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

March 27, 2015

Mr. Joseph W. Shea
Vice President, Nuclear Licensing
Tennessee Valley Authority
1101 Market Street, LP 3D-C
Chattanooga, TN 37402-2801

SUBJECT: WATTS BAR NUCLEAR PLANT, UNITS 1 AND 2 – SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 (TAC NOS. MF0950, MF0951, MF1177, AND MF1178)

Dear Mr. Shea:

On March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued 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, “Order to Modify Licenses With Regard To Reliable Spent Fuel Pool Instrumentation,” (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML12054A736 and ML12054A679, respectively). The orders require holders of operating reactor licenses and construction permits issued under Title 10 of the *Code of Federal Regulations* Part 50 to modify the plants to provide additional capabilities and defense-in-depth for responding to beyond-design-basis external events, and to submit for review Overall Integrated Plans (OIPs) that describe how compliance with the requirements of Attachment 2 of each order will be achieved.

By letter dated February 28, 2013 (ADAMS Accession No. ML13067A030), Tennessee Valley Authority (TVA) submitted its OIP for Watts Bar Nuclear Plant, Units 1 and 2 (Watts Bar) in response to Order EA-12-049. By letters dated August 28, 2013, February 7, 2014, and August 28, 2014 (ADAMS Accession Nos. ML13247A288, ML14062A050, and ML14248A517, respectively), TVA submitted six-month updates to the OIP. By letter dated August 28, 2013 (ADAMS Accession No. ML13234A503), the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, “Regulatory Audits” (ADAMS Accession No. ML082900195). By letters dated December 20, 2013 (ADAMS Accession No. ML13343A036), and May 15, 2014 (ADAMS Accession No. ML14128A129), the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the TVA's progress. By letter dated October 29, 2014 (ADAMS Accession No. ML14303A546), TVA submitted a compliance status letter and final integrated plan (FIP) in response to Order EA-12-049. The compliance status letter provided a status of open items that needed to be addressed before full compliance could be achieved. By letter dated March 12, 2015 (ADAMS Accession No. ML15072A116), TVA submitted its full compliance letter and revised FIP for Watts Bar, Units 1 and 2.

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A440), TVA submitted its OIP for Watts Bar in response to Order EA-12-051. By letter dated August 2, 2013 (ADAMS Accession No. ML13204A231), the NRC staff sent a request for additional information (RAI) to TVA. TVA provided a response by letter dated September 6, 2013 (ADAMS Accession No. ML13254A065). By letters dated October 24, 2013 (ADAMS Accession No. ML13275A373), and May 15, 2014 (ADAMS Accession No. ML14128A129), the NRC staff issued an ISE, including RAIs, and an audit report to TVA. By letters dated November 22, 2013, January 10, 2014, and June 25, 2014 (ADAMS Accession Nos. ML13333B282, ML14014A137, and ML14177A526, respectively), TVA provided supplemental information. By letter dated March 26, 2014 (ADAMS Accession No. ML14083A620), the NRC notified all licensees and construction permit holders that the staff is conducting in-office and onsite audits of their responses to Order EA-12-051 in accordance with NRC NRR Office Instruction LIC-111, similar to the process used for Order EA-12-049. By letters dated August 28, 2013, February 28, 2014, and August 28, 2014 (ADAMS Accession Nos. ML13254A297, ML14064A238, and ML14248A484, respectively), TVA submitted six-month updates to the OIP. By letter dated October 29, 2014 (ADAMS Accession No. ML14303A561), TVA submitted its compliance letter, including one open item, in response to Order EA-12-051. By letter dated December 19, 2014 (ADAMS Accession No. ML15002A202), TVA notified the NRC that the open item has been resolved.

The enclosed safety evaluation (SE) provides the results of the staff's review of TVA's strategies for Watts Bar. The intent of the SE is to inform TVA on whether or not their integrated plans, if implemented as described, provide a reasonable path for compliance with Orders EA-12-049 and EA-12-051. The staff will evaluate implementation of the plans through inspection Temporary Instruction 191, "Implementation of Mitigation Strategies and Spent Fuel Pool Instrumentation Orders and Emergency Preparedness Communications/Staffing/ Multi-Unit Dose Assessment Plans" (ADAMS Accession No. ML14273A444), which is scheduled to begin on March 30, 2015, at Watts Bar.

If you have any questions, please contact Jason Paige, Orders Management Branch, Watts Bar Project Manager, at 301-415-5888 or at Jason.Paige@nrc.gov.

Sincerely,

Mandy K Halter

Mandy Halter, Acting Chief
Orders Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos.: 50-390 and 50-391

Enclosure:
Safety Evaluation

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RELATED TO ORDERS EA-12-049 AND EA-12-051

TENNESSEE VALLEY AUTHORITY

WATTS BAR NUCLEAR PLANT, UNITS 1 AND 2

DOCKET NOS. 50-390 AND 50-391

1.0 INTRODUCTION

The earthquake and tsunami at the Fukushima Dai-ichi nuclear power plant in March 2011 highlighted the possibility that extreme natural phenomena could challenge the prevention, mitigation and emergency preparedness defense-in-depth layers already in place in nuclear power plants. At Fukushima, limitations in time and unpredictable conditions associated with the accident significantly challenged attempts by the responders to prevent core damage and containment failure. During the events at Fukushima, the challenges faced by the operators were beyond any faced previously at a commercial nuclear reactor and beyond the anticipated design-basis of the plants. The U.S. Nuclear Regulatory Commission (NRC) determined that additional requirements needed to be imposed to mitigate such beyond-design-basis external events (BDBEEs).

On March 12, 2012, the NRC issued Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12054A736). This order directed licensees to develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool (SFP) cooling capabilities in the event of a BDBEE. Order EA-12-049 applies to all power reactor licensees and all holders of construction permits for power reactors.

The NRC also issued Order EA-12-051, "Order Modifying Licenses With Regard to Reliable Spent Fuel Pool Instrumentation" (ADAMS Accession No. ML12054A679). This order directed licensees to install reliable SFP level instrumentation with a primary channel and a backup channel, and with independent power supplies that are independent of the plant alternating current (ac) and direct current (dc) power distribution systems. Order EA-12-051 applies to all power reactor licensees and all holders of construction permits for power reactors.

Enclosure

2.0 REGULATORY EVALUATION

Following the events at the Fukushima Dai-ichi nuclear power plant on March 11, 2011, the NRC established a senior-level agency task force referred to as the Near-Term Task Force (NTTF). The NTTF was tasked with conducting a systematic and methodical review of the NRC regulations and processes and determining if the agency should make additional improvements to these programs in light of the events at Fukushima Dai-ichi. As a result of this review, the NTTF developed a comprehensive set of recommendations, documented in SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," dated July 12, 2011 (ADAMS Accession No. ML11186A950). Following interactions with stakeholders, these recommendations were enhanced by the NRC staff and presented to the Commission.

On February 17, 2012, the NRC staff provided SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," (ADAMS Accession No. ML12039A103) to the Commission. This paper included a proposal to order licensees to implement enhanced BDBEE mitigation strategies. As directed by SRM-SECY-12-0025, the NRC staff issued Orders EA-12-049 and EA-12-051.

2.1 Order EA-12-049

Order EA-12-049, Attachment 2, requires that operating power reactor licensees and construction permit holders use a three-phase approach for mitigating BDBEEs. The initial phase requires the use of installed equipment and resources to maintain or restore core cooling, containment and SFP cooling capabilities. The transition phase requires providing sufficient, portable, onsite equipment and consumables to maintain or restore these functions until they can be accomplished with resources brought from off site. The final phase requires obtaining sufficient offsite resources to sustain those functions indefinitely. Specific requirements of the order are listed below:

1) Licensees or construction permit (CP) holders shall develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and SFP capabilities following a beyond-design-basis external event.

2) These strategies must be capable of mitigating a simultaneous loss of all ac power and loss of normal access to the ultimate heat sink [UHS] and have adequate capacity to address challenges to core cooling, containment, and SFP capabilities at all units on a site subject to the Order.

3) Licensees or CP holders must provide reasonable protection for the associated equipment from external events. Such protection must demonstrate that there is adequate capacity to address challenges to core cooling, containment, and SFP capabilities at all units on a site subject to the Order.

4) Licensees or CP holders must be capable of implementing the strategies in all modes of operation.

5) Full compliance shall include procedures, guidance, training, and acquisition, staging, or installing of equipment needed for the strategies.

On August 21, 2012, following several submittals and discussions in public meetings with NRC staff, the Nuclear Energy Institute (NEI) submitted document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 0 (ADAMS Accession No. ML12242A378) to the NRC to provide specifications for an industry-developed methodology for the development, implementation, and maintenance of guidance and strategies in response to the Mitigation Strategies order. The NRC staff reviewed NEI 12-06 and on August 29, 2012, issued its final version of Japan Lessons-Learned Directorate (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," (ADAMS Accession No. ML12229A174) endorsing NEI 12-06, Revision 0, with comments as an acceptable means of meeting the requirements of Order EA-12-049, and published a notice of its availability in the *Federal Register* (77 FR 55230).

2.2 Order EA-12-051

Order EA-12-051, Attachment 2, requires that operating power reactor licensees and construction permit holders install reliable SFP level instrumentation. Specific requirements of the order are listed below:

> All licensees identified in Attachment 1 to the Order shall have a reliable indication of the water level in associated spent fuel storage pools capable of supporting identification of the following pool water level conditions by trained personnel: (1) level that is adequate to support operation of the normal fuel pool cooling system, (2) level that is adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck, and (3) level where fuel remains covered and actions to implement make-up water addition should no longer be deferred.
>
> 1. The spent fuel pool level instrumentation shall include the following design features:
>
>   1.1 Instruments: The instrumentation shall consist of a permanent, fixed primary instrument channel and a backup instrument channel. The backup instrument channel may be fixed or portable. Portable instruments shall have capabilities that enhance the ability of trained personnel to monitor spent fuel pool water level under conditions that restrict direct personnel access to the pool, such as partial structural damage, high radiation levels, or heat and humidity from a boiling pool.
>
>   1.2 Arrangement: The spent fuel pool level instrument channels shall be arranged in a manner that provides reasonable protection of the level indication function against missiles that may result from damage to the

structure over the spent fuel pool. This protection may be provided by locating the primary instrument channel and fixed portions of the backup instrument channel, if applicable, to maintain instrument channel separation within the spent fuel pool area, and to utilize inherent shielding from missiles provided by existing recesses and corners in the spent fuel pool structure.

1.3 Mounting: Installed instrument channel equipment within the spent fuel pool shall be mounted to retain its design configuration during and following the maximum seismic ground motion considered in the design of the spent fuel pool structure.

1.4 Qualification: The primary and backup instrument channels shall be reliable at temperature, humidity, and radiation levels consistent with the spent fuel pool water at saturation conditions for an extended period. This reliability shall be established through use of an augmented quality assurance process (e.g., a process similar to that applied to the site fire protection program).

1.5 Independence: The primary instrument channel shall be independent of the backup instrument channel.

1.6 Power supplies: Permanently installed instrumentation channels shall each be powered by a separate power supply. Permanently installed and portable instrumentation channels shall provide for power connections from sources independent of the plant ac and dc power distribution systems, such as portable generators or replaceable batteries. Onsite generators used as an alternate power source and replaceable batteries used for instrument channel power shall have sufficient capacity to maintain the level indication function until offsite resource availability is reasonably assured.

1.7 Accuracy: The instrument channels shall maintain their designed accuracy following a power interruption or change in power source without recalibration.

1.8 Testing: The instrument channel design shall provide for routine testing and calibration.

1.9 Display: Trained personnel shall be able to monitor the spent fuel pool water level from the control room, alternate shutdown panel, or other appropriate and accessible location. The display shall provide on-demand or continuous indication of spent fuel pool water level.

2. The spent fuel pool instrumentation shall be maintained available and reliable through appropriate development and implementation of the following programs:

2.1 Training: Personnel shall be trained in the use and the provision of alternate power to the primary and backup instrument channels.

2.2 Procedures: Procedures shall be established and maintained for the testing, calibration, and use of the primary and backup spent fuel pool instrument channels.

2.3 Testing and Calibration: Processes shall be established and maintained for scheduling and implementing necessary testing and calibration of the primary and backup spent fuel pool level instrument channels to maintain the instrument channels at the design accuracy.

