exceed the yard elevation of 760 ft (231.64 m) MSL and safety-related building floor elevations of 760.5 ft (231.80 m) MSL (Duke, 2014c). The licensee performed a sensitivity run with non-overtopping type failure of Cowans Ford dam. However, they determined that this scenario is not credible as high overtopping velocities would certainly induce an erosion of the Cowans Ford earthen embankment downstream section enough to lead an overtopping failure of the earthen embankment (Duke, 2014a).

### 3.4.3 Coincident Wind and Wave Activity

For the dam failure, the licensee also analyzed in Section 2.4 of its FHRR, a combined effect scenario by addressing a wind driven wave effect coincident with dam failure (Duke, 2014a). The licensee developed wind driven wave heights using the Coastal Engineering Design and Analysis System (CEDAS) Automated Coastal Engineering Software (Leenknecht et al., 1992). The licensee considered a 40 mi/h (64 km/h), 2-year speed wind for wave analysis combined with the PMF event, which included dam failure. The licensee chose the representative wind speed based on ANSI/ANS-2.8 (ANSI/ANS, 1992) in conjunction with a reduction factor according to the Bureau of Reclamation (USBR, 1981). The wind speed is representative of a 1.5-min wind duration (Duke, 2014a).

The licensee estimated wave spill over volumes at Cowans Ford Dam and the intake and discharge dike using a 1-D Boussinesq model (COULWAVE) (Lynnette et al., 2002) to model the overtopping during the PMF. This accounts for approximately 0.04 ft (0.012 m) of additional water surface elevation (Duke, 2015). The resulting peak water surface elevation at Cowans Ford Dam with seiching (wind-driven waves) is 778.5 ft (237.29 m) MSL (Duke, 2014a). The licensee noted in its FHRR that the section of Cowans Ford Dam transitioning from 775 ft (236.22 m) to 780 ft (237.74 m) MSL has adequate upstream slope protection for the wind wave scenario. The combined effects of dam failure coincident with wind and wave activity results in waves spilling over the intake and discharge dike (crest elevation 780 ft (237.74 m) MSL) and onto the McGuire site. This results in a water surface elevation on-site of 760.7 ft (231.86 m) MSL.

### 3.4.4 Conclusions

The NRC staff reviewed the licensee's methodology for the PMF analysis, including the dam screening process, Manning's n values sensitivity runs, and dam breach parameters and concludes that the methods are appropriate for the purposes of the 50.54(f) letter. The NRC staff confirms the licensee's conclusion that the reevaluated flood hazard for failure of dams and onsite water control or storage structures of 778.5 ft (237.29 m) MSL (with wind effects) is not bounded by the CDB flood hazard of 767.71 ft (234 m) MSL. Therefore, the NRC staff expects that the licensee will submit a focused evaluation 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, Revision 0 (NRC, 2016b).

## 3.5 Storm Surge

The licensee reported in its FHRR that the reevaluated flood hazard for storm surge and seiche has an elevation of 778.5 ft (237.29 m) MSL (Duke, 2014a). This flood-causing mechanism is discussed in the licensee's CDB, and the PMF stillwater-surface elevation is 760.0 ft (231.65 m) MSL, including wind effects results in an elevation of 774.8 ft (236.16 m) MSL (Duke, 2014a).

The licensee stated in its FHRR that McGuire is not subject to ocean storm surge because it is located approximately 150 mi (241 km) inland from the Atlantic Ocean. The licensee also stated that the pressure differential across Lake Norman would not be large enough to result in the significant water level variations associated with a major storm (Duke, 2014a). Section 2.4 in the FHRR does, however, present an analysis of the potential flood hazard associated with hurricane wind-driven surge and seiche wave on Lake Norman.

The licensee used the Coastal Engineering Design and Analysis System CEDAS Automated Coastal Engineering Software to develop the wind-driven wave heights at six locations around the MNS site (Duke, 2014a). The licensee considered the bounding wind-driven wave height combined with estimated maximum flood inundation reservoir level of 778.5 ft (237.29 m) MSL. The licensee calculated the wind-driven seiche, as described in Subsection 3.4.3. The licensee analyzed differing hurricane wind and PMF scenarios and used a 2-year overland wind speed of 40 mi/h (64 km/h) for the PMF wave, which was the bounding scenario. For the average water depth of 98.5 ft (30.02 m) and wind speed of 34.6 mi/h (55.7 km/h), the licensee estimated a wind setup of 0.04 ft (0.012 m) using the formula from the Bureau of Reclamation (USBR, 1981) and a bounding maximum water surface elevation of 778.5 ft (237.29 m) MSL (Duke, 2014a).

The NRC staff reviewed the method used in the licensee's analysis and agrees that the approach is conservative. The NRC staff confirms the licensee's conclusion that the reevaluated hazard of 778.5 ft (237.29 m) MSL for flooding from storm surge is not bounded by the CDB flood hazard elevation of 774.8 ft (236.1 m) MSL. Therefore, the NRC staff expects that the licensee will submit a focused evaluation 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, Revision 0 (NRC, 2016b).

