I. Office of Special Counsel, Request for Updates

"I went through the report again and identified references on the following pages to actions that were planned to be completed by the end of 2016:

- p. 15
- p. 17 (Beaver Valley and Browns Ferry)
- p.18 (Cooper and Fort Calhoun)
- p. 19 (Hope Creek and Indian Point)
- p.20 (Oconee and Peach Bottom)
- p. 21 (Prairie Island and Sequoyah)
- p. 22 (Three Mile Island [TMI] and Waterford)
- p. 23 (Watts Bar)
- p. 24 (Arkansas Nuclear One)
- p. 41
- p. 46
- p. 50
- p. 57
- p. 58
- p. 63
- p. 64
- p. 74
- p. 79
- p. 91
- p. 97
- p. 101
- p. 105
- p. 125
- p. 128

We ask that when you provide your update on these actions that you provide a detailed description of what was submitted or what action was taken, including details on improvements made or whether there were changes to the flooding estimates. As we discussed at our meeting, if this information cannot be made public we can redact information before placing it in the public file. The details would be helpful in order for us to properly evaluate the report."

Response

The following pages provide updates to information presented in the report, with references and details consistent with those provided in the report for actions that were complete at the time of its writing. Updated text is provided in italics. All requested items are addressed, as well as several other items that were noted as not yet complete at the time the report was written.

For the 44 items updated below, nearly all expected actions have been completed. The two exceptions are: (1) actions related to Fort Calhoun (which permanently ceased operation in October 2016) and (2) field implementation of a flood mode management system (FMMS) at Sequoyah and Watts Bar (which is ready for installation, but, in light of upgrades already made, was deferred by the licensee until detailed precipitation information is complete). The mitigation of beyond-design-basis events final rule, while not complete, is proceeding on schedule and is currently with the Commission for consideration.

1. **Text on p.15:** "This guidance [Phase 1], which will be completed during the summer of 2016, would enable some licensees to perform focused evaluations (rather than a full integrated assessment) to ensure appropriate actions are taken to protect the plant from the reevaluated flooding hazard, and that these actions are reasonable, effective, and implemented in a timely manner."
   - **Updated Text (Action Complete):** *The guidance for Phase 1 was completed in July 2016.*[1] *This guidance endorses an industry guidance document,*[2] *with some clarifications. This guidance enables* some licensees to perform focused evaluations (rather than a full integrated assessment) to ensure appropriate actions are taken to protect the plant from the reevaluated flooding hazard, and that these actions are reasonable, effective, and implemented in a timely manner.

[1] Japan Lessons-Learned Division Interim Staff Guidance (JLD-ISG) 2016-01, "Guidance for Activities Related to Near-Term Task Force Recommendation 2.1; Focused Evaluation and Integrated Assessment," dated July 11, 2016. Agencywide Documents Access and Management System (ADAMS) Accession No. ML16162A301.

[2] Nuclear Energy Institute (NEI) 16-05, "External Flooding Integrated Assessment Guidelines," dated June 2016. ADAMS Accession No. ML16165A178.

2. **Text on p.15:** "The final decision-making criteria to be used in Phase 2 is currently being considered with input from stakeholders. The NRC staff plans to complete the Phase 2 guidance later in 2016."
   - **Updated Text (Action Complete):** *The guidance for Phase 2 decision-making, which was developed following interactions with the Advisory Committee on Reactor Safeguards and other stakeholders, was completed in September 2016.*[3] *This guidance will be implemented following receipt of the first assessments in 2017.*

3. **Text on p.16:** "As noted above, the NRC is preparing a final regulation on mitigating beyond-design-basis events that will, in part, make the requirements of Order EA-12-049 generically applicable. Compliance with this regulation is expected to include ensuring that the mitigating strategies are sufficient to address the reevaluated flooding hazard. While the final regulation is not yet effective, licensees are nonetheless expected to address higher reevaluated flood levels and any potential effects on their established mitigating strategies through their current corrective action programs, consistent with the guidance described above."
   - **Updated Text (Action on Schedule):** As noted above, the NRC is preparing a final regulation on mitigating beyond-design-basis events that will, in part, make the requirements of Order EA-12-049 generically applicable. *The draft final rule for mitigation of beyond-design-basis events was signed on December 15, 2016, and is currently under consideration by the Commission.*[4] *Section 50.155(b)(2) of the draft final rule text addresses consideration of reevaluated seismic and flooding hazards in the mitigating strategies.* While the final regulation is not yet effective, licensees nonetheless *have been addressing* higher reevaluated flood levels and any potential effects on their established mitigating strategies through their current corrective action programs, consistent with the guidance described above.

4. **Text on p.17:** Arkansas Nuclear One (ANO) flooding hazard reevaluations – "Licensee report due in September 2016"
   - **Updated Text (Action Complete):** Licensee *reevaluation complete (September 2016)*

5. **Text on p.17:** Beaver Valley mitigating strategies for beyond-design-basis events – "Order compliance achieved for Unit 2 (December 2015); compliance expected for Unit 1 in Fall 2016"
   - **Updated Text (Action Complete):** Order compliance achieved *(December 2016)*

6. **Text on p.17:** Browns Ferry flooding hazard reevaluations – "NRC staff assessment in progress"; mitigating strategies for beyond-design-basis events – "Order compliance expected by the end of 2016" and "Mitigating strategies assessment in progress"
   - **Updated Text (Actions Complete or on Schedule):**
     NRC staff assessment *complete (August 2016)*
     Order compliance *achieved for Unit 1 (November 2016); compliance expected for*

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3 Michael X. Franovich, NRC, memorandum to William M. Dean, NRC, "Regulatory Decision-Making for Reevaluated Flooding and Seismic Hazards for Operating Nuclear Power Plants," dated September 21, 2016. ADAMS Accession No. ML16237A103.

4 SECY-16-0142, "Draft Final Rule—Mitigation of Beyond-Design-Basis Events (RIN 3150-AJ49)," dated December 15, 2016. ADAMS Accession No. ML16301A005.

Units 2 and 3 in Spring 2017 and Spring 2018, respectively.
Mitigating strategies assessment *complete (December 2016)*

7. **Text on p.18:** Columbia flooding hazard reevaluations – "U.S. Army Corps of Engineers input in progress"
   - **Updated Text (Action Complete):** *Licensee reevaluation complete (October 2016)*
8. **Text on p.18:** Cooper flooding hazard reevaluations – "Licensee's … two-dimensional modeling in progress"; mitigating strategies for beyond-design-basis events – "Order compliance expected in Fall 2016"
   - **Updated Text (Actions Complete):**
     Revised licensee reevaluation complete (September 2016)
     Order compliance *achieved (January 2017)*

9. **Text on p.18:** Fort Calhoun flooding hazard reevaluations – "Licensee's … two-dimensional modeling in progress"; mitigating strategies for beyond-design-basis events – "Order compliance expected in December 2016"
   - **Updated Text (Actions Not Complete / Not Needed):**
     Fort Calhoun permanently ceased operations on October 24, 2016, and has permanently defueled the reactor vessel. Accordingly, the licensee no longer intends to submit a revised flooding hazard reevaluation report. The licensee views the request for information under 10 CFR 50.54(f) as applicable to operating reactors only and does not intend to proceed further with the flooding hazard reevaluation or to submit a revised flooding hazard reevaluation report.[5, 6]
     Fort Calhoun permanently ceased operations on October 24, 2016, and has permanently defueled the reactor vessel. Accordingly, the NRC relaxed the scheduling requirements for compliance with Order EA-12-049 to August 31, 2017.[7]

10. **Text on p.19:** H.B. Robinson flooding hazard reevaluations – "NRC staff assessment in progress"
    - **Updated Text (Action Complete):** NRC staff assessment *complete (January 2017)*

11. **Text on p.19:** Hope Creek/Salem flooding hazard reevaluations – "NRC staff assessment in progress"; mitigating strategies for beyond-design-basis events – "Order compliance for Hope Creek in January 2017 and for Salem in Summer 2016" and "Mitigating strategies assessment in progress"
    - **Updated Text (Actions Complete):**
      NRC staff assessments *complete (October 2016)*
      Order compliance *achieved (Hope Creek in January 2017 and Salem in*

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5 Shane M. Marik, Omaha Public Power District, letter to NRC, "Fort Calhoun Station Final Response to the Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident and Corresponding Commitments," dated November 18, 2016. ADAMS Accession No. ML16323A206.