On August 24, 2012, following several NEI submittals and discussions in public meetings with NRC staff, the NEI submitted document NEI 12-02, "Industry Guidance for Compliance With NRC Order EA-12-051, 'To Modify Licenses With Regard to Reliable Spent Fuel Pool Instrumentation,'" Revision 1 (ADAMS Accession No. ML12240A307) to the NRC to provide specifications for an industry-developed methodology for compliance with Order EA-12-051. On August 29, 2012, the NRC staff issued its final version of JLD-ISG-2012-03, "Compliance with Order EA-12-051, Reliable Spent Fuel Pool Instrumentation," (ADAMS Accession No. ML12221A339) endorsing NEI 12-02, Revision 1, as an acceptable means of meeting the requirements of Order EA-12-051 with certain clarifications and exceptions, and published a notice of its availability in the *Federal Register* (77 FR 55232).

3.0 TECHNICAL EVALUATION OF ORDER EA-12-049

By letter dated February 28, 2013 (ADAMS Accession No. ML13067A030), Tennessee Valley Authority (TVA) submitted its OIP for Watts Bar Nuclear Plant, Units 1 and 2 (Watts Bar) in response to Order EA-12-049. By letters dated August 28, 2013, February 7, 2014, and August 28, 2014 (ADAMS Accession Nos. ML13247A288, ML14062A050, and ML14248A517), TVA submitted six-month updates to the OIP. By letter dated August 28, 2013 (ADAMS Accession No. ML13234A503), the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" (ADAMS Accession No. ML082900195). By letters dated December 20, 2013 (ADAMS Accession No. ML13343A036), and May 15, 2014 (ADAMS Accession No. ML14128A129), the NRC issued an Interim Staff Evaluation (ISE) and audit report on TVA's progress. By letter dated October 29, 2014 (ADAMS Accession No. ML14303A546), TVA submitted a compliance status letter and final integrated plan (FIP) in response to Order EA-12-049. The compliance status letter provided a status of open items that needed to be addressed before full compliance could be achieved. By letter dated March 12, 2015 (ADAMS Accession No. ML15072A116), TVA submitted its full compliance letter and revised FIP for Watts Bar, Units 1 and 2.

The staff completed the Watts Bar review using the audit process, per NRR Office Instruction LIC 111. This evaluation references discussions which occurred during the audit review. To document pertinent information from the discussions, the licensee included Enclosure 2 of the March 12, 2015, compliance letter to provide a summary of the answers to the ISE open and confirmatory items as well as answers to significant issues that arose after the issuance of the May 15, 2014, audit report.

3.1 Overall Mitigation Strategy

Attachment 2 to Order EA-12-049 describes the three-phase approach required for mitigating BDBEEs in order to maintain or restore core cooling, containment and SFP cooling capabilities. The phases consist of an initial phase (Phase 1) using installed equipment and resources, followed by a transition phase (Phase 2) in which portable onsite equipment is placed in service, and a final phase (Phase 3) in which offsite resources may be placed in service. The timing of the transitions from one phase to the next is determined by plant-specific analyses.

While the initiating event is undefined, it is assumed to result in an extended loss of ac power (ELAP) with loss of normal access to the ultimate heat sink (LUHS). This event is used as a surrogate for a BDBEE. The initial conditions and assumptions for the analyses are stated in NEI 12-06, Revision 0, Section 3.2.1, and include the following:

1. The reactor is assumed to have safely shutdown with all rods inserted (subcritical).
2. The dc power supplied by the plant batteries is initially available, as is the ac power from inverters supplied by those batteries; however, over time the batteries may be depleted.
3. There is no core damage initially.
4. There is no assumption of any concurrent event.
5. Because the loss of ac power presupposes random failures of safety-related equipment (emergency power sources), there is no requirement to consider further random failures.

Watts Bar, Units 1 and 2 are pressurized-water reactors (PWRs) with ice condenser containments and separate SFPs. The FIP describes Watts Bar's three-phase approach to mitigate a postulated ELAP event. The approach is slightly different if the plant receives warning of a pending flood, but the initial actions are similar.

At the onset of an ELAP, the reactor trips and the reactor coolant system (RCS) stabilizes with natural circulation flow. Decay heat is removed by steaming the steam generators (SGs) through the atmospheric relief valves, and makeup to the SGs is provided by the turbine-driven auxiliary feedwater pump (TDAFW). Within one hour, TVA will open the atmospheric dump valves (ADVs) to begin a controlled cooldown and depressurization of the RCS. This reduces leakage from the reactor coolant pump (RCP) seals (a 20.3 gallon per minute (GPM) leak is assumed to occur from the standard RCP shaft seals at rated RCS pressure) and preserves RCS inventory. RCS makeup to account for RCP seal leakage and RCS inventory contraction is initially provided from the Safety Injection System Cold Leg Accumulators. RCS cooldown is controlled to prevent nitrogen in the accumulators from entering the RCS.

The water supply for the TDAFWP is initially the protected auxiliary feedwater storage tank (AFWST). The AFWST will provide approximately 15 hours of inventory for each unit before the AFWST is depleted. As TVA transitions to Phase 2, at approximately 5 hours into the event, the FLEX 6.9 kV diesel generator (DG) will be aligned to power an installed SIP to provide borated make-up water to the RCS from either the refueling water storage tank (RWST) or boric acid tank. The SIP operation will provide boration and restore RCS inventory and maintain pressurizer level until the High Pressure (HP) FLEX Pump assumes this task. Approximately 8.5 hours after the initiating event, the pre-staged 480V motor-driven HP FLEX pumps will be available for service. Once RCS pressure is reduced, RCP seal leak rate is concurrently reduced and RCS inventory is recovered, and the HP FLEX pump is then capable of maintaining the RCS inventory. TVA's longer-term core cooling and RCS inventory strategy involves utilizing the FLEX 6.9 kV DGs to power the installed residual heat removal, component cooling, and motor-driven auxiliary feedwater pumps (MDAFWPs) and connecting FLEX HP and intermediate pressure (IP) pumps to draw from remaining clean and/or borated water sources and ultimately the Tennessee River. The FLEX 225 kVA 480 Volt Alternating Current (Vac) DGs will power the 125 Vdc vital battery chargers and allow energizing critical loads such as required motor-operated valves, dc components, and desired ac instrumentation. For the final phase, additional equipment and supplies, such as a mobile water purification system to provide demineralized water makeup to the AFWST, will be delivered from one of two National SAFER Response Centers (NSRCs) established by the nuclear power industry to provide supplemental mitigation equipment (see Section 3.8).

The Watts Bar units have ice condenser containment buildings. Watts Bar performed a containment evaluation and determined that no immediate containment cooling or action is required due to the results of the containment temperature and pressure staying within acceptable levels in the early phase of the event. At approximately 60 hours into the event, the containment analysis recommends a 10 minute run of a Containment Air Return Fan. This operation ensures ice condenser doors open and enhance flow through the ice condenser to mitigate containment conditions for a significant period of time past 72 hours of the event. If needed, to support long term containment integrity, TVA plans to utilize the 6.9 kV FLEX DGs to power hydrogen igniters for hydrogen mitigation and provide the Lower Compartment Coolers (LCCs) with cooling water supplied by the Essential Raw Cooling Water (ERCW) system headers fed by deployed diesel powered low pressure (LP) FLEX pumps.

To maintain SFP cooling capabilities, TVA stated that the required action is to establish ventilation before SFP boiling starts so that personnel can access the SFP area to accomplish the coping strategies. The pool will initially heat up due to the unavailability of the normal cooling system. Depending on the condition of the SFP and the associated time calculated for boiling to start, the licensee will open doors before boiling starts to establish air movement and ventilation of the SFP building. To makeup to the SFP, TVA has a primary and alternate strategy to account for the condition of the pool. If the refuel floor is accessible and habitable, TVA's primary SFP strategy is to connect two FLEX hoses, one each, to the Unit 1 and Unit 2 ERCW supply headers. The discharge ends of these hoses are either routed all the way to the spent fuel pit, with the discharge ends positioned over the edge of the pit or connected to water cannons, positioned to discharge a water spray over the spent fuel pit. If the refuel floor is not accessible or habitable, the alternate strategy is to stage and connect a single FLEX hose from one of the ERCW supply headers to the FLEX connection on the demineralized water makeup line to the SFP.

3.1.1 Alternatives to NEI 12-06, Revision 0

TVA identified the pre-staging of the 480V (225kVA) and 6.9 kV (3 MW) FLEX DGs and pumps (i.e., motor-driven, IP FLEX pumps) that will be powered through the existing electrical distribution system as an alternative from the guidance in NEI 12-06, Revision 0. TVA identified this as an alternative approach due to the reliance on permanently installed plant structures and systems (i.e., electrical distribution system) and components (pre-staged DGs and pumps) in lieu of reliance on complete deployment and alignment of portable generators and diesel driven pumps to accomplish ELAP mitigation.

Below are specific details on TVA's strategies for Watts Bar to restore or maintain core cooling, containment, and SFP cooling capabilities in the event of a BDBEE and the results of the staff's review of TVA's strategies. The NRC staff evaluated TVA's strategies against the endorsed NEI 12-06, Revision 0, guidance.

3.2 Reactor Core Cooling Strategies

In accordance with Order EA-12-049, licensees are required to maintain or restore cooling to the reactor core in the event of an ELAP concurrent with a LUHS. Although the ELAP results in an immediate trip of the reactor, sufficient core cooling must be provided to account for fission product decay and other sources of residual heat. Consistent with endorsed guidance from NEI 12-06, Phase 1 of TVA's core cooling strategy credits installed equipment (other than that presumed lost to the ELAP/LUHS) that is robust in accordance with the guidance in NEI 12-06. In Phase 2, robust installed equipment is supplemented by onsite FLEX equipment, which is used to cool the core either directly (e.g., pumps and hoses) or indirectly (e.g., FLEX electrical generators and cables repowering robust installed equipment). The equipment available onsite for Phases 1 and 2 is further supplemented in Phase 3 by equipment transported from the NSRCs.

To adequately cool the reactor core, two fundamental physical requirements exist: (1) a heat sink is necessary to accept the heat transferred from the reactor core to coolant in the RCS and (2) sufficient RCS inventory is necessary to transport heat from the reactor core to the heat sink via natural circulation. Furthermore, inasmuch as heat removal requirements for the ELAP event consider only residual heat, the RCS inventory should be replenished with borated coolant in order to maintain the reactor in a subcritical condition.

As reviewed in this section, TVA's core cooling analysis for the ELAP/LUHS event presumes that, per endorsed guidance from NEI 12-06, both units at Watts Bar would have been operating at full power prior to the event. Therefore, the steam generators may be credited as the heat sink for core cooling during the ELAP/LUHS event. Maintenance of sufficient RCS inventory, despite ongoing system leakage expected under ELAP conditions, is accomplished through a combination of installed systems and FLEX equipment. The specific means used by TVA to accomplish adequate core cooling during the ELAP/LUHS event are discussed in further detail below. Because certain actions within the mitigating strategy and their timeline vary depending on whether the ELAP/LUHS results from (1) flooding or (2) other natural hazards not associated with flooding, separate discussions are provided for each case, assuming the reactor is initially operating at full power. TVA's strategy for ensuring compliance with Order EA-12-049 for conditions where one or more units are shut down or refueling is reviewed separately in Section 3.11 of this evaluation.

3.2.1 Core Cooling Strategy for Non-Flooding Event

3.2.1.1 Phase 1

As stated in TVA's October 29, 2014, FIP, the heat sink for core cooling in Phase 1 would be provided by the four SGs at each unit, which would be fed simultaneously by the unit's TDAFWP with inventory supplied from the newly constructed AFWST. During the audit review, TVA confirmed that the TDAFWP is ac-independent and that this pump, the AFWST, and the associated flow path meet applicable criteria for robustness, per NEI 12-06.

Throughout the ELAP event, RCS inventory would gradually diminish due to leakage through RCP seals and other leakage points. As is typical of operating PWRs, Watts Bar does not have installed ac-independent primary makeup capability. Therefore, TVA has performed an analysis and concluded that the SI accumulators will maintain sufficient RCS inventory in Phase 1 to support heat transfer to the SGs via natural circulation.