## 3.6 Seiche

The licensee evaluated seiche and storm surge together in its FHHR, along with wind wave runup (Duke, 2014a). The NRC staff considered that the combination of storm surge and high winds may be the only plausible seiche mechanisms for Lake Norman. This combined surge and seiche event is discussed in Section 3.5 (Duke, 2014a).

A seiche caused by landslide is not considered credible based on the topography and geology near the McGuire (Duke, 2014a). The licensee evaluated the wave impacts on reservoir flooding, not for seiche-driven wave formation, but for maximum hurricane wind-driven wave formation, as discussed in Section 3.5. The licensee also indicated that the spatial scale of a strong storm system that would significantly drop atmospheric pressure would typically be very large compared to the size of Lake Norman. Consequently, the pressure differential across the lake would not be large enough to result in significant water surface variations that would cause seiche flooding. For the same reasons, the NRC staff agrees with the licensee's conclusion that a meteorological seiche in Lake Norman is not likely to occur.

The NRC staff reviewed the information provided by the licensee and agrees that a seiche only event at the site is not likely and therefore will not impact the site. Therefore, the NRC staff concludes that flooding from seiche alone does not need to be analyzed in a focused evaluation or a revised integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b).

## 3.7 Tsunami

The licensee reported in its FHRR that the reevaluated hazard analysis for tsunami does not impact the site since this flood mechanism does not inundate the plant site, and thus did not report a tsunami-caused flood elevation. This flood-causing mechanism is discussed in the licensee's CDB as not impacting the site (Duke, 2014a).

The licensee stated in FHRR Section 2.5 that tsunami-induced flooding from the Atlantic Ocean will not produce the maximum water level at the site because the plant site is located inland, more than 150 mi (241 km) from the Atlantic coast (Duke, 2014a). The NRC staff considers this distance to be too far for any credible hazard of tsunamis from oceanic sources, such as offshore earthquakes or large-scale slope collapses.

In relation to landslide tsunamis in Lake Norman, the NRC staff found that the McGuire site is not near any major seismic faults and the UFSAR (Duke, 2012a) stated there is little danger of a seismic shock causing a landslide into Lake Norman that could cause a flood wave. Furthermore, the NRC staff noted, from the 2010 Hazard Mitigation Plan for Mecklenburg County on the east side of Lake Norman, that landslides near Lake Norman are possible but their impact minor and spatial extent negligible (Lincoln County, 2009; Charlotte-Mecklenburg Emergency Management, 2010).

The NRC staff reviewed the information provided by the licensee and confirms the licensee's conclusion that the flood hazard from tsunami does not impact the site and is not a plausible hazard, based primarily on the geographical location of the site. Therefore, the NRC staff determined that flooding from tsunami does not need to be analyzed in a focused evaluation or a revised integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b).

## 3.8 Ice-Induced Flooding

The licensee reported in its FHRR that the reevaluated hazard analysis for ice-induced flooding does not impact the site and therefore, did not report a PMF elevation. This flood-causing mechanism is discussed in the licensee's CDB as not impacting the site (Duke, 2014a).

In FHRR Section 2.6 the licensee stated that the McGuire site is not located in an area of the U.S. subject to periods of extreme cold weather that have been reported to produce surface water ice. The climate at the McGuire site is characterized by short, mild winters and long, humid summers. The licensee reported that local climatology data for Winthrop College near Rock Hill, SC, for a period of December 1899 through March 2012 show an average annual minimum air temperature of 50.7° Fahrenheit (Duke, 2014a).

The licensee reported that there has not been a recorded event of significant surface ice formation on Lake Norman or any of the other FERC-regulated developments on the Catawba River in the last 100 years and water temperatures in the area consistently remain above freezing (Duke, 2014a). The licensee also indicated in its FHRR that there are no recorded ice jam events in the upper reach of Lake Norman of the Catawba River. Therefore, the licensee concluded that ice-induced flooding would not produce a credible maximum water level at the site and is not considered a realistic external flooding hazard to McGuire (Duke, 2014a).

The NRC staff confirmed, through a review of the USACE's Ice Jam Database (USACE, 2012), that there are no recorded ice jams on the Catawba River and its tributary; therefore, the NRC staff agrees that there are no flooding impacts from ice-induced events on the river and near the McGuire site. Therefore, the NRC staff concludes that ice-induced flooding does not need to be analyzed in a focused evaluation or a revised integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b).

### 3.9 Channel Migrations or Diversions

The licensee reported in its FHRR that the reevaluated hazard analysis for channel migration or diversion does not impact the site, and thus did not report a PMF elevation. This flood-causing mechanism is discussed in the licensee's CDB as not impacting the site (Duke, 2014a).

Section 2.7 in the FHRR stated that the Catawba River is highly regulated by a series of dams and back-to-back reservoirs, such that backwater effects of each dam mitigate river flow velocities that are in general necessary to produce channel diversion. Over a period of more than a hundred years of regulation, the section of the Catawba River where the McGuire is located has not exhibited any tendency to meander toward or migrate away from the McGuire site. Therefore, the licensee concluded that channel diversion on the Catawba River is not considered a credible flooding event (Duke, 2014a).