6 Shane M. Marik, Omaha Public Power District, letter to NRC, "Revision to Response to Request for Information Regarding Flooding Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident- Fort Calhoun Station Flood Hazard Reevaluation Report," dated September 14, 2016. ADAMS Accession No. ML16258A364.

7 William M. Dean, NRC, letter to Shane M. Marik, Omaha Public Power District, "Fort Calhoun Station, Unit 1 – Relaxation of the Schedule Requirements for Order EA-12-049 'Issuance of Order To Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events' (CAC No. MF0969)," dated November 21, 2016. ADAMS Accession No. ML16277A509.

September 2016)
Mitigating strategies assessments *complete (December 2016)*

12. **Text on p.19:** Indian Point flooding hazard reevaluations – "NRC staff assessment in progress"; mitigating strategies for beyond-design-basis events – "Order compliance expected in Summer 2016" and "Mitigating strategies assessment in progress"
    - **Updated Text (Actions Complete):**
      Order compliance *achieved (August 2016)*
      Mitigating strategies assessment *complete (October 2016)*

13. **Text on p.20:** McGuire flooding hazard reevaluations – "NRC staff assessment in progress"; mitigating strategies for beyond-design-basis events – "Mitigating strategies assessment in progress"
    - **Updated Text (Actions Complete):**
      NRC staff assessment *complete (October 2016)*
      Mitigating strategies assessment *complete (December 2016)*

14. **Text on p.20:** Oconee mitigating strategies for beyond-design-basis events – "compliance expected for Unit 3 in Spring 2016 and for Unit 1 in Fall 2016" and "Mitigating strategies assessment in progress"
    - **Updated Text (Actions Complete):**
      Order *compliance achieved (January 2017)*
      Mitigating strategies assessment *complete (January 2017)*

15. **Text on p.20:** Peach Bottom mitigating strategies for beyond-design-basis events – "Order compliance expected by end of 2016" and "Mitigating strategies assessment in progress"
    - **Updated Text (Actions Complete):**
      Order compliance *achieved (January 2017)*
      Mitigating strategies assessment *complete (June 2016)*
      NRC review of mitigating strategies assessment complete (January 2017)

16. **Text on p.21:** Prairie Island flooding hazard reevaluations – "NRC staff review in progress"; mitigating strategies for beyond-design-basis events – "compliance expected for Unit 1 in Fall 2016" and "Mitigating strategies assessment in progress"
    - **Updated Text (Actions Complete):**
      NRC *interim response complete (September 2016)*
      Order compliance *achieved (December 2016)*
      Mitigating strategies assessment *complete (December 2016)*

17. **Text on p.21:** Sequoyah flooding hazard reevaluations – "NRC staff assessment in progress"; mitigating strategies for beyond-design-basis events – "Mitigating strategies assessment in progress"; additional plant-specific actions – "Designed an improved flood mitigation system to be implemented by December 2016"
    - **Updated Text (Actions Complete):**
      NRC staff assessment *complete (July 2016)*
      Mitigating strategies assessment *complete (December 2016)*
    - **Updated Text (Action Not Complete / Deferred):** Designed *and procured* an improved flood mitigation system to be implemented by *September 2018*
      [see details below (p.11-12)]

18. **Text on p.21:** South Texas Project (STP) mitigating strategies for beyond-design-basis events – "Mitigating strategies assessment in progress"
    - **Updated Text (Action Complete):** Mitigating strategies assessment *complete (September 2016)*

19. **Text on p.22:** Surry flooding hazard reevaluations – "NRC staff assessment in progress"
    - **Updated Text (Action Complete):** NRC staff assessment *complete (December 2016)*

20. **Text on p.22:** TMI mitigating strategies for beyond-design-basis events – "Order compliance expected in Spring 2016" and "Mitigating strategies assessment in progress"
    - **Updated Text (Actions Complete):**
      Order compliance *achieved (December 2016)*
      Mitigating strategies assessment *complete (June 2016)*
      NRC review of mitigating strategies assessment complete (January 2017)

21. **Text on p.22:** Waterford mitigating strategies for beyond-design-basis events – "Order compliance expected by July 2016" and "Mitigating strategies assessment in progress"
    - **Updated Text (Actions Complete):**
      Order compliance *achieved (July 2016)*
      Mitigating strategies assessment *complete (November 2016)*

22. **Text on p.23:** Watts Bar mitigating strategies for beyond-design-basis events – "Mitigating strategies assessment in progress"; additional plant-specific actions – "Designed an improved flood mitigation system to be implemented by December 2016"
    - **Updated Text (Actions Complete):**
      Mitigating strategies assessment *complete (December 2016)*
    - **Updated Text (Action Not Complete / Deferred):** Designed *and procured* an improved flood mitigation system to be implemented by *September 2018*
      [see details below (p.11-12)]

23. **Text on p.24:** ANO – "Report [hazard reevaluation] is due in September 2016 after considering U.S. Army Corps of Engineers input."
    - **Updated Text (Actions Complete):**
      Included in limiting flood
      • Flood from PMF, dam break, and wind waves would be below the protection level.

24. **Text on p.24:** Columbia – "U.S. Army Corps of Engineers is developing input [on hazard reevaluation]."
    - **Updated Text (Actions Complete):**
      Included in limiting flood
      • Dam failures (including a combined effect flood with wind waves) resulted in a higher flood level than the design basis, but still lower than the critical elevation at which safety-related structures would be affected.
      • Licensee inspected flood protection features but did not identify the need for any other interim actions.

25. **Text on p.39:** ANO – "As discussed in a public meeting on April 6, 2016, the NRC will issue a Confirmatory Action Letter to identify key actions from the Comprehensive Recovery Plan that will receive follow-up inspections. When all of the Confirmatory Action Letter items are closed, the Confirmatory Action Letter will be closed. Historically, this process has taken plants at least two years."
    - **Updated Text (Action Complete):** *In a letter dated May 17, 2016 (ADAMS Accession No. ML16139A059), Entergy notified the NRC of its plan to perform specific actions to resolve the causes for declining performance at ANO, and provided a summary of that plan. On June 17, 2016, the NRC issued a Confirmatory Action Letter (ADAMS Accession No. ML16169A193) to confirm commitments made by Entergy concerning ANO. Certain actions are to be completed by December 2016, October 2017, and June 2018.* When all of the Confirmatory Action Letter items are closed, the Confirmatory Action Letter will be closed.

26. **Text on p. 41:** ANO – "The NRC transmitted the results of the U.S. Army Corps of Engineers analysis to the licensee in March 2016 and noted that the licensee needs to complete its flooding hazard reevaluation report by September 2016."
    - **Updated Text (Action Complete):** The NRC transmitted the results of the U.S. Army Corps of Engineers analysis to the licensee in March 2016.[8] *The licensee then submitted its flooding hazard reevaluation report on schedule in September 2016.[9] The licensee noted that the reevaluated hazard for nearly all flooding mechanisms (including dam breaches/failures) were either screened out or bounded by the current design basis. The only exception was local intense precipitation; however, the reevaluated hazard from local intense precipitation does not challenge structures, systems, and components important to safety.*

      Specific to dam failures, the licensee noted that the controlling design-basis event for still water flood levels for ANO is caused by an Arkansas River probable maximum flood (PMF) coincident with a sudden failure of the upstream Ozark Dam. In the reevaluated flood hazard, the Arkansas River PMF coincident with upstream dam failure and wind-generated waves results in still water levels below the controlling design-basis still water level and peak flood hazard elevations (including waves) below the controlling design basis peak flood hazard. As a result, these reevaluated flood hazards were determined by the licensee to be bounded by the design basis.