TVA's Phase 1 strategy directs the initiation of a cooldown and depressurization of the RCS within one hour of the initiation of the ELAP/LUHS event. Over a period of approximately 3 hours, TVA would gradually cool down the RCS from post-trip conditions until a SG pressure of 300 psig is reached. Cooldown and depressurization of the RCS significantly extends the expected coping time under ELAP/LUHS conditions because it (1) reduces the potential for damage to RCP seals (as discussed in Section 3.2.3.3) and (2) allows coolant stored in the nitrogen-pressurized accumulators to inject into the RCS to offset system leakage. TVA's evaluation indicates that the water added by the accumulators is sufficient to make up for RCP seal leakage and RCS inventory contraction (caused by the cooldown). TVA's cooldown stragety is designed to prevent nitrogen in the accumulators from entering the RCS.

3.2.1.2 Phase 2

TVA's FIP states that the primary strategy for core cooling in Phase 2 would be to continue using the SGs as a heat sink, with SG secondary inventory being supplied by the TDAFWP. According to TVA's calculations, the 500,000-gallon AFWST is capable of supplying SG makeup to both units for approximately 15 hours. TVA further stated that standing inventory in ERCW headers would provide SG makeup for an additional 7 hours for Unit 1 and 4.7 hours for Unit 2. To provide an unlimited source of secondary makeup in Phase 2, TVA stated that a LP FLEX pump would be deployed at the intake pumping station. This pump would draw suction from the intake canal (i.e., Tennessee River water) and discharge to the ERCW headers, which could in turn be aligned to provide suction to the TDAFWP.

In addition to the primary core cooling strategy discussed above, TVA indicated that a large number of flexible and redundant options exist for supplying SG makeup. Options include (1) restoring power to MDAFWPs via FLEX DGs, (2) using portable, diesel-driven, IP FLEX pumps, and (3) pre-staged, motor-driven, IP FLEX pumps. TVA further noted that portable, LP FLEX pumps could also be used to provide secondary makeup if the SGs were depressurized further to 150 psig. TVA stated that use of available clean water sources would be prioritized above raw water. Although not fully robust relative to all natural hazards associated with Order EA-12-049, TVA identified a number of clean water sources that could be available in some ELAP/LUHS scenarios, including the tritiated water storage tank, primary water storage tanks, and the demineralized water storage tank (DWST).

In order to maintain sufficient RCS inventory in Phase 2 to support natural circulation, TVA stated that FLEX DGs would be used to repower installed safety injection pumps (SIPs) and their support equipment, including the component cooling water (CCW) system. TVA stated that the SIPs would be aligned to inject borated coolant from the RWST by approximately 5 hours after ELAP/LUHS initiation. As further elaborated in Section 3.2.3.4 of this evaluation, TVA stated that at approximately 8.5 hours into the event, pre-staged, motor-driven, HP FLEX pumps would also be available to inject inventory from the RWST into the RCS. Optionally, the boric acid tanks, which contain a more highly concentrated boric acid solution than the RWST, could be used as the source for RCS makeup. TVA further stated that additional redundant equipment that could provide makeup to the RCS includes a spare pre-staged, HP FLEX pump and, if RCS pressure is reduced, diesel-driven IP FLEX pumps.

Following restoration of electrical power to the SIPs and restoration of the RCS inventory, TVA intends to isolate the accumulators and continue to cool down and depressurize the reactor until a pressure of 160 psig is reached in the SGs. Shutdown margin analysis provided to the staff during the audit indicated that the cooldown to 160 psig in the SGs would start at approximately 16 hours into the ELAP event. The analysis assumed a further cooldown to 350 °F in the RCS beginning at 20 hours into the event, in order to ensure long-term integrity of the RCP second-stage seals. Confirmatory ideal-gas-law calculations performed by the staff during the audit review indicated that TVA's strategy of isolating the accumulators prior to depressurizing below 300 psig in the SGs would be sufficient to preclude pressurized nitrogen gas from the accumulators entering the RCS and potentially interfering with natural circulation.

3.2.1.3 Phase 3

According to its FIP, TVA's core cooling strategy for Phase 3 is a continuation of the Phase 2 strategy with additional offsite equipment and resources.

As discussed above, FLEX pumps drawing suction from the intake canal, as supplemented by Phase 3 equipment from the NSRCs, is capable of providing a long-term heat sink for the RCS for an indefinite coping period. TVA's FIP stated that the Phase 3 equipment that Watts Bar would request includes water purification equipment that could be used to supply clean makeup to the SGs or for blending borated makeup for the RCS. However, TVA's October 29, 2014 FIP did not identify a long-term strategy for providing sufficient borated makeup to the RCS to support adequate heat transport to the SGs via natural circulation for an indefinite coping period. During the audit review, the NRC staff discussed this issue with TVA. Analysis performed by TVA concluded that the onsite inventory of borated coolant contained in the protected portions of the RWSTs and the protected boric acid tanks would provide a sufficient quantity of primary makeup for at least approximately four days (see Section 3.10.2). The NRC staff performed confirmatory hand calculations during the audit to verify this conclusion, based on the RCS leakage rates assumed by TVA. To address the need for indefinite coping capability, TVA revised the mitigating strategy for Watts Bar to request a mobile boration unit from the NSRCs. In addition, TVA stated that the mobile boration and water purification units would be placed into service within four days, prior to the depletion of the onsite inventory of borated coolant.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

TVA's core cooling strategy for a flood-induced ELAP/LUHS is similar to the strategy for the non-flood-induced event. Because the strategy for a flood-induced event assumes a 27-hour warning period before the site grade elevation becomes flooded, which is consistent with Watts Bar's current licensing basis, a sufficient preparation period is available wherein the initial actions from the strategy for non-flooding events may be used. As flood waters approach, however, TVA will remove from service any equipment that is not qualified for submerged operation and transition to core cooling strategies that have been qualified to the design-basis flood level. TVA's FIP further notes that, because an ELAP could occur at any time during the flood preparation or a flood event, FLEX equipment must be staged and ready for implementation if required.

Throughout each phase, the core cooling strategy for the flood-induced ELAP/LUHS event generally attempts to accomplish the same actions using approximately the same timeline as the non-flood-induced event. However, due to the potential for flooding certain areas of the plant site, (1) the specific equipment relied upon to accomplish a given function may be different (e.g., motor-driven FLEX pumps as opposed to diesel-driven FLEX pumps), and (2) the degree of redundancy for certain functions may be reduced (though remaining adequate). Key flooding-specific actions that would be taken by TVA to support core cooling include the following:

- Relocation of the LP FLEX pumps staged at the intake pumping station to higher ground prior to the arrival of floodwaters;
- Staging and aligning a second set of LP FLEX pumps;
- Align the 480-volt, motor-driven, HP FLEX pumps; and
- Align the 480-volt, motor-driven, IP FLEX pumps.

Similar to the non-flooding event, TVA's FIP for the flooding-induced event did not provide a long-term strategy for supplying sufficient borated makeup to the RCS to support natural circulation for an indefinite coping period. Consequently, during the audit review, the NRC staff requested that TVA develop a robust strategy for long-term boration that is applicable to the flooding scenario. As mentioned above and discussed in Section 3.10.2, TVA performed an analysis during the audit that concluded that the onsite inventory of borated coolant contained in the RWSTs would provide a sufficient quantity of primary makeup for at least approximately eight days. The coping time for the flooding-induced ELAP scenario is extended relative to the non-flooding scenario because additional water in the upper portions of the RWSTs is assumed to be available. This water volume is not credited in the non-flooding scenarios because the upper portions of the RWSTs are potentially vulnerable to damage from externally generated (tornado) missiles. The NRC staff performed confirmatory hand calculations to verify this conclusion, based on the RCS leakage rates assumed by TVA. As stated above, TVA revised its mitigating strategy to request a mobile boration unit from the NSRCs. In addition, TVA indicated that floodwaters would recede within four days and that the mobile boration and water purification units would be placed into service following the recession of floodwaters.

3.2.3 Staff Evaluations

3.2.3.1 Availability of Structures, Systems, and Components (SSCs)

NEI 12-06 provides guidance that the baseline assumptions have been established on the presumption that other than the loss of the ac power sources and normal access to the UHS, installed equipment that is designed to be robust with respect to design basis external events is assumed to be fully available. Installed equipment that is not robust is assumed to be unavailable. Below are the baseline assumptions for the availability of SSCs for core cooling at Watts Bar during an ELAP caused by a BDBEE.

3.2.3.1.1 Plant SSCs

Core Cooling – SG - MODES 1-4 only

Condition 6 of NEI 12-06, Section 3.2.1.3, states that permanent plant equipment contained in structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles, are available. TVA's core cooling FLEX strategies rely on its existing TDAFWP to remove heat from the RCS by providing cooling water to the four SGs as described in TVA's FIP. As described in the Watts Bar Updated Final Safety Analysis Report (UFSAR) Table 3.2-2, the TDAFWP is a seismic Category I component located in the Auxiliary Building, which is a Category I Structure (UFSAR Section 3.8.4). Based on the location of the TDAFWP, it should be available during an ELAP caused by a BDBEE, consistent with Condition 6 of NEI 12-06, Section 3.2.1.3.

In addition, TVA's core cooling FLEX strategies rely on the use of its atmospheric relief valves to control SG pressure, as described in TVA's FIP. During the audit review, TVA stated that the Unit 1 and Unit 2 SG Power Operated Relief Valves (PORVs) (Atmospheric Relief Valves) are located in Main Steam Valve Vaults (MSVVs), which are safety related and protected from major natural phenomena events. TVA stated that these valves are powered from safety related sources and supplied by a safety related control air source when required. TVA explained that as part of FLEX, backup control stations will be provided in the shutdown board rooms above the site probable maximum flood (PMF) level and procedural guidance is provided for remote manual operation of the SG PORVs. The staff confirmed in UFSAR Table 3.2-2 that the MSVVs are seismic Category I components located in the Auxiliary Building, which is a Category I structure. Based on the location of the atmospheric relief valves and TVA's proposed backup control stations in the shutdown board rooms, these valves should be available during an ELAP caused by a BDBEE, consistent with Condition 6 of NEI 12-06, Section 3.2.1.3, if implemented appropriately.

Condition 3 of NEI 12-06, Section 3.2.1.3, states that cooling and makeup water inventories contained in systems or structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles are available. The staff noted that the normal water supply for the TDAFWP is the condensate storage tank (CST); however, since this tank is not robust per NEI 12-06 it cannot be relied upon as a cooling and makeup water sources for TVA's FLEX strategies. Therefore, in its first six-month status report to Order EA-12-049 dated August 28, 2013, TVA stated that a new qualified AFWST will be installed to support FLEX. In TVA's FIP, TVA stated that the AFWST and associated piping will be qualified to be robust with respect to high winds and seismic events. The AFWST and associated piping should be available, if implemented appropriately, as a suction source for the TDAFWP for TVA's FLEX strategies consistent with Condition 3 of NEI 12-06, Section 3.2.1.3.

Condition 4 of NEI 12-06, Section 3.2.1.3, states that normal access to the UHS is lost, meaning the motive force for UHS flow (i.e., pumps) is assumed to be lost with no prospect for recovery, but the water inventory in the UHS remains available and robust piping connecting the UHS to plant systems remains intact. TVA's FIP states when the AFWST is depleted, suction flow to the TDAFWP can be provided by standing water in the ERCW headers. UFSAR Section 9.2.1 describes the ERCW system as a safety-related system that provides a safety-related source for AFW through the ERCW discharge only when preferred supply from the CST is unavailable. The staff noted that the ERCW header is located in the Auxiliary Building, which is a Category I structure. Since the motive force for UHS flow is lost with no prospect for recovery during an ELAP/LUHS event, TVA is only relying upon the standing water in the ERCW headers. During the audit, TVA provided "Evaluation of ERCW Availability during Extended Station Blackout," MDQ00006720102190, and concluded that the standing water in the ERCW system can provide gravity feed to the TDAFWP for approximately 15.5 hours for Unit 1 only. Furthermore, under dual unit operation, the TDAFWPs can be supplied for approximately 7.0 hours for Unit 1 and 4.7 hours for Unit 2. Based on TVA's calculation, the staff noted that the standing water in the ECRW header gravity drains to the suction of the TDAFW pump since the ERCW piping is at a higher elevation compared to the TDAFW pump. The staff also noted that check valves at the discharge of the ERCW pump prevent backflow to the river and check valves in the ERCW branch piping prevent backflow to the supply headers. The NRC staff review of this document did not identify any discrepancies. The standing water in the safety-related ERCW header should be available, if implemented appropriately, as a suction source for the TDAFWP for TVA's FLEX strategies consistent with Condition 4 of NEI 12-06, Section 3.2.1.3.