In its review of the FHRR, the NRC staff also performed independent confirmation of the potential for flooding due to channel migration and diversion along the Catawba River and its tributaries upstream from the plant site using topographic maps and the U.S. Geological Survey (USGS) landslide hazard maps (USGS, 2015). The USGS classified the Lake Norman watershed area as a no landslide hazard zone, therefore the NRC staff concludes that flooding caused by channel migration and diversion caused by landslides is not plausible. The NRC staff also agrees that the Catawba River is a FERC-regulated river system consisting of dams and reservoirs, and therefore lacks the velocities needed for channel diversion to occur.

The NRC staff reviewed the information provided by the license and confirms the licensee's conclusion that the flood hazard from channel migrations or diversions is not a plausible flooding mechanism at the McGuire site. Therefore, the NRC staff concludes that flooding from channel migration or diversion does not need to be analyzed in a focused evaluation or a revised integrated assessment consistent with the process and guidance discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b).

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

### 4.1 Reevaluated Flood Elevation 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 elevation results. Table 4.1-1 contains the maximum flood elevation results, including waves and runup, for flood mechanisms not bounded by the CDB. The NRC staff agrees with the licensee's conclusion that LIP, streams and rivers (PMF on Lake Norman), dam failure (combined with PMF and wind effects), and storm surge (combined event) are the 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, Revision 0 (NRC, 2016b), the NRC staff anticipates the licensee will submit a focused evaluation for LIP. For the rivers and streams, dam failure, and combined storm surge flood-causing mechanisms, the NRC staff anticipates the licensee will perform an additional assessments of plant response, either a focused evaluation or an integrated assessment, as discussed in COMSECY-15-0019 (NRC, 2015b) and JLD-ISG-2016-01, Revision 0 (NRC, 2016b).

### 4.2 Flood Event Duration for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in Duke's 50.54(f) responses (Duke, 2014a; Duke, 2014b; Duke, 2015) regarding the 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.

For LIP, the licensee stated that the external flooding procedure will be entered 72-h prior to the LIP event, allowing time to install temporary door panels and stage pumps for potential removal of water in the dry cask yard (Duke, 2015). The LIP event creating the maximum flood elevation has a conservative maximum inundation duration of 2-h and 29-min (Table 2.1.4-1 in the FHRR) (Duke, 2014a). This inundation time was evaluated using a 2-D ICM with a postulated 1-hr front-peak-loading PMP scenario as discussed in Section 3.2. The NRC staff confirmed that the licensee's reevaluation of the warning time and inundation periods for LIP used present-day methodologies and regulatory guidance. The licensee did not provide the recession period for LIP, but the NRC staff would expect the recession time for LIP to have minimal impacts on the site.

For the combined storm surge event, the licensee stated that the external flooding procedure will be entered 72-h prior to the combined storm surge event occurring in Lake Norman, allowing time to install temporary door panels and stage pumps for potential removal of water in the dry cask yard (Duke, 2015). The combined surge event creating the maximum flood elevation in Lake Norman has a maximum inundation duration of 12-h and 13-min in the dry cask yard (Table 2.8.1-1 in FHRR) (Duke, 2014a). This inundation time was evaluated using a HEC-RAS model with a combined effect of PMF, dam failure including the overtopping of the downstream Cowan Ford earthen dam, and storm surge caused by 2-year-frequency wind effects. The licensee further assumed conservatively that the dry cask yard drains are blocked during this flooding event (Duke, 2015). The NRC staff confirmed that the licensee's reevaluation of the warning time and inundation periods for the combined storm surge event used present-day methodologies and regulatory guidance and is appropriate for use in future assessments. The licensee did not provide the recession period for the storm surge combined event and therefore the staff would expect this information to be included in the subsequent flooding assessment. The licensee did not specified the FED parameters for streams and rivers flood and dam failure flood separately because these flood events are bounded by a combined storm surge event.

The NRC staff concludes the licensee's methods were appropriate and the FED parameter results that were provided are reasonable for use in additional assessments. The licensee stated that the missing FED parameter will be included in additional assessments (Duke, 2015). The licensee is expected to develop the period of recession for the combined dam failure event to conduct the MSA and the focused evaluations or revised integrated assessments, as discussed in NEI 12-06 (Revision 2), Appendix G (NEI, 2015), and outlined in COMSECY-15-0019 (NRC, 2015b), JLD-ISG-2012-05 (NRC, 2012d), JLD-ISG-2012-01, Revision 1 (NRC, 2016a), and JLD-ISG-2016-01, Revision 0 (NRC, 2016b), respectively. The NRC staff will review this FED parameter as part of future additional assessments of plant response, if applicable to the assessment.

## 4.3 Associated Effects for Hazards Not Bounded by the CDB

The NRC staff reviewed information provided in Duke's 50.54(f) response (Duke, 2014a; Duke, 2014b; Duke, 2015) regarding 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 elevation, such as waves and runup, are presented in Table 4.1-1. The AE parameters not directly associated with total water elevation are listed in Table 4.3-1.