      In December 2016, the NRC staff issued an interim response to the ANO flooding hazard reevaluation report.[10] The NRC staff concluded that the licensee's reevaluated flooding hazard information is suitable for the assessment of mitigating strategies developed in response to Order EA-12-049 for ANO. Further, the NRC staff concluded that the licensee's reevaluated flooding hazard information is a suitable input for further

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8 Victor Hall, NRC, letter to Entergy Operations, Inc., "Arkansas Nuclear One, Units 1 and 2 Transmittal of U.S. Army Corps of Engineers Flood Hazard Reevaluation Information," dated March 21, 2016. ADAMS Accession No. ML16071A452.

9 Richard L. Anderson, Entergy Operations, Inc., letter to NRC, "Flooding Hazard Re-evaluation Report – Required Response for Near-Term Task Force (NTTF) Recommendation 2.1 – Arkansas Nuclear One – Units 1 and 2," dated September 14, 2016. ADAMS Accession No. ML16260A060.

10 Robert Bernardo, NRC, letter to Entergy Operations, Inc., "Arkansas Nuclear One, Units 1 and 2 – Interim Staff Response to Reevaluated Flood Hazards Submitted in Response to 10 CFR 50.54(f) Information Request – Flood-Causing Mechanism Reevaluation (CAC Nos. MF8379 and MF8380)," dated December 2, 2016. ADAMS Accession No. ML16327A482.

assessment such as the integrated assessment noted above.

After the licensee provides its Phase 1 submittal, the NRC staff will review this information and determine whether the licensee can address any identified plant vulnerabilities appropriately, or if a plant-specific backfit evaluation of potential regulatory actions should be undertaken.

27. **Text on p. 43:** ANO – "The NRC staff will complete a final safety evaluation considering the updated information and inspect the licensee's implementation before considering the order actions complete. This process is expected to take approximately a year after the licensee notifies the NRC of full compliance."
    - **Updated Text (Action Complete):** The NRC safety evaluation *on Order EA-12-049 implementation was completed in September 2016.*[11]

28. **Text on p. 46:** Beaver Valley – "On December 21, 2015, the licensee notified the NRC that Beaver Valley, Unit 2 is in full compliance with Order EA-12-049.[12] All modifications have been implemented, procedures and training are complete, and the licensee has responded to all of the NRC staff's open and confirmatory items. For Beaver Valley, Unit 1, the NRC staff approved relaxation of the compliance date to Fall 2016 so that technical issues associated with the reactor coolant pump seals could be resolved."
    - **Updated Text (Action Complete):** On December 21, 2015, the licensee notified the NRC that Beaver Valley, Unit 2 is in full compliance with Order EA-12-049.[13] *On December 15, 2016, the licensee notified the NRC that both units are in compliance with Order EA-12-049.* All modifications have been implemented, procedures and training are complete, and the licensee has responded to all of the NRC staff's open and confirmatory items.

29. **Text on p. 50:** Browns Ferry – "The licensee expects to implement the requirements of Order EA-12-049 for all three units by the end of 2016, following the Unit 1 refueling outage."
    - **Updated Text (Actions Complete):** *The licensee completed implementation of actions specific to Order EA-12-049 for all three units by November 2016. The full compliance schedules for Units 2 and 3 were relaxed to Spring 2017 and Spring 2018, respectively, to enable completion of hardened vent actions under Order EA-13-109 (ADAMS Accession No. ML14281A198).*[14] *These actions were completed for Unit 1 in November 2016, so Unit 1 has completed actions needed for full compliance with Order EA-12-049.*

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[11] Mandy Halter, NRC, letter to Entergy Operations, Inc., "Arkansas Nuclear One, Units 1 and 2 – Safety Evaluation Regarding Implementation of Mitigating Strategies and Reliable Spent Fuel Pool Instrumentation Related to Orders EA-12-049 and EA-12-051 (CAC Nos. MF0942, MF0943, MF0944, and MF0945)," dated September 19, 2016. ADAMS Accession No. ML16224A106.

[12] Timothy F. Steed, FENOC, letter to NRC, "Completion of Required Action by NRC Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (TAC No. MF0842) and NRC Order EA-12-051, Reliable Spent Fuel Pool Instrumentation (TAC No. MF0800)," dated December 21, 2015. ADAMS Accession No. ML15355A397.

[13] Timothy F. Steed, FENOC, letter to NRC, "Completion of Required Action by NRC Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (TAC No. MF0842) and NRC Order EA-12-051, Reliable Spent Fuel Pool Instrumentation (TAC No. MF0800)," dated December 21, 2015. ADAMS Accession No. ML15355A397.

[14] These relaxations were in place at the time of the initial report and refer to the need to install a hardened wetwell vent (in response to Order EA-13-109) before full compliance with Order EA-12-049 is achieved. For this

30. **Text on p. 57:** Cooper – "In Enclosure 1 to the NRC staff's interim response, the NRC staff noted that certain analyses of dam failures were ongoing. An evaluation of these scenarios using a two-dimensional model is expected to be submitted by September 30, 2016. The NRC staff noted that the reevaluated flood evaluation is expected to be bounded by another scenario already submitted, but that the effects and durations will differ and will be separately evaluated in this later submittal."
   - **Updated Text (Action Complete):** In Enclosure 1 to the NRC staff's interim response, the NRC staff noted that certain analyses of dam failures were ongoing. *The licensee submitted a white paper on dam failure modeling in July 2016,*[15] *and subsequently submitted a revision to its flooding hazard reevaluation report on schedule in September 2016.*[16] *In this revision, dam breaches and failures and channel migration or diversion remain the two flood-causing mechanisms that could affect the site. The licensee has maintained the interim actions described in the original flooding hazard evaluation report and the commitment to conduct an integrated assessment. The revision includes updated flood levels for the dam breach hazard that reflect the two-dimensional modeling.*

31. **Text on p. 58:** Cooper – "The licensee expects to be in full compliance with Order EA-12-049 in Fall 2016."
   - **Updated Text (Action Complete):** *On January 4, 2017, the licensee notified the NRC that Cooper is* in full compliance with Order EA-12-049.[17]

32. **Text on p. 63:** Fort Calhoun – "An evaluation of these scenarios using a two-dimensional model is expected to be submitted by September 30, 2016. The NRC staff noted that the reevaluated flood evaluation is expected to be bounded by another scenario already submitted, but that the effects and durations will differ and will be separately evaluated in this later submittal.
    After the licensee provides its Phase 1 submittal, the NRC staff will review this information and determine whether the licensee can address any identified plant vulnerabilities appropriately, or if plant-specific regulatory actions should be undertaken."
   - **Updated Text (Action Not Complete / Not Needed):** An evaluation of these scenarios using a two-dimensional model *was originally planned*. *As noted above, however, Fort Calhoun permanently ceased operations on October 24, 2016, and has permanently defueled the reactor vessel. Accordingly, the licensee no longer intends to submit a revised flooding hazard reevaluation report. The licensee views the request for information under 10 CFR 50.54(f) as applicable to operating reactors only and does not intend to proceed further with the flooding hazard reevaluation or to submit a revised*

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reason, the original report referred to "implementation," referring to modifications specific to Order EA-12-049. These implementation outages were completed by the end of 2016 as expected.

15 Oscar A. Limpias, Nebraska Public Power District, letter to NRC, "Nebraska Public Power District's Dam Failure Modeling White Paper in Regard to Nuclear Regulatory Commission Interim Staff Response to Reevaluated Flood Hazards for Cooper Nuclear Station," dated July 28, 2016. ADAMS Accession No. ML16221A348.

16 Oscar A. Limpias, Nebraska Public Power District, letter to NRC, "Revision to Nebraska Public Power District's Flood Hazard Reevaluation Report," dated September 29, 2016. ADAMS Accession No. ML16279A421.