Primary and alternate connection points for AFW

Section 3.2.2 of NEI 12-06 states that the portable pumps for core and SFP cooling functions are expected to have a primary and an alternate connection or delivery point. It further states that at a minimum, the primary connection point should be an installed connection suitable for both the on-site and off-site equipment and the secondary connection point may require reconfiguration if it can be shown that adequate time and resources are available to support the reconfiguration. Finally, both the primary and alternate connection points do not need to be available for all applicable hazards, but the location of the connection points should provide reasonable assurance that one connection will be available. In the FIP, TVA provided the locations of the primary and alternate FLEX connection points for maintaining core cooling. TVA stated that the primary connection for the IP FLEX pumps will be located in the south MSVV on elevation 729' upstream of the level control valves on the TDAFWP discharge piping. The secondary connection will be located in the Auxiliary Building on elevation 737' upstream of the level control valves on the MDAFWP discharge piping. For both the primary and alternate FLEX connections for maintaining core cooling, TVA indicated that as part of the modifications for these connections points a Storz adapter would be used for the new branch. The staff noted that the UFSAR Section 3.8.4 indicates that the south MSVV and Auxiliary Building are Category I structures. TVA also clarified in its revised OIP to Order EA-12-049 that procedural steps will be taken to ensure that hose connections in these areas are made before flood levels reach the connection. TVA has provided a primary and alternate FLEX connection suitable for both the on-site and off-site equipment, which is located in areas such that there should be reasonable assurance at least one connection will be available, consistent with Section 3.2.2 of NEI 12-06, if implemented appropriately.

Section 3.2.1.3, Condition 6, of NEI 12-06, states that permanent plant equipment that is contained in structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles, are available. In addition, TVA stated that in order to provide an unlimited supply of water for core cooling during Phase 2, LP FLEX pumps will take suction from the intake channel and discharge to four ERCW FLEX connections inside the intake pumping station. The staff noted that UFSAR Table 3.2-1, Category I structures, indicates that the intake pumping station is a Category I structure. If implemented appropriately and consistently with the FIP, it appears that TVA has provided the additional FLEX connections that should ensure the success of its FLEX strategies, consistent with Section 3.2.1.3, Condition 6, of NEI 12-06.

RCS Inventory Control - MODES 1-4 only

Condition 3 of NEI 12-06, Section 3.2.1.3, states that cooling and makeup water inventories contained in systems or structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles are available. In its FIP, TVA states that RCS inventory is a significant concern for the ELAP scenario due to the RCP seal design. Timely RCS cooldown and depressurization while holding SG pressure to greater than 300 psig ensures no nitrogen injection into the RCS from cold leg accumulators. Furthermore, RCS makeup is required to compensate for the RCP seal leakage and from shrinkage due to cooldown; thus, Phase 1 RCS inventory makeup is provided from the safety injection system cold leg accumulators. The staff noted that UFSAR Table 3.2-2 indicates that the cold leg accumulators are seismic Category I components located in the Containment Building, which is a Category I structure. If implemented appropriately and consistently with the FIP, it appears that the water inventory in the cold leg accumulators should be available for Phase 1 RCS inventory makeup provided that SG pressure is maintained greater than 300 psig to ensure nitrogen is not injected into the RCS from the cold leg accumulators, consistent with Condition 3 of NEI 12-06, Section 3.2.1.3.

TVA's RCS inventory control Phase 2 FLEX strategies rely on its existing component cooling system pumps and SIPs to inject through all 4 cold legs to recover RCS pressurizer level. The staff noted that the component cooling system pump serves the SIP lube oil coolers (UFSAR Section 9.2.2.1). As described in UFSAR Table 3.2-2, the CCW pumps and SIPs are seismic Category I components located in the Auxiliary Building, which is a Category I structure (UFSAR Section 3.8.4). If implemented appropriately and consistently with the FIP, it appears that the CCW pumps and SIPs should be available for TVA's RCS inventory control FLEX strategies consistent with Condition 6 of NEI 12-06, Section 3.2.1.3. The discussion of the suction source for these pumps is discussed in Section 3.10 of this SE.

Primary and Alternate Connection Points for RCS Inventory Control

Section 3.2.2 of NEI 12-06 states that the portable pumps for core and SFP cooling functions are expected to have a primary and an alternate connection or delivery point. It further states that at a minimum, the primary connection point should be an installed connection suitable for both the on-site and off-site equipment and the secondary connection point may require reconfiguration if it can be shown that adequate time and resources are available to support the reconfiguration. Finally, both the primary and alternate connection points do not need to be available for all applicable hazards, but the location of the connection points should provide reasonable assurance of at least one connection being available. In its FIP, TVA provided the locations of the primary and alternate FLEX connection points for RCS inventory control. TVA indicated that the primary RCS makeup FLEX connection will be on the SIP Train B discharge line, and the secondary (or alternate) RCS makeup FLEX connection will be on the SIP Train A discharge line, with both connections in the SIP room at elevation 692'. For both the primary and alternate FLEX connections for RCS inventory control TVA indicated that as part of the modifications for these connections points hose adapters would be added. The staff noted from UFSAR Table 3.2-2 that the SIPs and discharge lines are seismic Category I components and located in a Category I structure. Furthermore, in the FIP, TVA stated that for the RWST connections required during flood conditions, procedures will ensure that hoses are connected before flood levels reach the connection. If implemented appropriately and consistently with the FIP, it appears that TVA has provided a primary and alternate FLEX connection suitable for both the on-site and off-site equipment, which is located in areas such that there should be reasonable assurance at least one connection will be available, consistent with Section 3.2.2 of NEI 12-06.

3.2.3.1.2 Plant Instrumentation

According to TVA's FIP, the following instrumentation would be relied upon to support its core cooling strategy:

- SG wide-range level or narrow-range level with AFW flow indication
- SG pressure
- AFWST level
- core exit thermocouple temperature
- RCS hot leg temperature (if core exit thermocouples are not available)
- RCS cold leg temperature
- RCS wide-range pressure
- pressurizer level
- reactor vessel level indicating system
- neutron flux
- accumulator level

For the flooding-induced ELAP/LUHS scenario, TVA stated that indications associated with cold leg temperature, core exit thermocouples, and the reactor vessel level indicating system would become unavailable due to submergence. If cold leg temperature indication becomes unavailable, TVA intends to infer cold leg temperature from the SG pressure via the saturation relationship. This substitution appears reasonable because TVA stated that natural circulation would be maintained in the RCS, which would ensure that the primary and secondary systems remain thermally coupled. Similarly, the NRC staff agrees with TVA's substitution of RCS hot leg temperature for the core exit thermocouple temperature given that natural circulation will be maintained. As discussed elsewhere in this evaluation (e.g., Section 3.2.3.4), TVA stated that sufficient borated makeup will be provided to the RCS to restore and maintain an indicated level in the pressurizer by the time the reactor vessel level indicating system could become unavailable due to flooding. Therefore, if implemented appropriately, the staff considers TVA's monitoring of RCS inventory during the ELAP/LUHS event to be acceptable.

TVA's FIP states that, as recommended by Section 5.3.3 of NEI 12-06, procedures have been developed to read the above instrumentation locally using a portable instrument, where applicable.

3.2.3.2 Thermal-Hydraulic Analyses

TVA concluded that its mitigating strategy for reactor core cooling would be adequate based in part on a generic thermal-hydraulic analysis performed for a reference Westinghouse four-loop reactor using the NOTRUMP computer code. The NOTRUMP code and corresponding evaluation model were originally submitted in the early 1980s as a method for performing licensing-basis safety analyses of small-break loss-of-coolant accidents (LOCAs) for Westinghouse PWRs. Although NOTRUMP has been approved for performing small-break LOCA analysis under the conservative Appendix K paradigm and constitutes the current evaluation model of record for many operating PWRs, the NRC staff had not previously examined its technical adequacy for performing best-estimate simulations of the ELAP event. Therefore, in support of mitigating strategy reviews to assess compliance with Order EA-12-049, the NRC staff evaluated licensees' thermal-hydraulic analyses, including a limited review of the significant assumptions and modeling capabilities of NOTRUMP and other thermal-hydraulic codes used for these analyses. The NRC staff's review included performing confirmatory analyses with the TRACE code to obtain an independent assessment of the duration that reference reactor designs could cope with an ELAP event prior to providing makeup to the RCS.

Based on its review, the NRC staff questioned whether NOTRUMP and other codes used to analyze ELAP scenarios for PWRs would provide reliable coping time predictions in the reflux or boiler-condenser cooling phase of the event because of challenges associated with modeling complex phenomena that could occur in this phase, including boric acid dilution in the intermediate leg loop seals, two-phase leakage through RCP seals, and primary-to-secondary heat transfer with two-phase flow in the RCS. Due to the challenge of resolving these issues within the compliance schedule specified in Order EA-12-049, the NRC staff requested that industry provide makeup to the RCS prior to entering the reflux or boiler-condenser cooling phase of an ELAP, such that reliance on thermal-hydraulic code predictions during this phase of the event would not be necessary.

Accordingly, the ELAP coping time prior to providing makeup to the RCS is limited to the duration over which the flow in the RCS remains in natural circulation, prior to the point where continued inventory loss results in a transition to the reflux or boiler-condenser cooling mode. In particular, for PWRs with inverted U-tube SGs, the reflux cooling mode is said to exist when vapor boiled off from the reactor core flows out the saturated, stratified hot leg and condenses on SG tubes, with the majority of the condensate subsequently draining back into the reactor vessel in countercurrent fashion. Quantitatively, as reflected in documents such as Pressurized-Water Reactor Owners Group (PWROG) PWROG-14064-P, Revision 0, "Application of NOTRUMP Code Results for Westinghouse Designed PWRs in Extended Loss of AC Power Circumstances," industry has proposed defining this coping time as the point at which the one-hour centered time-average of the flow quality passing over the SG tubes' U-bend exceeds one-tenth (0.1). As discussed further in Section 3.2.3.4 of this evaluation, a second metric for ensuring adequate coping time is associated with maintaining sufficient natural circulation flow in the RCS to support adequate mixing of boric acid.

With specific regard to NOTRUMP, preliminary results from the NRC staff's independent confirmatory analysis performed with the TRACE code indicated that the coping time for Westinghouse PWRs under ELAP conditions could be shorter than predicted in WCAP-17601-P, "Reactor Coolant System Response to the Extended Loss of AC Power Event for Westinghouse, Combustion Engineering and Babcock & Wilcox NSSS Designs." Subsequently, a series of additional simulations performed by the staff and Westinghouse identified that the discrepancy in predicted coping time could be attributed largely to differences in the modeling of RCP seal leakage. (The topic of RCP seal leakage will be discussed in greater detail in Section 3.2.3.3 of this SE.) These comparative simulations showed that when similar RCP seal leakage boundary conditions were applied, the coping time predictions of TRACE and NOTRUMP were in adequate agreement. From these simulations, as supplemented by review of key code models, the NRC staff obtained sufficient confidence that the NOTRUMP code may be used in conjunction with the WCAP-17601-P evaluation model for performing best-estimate simulations of ELAP coping time prior to reaching the reflux cooling mode.

Although the NRC staff obtained confidence that the NOTRUMP code is capable of performing best-estimate ELAP simulations prior to the initiation of reflux cooling using the one-tenth flow-quality criterion discussed above, the staff was unable to conclude that the generic analysis performed in WCAP-17601-P could be directly applied to all Westinghouse PWRs, as the vendor originally intended. In PWROG-14064-P, Revision 0, the industry subsequently recognized that the generic analysis would need to be scaled to account for plant-specific variation in RCP seal leakage. However, the staff's review, supported by sensitivity analysis performed with the TRACE code, further identified that plant-to-plant variation in additional parameters, such as RCS cooldown terminus, accumulator pressure and liquid fraction, and initial RCS mass, could also result in substantial differences between the generically predicted reference coping time and the actual coping time that would exist for specific plants.