For the LIP event, the licensee stated that the hydrodynamic loading and debris loading did not impact the site because no challenge to site safety-related structures occurs due to shallow water depth and low velocities (Duke, 2015). The licensee also stated that the sediment deposition and erosion from the LIP flood event was found to not impact the site by not challenging site safety-related structures due to shallow water depths, low velocities, and short inundation periods. The licensee described that the exterior wall filter drain system to control groundwater is located around the perimeter of the safety-related structure. Therefore, it will not be flooded by surface flood water since the top of the wall filter is located 5 ft (1.54 m) below the plant yard and has a cover of earthen backfill of 5 ft (1.54 m) thick. The licensee said all other associated effects, including sediment loading, other pertinent factors, and concurrent conditions are not applicable. The NRC staff identified from FHRR Table 2.1.4.1, the maximum flood depth of 1.9 ft (0.58 m) at the cask storage west and the maximum flow velocity of 3.1 ft/s (0.94 m/s) at the Unit 2 doghouse are insignificant in terms of hydrostatic and hydrodynamic loadings when considered in the safety of plant structures. The NRC staff confirmed (based on the review of the licensee-provided LIP model input and output files) that the justifications and discussions related to AE parameters are reasonable and acceptable. Therefore, the NRC staff concurs with the licensee's conclusion that the AE parameters for LIP are either minimal or not applicable.

For the combined storm surge event, the licensee stated that the hydrodynamic loading and debris loading were found to not challenge the site safety-related structures due to shallow water depth and low velocities (Duke, 2015). The licensee also stated that the sediment deposition and erosion from the combined storm surge event was found to not challenge the site safety-related structures due to shallow water depths, low velocities and short inundation periods. The licensee described that the exterior wall filter drain system to control groundwater is located around the perimeter of the safety-related structures. Therefore, there is no impact to the site as safety-related structures will not be flooded by surface flood water since the top of the wall filter is located 5 ft (1.54 m) below the plant yard and has a cover of earthen backfill of 5 ft (1.54 m) thick. The licensee said all other associated effects, including sediment loading, other pertinent factors, and concurrent conditions are not applicable. The NRC staff identified from the FHRR Table 2.8.1-1 the maximum flood depth of 2.4 ft (0.73 m) at the cask storage west and the maximum flow velocity of 1.1 ft/s (0.34 m/s) at the cask storage east, which are insignificant in terms of hydrostatic and hydrodynamic loadings considered in the safety of plant structures. The NRC staff confirmed (based on the review of the LIP model input and output files (Duke, 2014b)) that the justifications and discussions related to AE parameters are reasonable and acceptable. Therefore, the NRC staff concurs with the licensee's conclusions for the AE parameters for storm surge. The licensee did not specify the AE parameters for streams and rivers flooding and dam failure flooding separately, because these flood events are bounded by the combined storm surge event.

The NRC staff concludes the licensee's methods were appropriate and the AE parameter results are reasonable for use in additional assessments associated with the MSA and the focused evaluations or revised integrated assessments as discussed in NEI 12-06, Revision 2, Appendix G (NEI, 2015), and outlined in COMSECY-15-0019 (NRC, 2015b), JLD-ISG-2012-05 (NRC, 2012d), JLD-ISG-2012-01, Revision 1 (NRC, 2016a), and JLD-ISG-2016-01, Revision 0 (NRC, 2016b), respectively.

## 4.4 Conclusion

Based upon the preceding analysis, NRC staff confirms that the reevaluated flood hazard information discussed in Section 4 is an 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, Revision 0 (NRC, 2016b).

The licensee is expected to develop the missing FED parameters identified as "not provided" in Table 4.2-1 to conduct the MSA and the focused evaluations or revised integrated assessments as discussed in NEI-12-06, Revision 2, Appendix G (NEI, 2015), JLD-ISG-2012-01, Revision 1 (NRC, 2016a), JLD-ISG-2012-05 (NRC, 2012d), and JLD-ISG-2016-01, Revision 0 (NRC, 2016b), respectively. The NRC staff will evaluate the missing FED parameters (i.e., recession time) during its review of future additional assessments of plant response, if applicable.

## 5.0 CONCLUSION

The NRC staff has reviewed the information provided for the reevaluated flood-causing mechanisms for McGuire, Units 1 and 2. Based on its review of available information provided in the Duke's 50.54(f) response (Duke, 2014a; Duke, 2014b; Duke, 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 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, the NRC staff confirms the licensee's conclusions that (1) the reevaluated flood hazard results for LIP, streams and rivers (PMF on Lake Norman), dam failure (combined with PMF and wind effects), and storm surge (combined event) are not bounded by the CDB flood hazard; (2) a focused evaluation of plant response will be performed for LIP, and a focused evaluation or revised integrated assessment will be performed for rivers and streams, combined dam failure, and the storm surge combined event flood-causing mechanisms; and (3) 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, 2015c), JLD-ISG-2012-01, Revision 1 (NRC, 2016a), and JLD-ISG-2016-01, Revision 0 (NRC, 2016b). The NRC staff has no additional information needs at this time with respect to Duke's 50.54(f) response.

## 6.0 REFERENCES

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


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

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

Sources: NRC, 2007; NRC, 2013a; NRC, 2013b

Notes:

1) SRP is the Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition.
2) JLD-ISG-2012-06 is the "Guidance for Performing a Tsunami, Surge, or Seiche Hazard Assessment".
3) JLD-ISFG-2013-01 is the "Guidance for Assessment of Flooding Hazards Due to Dam Failure".