17 Kenneth Higginbotham, Nebraska Public Power District, letter to NRC, "Completion of Required Action by NRC Order EA-12-049 - Mitigation Strategies for Beyond-Design-Basis External Events," dated January 4, 2017. ADAMS Accession No. ML17017A166.

flooding hazard reevaluation report.[18, 19] *The NRC is finalizing its actions with respect to the 10 CFR 50.54(f) letter for Fort Calhoun.*

33. **Text on p. 64:** Fort Calhoun – "All open items from the NRC staff's review have been addressed according to the licensee (though some confirmatory items remain), and the licensee expects to be in full compliance with Order EA-12-049 by December 2016. The NRC staff will complete a final safety evaluation considering the updated information and inspect the licensee's implementation before considering the order actions complete. This process is expected to take approximately a year after the licensee notifies the NRC of full compliance."
    - **Updated Text (Action Not Complete / Not Needed):** All open items from the NRC staff's review *were* addressed, according to the licensee (though some confirmatory items remain). *Subsequent to these updates, Fort Calhoun permanently ceased operations on October 24, 2016, and has permanently defueled the reactor vessel. Accordingly, the NRC relaxed the scheduling requirements for compliance with Order EA-12-049 to August 31, 2017.*[20] *At this point, the NRC would finalize its actions with respect to Order EA-12-049 for Fort Calhoun.*

34. **Text on p. 74:** Hope Creek/Salem – "The licensee has completed most of its guidance development and all training for its strategies and is in the process of implementing the necessary modifications. Given a Fall 2016 implementation outage, the licensee expects Hope Creek to be in full compliance with Order EA-12-049 by the end of 2016 (with notification to the NRC to occur in January 2017). For Salem, modifications have been implemented for Unit 2 and are being implemented for Unit 1 (including final validation of the associated guidance) in May 2016; therefore, the licensee intended to notify the NRC of full compliance for both units by Summer 2016."
    - **Updated Text (Actions Complete):** *Plant modifications, guidance, and training are complete for both Salem and Hope Creek. On September 28, 2016, the licensee notified the NRC that Salem, Units 1 and 2, are in compliance with Order EA-12-049. In addition, on January 25, 2017, the licensee notified the NRC that Hope Creek is in compliance with Order EA-12-049.*

35. **Text on p. 79:** Indian Point – "The licensee has completed guidance development, training, and procurement for its strategies. Modifications have been implemented for Unit 3 and are being implemented for Unit 2 during the Spring 2016 refueling outage; therefore, the licensee intends to notify the NRC of full compliance for both units by Summer 2016."
    - **Updated Text (Action Complete):** The licensee has completed guidance development, training, and *plant modifications* for its strategies. *On August 12, 2016, the licensee*

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[18] Shane M. Marik, Omaha Public Power District, letter to NRC, "Fort Calhoun Station Final Response to the Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident and Corresponding Commitments," dated November 18, 2016. ADAMS Accession No. ML16323A206.

[19] Shane M. Marik, Omaha Public Power District, letter to NRC, "Revision to Response to Request for Information Regarding Flooding Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident- Fort Calhoun Station Flood Hazard Reevaluation Report," dated September 14, 2016. ADAMS Accession No. ML16258A364.

[20] William M. Dean, NRC, letter to Shane M. Marik, Omaha Public Power District, "Fort Calhoun Station, Unit 1 – Relaxation of the Schedule Requirements for Order EA-12-049 'Issuance of Order To Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events' (CAC No. MF0969)," dated November 21, 2016. ADAMS Accession No. ML16277A509.

notified the NRC that Indian Point, Unit 2, is in compliance with Order EA-12-049.[21] *Unit 3 was already in compliance as of May 20, 2015.*[22]

36. **Text on p. 91:** Oconee – "As of its last formal update to the NRC, the licensee was in the process of implementing its mitigating strategies to support compliance with Order EA-12-049. Unit 2 is already in compliance, including modifications, training, and walkdowns, following its Fall 2015 refueling outage. Implementation for Unit 3 is scheduled for the Spring 2016 refueling outage, and the licensee intended to be in full compliance following the Fall 2016 refueling outage for Unit 1. This update also indicates that the two open items noted above regarding the PMP and dam-failure flooding analyses were closed based on an NRC staff audit in July 2015."
    - **Updated Text (Action Complete):** *Following previous notifications for Units 2 and 3,*[23] *on January 26, 2017, the licensee notified the NRC that all three units at Oconee are in compliance with Order EA-12-049*, including modifications, training, and walkdowns.[24] *This notification was accompanied by the Overall Integrated Plan for Oconee's mitigation strategies, including a "warning time" strategy that addresses the flooding concerns identified in the NRC's 2010 Confirmatory Action Letter, as described above [in the report]. This strategy would be initiated upon receipt of notification of imminent or potential failure of the Jocassee main dam, approximately 7 hours before potential loss of the standby shutdown facility (SSF) by flood waters overtopping the flood wall. A "T=0" strategy (i.e., in which alternating current power and access to the ultimate heat sink are lost at the beginning of the event) is employed for other scenarios than the dam failure and makes use of the SSF.*

37. **Text on p.93**: Oconee – "The NRC staff noted that it would not make a final determination on the closure of the Confirmatory Action Letter until the permanent plant modifications were completed (which they were in April 2016 as noted above)."
    - **Updated Text (Action Complete):** The NRC staff noted that it would not make a final determination on the closure of the Confirmatory Action Letter until the permanent plant modifications were completed. *On June 16, 2016, the NRC issued an inspection report documenting the licensee's actions in response to the CAL and the closure of the CAL.*[25]

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[21] Lawrence Coyle, Entergy Nuclear Northeast, letter to NRC, "Notification of Full Compliance with Order EA-12-049 'Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events' and Order EA-12-051 'Modifying Licenses with Regard to Requirements for Reliable Spent Fuel Pool Instrumentation' (TAC Nos. MF0744 and MF0737) – Indian Point Unit Number 2," dated August 12, 2016. ADAMS Accession No. ML16235A292.

[22] Lawrence Coyle, Entergy Nuclear Northeast, letter to NRC, "Notification of Full Compliance with Order EA-12-049 'Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events' and Order EA-12-051 'Modifying Licenses with Regard to Requirements for Reliable Spent Fuel Pool Instrumentation' (TAC Nos. MF0745 and MF0738) – Indian Point Unit Number 3," dated May 20, 2015. ADAMS Accession No. ML15149A140.

[23] Scott L. Batson, Duke Energy, letter to NRC, "Notification of Compliance with Order EA-12-049, 'Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond Design Basis External Events' for Oconee Nuclear Station, Unit 3," dated July 11, 2016. ADAMS Accession No. ML16200A315.

[24] Tom D. Ray, Duke Energy, letter to NRC, "Notification of Compliance with OrderEA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond Design Basis External Events" for Oconee Nuclear Station, Unit 1 and FLEX Final Integrated Plan (FIP) for Oconee Nuclear Station, Units 1, 2, and 3," dated January 26, 2017. ADAMS Accession No. ML17031A431.

[25] Catherine Haney, NRC, letter to Scott Batson, Duke Energy, "Oconee Nuclear Station—Confirmatory ," dated June 16, 2016. ADAMS Accession No. ML16168A176.