The NRC staff's audit review identified that TVA was relying on the generic industry methodology outlined in PWROG-14064-P that would scale the NOTRUMP reference analysis only according to the expected RCP seal leakage rate. Although TVA's FIP stated that no deviations exist relative to the generic Westinghouse four-loop reference analysis in WCAP-17601-P, the staff identified differences between plant-specific parameters for Watts Bar and those used in the reference case that had not been accounted for, which could impact the predicted coping time. Some of these differences would adversely affect the predicted coping time (e.g., increased final cooldown pressure and accumulator design parameters for Watts Bar would lead to reduced passive injection), whereas others could have a favorable impact if justifiable (e.g., earlier cooldown initiation time, increased cooldown rate, increased initial RCS mass). According to TVA's original calculations, a core cooling strategy providing makeup to the RCS within five hours would have resulted in a margin of approximately 4.5 hours to the onset of reflux cooling. However, in light of staff estimates that the coping time could be significantly reduced by plant-specific differences that were not accounted for in the generic scaling process (most notably the difference in cooldown terminus and accumulator design parameters), the staff was unable to conclude that TVA's planned time for initiating RCS makeup would be sufficient.

To address the staff's concern, TVA performed a more detailed hand calculation to scale the generically calculated coping time to Watts Bar. The revised calculation explicitly accounted for differences in the cooldown terminus and accumulator design, but did not credit conservatisms associated with the earlier cooldown time and larger initial RCS mass. The revised calculation concluded that reflux cooling would not be entered sooner than 5.8 hours after initiation of the ELAP event. The NRC staff audited the calculation, performed confirmatory hand calculations, and compared the results with earlier generic Westinghouse four-loop simulations using the TRACE code. The staff's review demonstrated adequate agreement with TVA's conclusion. The NRC staff also considered the retention of conservative margins in TVA's calculated time to entering reflux cooling to be an important factor in its evaluation, given the presence of nonconservative simplifications in the generic method established by the PWROG for approximating the integrated seal leakage during the ELAP event.

Therefore, based on the evaluation above, TVA's analytical approach should appropriately determine the sequence of events, including time-sensitive operator actions, and the required equipment to mitigate the analyzed ELAP event, including pump sizing and cooling water capacity.

3.2.3.3 Reactor Coolant Pump Seals

Leakage from the RCP seals is among the most significant factors in determining the duration that a pressurized-water reactor can cope with an ELAP event prior to initiating RCS makeup. An ELAP event would interrupt cooling to the RCP seals, resulting in increased leakage and the potential for failure of elastomeric o-rings and other components, which could further increase the leakage rate. As discussed above, as long as adequate inventory is maintained in the RCS, natural circulation can effectively transfer residual heat from the reactor core to the SGs and limit local imbalances in boric acid concentration. Along with cooldown-induced shrinkage of the RCS inventory, cumulative leakage from RCP seals governs the duration over which natural circulation can be maintained in the RCS. Furthermore, the seal leakage rate at the depressurized condition can be a controlling factor in determining the flow capacity requirement for FLEX pumps to offset ongoing RCS leakage and recover adequate system inventory.

The Model 93AS RCPs at Watts Bar use a standard three-stage Westinghouse seal package. As noted in Section 3.2.3.2, TVA is relying on thermal-hydraulic analysis performed with the NOTRUMP code, as documented in Sections 5.2.1 and 5.2.2 of WCAP-17601-P, to determine the time at which makeup would be required to maintain adequate natural circulation flow in the RCS. In accordance with analysis and testing documented in WCAP-10541-P, "Westinghouse Owners Group Report, Reactor Coolant Pump Seal Performance Following a Loss of All AC Power," Revision 2, the ELAP analysis in WCAP-17601-P assumed a leakage rate at generic post-trip cold leg conditions (i.e., 2250 psia and 550 °F) of 21 gpm for each of the four RCPs, plus an additional 1 gpm of operational leakage. In the WCAP-17601-P analysis, both seal and operational leakage were assumed to vary according to the critical flow correlation modeled in the NOTRUMP code as the reactor was cooled down and depressurized.

Recent assessments of RCP seal leakage behavior under ELAP conditions by industry analysts and NRC staff identified several issues with the original treatment of seal leakage from standard Westinghouse seal packages. The concerns are documented in the Westinghouse Nuclear

Safety Advisory Letter (NSAL) NSAL-14-1, dated February 10, 2014, including (1) the initial post-trip leakage rate of 21 gpm does not apply to all Westinghouse pressurized-water reactors due to variation in seal leak off line hydraulic configurations, (2) seal leakage does not appear to decrease with pressure as rapidly as predicted by the analysis in WCAP-17601-P, and (3) some reactors may experience post-trip cold leg temperatures in excess of 550 °F, depending on the lowest main steam safety valve lift setpoint. To address these issues, the PWROG performed additional analytical calculations using Westinghouse's seal leakage model (i.e., ITCHSEAL). These calculations included (1) benchmarking calculations against test data and (2) additional generic calculations for several groups of plants (categorized by similarity of first-stage seal leakoff line design) to determine the maximum leakage rates as well as the maximum pressures that may be experienced in the first-stage seal leakoff line piping.

During the audit review, TVA indicated that Watts Bar is relying on the generic Westinghouse RCP seal leakage calculations that have been performed by the PWROG. The generic PWROG calculations audited by the staff, including proprietary reports PWROG-14015, "No. 1 Seal Flow Rate for Westinghouse Reactor Coolant Pumps Following Loss of All AC Power," and PWROG-14027, "No. 1 Seal Flow Rate for Westinghouse Reactor Coolant Pumps Following Loss of All AC Power, Task 3: Evaluations of Revised Seal Flow Rate on Time to Enter Reflux Cooling and Time at which the Core Uncovers," classify Watts Bar in the second generic analysis category (i.e., Category 2) specified in NSAL-14-1. As noted above, the generic analysis category definitions used in these reports were established based on the hydraulic characteristics of the first-stage seal leakoff line. TVA provided further information which confirmed that the leakoff line hydraulic characteristics for Watts Bar are bounded by the assumed characteristics analyzed for Category 2. The analysis for Category 2 plants showed a substantial reduction in the permissible coping time prior to the onset of reflux cooling as compared to the original analysis from WCAP-17601-P. Whereas the original coping time from WCAP-17601-P using the criterion of one-tenth flow quality in the SG U-bend was calculated to be 17.2 hours, when scaled to account for the increased integrated leakage associated with Category 2, this category's generic coping time was reduced to 9.6 hours. (As noted in the previous section, a conservative calculation for Watts Bar reviewed by the staff during the audit concluded that this time could be further reduced to 5.8 hours based on specific characteristics associated with the Watts Bar plant.)

In support of beyond-design-basis mitigating strategy reviews, the NRC staff performed an audit of the PWROG's generic effort to determine the expected seal leakage rates for Westinghouse RCPs under loss-of-seal-cooling conditions. A key audit issue was the capability of Westinghouse's ITCHSEAL code to reproduce measured seal leakage rates under representative conditions. Considering known testing and operational events according to their applicability to the thermal-hydraulic conditions associated with the analyzed ELAP event, the benchmarking effort focused on comparisons of ITCHSEAL simulations to RCP seal leakage testing performed in the mid-1980s at Electricite de France's Montereau facility. Comparisons of analytical results to the Montereau data indicated that, while the leakage rate simulated by ITCHSEAL could be tuned to reproduce the measured seal leakage rate data, good agreement with respect to pressure could not be obtained simultaneously. During the audit, the NRC staff also reviewed the limited information available from Westinghouse and AREVA associated with corrosion of the silicon nitride ceramic used to fabricate the first-stage seal faceplates currently used in Westinghouse-designed RCP seals. This specific material corrosion phenomenon was not present in the Montereau testing because that test article's faceplates were fabricated from aluminum oxide, consistent with the seals of actual Westinghouse-designed RCPs of that era. However, this corrosion phenomenon became a focus later in the audit when preliminary results of recent seal leakage rate testing conducted with silicon nitride faceplates at AREVA's Karlstein facility were discussed verbally with the NRC staff. Industry hypothesized that unexpected increases in the measured leakage in the mid-to-late stages of the AREVA Karlstein tests resulted from material degradation of silicon nitride, and that the material degradation could be prevented in an actual ELAP event by an early cooldown of the RCS (as discussed above, e.g., Section 3.2.1.1). Industry provided information to support its hypothesis; however, the information presented during the Watts Bar audit was not sufficient to definitively confirm this hypothesis.

Based on the summary above, at the present time the NRC staff is unable to conclude that Westinghouse's analytical modeling of RCP seal leakage is acceptable on its own merits. However, in the context that this seal leakage model is an input to the greater FLEX mitigating strategy for Watts Bar that is specifically under review, the NRC staff made the following observations that balance the above modeling uncertainties and potential deficiencies:

- The PWROG's generic ITCHSEAL calculations contain known conservatisms, for example, as observed in the comparison of the results of the generic analysis to the Montereau test data and in the application of the generic leakoff line configuration assumptions for each maximum leakage analysis category to individual plants' leakoff lines.

- The mitigating strategy for Watts Bar incorporates a number of favorable aspects, such as initiating an RCS cooldown no later than one hour into the ELAP event, possessing the capability to initiate RCS makeup within 5 hours, having abundant supplies of borated coolant onsite, and having a relatively large capacity for injecting borated coolant from the RWSTs using an installed SIP.

- TVA's calculated time for entering reflux cooling conservatively neglected certain beneficial characteristics of Watts Bar relative to the reference plant, including increased initial RCS mass and an earlier cooldown initiation time.

- According to its FLEX procedures, TVA will monitor RCS inventory (e.g., reactor pressure vessel level) during the ELAP event and would attempt to implement primary makeup more rapidly if signs of increased RCP seal leakage were detected.

- Although entry into reflux cooling is undesirable and has not been fully analyzed in the context of the ELAP event, the NRC staff expects that the use of this threshold as an acceptance criterion provides significant margin to uncover and severely damage the core.

Based on consideration of the above observations and according to our present understanding, the staff considered RCP seal leakage modeling to be resolved with respect to its impact on the mitigating strategy for Watts Bar. However, if subsequent efforts associated with modeling RCP seal leakage demonstrate significant reductions in margin relative to the staff's current understanding, it is the staff's expectation that TVA take corrective actions to recover the lost margin, such that natural circulation in the RCS can be ensured during the analyzed ELAP event and compliance with the order is maintained.

The generic seal leakoff analysis discussed above assumes no failure of the seal design, including the elastomeric o-rings. During the audit review, TVA stated that Watts Bar began using high-temperature-qualified o-rings soon after their introduction in 1991. The audited information further asserted that existing Watts Bar procedures include a specification for o-ring part numbers that have been verified to be high-temperature qualified where high-temperature service is required. However, TVA's completion of a more detailed assessment in response to the NRC staff's questions revealed that two o-rings of the earlier 7228-B design are currently installed in two different RCPs at Watts Bar, Unit 1. Unlike subsequent designs, 7228-B and earlier o-rings were not specifically qualified to withstand extended exposure to the maximum temperatures that could be experienced by Watts Bar and many other PWRs during a loss-of-seal-cooling event. In its review of the impact of these two 7228-B o-rings with respect to the beyond-design-basis ELAP event, the NRC staff considered the following relevant information provided during the audit: (1) 7228-B o-rings have been qualified for a temperature reasonably close to the maximum temperature applicable to Watts Bar for an extended period of time, (2) TVA intends to initiate the RCS cooldown without delay, (3) the two 7228-B o-rings are installed at locations that were shown in WCAP-10541-P, Revision 2, not to be limiting for o-ring qualification, and (4) TVA's intent to replace both 7228-B o-rings by Spring 2017, and henceforth to use only o-rings qualified for the maximum temperatures applicable to Watts Bar during an ELAP event. Based on these factors, the staff's audit review concluded that o-ring failure for Watts Bar during a beyond-design-basis ELAP event would not be expected.

In order to ensure that the generic Category 2 (from NSAL-14-1) leakage rates are applicable to Watts Bar, the NRC staff requested during the audit that TVA confirm that applicable portions of the first-stage seal leakoff line piping can withstand the maximum pressure experienced during an ELAP event. According to generic calculations performed by Westinghouse using the ITCHSEAL code, Category 2 plants would be expected to experience choked flow at the flow-measurement orifice in the first-stage seal leakoff line, even after completion of the RCS cooldown. Therefore, to support application of the generic Category 2 leakage rates, it is necessary for TVA to demonstrate that a rupture in the pressure boundary of leakoff line piping or components upstream of the flow orifice would not occur at Watts Bar. During the audit, the NRC staff reviewed a bounding analysis of the piping stress that could potentially occur during an ELAP event for Watts Bar. The analysis assumed a maximum pressure of 2500 psig and included additional stresses from thermal, deadweight, water hammer, and relief valve loads. The NRC staff review of this analysis did not identify any discrepancies.