**Table 3.1-1. Summary of Controlling Flood-Causing Mechanisms**

| Reevaluated Flood-Causing Mechanisms and Associated Effects that May Exceed the Powerblock Elevation 760.0 ft (231.65 m) MSL [1,2] | ELEVATION in MSL |
|---|---|
| **LIP and Associated Drainage**<br>Powerblock Area | 761.1 ft (232.98 m) |
| **Streams and Rivers**<br>Reservoir Level at Cowans Ford Dam | 777.9 ft (237.10 m) |
| **Failure of Dams and Onsite Water Control/Storage Structures** | |
| Upstream Dam Failure (combined event) | 778.5 ft (237.29 m) |
| **Storage Surge and Seiche[3]** | 778.5 ft (237.29 m) |

Source: Duke, 2014a

Notes:

[1] Flood Height and Associated Effects as defined in JLD-ISG-2012-05.

[2] The plant grade has an elevation of 760 ft (231.65 m) MSL, while the Intake and Discharge Dike on the north side of the plant has a crest elevation of 780.0 ft (237.74 m) MSL.

[3] Storm surge and seiche applied to dam failure event involving wind-wave effect spill-over the East Embankment onto the site.

**Table 3.1.-2. Current Design Basis Flood Hazards**

| Mechanism | Stillwater Elevation | Waves/ Runup | Design Basis Hazard Elevation | Reference |
|---|---|---|---|---|
| **Local Intense Precipitation** | | | | |
| Powerblock Area | 760.4 ft MSL | Minimal | 760.4 ft MSL | FHRR Section1.2.1 |
| Standby Nuclear Service Water Pond | 746.9 ft MSL | Minimal | 746.9 ft MSL | FHRR Section 1.2 |
| **Streams and Rivers** | | | | |
| Reservoir Level at Cowans Ford Dam (upstream) | 767.9 ft MSL | 5.11 ft | 773.0 ft MSL | FHRR Section 1.2.2<br>FHRR Section 1.2.8 (Table 1.2.8-1) |
| **Failure of Dams and Onsite Water Control/Storage Structures** | | | | |
| Upstream Dam Failures (combined event) | 762.6 ft MSL | 5.11 ft | 767.7 ft MSL | FHRR Section 1.2.3<br>FHRR Section 1.2.3 (Table 1.2.8-1) |
| Standby Nuclear Service Water Pond (combined event) | 746.9 ft MSL | 1.5 ft | 748.4 ft MSL | FHRR Table 3-1 |
| Standby Nuclear Service Water Pond Dam Downstream (combined event) | 727.8 ft MSL | Not applicable | 727.8 ft MSL | FHRR Table 3.1 |
| **Storm Surge and Seiche** | | | | |
| Surge in Lake Norman | 760.0 ft MSL | 14.8 ft | 774.8 ft MSL | FHRR Section 1.2.4 |
| **Tsunami** | Not Included in CDB | Not Included in CDB | Not Included in CDB | FHRR Section 1.2 |
| **Ice-Induced** | Not Included in CDB | Not Included in CDB | Not Included in CDB | FHRR Section 1.2 |
| **Channel Migrations/Diversions** | Not Included in CDB | Not Included in CDB | Not Included in CDB | FHRR Section 1.2 |

Source: NRC, 2015c
Notes:

1) Reported values are rounded to the nearest one-tenth of a foot.
2) The wave height value of 5.1 ft for the Streams and Rivers, and Upstream Dam Failures (combined event) is wave setup plus runup.

**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** | | | | |
| Powerblock Area | 761.1 ft MSL | Minimal | 761.1 ft MSL | FHRR Section 2.1 |
| **Streams and Rivers** | | | | |
| Reservoir Level at Cowans Ford Dam upstream | 777.9 ft MSL | Not Provided[5] | 777.9 ft MSL | FHRR Section 2.2 and 2.8 |
| **Failure of Dams and Onsite Water Control/Storage Structures** | | | | |
| Upstream Dam Failure (combined event) | 778.5 ft MSL | Minimal | 778.5 ft MSL | FHRR Sections 2.3 and 2.8 |
| Standby Nuclear Service Water Pond Dam Downstream (combined event) | 735.9 ft MSL | 0.9 ft | 736.8 ft MSL | FHRR Tables 2.4.2-1 and 2.4.2-2 |
| **Storm Surge and Seiche** | 778.5 ft MSL | 0.0 ft | 778.5 ft MSL[6] | FHRR Table 3-1 FHRR Section 2.4.1 (Table 2.4.1-1) |

Source: NRC, 2015c
Notes:

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.
2) Reevaluated hazard mechanisms bounded by the current design-basis (see Table 3.1-1) are not included in this table.
3) Reported values are rounded to the nearest one-tenth of a foot.
4) The licensee evaluated the wind effects for PMF and Dam Failure which resulted in a height of 0.04 ft. This is considered to be minimal. Refer to Section 3.4.4 of this staff assessment for further details.
5) The wind waves and runup effects was not evaluated because this event is bounded by surge and seiche event.
6) This is a bounding event with the flood elevation of 778.5 ft (237.29 m) MSL as reported in the FHRR.