38. **Text on p. 97:** Peach Bottom – "The strategies (including physical modifications guidance development) have been implemented for Unit 3 and are being implemented for Unit 2 as part of the Fall 2016 refueling outage; therefore, the licensee is expected to notify the NRC of full compliance for both units by the end of 2016."
   - **Updated Text (Action Complete):** The strategies (including physical modifications and guidance development) have been implemented for *both units*. *On January 6, 2017, the licensee notified the NRC that Peach Bottom, Units 2 and 3, are in compliance with Order EA-12-049.*[26]

39. **Text on p. 101:** Prairie Island – "The licensee notified the NRC on January 14, 2016, that Unit 2 is in full compliance with Order EA-12-049. For Unit 1, the licensee is in the process of procuring equipment and developing procedures and training. Full implementation of the modifications is expected as part of the Fall 2016 refueling outage."
   - **Updated Text (Action Complete):** The licensee notified the NRC on January 14, 2016, that Unit 2 is in full compliance with Order EA-12-049.[27] *The licensee notified the NRC on December 13, 2016, that Unit 3 is in compliance with Order EA-12-049.*[28]

40. **Text on p. 105:** Sequoyah – "To provide additional margin, however, the licensee decided to design an improved flood mitigation system, to be fully implemented by the end of December 2016. The system includes a hardened structure located at least 15 feet above current PMF levels, additional diesel generators, and hardened enhanced flood-mode systems for decay heat removal and reactor coolant system makeup. This approach will use certain elements of the FLEX equipment described further in the 'Mitigating Strategies' section below. The licensee has provided twelve status reports on the progress of its activities and currently estimates that it will meet this December 2016 implementation schedule."
   - **Updated Text (Action Not Complete / Deferred):** To provide additional margin, however, the licensee decided to design an improved *FMMS*, to be fully implemented by the end of December 2016. The system includes a hardened structure located at least 15 feet above current PMF levels, additional diesel generators, and hardened enhanced flood-mode systems for decay heat removal and reactor coolant system makeup. This approach will use certain elements of the FLEX equipment described further in the 'Mitigating Strategies' section below. The licensee has provided *periodic* status reports on the progress of its activities, *and procurement of the needed equipment is complete*. *In a July 2016 letter, the licensee notified the NRC that, given recent and ongoing flooding reevaluations and the completion of upgrades and improvements to date, field implementation of the FMMS will be delayed until September 2018.*[29] *Deferral of final implementation will enable the licensee to complete revised precipitation modeling and*

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26 James Barstow, Exelon Generation Company, LLC, letter to NRC, "Report of Full Compliance with March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," dated January 6, 2017. ADAMS Accession No. ML17006A167.

27 Kevin Davison, Xcel Energy, letter to NRC, "Notification of Compliance with NRC Order EA-12-049, 'Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,' Prairie Island Nuclear Generating Plant Unit 2 (TAC No. MF0835)," dated January 14, 2016. ADAMS Accession No. ML16014A754.

28 Scott Northard, Xcel Energy, letter to NRC, "Notification of Full Compliance with NRC Order EA-12-049, 'Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,' Prairie Island Nuclear Generating Plant, Units 1 and 2 (TAC Nos. MF0834 and MF0835)," dated December 13, 2016. ADAMS Accession No. ML16351A208.

29 Joseph W. Shea, TVA, letter to NRC, "Notification of Change in Completion Schedule Regarding the Improved Flood Mitigation System Project," dated July 15, 2016. ADAMS Accession No. ML16197A350.

determine with finality the margin to design into additional flood mitigating systems. The licensee will provide an update regarding the reevaluated flood levels using updated precipitation data by October 2017.

41. **Text on p.117:** Surry – "[Note 386] The audit report was not yet available at the time this report was developed."
    - **Updated Text (Action Complete):** [Note 386] *Lauren K. Gibson, NRC, letter to David A. Heacock, Virginia Electric and Power Company, dated August 12, 2016. ADAMS Accession No. ML16183A021.*

42. **Text on p. 125:** TMI – "The licensee intended to be in full compliance by April 30, 2016, but has not yet made formal notification of this status."
    - **Updated Text (Action Complete):** The licensee *notified the NRC on June 29, 2016, that TMI, Unit 2 is in compliance with Order EA-12-049.*[30]

43. **Text on p. 128:** Waterford – "The licensee expects to be in full compliance with Order EA-12-049 by July 2016."
    - **Updated Text (Action Complete):** The licensee *notified the NRC on July 21, 2016, that Waterford, Unit 3, is in compliance with Order EA-12-049.*[31]

44. **Text on p.129:** Watts Bar – "For Unit 2, construction was recently restarted after many years on hold, and the operating license was issued in 2015 for a term that expires in 2055. Unit 2 is conducting startup activities and has not yet begun commercial operation."
    - **Updated Text (Action Complete):** For Unit 2, construction was recently restarted after many years on hold, and the operating license was issued in 2015 for a term that expires in 2055. Unit 2 *began* commercial operation *in October 2016.*[32]

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30 James Barstow, Exelon Generation Company, LLC, letter to NRC, "Report of Full Compliance with March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," dated June 29, 2016. ADAMS Accession No. ML16183A025.

31 Michael R. Chisum, Entergy Operations, Inc., letter to NRC, "Notification of Full Compliance with EA-12-049, Order Modifying Licenses With Regard To Requirements for Mitigating Strategies for Beyond-Design-Basis External Events Waterford Steam Electric Station, Unit 3 (Waterford 3)," dated July 21, 2016. ADAMS Accession No. ML16203A321.

32 https://www.tva.com/Newsroom/Watts-Bar-2-Project

Office of Special Counsel, Questions on Oconee

The OSC email (Sheri Shilling to Maxwell Smith and Tracey Stokes, 1/27/17) requested [1] "a detailed explanation of what actions were taken to mitigate the risk from flooding at Oconee, including the height of walls, etc. We also ask that you [2] explain any changes to the flood estimates at the site."

Response to part [1]… Actions Taken to Mitigate the Risk from Flooding

The actions taken to mitigate the risk from flooding at the Oconee nuclear power plant site can be organized into four broad categories: actions to reduce the likelihood of dam failure, actions to provide early warning of potential flooding, actions to minimize the adverse effects of flooding on the Oconee site (e.g. walls and other protective features), and actions to provide adequate equipment to maintain plant safety functions during and following a flood. Actions in all of these areas have been taken in response to NRC orders, requests for information, and inspection findings.

The investigative report sent to OSC by former Chairman Burns includes an extensive discussion of the history of regulatory actions taken on the Oconee nuclear power plant and related licensee (Duke Energy) implementation activities (11 pages and 61 references). Sections 4.1.1 and 4.1.2, and sections B 11 through B 11.4 present that information.

Included below is supplemental information reflecting actions completed since June 2016. Also included is a comprehensive summary and explanation of all the flooding protection and mitigation measures currently in place at the Jocassee dam and the Oconee facility. The relevant physical changes and related procedures include all those made since 2010.

In January 2010, interim actions were taken to mitigate flooding from a failure of Jocassee Dam (upstream of the Oconee facility). These actions remain in place and included the folllowing:

- Extending the height of the flood wall around the standby shutdown facility by 2.5 feet to 803.5 feet above Mean Sea Level (MSL);
- Replacing the operating chains on the spillway gates at Jocassee Dam;
- Conducting periodic safety inspections of Jocassee Dam, observing the dam during routine maintenance, and coordinating additional inspections with the Federal Energy Regulatory Commission;
- Monitoring the dam continuously from the Hydro Central operating center in Charlotte, NC, as well as using level alarms to detect developing dam failure;
- Developing procedures, including an Emergency Action Plan for Jocassee Dam that includes notifying Oconee of an actual or imminent failure and a plant procedure to mitigate dam failure that included pre-staging a portable pump to feed the steam generators.

In June 2010 the licensee committed to, and has since completed, the following actions:

- Implementing guidance and procedures to mitigate postulated flood events that could render the standby shutdown facility inoperable;

- Consolidating river management and storm management processes into one guidance document;

- Inspecting Jocassee Dam at various frequencies, by both licensee and Federal Energy Regulatory Commission representatives;

- Monitoring various hydrologic parameters, including continuous remote monitoring from the Hydro Central Operating Center;

- Assigning an Oconee engineer as the Jocassee Dam contact;

- Installing electrical meters on Keowee spillway gates to monitor the condition of equipment;

- Providing forebay and tailrace level alarms for Jocassee Dam to detect a developing dam failure;

- Adding a storage building adjacent to the Jocassee spillway to house backup gate operating equipment staging a portable generator and motor near the Jocassee spillway gates to serve as secondary backup gate operating equipment;

- Providing instruments and alarms for seepage monitoring in selected locations for timely detection of degrading conditions;

- Providing additional video monitoring of the Jocassee dam.