During the audit review, TVA confirmed that, following the loss of seal cooling that results from the ELAP event, seal cooling will not be restored. The NRC staff considers this practice appropriate because it prevents thermal shock, which, as described in Information Notice 2005-14, "Fire Protection Findings on Loss of Seal Cooling to Westinghouse Reactor Coolant Pumps," could lead to increased leakage seal leakage.

In conjunction with the revised seal leakage analysis that Westinghouse performed, as described above, the PWROG generic effort also sought to demonstrate that the second-stage seal will remain fully closed during the ELAP event. If the second-stage seal were to open, an additional term accounting for leakage past the second-stage seal and up the pump shaft could add to the first-stage seal leakoff line flow that has been considered in TVA's evaluation discussed in this section. Previous calculations documented in WCAP-10541-P indicated that second-stage seal closure could be maintained under the set of station blackout conditions and associated assumptions analyzed therein. However, based on (1) enhanced understanding of seal performance under ELAP conditions that include a cooldown of the RCS and (2) revised modeling assumptions that better correspond to realistic leakoff line configurations, additional vendor calculations were performed to determine the expected second-stage seal behavior under ELAP conditions. In addition, the pump vendor reviewed available seal leakage test data under conditions that envelop those associated with the analyzed ELAP event for a Westinghouse plant following the generically recommended cooldown strategy. The results of the review indicated that essentially no leakage through the second-stage seal was observed in the applicable tests. Although the staff was unable to assess the degree of uncertainty in the vendor's analysis, based on the strength of the evidence associated with the applicable RCP seal leakage tests, the staff considered TVA's assumption of no significant leakage through the second-stage seal to be justified for the beyond-design-basis ELAP event. During the audit review, TVA further confirmed that it would implement an additional cooldown of the RCS to below 350 °F and 400 psig within 24 hours to satisfy recommendations from Westinghouse associated with maintaining long-term integrity of the second-stage seal.

Based upon the discussion above, the NRC staff concludes that the RCP seal leakage rates assumed in TVA's thermal-hydraulic analysis may be applied to the beyond-design basis ELAP event for Watts Bar.

3.2.3.4 Shutdown Margin Analyses

In an analyzed ELAP event, the loss of electrical power to control rod drive mechanisms is assumed to result in an immediate reactor trip with the full insertion of all control rods into the core. The insertion of the control rods provides sufficient negative reactivity to achieve subcriticality at post-trip conditions. However, as the ELAP event progresses, the shutdown margin for PWRs is typically affected by several primary factors:

- the cooldown of the RCS and fuel rods adds positive reactivity
- the concentration of xenon-135
    - initially increases above its equilibrium value following reactor trip, thereby adding negative reactivity
    - peaks at roughly 12 hours post-trip and subsequently decays away gradually, thereby adding positive reactivity
- the injection of borated makeup from passive accumulators due to the depressurization of the RCS, which adds negative reactivity

At some point following the cooldown of the RCS, PWR licensees' mitigating strategies generally require active injection of borated coolant via FLEX equipment. In many cases, boration would become necessary to offset the gradual positive reactivity addition associated with the decay of xenon-135; but, in any event, borated makeup would eventually be required to offset ongoing RCS leakage. The necessary timing and volume of borated makeup depend on the particular magnitudes of the above factors for individual reactors.

The NRC staff requested that the industry provide additional information to justify that borated makeup would adequately mix with the RCS volume under natural circulation conditions potentially involving two-phase flow. In response, the PWROGs submitted a position paper, dated August 15, 2013 (withheld from public disclosure due to proprietary content), which provided test data regarding boric acid mixing under single-phase natural circulation conditions and outlined applicability conditions intended to ensure that boric acid addition and mixing during an ELAP would occur under conditions similar to those for which boric acid mixing data is available. In a letter dated January 8, 2014 (ADAMS Accession No. ML13276A183), the NRC staff endorsed the above position paper with three conditions:

- The required timing and quantity of borated makeup should consider conditions with no RCS leakage and with the highest applicable leakage rate.
- Adequate borated makeup should be provided either (1) prior to the RCS natural circulation flow decreasing below the flow rate corresponding to single-phase natural circulation, or (2) if provided later, then the negative reactivity from the injected boric acid should not be credited until one hour after the flow rate in the RCS has been restored and maintained above the flow rate corresponding to single-phase natural circulation.
- A delay period adequate to allow the injected boric acid solution to mix with the RCS inventory should be accounted for when determining the required timing for borated makeup. Provided that the flow in all loops is greater than or equal to the corresponding single-phase natural circulation flow rate, a mixing delay period of one hour is considered appropriate.

During the audit review, TVA confirmed that Watts Bar will comply with the August 15, 2013, position paper on boric acid mixing, including the conditions imposed in the staff's corresponding endorsement letter.

According to the FIP, TVA expects that the RCS would be refilled by approximately 6 hours into the ELAP using a repowered SIP drawing from the RWST. As such, the RCS would be restored to single-phase natural circulation flow conditions that would facilitate adequate boric acid mixing well prior to the negative reactivity peak provided by the buildup of xenon-135.

TVA performed calculations at various times in core life to determine the quantity of injected boric acid that would be necessary, if any, to ensure that Watts Bar will have adequate shutdown margin following xenon decay for an ELAP initiated at any time during the operating cycle. TVA's calculations considered cases with the highest expected RCP seal leakage as well as cases with no RCS leakage. During the audit, the NRC staff reviewed TVA's shutdown margin calculation. As noted previously, TVA would have a SIP available for injection at approximately 5 hours into the event, and pre-staged, motor-driven, HP FLEX pumps available at approximately 8.5 hours. Both pumps would preferentially draw suction from the RWST, but the pre-staged, motor-driven, HP FLEX pumps could alternately draw suction from the boric acid tanks. From discussions with TVA during the audit review, the staff understands that the SIPs would be used to refill the RCS rapidly to compensate for integrated RCS leakage and cooldown-induced contraction of the RCS inventory. Subsequently, TVA would make up for continuing system leakage by placing into service the HP FLEX pumps, which have a reduced flow capacity that is closer to the expected RCS leakage rate following depressurization.

The staff observed during the audit review that the shutdown margin calculation appeared to be based on core design information from specific recent operating cycles. The staff considered this practice appropriate but suggested during the audit that TVA revise its core reload procedure to include a step to verify that the shutdown margin calculation for ELAP conditions remains bounding for core designs in future operating cycles. During the audit review, TVA stated that future core designs will be verified to be bounded by the existing ELAP shutdown margin analysis and that Watts Bar's procedure for nuclear core design and analysis has been revised to reflect this commitment.

The staff further observed that the shutdown margin calculation originally reviewed during the audit was based on a final cooldown temperature of 430 °F, which corresponds approximately to the expected initial RCS temperature at a SG pressure of 300 psig. The NRC staff's review identified two issues associated with this calculation, which are described below along with their resolution:

- First, TVA's FIP included a new action to reduce the SG pressure to 160 psig at 6 hours in both the flood and non-flood induced ELAP scenarios. Due to primary-secondary thermal coupling, via the saturation relationship, the reduced SG pressure would result in additional cooling of the RCS, to approximately 370°F. The positive reactivity added by the extended RCS cooldown did not appear to have been considered in the shutdown margin calculations provided to the staff for audit review. As a result, the NRC staff was unable to conclude that adequate shutdown margin exists to support the extended cooldown proposed in TVA's FIP. During the audit review, the NRC staff raised this issue with TVA. Based on discussions during the audit, the staff understood that the licensee would pursue an extended RCS cooldown to a temperature below 350 °F within 24 hours to support compliance with vendor recommendations to ensure the integrity of the second-stage RCP seals. Near the conclusion of the audit, the NRC staff reviewed a revised shutdown margin analysis for Watts Bar which showed that adequate shutdown margin would exist to support an additional RCS cooldown such that (1) a reduction in SG pressure to 160 psig could be accomplished starting at 16 hours into the ELAP event and that (2) a cooldown to 350 °F could be achieved within 24 hours according to the RCP vendor's recommended timeframe. Therefore, the staff considered the cooldown strategy outlined in the shutdown margin calculation to be appropriate for Watts Bar.

- Second, assuming an RCS temperature of 430 °F would be a nonconservative input to the shutdown margin calculation at a SG pressure of 300 psig because increased positive reactivity would be added as the RCS continues to cool down beyond this temperature. During the audit review, TVA provided a revised version of the shutdown margin calculation which recognized the issue and provided a more representative determination of cold leg temperature as a function of time during an ELAP event. The analysis specifically considered the cooling effect associated with providing RCS makeup per the planned FLEX

> mitigating strategy. The audited calculation further indicated that required boron concentrations in the revised best-estimate calculation incorporate conservatism (e.g., if the RCS temperature is predicted to be 380 °F, then a value as low as 350 °F is selected).

In light of the revised shutdown margin analysis for Watts Bar that was reviewed by the NRC staff near the conclusion of the audit, the NRC staff considered the above issues from the audit to be resolved.

The NRC staff reviewed the mitigating strategy described in TVA's FIP to ascertain whether sufficient sources of long-term borated makeup had been identified to replenish RCS inventory for an indefinite coping period. Although (1) sufficient borated makeup was demonstrated to satisfy the shutdown margin requirement for the xenon-free condition at a SG pressure of 300 psig, and (2) the flow capacity provided by the repowered SIP and available HP FLEX pumps appeared sufficient to offset expected long-term RCS leakage, TVA's FIP did not provide sufficient confidence that adequate borated makeup could be prepared and injected via FLEX equipment or installed robust systems for an indefinite period (i.e., to offset ongoing system leakage). Therefore, the NRC staff requested during the audit that TVA provide further description of (1) the equipment that would be credited with preparing and injecting borated makeup over an indefinite coping period for both the non-flooding and flooding scenarios, (2) a description of whether any credited installed equipment is robust as defined in NEI 12-06, (3) whether filtration equipment would be used to prevent debris suspended in raw water sources from being introduced into the reactor vessel, and (4) the long-term leakage rate from the RCS that would need to be offset by borated makeup. During the audit review, TVA discussed its responses to these information requests. As noted previously, TVA revised the Watts Bar mitigating strategy to request a mobile boration unit from the NSRCs. TVA indicated that the mobile boration equipment would be delivered and aligned prior to the depletion of onsite, robust sources of borated coolant in both the non-flooding and flooding scenarios. In addition, TVA stated that Watts Bar will use filtration equipment to purify the water used for RCS makeup. The RCS leakage rate considered in the determination of the requisite volume of borated coolant and the necessary makeup flow rate was consistent with the values from the generic PWROG program (see Section 3.2.3.3 above) and conservatively did not credit extending the cooldown to a SG pressure of 160 psig starting at approximately 16 hours and to an RCS temperature below 350 °F by 24 hours. In light of this information reviewed during the audit, the NRC staff's technical concerns associated with the long-term boration capability for Watts Bar were resolved.

Based upon a review of TVA's procedures for implementing its mitigating strategy, the NRC staff observed that, if venting of the RCS were necessary to support the injection of borated makeup, TVA would preferentially vent via PORVs on the pressurizer rather than the reactor vessel head vent system. Venting the RCS may be necessary under ELAP conditions for some PWRs to limit the pressure increase associated with injected coolant compressing accumulated vapor (e.g. in the vessel upper head or pressurizer) or in some cases to avoid water-solid conditions in the RCS. The staff noted that, consistent with NUREG-0737, "Clarification of TMI Action Plan Requirements," the reactor vessel head vent system was designed to provide reliable capability to vent noncondensable gas or steam from the reactor vessel head under post-accident conditions. During the audit review, the NRC staff suggested that use of the reactor vessel head vent system would be preferable to pressurizer PORVs for two main reasons: (1) use of the smallest vent path capable of providing the required letdown is desirable, especially under ELAP/LUHS conditions where the availability of HP pumps and borated makeup may be limited, and (2) the reactor vessel head vent system is safety-related and redundant, which provides increased confidence in the capability to isolate the vent path when it is no longer required. The staff further noted that the need for venting the RCS to assure the availability of adequate volume to accept borated makeup could be lessened through the use of a highly concentrated boric acid makeup solution, such as that available in the boric acid tanks. Following audit discussions with the NRC staff, the Watts Bar FLEX procedures were revised to vent the RCS, if necessary, using the reactor pressure vessel head vents as a first preference. If RCS venting were required and plant operators could not achieve satisfactory venting using the head vents, procedures would then allow venting via the pressurizer PORV under certain conditions (e.g., provided that the associated block valve is also available). The NRC staff considered the change in venting strategy to be prudent and appropriate in light of uncertainties associated with natural hazards of sufficient magnitude to initiate an ELAP event. The NRC staff further noted that the revised shutdown margin calculation reviewed near the conclusion of the audit indicated that venting of the RCS would not be expected to be necessary for the analyzed ELAP event.