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

| Flood-Causing Mechanism | Time Available for Preparation for Flood Event | Duration of Inundation of Site | Time for Water to Recede from Site |
|---|---|---|---|
| Local Intense Precipitation and Associated Drainage | 72 h | 2 h 29 min | Not Provided[2] |
| Streams and Rivers – River PMF in Lake Norman[1] | Not applicable | Not applicable | Not applicable |
| Failure of Dams and Onsite Water Control/Storage Structures[1] | Not applicable | Not applicable | Not applicable |
| Storm Surge and seiche | 72 h | 12 h 13 min | Not provided |

Source: Duke, 2015
Note:
[1] Accompanied by storm surge wind-wave effects resulting in spillover the East Embankment wall onto the site. The dam failure is a special case of the PMF. Meteorological conditions are monitored and a three day forecast is used to as a trigger for the event of a PMF leading up to a potential dam failure.

**Table 4.3-1. Associated Effects Parameters Not Directly Associated With Total Water Elevation For Flood-causing Mechanisms Not Bounded by the CDB**

| | Flooding Mechanism | | | |
|---|---|---|---|---|
| **Associated Effects Factor** | **Local Intense Precipitation** | **Streams and River** | **Failure of Dams** | **Storm Surge** in combination with PMF/Dam Failure |
| Hydrodynamic loading at plant grade | No impact to the site identified | Not applicable | Not applicable | No impact to the site identified |
| Debris loading at plant grade | No impact to the site identified | Not applicable | Not applicable | No impact to the site identified |
| Sediment loading at plant grade | Not applicable | Not applicable | Not applicable | Not applicable |
| Sediment deposition and erosion | No impact to the site identified | Not applicable | Not applicable | No impact to the site identified |
| Concurrent conditions, including adverse weather | Not Applicable [1] | Not applicable | Not applicable | Concurrent site conditions analyzed in combined effects calculation per NUREG/CR-7046 |
| Groundwater ingress | No impact to the site identified | Not applicable | Not applicable | No impact to the site identified |
| Other pertinent factors (e.g., waterborne projectiles) | Not applicable | Not applicable | Not applicable | Not applicable |

Source: Duke, 2015.

Notes:

1) The licensee states that concurrent site conditions are analyzed in the combined effects calculation per NUREG/CR-7046.