In April 2016 the licensee confirmed that the following final modifications, which were developed considering the results of the flooding hazard re-evaluation report (FHRR) (discussed below) had been completed.

- Armoring some of the slopes on site to protect embedded piping for the condenser circulating water system. This modification includes approximately 150,000 square feet of scour protection of various types to prevent flood waters from eroding the embankment.

- Armoring the intake dike in high water velocity locations to protect both the dike and the condenser circulating water system piping. This modification includes scour protection and an auxiliary drain system to protect grass cover that is credited to prevent flood waters from eroding the embankment.

- Directing water away from the site grade to protect the condenser circulating water system embedded piping and reduce initial flooding levels. This modification includes a 206-foot-long flood-diversion wall with a top elevation of 828 feet MSL [mean sea level].

- Relocating the back-up power transmission line towers above the floodplain to supply emergency power to the site. This modification included acquiring a new right-of-way and relocating 22 transmission towers.

With respect to the mitigation capability for flooding events, Duke Energy has recently (January 26, 2017) confirmed completion of all the actions required by the NRC Order of March 12, 2012 at Oconee unit 1 (units 2 and 3 completed these actions earlier) including the following.

STRATEGIES - COMPLETE

ONS [Oconee Nuclear Station] Unit 1 strategies are in compliance with Order EA-12-049. All strategy related Open Items, Confirmatory Items or Audit Questions/Audit Report Open Items have been addressed and are considered complete pending NRC closure.

MODIFICATIONS - COMPLETE

The modifications required to support the FLEX strategies [FLEX is the generic nuclear industry term for a flexible approach to providing basic safety functions in the event of loss of normal and (redundant) backup systems; often involving portable equipment] for ONS Unit 1 have been fully implemented in accordance with the station design control process.

EQUIPMENT - PROCURED AND MAINTENANCE & TESTING - COMPLETE

The equipment required to implement the Mitigation Strategies has been procured and is ready for use at ONS Unit 1. Testing and maintenance processes have been established through the use of industry endorsed Electric Power Research Institute (EPRI) guidelines and the ONS Preventative Maintenance program such that FLEX equipment reliability is achieved.

PROTECTED STORAGE - COMPLETE

The storage facility required to implement the FLEX strategies for ONS Unit 1 has been completed and provides protection from the applicable site hazards. The equipment required to implement the FLEX strategies for ONS Unit 1 is stored in its protected configuration and is ready for use.

PROCEDURES - COMPLETE

FLEX Guidelines (FGs) for ONS Unit 1 have been developed in accordance with NEI 12-06, Revision 0, Section 3.2.2 [generic industry-developed guidance, approved by NRC]. The FGs and affected existing procedures have been verified and are available for use in accordance with the site procedure control program.

TRAINING - COMPLETE

Training for ONS Unit 1 has been completed using the ONS Systematic Approach to Training (SAT) as recommended in NEI 12-06, Revision 0, Section 11.6. [an NRC-approved approach to plant staff training]

STAFFING - COMPLETE

The staffing study for ONS has been completed in accordance with NEI 12-01, Revision 0 and Recommendation 9.3 of the [NRC] 10 CFR 50.54(f) letter, "Request for Information Pursuant to Title 10 of the Code of Federal Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," and confirmed that ONS has adequate staffing to perform the actions to mitigate beyond design basis events. The ONS study is documented by letter dated June 17, 2015.

NATIONAL SAFER RESPONSE CENTERS - COMPLETE

Duke Energy has established a contract with the Pooled Equipment Inventory Company (PEICo) and has joined the Strategic Alliance for FLEX Emergency Response (SAFER)-Team Equipment Committee for off-site facility coordination. It has been confirmed that PEICo is ready to support ONS with Phase 3 equipment stored in the National SAFER Response Centers in accordance with the site specific SAFER Response Plan. [this item refers to two industry-established centers (Memphis and Phoenix) where backup equipment is stored and available for delivery to facilities needing long-term (greater than 24 hours) support]

VALIDATION - COMPLETE

Duke Energy has performed a validation in accordance with industry developed guidance which assures that required tasks, manual actions and decisions for FLEX strategies are feasible and can be executed.

FLEX PROGRAM DOCUMENT - ESTABLISHED

The FLEX Program Document for ONS has been developed in accordance with the requirements of NEI 12-06, Revision 0.

All of the actions listed above to support dam failure flood mitigation are applicable to a range of postulated flood levels, including the Jocassee breach event in the FHRR. The range of postulated floods are addressed in a three part Oconee strategy for responding to external flooding events. Less extreme flooding would be handled with normal plant equipment. Extensive flooding on the site would be handled using the Oconee Standby Shutdown Facility (SSF). Flooding in excess of the capability of the SSF would be handled through the plant's FLEX strategy. The NRC has reviewed this strategy for handling the potential flooding scenarios at Oconee and found it acceptable.

Response to Part [2]… "Explain Any Changes to the Flood Estimates at the Site"

Section B.11.4 of the Investigative Report states, "In April 2016, the NRC staff completed its assessment of the flooding hazard reevaluation report. The NRC staff concluded that the 2010 licensee analysis (previously accepted by the NRC staff in the January 28, 2011, safety evaluation) reflects a bounding flooding hazard analysis based on conservative assumptions. The 2015 reevaluation reflects a reasonable analysis that removes some conservatism and is consistent with recent Commission direction."

The difference between a "bounding flooding hazard analysis" and "reasonable analysis" is based on the choice of values used for important parameters in the analysis of important mechanisms and processes. A "bounding flooding hazard analysis" uses bounding, conservative, or extreme values; and a "reasonable analysis" uses reasonable, realistic, or best-estimate values. A reasonable analysis also considers a range of possible values of important parameters and the effect on the resulting flooding level (sensitivity analysis). The bounding flood hazard may not be physically impossible; but it is an extremely unlikely consequence of an extremely unlikely initiating event. The licensee's analysis and the NRC staff's evaluation of the important flooding mechanisms, processes, and their modeling are discussed below. Numerous physical models were considered, and many outside experts were consulted in this effort.

The selection and application of breach parameters and hydraulic models used in the evaluation produced variations in the timing and maximum water height at the ONS. A reasonable basis exists for several alternative analyses, all of which can generate higher or lower predications of maximum water surface elevations. For both the 2010 and 2015 evaluations, the NRC staff determined that the licensee appropriately followed engineering and regulatory guidance to compute flood levels at the site within the range of the inherent uncertainties. The 2010 licensee evaluation reflects a bounding analysis and is based on several conservative assumptions including the following: (1) conservative breach size selection given the dam's construction and bedrock type at the dam site and (2) a hypothetical time to reach a peak outflow, based on the quality of construction, basal rock type, and degree of monitoring of the Jocassee dam. The 2015 evaluation reflects a reasonable analysis that removes some conservatism in the 2010 analysis, and is consistent with recent NRC Commission direction regarding licensees' flood hazard reevaluation in response to the 50.54(f) letter. Therefore, the NRC staff concluded that the licensee's estimated flood levels at the ONS are considered reasonable and satisfy the information requests for each letter. Further, the staff concludes that the revised 2015 Flood Hazard Reevaluation Report (FHRR) provides an acceptable evaluation of a postulated sunny-day failure of the Jocassee Dam (a failure involving no advance warning and no additional precipitation), and is appropriate to consider in assessing the need for specific actions included in the June 22, 2010 NRC Confirmatory Action Letter.

The results of the staff's review of the FHRR are documented in an April 14, 2016 letter to Duke Energy. That review included analysis of a full range of possible flooding mechanisms: Local Intense Precipitation, potential hydrologic dam failure (from overtopping), potential seismic dam failure, and potential sunny-day dam failure (due to internal piping (leakage)), storm surge, tsunami, seiche (tsunami-like event on a lake), ice-induced flooding, and channel migrations or diversions.