Therefore, based on the evaluation above, the sequence of events in the proposed mitigating strategy should result in acceptable shutdown margin for the analyzed ELAP event.

3.2.3.5 FLEX Pumps and Water Supplies

The staff noted that TVA identified the performance criteria (e.g., flow rate, discharge pressure, total dynamic head) for its FLEX Phase 2 and Phase 3 portable pumps in its FIP dated October 29, 2014. The staff noted that the performance criteria for the FLEX Phase 2 portable pumps are consistent with the FLEX Phase 3 portable pumps. During the audit review, TVA provided the FLEX as-built hydraulic calculation (Watts Bar, Units 1 and 2 As-Built FLEX System Fathom Model, CN-FSE-14-36, Revision 0), which demonstrated that the FLEX Phase 2 portable pumps identified in its revised OIP are capable of providing sufficient make-up to the SGs, RCS and refilling the AFWST. The staff noted that TVA's calculation relied upon Applied Flow Technology Fathom models to create an as-built hydraulic model using FLEX strategies contained in its revised OIP and the purchased valve datasheets and pump curves for each FLEX valve and pump. The staff noted that TVA's calculation relied upon actual piping isometrics, FLEX valves and connections, and hose lengths and diameters (suction and discharge) to ensure the FLEX pumps can support each FLEX safety function. The staff also noted that TVA's calculation determined that the actual flow rates provided by the FLEX Phase 2 portable pumps exceeds the required flow rates for each of the FLEX safety functions; thus, the FLEX pumps TVA have available are capable of providing the necessary water for the SGs, RCS or refilling the AFWST. The available water sources for these Phase 2 and 3 FLEX portable pumps are discussed in Section 3.10 of this SE.

Based on its review, the staff finds that TVA, if implemented appropriately, has demonstrated that its FLEX portable pumps are capable of supporting the water make-up to the SGs, RCS and refilling the AFWST.

3.2.3.6 Electrical Analyses

TVA's electrical FLEX strategies are identical for maintaining or restoring core cooling, containment, and spent fuel pool cooling, except as noted in Sections 3.3.4.4 and 3.4.4.4 of this SE. Furthermore, the electrical coping strategies are the same for all modes of operation.

Watts Bar is using two pre-staged 480 V (225 kVA) and two pre-staged 6.9 kV (3 MW) FLEX DGs and pre-staged pumps that will be powered through the existing electrical distribution system as part of their strategy. TVA identified this as an alternative approach from the strategies identified in NEI 12-06, as endorsed, by the NRC in JLD-ISG-2012-01, due to reliance on permanently installed plant structures and systems (i.e., electrical distribution system) and components (pre-staged DGs and pumps) in lieu of reliance on complete deployment and alignment of portable DGs and diesel driven pumps as part of ELAP event mitigation.

The 480 V FLEX DGs are pre-staged to provide power to the 125 Vdc Vital Batteries and the 120 Vac Vital Instrument Power System through the Vital Inverters. These DGs are pre-staged on the Auxiliary Building roof and are protected from external hazards with an initial supply of fuel for 8 hours of operation. Additionally, the onsite 6.9 kV FLEX DGs are pre-staged in the FLEX Equipment Storage Building (FESB) to provide power to the existing 6.9 kV Shutdown Power distribution system and via the 480 V Shutdown Transformers for the 480 V Shutdown Power distribution system. The 6.9 kV FLEX DGs also provides an alternate power source capability for the loads supplied by the on-site 480 V FLEX DGs. The 6.9 kV FLEX DGs' electrical distribution network is protected from external hazards.

According to TVA's FIP, ELAP entry conditions can be verified by control room staff. ELAP would be declared after TVA validates that offsite power and the emergency DGs (EDGs) are not available. This step is time sensitive and needs to occur within 1 hour following the start of the event. During the first phase of the ELAP event, TVA will be relying on the Class 1E station batteries to cope until additional power supplies (i.e., FLEX DGs) can be aligned and connected to the Watts Bar electrical distribution system (Phase 2). Transitioning to Phase 2 includes aligning and placing into service the pre-staged 480 V FLEX DGs and the 6.9 kV FLEX DGs. The 480 V FLEX DGs would provide charging current to the 125 Vdc Vital Batteries and ensure that 125 Vdc Vital Battery power (control) and the 120 Vac Vital Instrument Power (instrument indication) remain available.

If the 125 Vdc Vital Chargers are not energized and thus not supplying the 125 Vdc Vital Batteries, then TVA's plan directs operators to complete an extended load shed for any Vital Battery not being supplied its required load within 90 minutes following the start of the ELAP event. This would ensure that the 125 Vdc Vital Batteries could supply power for an 8-hour coping duration and provide sufficient time to align and connect the FLEX DGs to the Watts Bar electrical distribution system.

To ensure switching at the EDG building and shutdown board rooms are complete, potential board loading is reduced and interlocks are cleared to allow the emergency feeder breaker to be used to safely power the 6.9 kV Shutdown Boards from the 6.9 kV FLEX DG.

TVA verified through calculations EDQ0009992013000147, Revision 0, "Technical Justification for Extended Station Blackout Diesel Generators," EDN0003602013000350, "6900V 3MW Flex

Generator 3A and 3B Electrical Cable System Analysis," WBNAPS4-004 Rev. 031, draft FLEX Support Instruction 0-FSI-5 (0-FSI-5.01, "Initial Assessment and FLEX Equipment Staging," 0-FSI-5.02, "6900v FLEX DG Startup and Alignment," 0-FSI-5.03, "6.9KV & 480 V Shutdown Board Initial FLEX Alignment," and 0-FSI-5.04, "6900 V FLEX DG Plant Equipment Loading"), the FLEX DG manufacturer specification sheets, conceptual single line electrical diagrams, and draft procedures, that the alternative approach is acceptable given the location of the pre-staged DGs (above the PMF), the design of the DG structures (built to withstand design-basis earthquakes and weather events), the protection and diversity of the power supply pathways, the separation and isolation of the pre-staged DGs from the Class 1E EDGs, protection of the fuel oil supply pathways, and availability of procedures to direct operators how to align, connect, and protect associated systems and components. In addition, the documents confirmed that the FLEX DGs should have sufficient capacity and capability to supply the necessary loads following a BDBEE. The NRC staff review of these documents did not identify any discrepancies.

During the audit, TVA provided dc system analysis, Calculation EDQ00023620070003, "125V DC Vital Battery System Analysis," to verify the capability of the dc system to supply the required loads during the first phase of the Watts Bar FLEX mitigation strategies plan for an ELAP as a result of a BDBEE. TVA's analysis identified the required loads and their associated ratings (amperage and minimum voltage) and loads that would be shed to ensure battery operation for at least 8 hours. TVA expects that power will be restored to the battery charger within 8 hours. Based on its review of this analysis and the guidance in 0-FSI-4, Revision 0, "DC Bus Management/Load Shed and 480 V FLEX DG Alignment," the NRC staff found no issues with the calculation.

Lighting

In an ELAP event, initial lighting for the Main Control room and shutdown board room areas is provided by the plant designed 125 Vdc powered emergency lighting system. This system utilizes light-emitting diode (LED) light bulbs. Consistent with 10 CFR Part 50, Appendix R, the auxiliary control room, access and egress routes, and areas that must be attended for safe shutdown operations are provided with 8-hour emergency battery lighting (EBL) units. The EBL units that support safe shutdown and emergency access and egress are routinely referred to as Appendix R battery packs. These Appendix R EBLs were upgraded to LED bulbs, which provide extended battery life. Traveling to and from the various areas necessary to implement the FLEX mitigation strategies, making required mechanical connections, operating electrical disconnects and breakers, monitoring instrumentation and component manipulations are similar to tasks previously walked down for B.5.b and Appendix R safe shutdown operations, which have been accepted by the staff for other regulatory actions.

TVA determined that the Battery Powered (Appendix 'R') emergency lights provide adequate lighting for all interior travel pathways needed to access the connection points. These emergency lights are designed and periodically tested under the plant's preventative maintenance program to ensure the battery pack will provide a minimum of 8-hours of lighting with no external ac power sources.

Once the 6.9 kV FLEX DGs repower the 6.9 kV shutdown boards and the 480 V shutdown powered distribution system, the Standby Lighting system could be directed to be repowered from the reactor motor operated valve boards supplying lighting and placing the 125 Vdc powered emergency lighting system back in a standby mode. TVA noted that the 6.9 kV FLEX DG loading should be evaluated prior to reenergizing the emergency lighting system.

There are no emergency lighting fixtures in the yard outside of the protected area to provide necessary lighting in those areas where portable FLEX equipment is to be deployed. However, Watts Bar has the capability to power lights using portable diesel powered generators. In addition, portable DG powered light stanchions, battery powered light packs, and small generators to provide power and battery charging capability are available to be deployed from the FESB to support fading light or night time operations. The FESB also includes a stock of flashlights with batteries to further assist the staff responding to an ELAP. Lastly, TVA has a stock of head lamps with batteries stored in the 5th DG building.

The NRC staff finds that, if implemented appropriately, TVA's lighting strategy is sufficient to ensure that operators can travel to and from the various areas necessary to implement the FLEX mitigation strategies, make required mechanical connections, operate electrical disconnects and breakers, and monitor instrumentation and component manipulations when the normal plant lighting is lost due to an ELAP as a result of a BDBEE.

3.2.4 Conclusions

Based on this evaluation, the NRC staff concludes that TVA has developed guidance that if implemented appropriately should maintain or restore core cooling following a BDBEE consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.3 Spent Fuel Pool Cooling Strategies

NEI 12-06, Table 3-2 and Appendix D summarize one acceptable approach for the SFP cooling strategies. This approach uses a portable injection source to provide 1) makeup via hoses on the refuel deck/floor capable of exceeding the boil-off rate for the design basis heat load; 2) makeup via connection to spent fuel pool cooling piping or other alternate location capable of exceeding the boil-off rate for the design basis heat load; and alternatively 3) spray via portable monitor nozzles from the refueling deck/floor capable of providing a minimum of 200 gallons per minute (gpm) per unit (250 gpm to account for overspray). This approach will also provide a vent pathway for steam and condensate from the SFP.

As described in NEI 12-06, Section 3.2.1.7 and JLD-ISG-2012-01, Section 2.1, strategies that have a time constraint to be successful should be identified and a basis provided that the time can be reasonably met. NEI 12-06, Section 3 provides the performance attributes, general criteria, and baseline assumptions to be used in developing the technical basis for the time constraints. Since the event is a BDBEE, the analysis used to provide the technical basis for time constraints for the mitigation strategies may use nominal initial values (without uncertainties) for plant parameters, and best-estimate physics data. All equipment used for consequence mitigation may assume to operate at nominal setpoints and capacities.
NEI 12-06, Section 3.2.1.2 describes the initial plant conditions for the at-power mode of operation; Section 3.2.1.3 describes the initial conditions; and Section 3.2.1.6 describes SFP initial conditions.

NEI 12-06, Section 3.2.1.1 provides the acceptance criterion for the analyses serving as the technical basis for establishing the time constraints for the baseline coping capabilities to maintain SFP cooling. This criterion is keeping the fuel in the SFP covered.

The sections below address the effects of a BDBEE on SFP cooling during operating, pre-fuel transfer or post-fuel transfer operations. The effects of a BDBEE with full core offload to the SFP will be addressed in Section 3.10.

3.3.1 Phase 1

TVA indicated in its FIP that during periods of operating, pre-fuel transfer or post-fuel transfer it takes approximately 85 hours for boil off to decrease the water level to 10 feet above the SFP racks following a safe shutdown earthquake (SSE) seismic event with an initial bulk water temperature in the pool of 100°F. In addition, this is based on reduction in SFP water inventory beginning from nominal pool level and on normal operating decay heat loads.