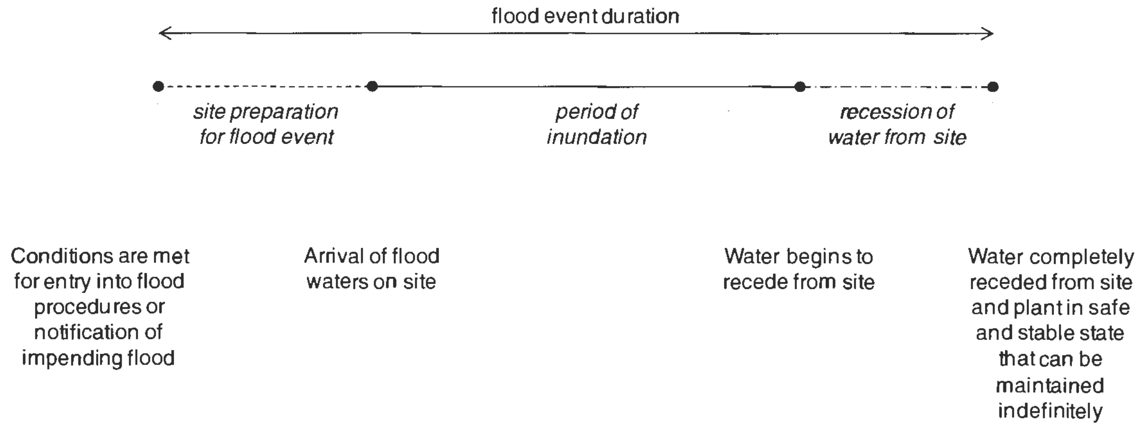


**Figure 2.2.4-1. Flood Event Duration (NRC, 2012d)**

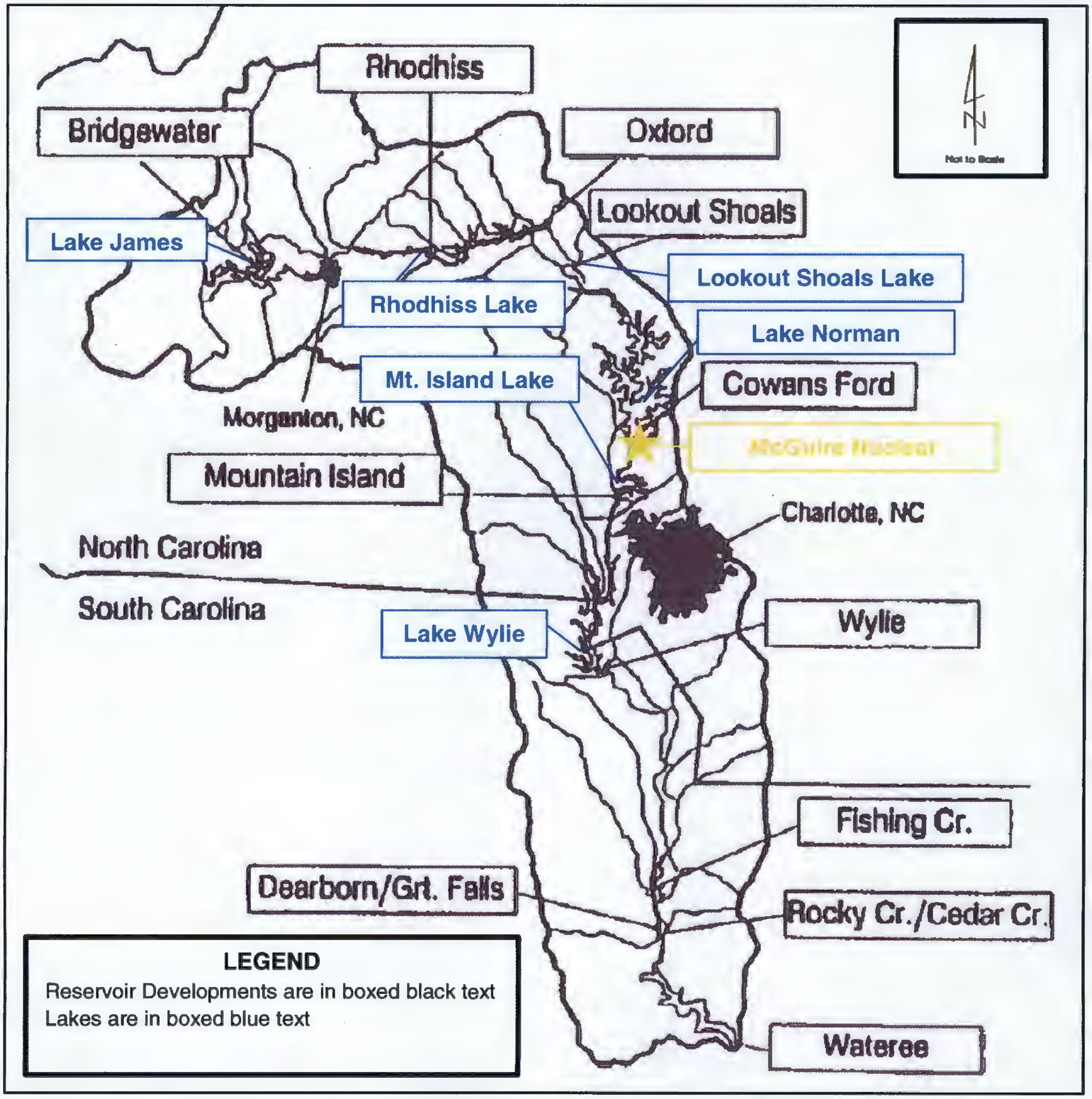


**Figure 3.1-1. Locations of Reservoir Developments on the Catawba River (Derived from Duke, 2014a)**

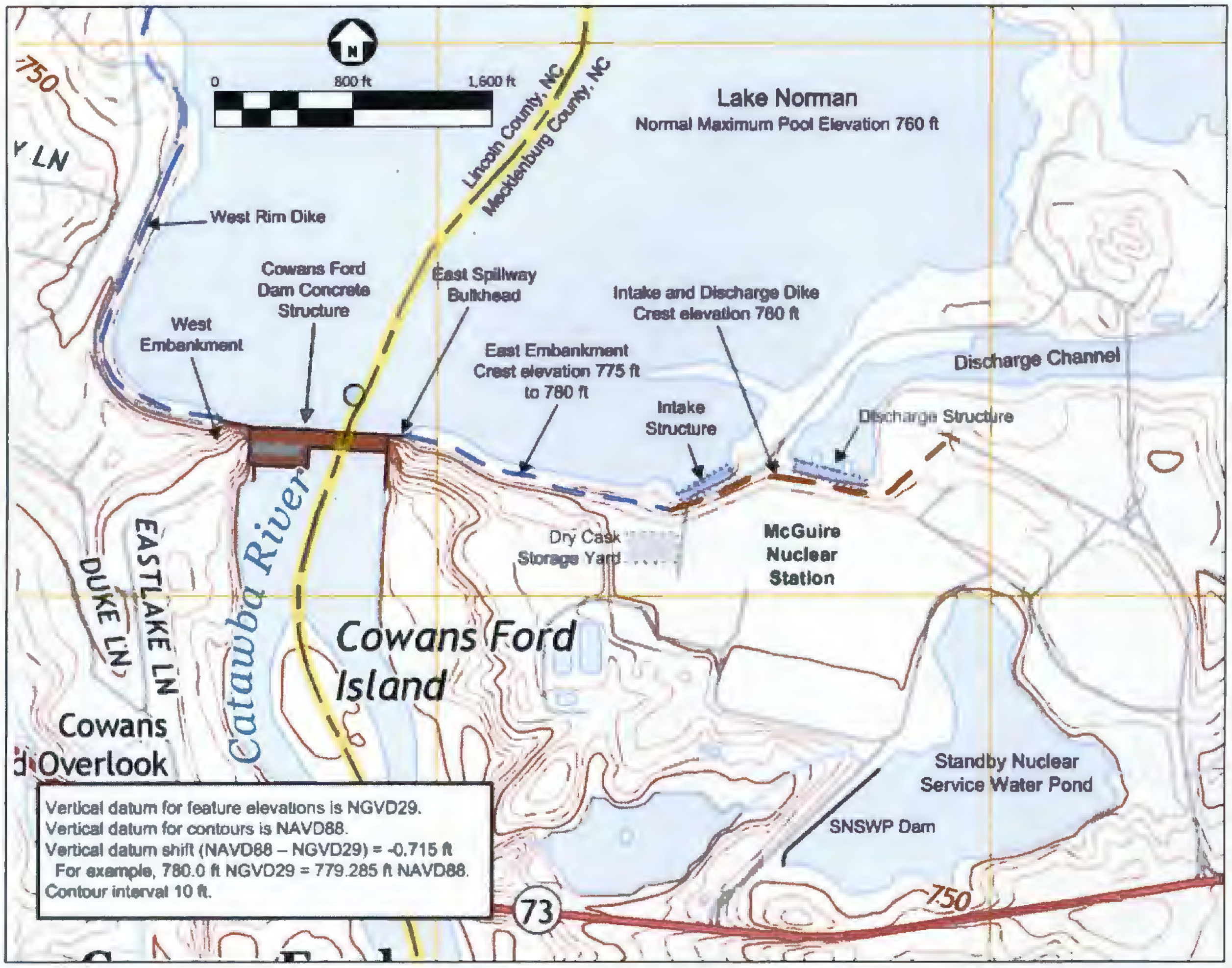


**Figure 3.1-2. McGuire Nuclear Station Structures and Hydrologic Features (derived from USGS, 2016)**


**Figure 3.2-1. ICM Model Area and Boundaries for the On-Site LIP Analysis (Derived from Duke, 2014d and Duke, 2014e)**


**Figure 3.2-2. Drainage Area of the Standby Nuclear