In its guidance document on flood hazard re-evaluation (JDL-ISG-2013-01) the NRC staff took the following position:

> "Because no widely accepted current engineering practice exists for estimating failure rates on the order of at the 1x 10-6 per year, sunny-day failure should be assumed to occur and the consequences estimated."

A sunny-day failure of the Jocassee dam was therefore required to be postulated and analyzed by Duke Energy. That analysis was reviewed and documented in the April 14, 2016 letter. The review included a detailed consideration of both dam breach parameters and breach process. The geometry and timing of a dam breach was evaluated in considerable detail as follows.

The initial submittal of the FHRR reported results of a dam-breach analysis that used regression equations developed by Xu and Zhang (Xu and Zhang, 2009) to estimate the geometry and timing of a dam breach and the subsequent release. One major difference between the Xu and Zhang methodology and most other regression-based methods is the inclusion of dam erodibility as a parameter. Using the published methodology of Xu and Zhang and treating the Jocassee Dam as a "low-erodibility" dam, the licensee generated ranges of values for breach parameters. The breach geometry values and failure time generated from the Xu and Zhang analysis were input to HEC-RAS (River Analysis System), and the orifice coefficient and weir coefficient parameters in HEC-RAS were iteratively adjusted until HEC-RAS reproduced a breach flow that matched flow predictions from the Xu and Zhang outflow equation. To support the dam breach analysis used as part of the FHRR evaluation, the licensee submitted a report developed by Ehasz and Bowles (Ehasz and Bowles, 2014) describing the process of developing these coefficients.

The NRC staff requested the U.S. Bureau of Reclamation (USBR) to provide an independent technical review of the Xu and Zhang methodology, and subsequently requested both the USBR and the Federal Energy Regulatory Commission (FERC) to review and comment on the licensee's implementation of the Xu and Zhang methodology and selection of breach parameters for the Jocassee Dam. The USBR review of the published Xu and Zhang methodology (Wahl, 2014a) determined that the Xu and Zhang methodology cannot be confidently applied to low-erodibility dams or to the prediction of failure time. Reviewing the specific application of the method for Jocassee Dam, Wahl determined that the dam should be classified as medium erodibility instead of low erodibility (Wahl, 2014b). Wahl also recommended "best estimate values" of breach parameters.

The FERC also commented (Allerton, 2014 and Brown and Burgess, 2014) on the lack of field observed data upon which to base a model for breaching of low-erodibility dams, and noted that the Jocassee Dam and Reservoir are much larger than the dams and reservoirs in the available historic data sets used to develop the Xu and Zhang methodology and other regression equations. The FERC described a suite of sensitivity studies related to the Jocassee Dam failure that the FERC staff had performed and recommended considering a full-height breach of Jocassee Dam.

The NRC staff issued an RAI (request for additional information) by letter dated September 15, 2014, requesting the licensee to reanalyze and resubmit the dam failure analyses for the FHRR after applying alternate breach-parameter estimations than those predicted using the Xu and Zhang methodology. For the analysis presented in its revised FHRR, the licensee estimated dam breach parameters via empirical regression methodologies and considered an array of different equations in developing these parameters (Froehlich, 1995a; Froehlich, 1995b; Froehlich, 2008, Walder and O'Connor, 1997; MacDonald and Langridge-Monopolis, 1984; and Von Thun and Gillette, 1990). These methodologies are used to estimate dam breach characteristics, as well as peak discharge from the breach. The breach parameters of principal interest are those for the failure of the Jocassee Dam, but it is important to note that for its assessment of flooding impacts at the ONS site, the licensee also developed dam breach parameters for Keowee Dam, its appurtenant West Saddle Dam, the ONS Intake Canal Dike, and Little River Dam.

The NRC staff noted that Jocassee Dam and the impoundment Jocassee Reservoir are substantially larger than the dams and reservoirs whose failures were evaluated for the development of empirical breach equations. Most of these regression methodologies rely on the same dataset of 108 historical dams. Also, most of these historical dam failures are earthen dams rather than rockfill dams, and the majority of the failures resulted from overtopping rather than piping.

Since the historical datasets used in development of empirical dam breach methodologies do not include dams as large as the Jocassee Dam and are more representative of earthen dams, the licensee relied heavily upon engineering judgment to estimate breach time, pattern, and size and considered eight different empirical methodologies in developing breach parameters.

As indicated in several dam failure literature sources (USACE, 2014; Wahl, 2004; Wahl, 2014a; and Chauhan et al., 2004), estimation of dam failure parameters and impacts is subject to a high degree of uncertainty. As such, the consideration of multiple scenarios is appropriate.

To develop the Jocassee Dam breach parameters, the licensee used various methods, including both empirical formulas and physical and hydraulic modeling.

The licensee used the National Weather Service (NWS) physically-based mathematical model (NWS BREACH) (Fread, 1991) to perform its analysis of the breach of the Jocassee Dam as part of the initial analysis. The NWS BREACH determines breach parameters and the breach outflow hydrograph by coupled analysis of reservoir inflow, breach outflow, and the sediment transport capacity of the unsteady flow through the breach channel, considering the material properties of the dam (Fread, 1991). Other physical models of the dam-breach process were considered, but were not used for reasons of unavailability or lack of previous acceptance by the NRC. The licensee provided a copy of the input file for NWS BREACH in response to a staff request. The NRC staff ran the model using the licensee's input file and obtained a predicted peak flow somewhat less than the licensee's reported result, and a failure time which is higher than the licensee's reported result. The NRC staff noted that the differences in the estimated values are acceptable for the subsequent analysis

The licensee stated that some of the results of the Jocassee NWS BREACH model are unrealistic; however, they used both the final breach invert elevation and the breach initiation phase results to inform its further analysis. Brown and Burgess reported (Brown and Burgess, 2014) that the FERC staff could not get the NWS BREACH model (which considers the strength of the constructed dam) to simulate a piping breach of the main dam until they increased the width of the initial pipe to a size which they consider an extremely unrealistic. The NRC staff also found that the NWS BREACH would not simulate a piping failure of the Jocassee Dam until the initial pipe size was increased to unrealistically high values. The licensee used the NWS BREACH progression shape as a basis for further progression modifications, which include no adjustment to the breach initiation phase, extension of the breach development time based on the failure time equation of Von Thun and Gillette (Von Thun and Gillette, 1990), and extension of the full-failure time to capture the time to fully drain the Jocassee Reservoir.

The licensee identified the empirical breach equations of Von Thun and Gillette (Von Thun and Gillette, 1990), Froehlich (Froehlich, 1995a; Froehlich, 1995b; and Froehlich, 2008) as the best candidates for analysis of the Jocassee Dam, then tested these equations by using them to estimate breach parameters for three historic dam failures (Hell Hole Dam, Teton Dam, and Oros Dam), and comparing the results with the observed values. The licensee found that the Von Thun and Gillette methodology had the least overall prediction error and therefore selected it for use in the breach analysis for Jocassee Dam. In addition, the licensee plotted breach widths for several historic dam failures versus reservoir volume, fitted a linear trend line to the data, and added the predicted breach widths for the Jocassee Reservoir volume to the graph. The Von Thun and Gillette prediction fell closest to the linear trend.

As discussed above, the NRC staff notes that essentially the same set of historical dam failures was used in developing all of the regression models and that the data set used for inter-comparison of the model predictions is limited with large error bands. Wahl (Wahl, 2004) found that the regression equations for dam breach analysis have uncertainties in the range of an order of magnitude. Wahl (Wahl, 2004) states that "uncertainty of breach parameter predictions is likely to be significantly greater than all other factors, and could thus dramatically influence the outcome." The report by Wahl (Wahl, 1998) analyzed and utilized many of the currently available equations to predict breach parameters for 108 documented case studies and provided plots of the predictions vs the observed values. The results indicated that prediction errors of ±75% were not uncommon for breach width, while prediction errors for failure time often exceeded one order of magnitude. The NRC staff notes that the linear relationship between breach width and reservoir volume that the licensee presented is a poor fit to widely diverse historical data and requires extrapolation to Jocassee's reservoir volume, which exceeds the volume of any historically observed failure. However, given the analysis provided by the licensee regarding consideration of various empirical regression methodologies and equations; the use of physical models; consideration of other models of the dam-breach processes; sensitivity analyses and the limited dataset on observed dam failures, the NRC staff found the licensee's selection of the Von Thun and Gillette method for estimating dam breach width and failure time to be reasonable and consistent with current guidance.

The Oconee site flooding as a result of a sunny-day dam failure of the Jocassee dam was evaluated with both a 1-D (one dimensional) hydraulic model (HEC-RAS) and a 2-D (two dimensional) hydrologic model.

To predict peak outflow passing through the Jocassee Dam breach, the licensee performed sensitivity analysis by varying input parameters in HEC-RAS. The HEC-RAS model attempts to simulate the breach by modeling storage, breach parameters, piping flow, and weir flow over time.

The licensee cited Chauhan et al. (Chauhan et al., 2004) as having stated that parameters resulting from regression equations can result in overestimates of peak outflows from breached dams when used in routing models such as HEC-RAS. The licensee stated that one reason for this is that the peak outflow is likely to occur sometime before the breach is fully formed. Chauhan et al. (Chauhan et al., 2004) recommended that fractional values of breach widths and breach formation times resulting from regression equations could be used to achieve "reasonably realistic" estimates of breach parameters instead of "conservative" estimates that would result from applying the full values. Based on this recommendation, the licensee defined a range of potential fractional reductions to the Von Thun and Gillette dam breach parameters, then evaluated the sensitivity of peak outflows from the Jocassee Dam to different combinations of these parameter values.

The two parameters that the licensee evaluated in its analysis of sensitivities of breach outflow were breach progression and breach width. The licensee reasoned that since the postulated piping failure would occur at an abutment and proceed in one direction, the breach width would be reduced below the model-predicted value, which is based on a dam breach that begins at the center of a dam.

In addition, the licensee qualitatively considered the Jocassee Dam's physical size and construction to be a limitation on how fast the failure would progress. The licensee stated that peak outflow would occur prior to full-breach development, due to decreases in head differential and water velocities across the dam (due in large part to the rise in water level on the downstream side). A site-specific breach-progression shape was developed via sensitivity runs to match the initiation phase predicted by NWS BREACH and extended out to the full-formation time as defined by HEC-RAS, which represents 100 percent breach completion. A total of nine Von Thun and Gillette sensitivity analyses were made by the licensee to compute peak outflow by altering breach width and breach progression.

The licensee selected an analysis which uses an intermediate progression and width scenario. The licensee's HEC-RAS model implementation simulated the breach outflow discharge from Jocassee assuming a weir coefficient and a piping coefficient, both of which appear to have been based on previous calibration to match peak outflow predicted by the Xu and Zhang method (Ehasz and Bowles, 2014). The licensee presented a comparison between the predicted peak breach flow, peak breach flows predicted by other methods, and estimates of the peak breach flows from eight historical dam failures.

The NRC staff reviewed the licensee's rationale for assessing the Jocassee Dam breach using fractional values of the Von Thun and Gillette dam breach parameters. Although the values selected do not represent the maximum or minimum values, they are within the range of the parameter estimates. The NRC staff understands the licensee's qualitative arguments for considering breach width and breach progression. However, the NRC staff notes that 1) regression-based techniques use unverified peak outflow values, 2) significant uncertainty exists in calculating best-fit peak outflow values from limited scattered data, and 3) there is significant uncertainty in extrapolation for dams and reservoirs at sizes much larger than represented by the historical dam failures. In order to understand the sensitivity of flood level to breach parameter uncertainty discussed above, the staff performed independent analysis, discussed in greater detail below.

In addition to the 1-D analysis, the licensee conducted 2-D modeling to simulate flow patterns in Keowee Reservoir and assess inundation at the ONS site. For the analysis presented in the original FHRR, the licensee used the SRH-2D model developed by the Bureau of Reclamation (Lai, 2008 and USBR). For the analysis presented in its revised FHRR, the licensee replaced SRH-2D with the 2-D depth-averaged TUFLOW FV (finite-volume) computer model (Build

Version 2014.01.007), (BMT WBM, 2013 and BMT WBM, 2014), which has additional features and capabilities. This 2-D model was used to resolve the complexity of the flow near the Keowee Dam, through the connecting canal (located between the Keowee and the Little River arms of Lake Keowee), and in the vicinity of the ONS SSF and includes routing to connect the Intake Canal Dike and Little River Dam outflow. The 2-D TUFLOW FV model is capable of processing the wetting and drying of grid cells, steady and unsteady flows, and sub/super-critical flows for complex channel geometries. The Keowee Dam spillway is modeled as an internal boundary condition, with both inflow and outflow boundaries specified within the 2-D model and taken from the 1-D flow hydrograph for the spillway and powerhouse portion of the Keowee Dam inline structure.

The upstream and downstream boundary conditions for the 2-D TUFLOW model were specified based on the 1-D HEC-RAS model results. The TUFLOW FV model was informed by the Jocassee Dam progression and width scenario output from HEC-RAS to assess flooding impacts at the ONS site.

The NRC staff focused its review of the dam failure modeling on reviewing the: 1) methodologies and scenarios being modeled and 2) the implementation of the modeling through review of parameters and sensitivity analyses. The NRC staff's review of the 2-D model centered on the model's performance with respect to its stability and capability to reasonably predict water surface levels on the ONS site. After reviewing the dam failure analysis provided with the original FHRR, the NRC staff issued an RAI by a letter dated March 20, 2014, requesting information about the location of the upstream boundary conditions, flow velocity distributions for the dam breach model, and discussions on any sensitivity runs.

In its response, the licensee identified that the velocity distribution is independent from its initial condition. The NRC staff concludes (based on engineering judgment), that in such a case involving extreme magnitudes of flow, the dam failure progression is more responsive to the flowrate and corresponding reservoir elevation as opposed to the velocity distribution entering the forebay of the Keowee Dam. The NRC staff performed a sensitivity analysis for a refinement of the mesh in the region of the canal that connects the Little River arm of Keowee Reservoir to the main Keowee River arm. In the flooding analysis, this region contains high gradients of velocity, contributing to appreciable water surface slopes in the reservoir on either side of the connecting canal. The refined mesh results produced by staff indicate a slight decrease of the water surface elevation on the ONS site. This indicates that the licensee's analysis is reasonable with respect to mesh refinement in the canal region.

The NRC staff performed independent sensitivity analyses to estimate the effects of dam breach parameters and other uncertain modeling parameters on water elevations at the ONS site, as described below. Given the large uncertainty associated with dam breach parameters and other assumptions required for model application, staff conducted sensitivity of a wide range of effects in order to composite a suite of sensitivities for assessing the licensee's analysis.

The licensee suggested that Jocassee dam breach progression and breach width are the most sensitive parameters affecting peak outflow. As a result, the NRC staff used HEC-RAS to evaluate the sensitivity of ONS site water elevations to the more severe values of breach parameters postulated by the licensee and also used TUFLOW FV (Build Version 2014.01.003) to examine the effects on water surface elevation and velocity from a subset of the more critical analyses. As described above, the NWS BREACH model results were used to inform the HEC-RAS 1D model.

In addition, the NRC staff evaluated the impacts of adjusting the side slopes of the breach opening at the Jocassee Dam, piping and weir coefficients for the HEC-RAS analysis of the Jocassee Dam breach, Keowee Dam time-to-failure, HEC-RAS model Manning's roughness coefficients, TUFLOW FV eddy viscosity values, TUFLOW FV mesh refinement, and TUFLOW FV canal constriction from bridge piers.

As a result of all of the above considerations, the NRC staff concluded that the 2015 flooding hazard re-evaluation report presented a reasonable basis for assessing and developing flood mitigation measures. It should be noted that the Oconee three-part flooding strategy (discussed above) also includes mitigation measures for potential floods in excess of the re-evaluated flood.