Service Water Pond for the On-Site LIP Analysis (Derived from Duke, 2014h)**

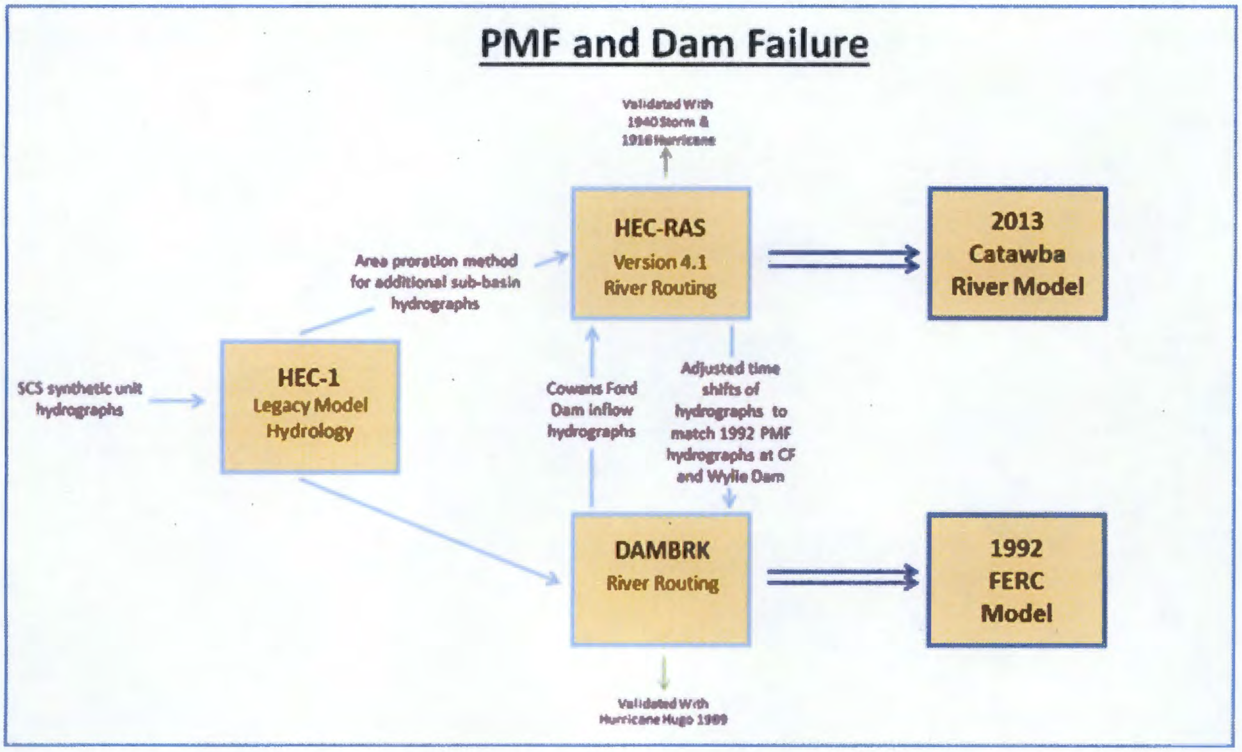


**Figure 3.3-1. Historical Development of the Catawba River Model (Derived from Duke, 2014f)**

If you have any questions, please contact me at (301) 415-3809 or e-mail at Juan.Uribe@nrc.gov.

Sincerely,

***/RA/***

Juan Uribe, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear reactor Regulation

Docket Nos. 50-369 and 50-370

Enclosure:
Staff Assessment of Flood Hazard Reevaluation Report

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