Furthermore, TVA stated that considering the maximum possible loss of water through the vents in SFP water inventory starting from nominal pool level, boil off would occur approximately 18.69 hours following an SSE seismic event. The calculated boil off time assumed an initial bulk water temperature in the pool of 100°F with a boil off rate for normal decay heat load of 32.56 gpm.

Access to the SFP area as part of Phase 2 response could be challenged due to environmental conditions near the pool. Therefore, the required action is to establish ventilation in this area and deploy equipment local to the SFP for the FLEX strategies. If the air environment in the SFP area requires the building to be ventilated, doors will be opened to establish air movement. For accessibility, establishing the SFP vent and any other actions required inside the fuel handling building should be completed before boil off occurs, which is consistent with NEI 12-06.

3.3.2 Phase 2

TVA indicated that the transition to Phase 2 strategies will occur as the inventory in the SFP slowly declines due to boiling. During the audit review, TVA clarified that for the primary SFP strategy, if the Refuel Floor is accessible and habitable, two FLEX hoses are connected, one each, to the Unit 1 and Unit 2 ERCW supply headers on Elev. 757'. The discharge ends of these hoses are either routed all the way to the spent fuel pit positioned over the edge of the pit or each hose is routed and connected to one of two water cannons, positioned to discharge a water spray over the spent fuel pit. The water spray provides cooling for spent fuel that is potentially uncovered. In addition, if the refuel floor is not accessible or habitable, the secondary SFP strategy is to stage and connect a single FLEX hose from one of the ERCW supply headers on Aux. Bldg. Elev. 737' to the FLEX connection on the demineralized water makeup line to the SFP, also on Elev.737'.

3.3.3 Phase 3

TVA indicated that the strategies described for Phase 2 can continue as long as there is sufficient inventory available to feed the strategies. TVA further stated that a mobile water purification unit to provide continued purified water to support this function and a backup or alternate set of Phase 2 equipment will be provided by one of two NSRCs, as needed.

3.3.4 Staff Evaluations

3.3.4.1 Availability of Structures, Systems, and Components

NEI 12-06 provides guidance that the baseline assumptions have been established on the presumption that other than the loss of the ac power sources and normal access to the UHS, installed equipment that is designed to be robust with respect to design basis external events is assumed to be fully available. Installed equipment that is not robust is assumed to be unavailable. Below are the baseline assumptions for the availability of SSCs for SFP cooling at Watts Bar during an ELAP caused by a BDBEE.

3.3.4.1.1 Plant SSCs

Condition 6 of NEI 12-06, Section 3.2.1.3, states that permanent plant equipment contained in structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles, are available. The staff noted that TVA's Phase 2 SFP cooling FLEX strategies, as described in the Watts Bar FIP, relies on the ERCW header as the water source. UFSAR Section 9.2.1 describes the ERCW as safety-related that provides a safety-related source for AFW through the ERCW discharge. In addition, the staff noted that TVA's Phase 2 SFP cooling FLEX strategies use the demineralized water makeup header in the demineralized water system to provide makeup to the SFP, even when the refueling floor is inaccessible. The staff noted that both the ERCW and demineralized water makeup headers are located in the auxiliary building, which is a Category I structure (UFSAR Section 3.8.4). The ERCW and demineralized water makeup headers should be available for TVA's SFP cooling FLEX strategies consistent with Condition 6 of NEI 12-06, Section 3.2.1.3.

During the audit review, TVA explained that the use of the SFP cooling system pumps, component cooling water system pumps and the air compressors is optional but will be used if available. TVA also explained that passive makeup to the SFP will be attempted first by using existing tanks and piping. As discussed below, TVA's FLEX SFP strategies include a primary and alternate strategy.

Primary and alternate connection for SFP Cooling

Section 3.2.2 of NEI 12-06 states that portable fluid connections for core and SFP cooling functions are expected to have a primary and an alternate connection or delivery point (e.g., the primary means to put water into the SFP may be to run a hose over the edge of the pool). It further states that at a minimum, the primary connection point should be an installed connection suitable for both the on-site and off-site equipment and the secondary connection point may require reconfiguration if it can be shown that adequate time and resources are available to support the reconfiguration. Finally, both the primary and alternate connection points do not need to be available for all applicable hazards, but the location of the connection points should provide reasonable assurance that one connection will be available. During the audit review, TVA stated that for the primary SFP strategy, if the refuel floor is accessible and habitable, two FLEX hoses are connected, one each, to the Unit 1 and Unit 2 ERCW supply headers on elevation, 757'. The discharge ends of these hoses are either routed all the way to the spent fuel pit, with the discharge ends positioned over the edge of the pit or connected to water cannons, positioned to discharge a water spray over the spent fuel pit. If the refuel floor is not accessible or habitable, the alternate strategy is to stage and connect a single FLEX hose from one of the ERCW supply headers on Aux. Bldg. Elev. 737' to the FLEX connection on the demineralized water makeup line to the SFP, also on Elev.737'. The staff noted that the primary and alternate connection points described above are consistent with those identified in the Watts Bar FIP. If implemented appropriately and consistent with its FIP, TVA has provided a primary and alternate FLEX connection suitable for both the on-site and off-site equipment, which are located in areas such that there should be reasonable assurance that at least one connection will be available, consistent with Section 3.2.2 of NEI 12-06.

3.3.4.1.2 Plant Instrumentation

In its FIP, TVA stated that the instrumentation of the key spent fuel pool parameters will align with the requirements of Order EA-12-051. Furthermore, TVA stated that these instruments will have initial local battery power with the capability to be powered from the 480 V FLEX DGs. The staff's review of the spent fuel pool level instrumentation, including the primary and back-up channels, the display to monitor the spent fuel pool water level and environmental qualifications to operate reliably for an extended period are discussed in Section 4 of this SE.

3.3.4.2 Thermal-Hydraulic Analyses

In its FIP, TVA stated that with no reduction in SFP water inventory starting from nominal pool level the time when boil off decreases the water level to 10 feet above the SFP racks for operating, pre-fuel transfer or post-fuel transfer is approximately 85 hours for an SSE seismic event with an initial bulk water temperature in the pool of 100°F. TVA stated that considering the maximum possible loss of water through the vents in SFP water inventory starting from nominal pool level, boil off would occur approximately 18.69 hours following an SSE seismic event. The calculated boil off time assumed an initial bulk water temperature in the pool of 100°F with a boil off rate for normal decay heat load of 32.56 gpm. During the audit review, TVA was requested to provide the basis for the heat loads in the spent fuel pool to generate the time for boil off to reach 10 feet above the fuel and the required makeup flow rates. TVA stated that all credible decay heat loads were determined based on plant calculated spent fuel pool decay heat values. Regarding the normal credible load, the decay heat was determined at the time in an outage when the core has been fully reloaded in the reactor vessel. The maximum credible decay heat load was determined at the time after shutdown for when the last fuel assembly from the core has been loaded into the spent fuel pool. The worst case heat load scenario is the design capability of the spent fuel pool cooling system, which is 47.4 MBTU/hr [UFSAR, page 9.1-6].

As summarized above, the required action is to establish ventilation in the area of the SFP and establish any equipment local to the SFP building to accomplish the coping strategies before boil off occurs. TVA's thermal-hydraulic analyses and FIP indicate that boiling begins at approximately 18.69 hours. The staff noted that TVA's sequence of events timeline, attachment 1A of the FIP, indicates that after six hours from event initiation, operators will deploy hoses and spray nozzles as a contingency for SFP makeup and is expected to take approximately two hours for deployment.

The staff noted that NEI 12-06, Section 3.2.1.6, SFP Conditions, states that one of the initial SFP conditions is that the SFP heat load assumes the maximum design basis heat load for the site. Consistent with NEI 12-06, Section 3.2.1.6, the staff finds that TVA has considered the maximum design-basis SFP heat load during operating, pre-fuel transfer or post-fuel transfer operations that equates to a boil-off rate of 32.56 gpm.

3.3.4.3 FLEX Pumps and Water Supplies

The staff noted that TVA identified the performance criteria (e.g., flow rate, discharge pressure, total dynamic head) for its FLEX Phase 2 and Phase 3 portable pumps in its FLEX FIP dated October 29, 2014. The staff noted that the performance criteria for the FLEX Phase 2 portable pumps are consistent with the FLEX Phase 3 portable pumps. During the audit review, TVA provided the FLEX as-built hydraulic calculation (Watts Bar Units 1 and 2 As-Built FLEX System Fathom Model, CN-FSE-14-36, Revision 0), which demonstrated that the FLEX Phase 2 portable pumps identified in its revised OIP are capable of providing sufficient make-up to the spent fuel pool. The staff noted that TVA's calculation relied upon Applied Flow Technology Fathom models to create an as-built hydraulic model using FLEX strategies contained in its revised OIP and the purchased valve datasheets and pump curves for each FLEX valve and pump. The staff noted that TVA's calculation relied upon actual piping isometrics, FLEX valves and connections, and hose lengths and diameters (suction and discharge) to ensure the FLEX pumps can support each FLEX safety function. The staff also noted that TVA's calculation determined that the actual flow rates provided by the FLEX Phase 2 portable pumps exceeds the required flow rates for each of the FLEX safety function; therefore, the FLEX pumps TVA have available are capable of providing the necessary water for the spent fuel pool. The available water sources for these Phase 2 and 3 FLEX portable pumps are discussed in Section 3.10 of this SE.

Based on its review, the staff finds that, if implemented appropriately, TVA has demonstrated that its FLEX portable pumps should be capable of supporting the water make-up requirements to the spent fuel pool.

3.3.4.4 Electrical Analyses

TVA implemented of DCN [Design Change Notice] 59683 to meet the requirements of NRC Order EA-12-051 and NEI 12-02. The SFP level instrument loops mounting are designed to meet or exceed the Watts Bar design-basis SSE protection requirements. All components are located in the Auxiliary Building, which is seismically qualified and missile protected. The SFP level instruments are powered from the 120 Vac Vital Power System. The primary power supply to Spent Fuel Level Continuous Monitoring Loop 1 (0-LI-78-43) is from 120 Vac Vital Power Board 2-III with its individual power supply battery backup (0-BAT-78-43). The primary power supply to Spent Fuel Level Continuous Monitoring Loop 2 (0-LI-78-42) is from 120 Vac Vital Power Board 2-IV with its individual battery backup power supply (0-BAT-78-42). The 120 Vac

Vital Power Boards are powered by 120 Vac Vital Inverters fed by its 125 Vdc Vital Battery Board.

The transition to Phase 2 strategies will occur as the inventory in the SFP slowly declines due to boiling. Spent fuel pool cooling through makeup and/or spray will be provided by LP FLEX pumps. The LP FLEX pumps will provide raw cooling or makeup water to the ERCW headers to make-up to the pool by means of the FLEX connection and hose deployment directly into the SFP, by spray from portable FLEX spray nozzles, or by FLEX connection and hose deployment into existing SFP demineralized water system makeup piping. The procedure for ERCW system alignment [0-FSI-5.05, ERCW Alignment for 5000 GPM Portable Diesel Pump (5PDP)] will direct operators to focus on raw cooling water availability and verify the 6.9 kV FLEX DG loadings necessary to energize the CCW and SFP cooling pumps to restore SFP cooling capability.

Two independent SFP level instrument loops have been provided. One loop on the Watts Bar, Unit 1 plant side on the Northwest corner of the spent fuel pool provides indication mounted on the South wall of the A Train 6.9 kV Shutdown Board. The other loop on the Watts Bar, Unit 2 plant side on the Southeast corner of the spent fuel pool provides indication mounted on the South wall of the B Train 6.9 kV Shutdown Board.

3.3.5 Conclusions

Based on this evaluation, the NRC staff concludes that TVA has developed guidance that, if implemented appropriately, should maintain or restore SFP cooling following a BDBEE consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.4 Containment Function Strategies

The industry guidance document, NEI 12-06, Table 3-2 provides some examples of acceptable approaches for demonstrating the baseline capability of the containment strategies to effectively maintain containment functions during all phases of an ELAP event. One such approach is for a licensee to perform an analysis demonstrating that containment pressure control is not challenged.

In accordance with NEI 12-06, TVA performed a containment evaluation, LTR-ISENG-14-1, Revision 0, "Containment Pressures and Temperatures at Watts Bar, Units 1 and 2 During an ELAP, Calculated with Modular Accident Analysis Program (MAAP) 4.07," which was based on the boundary conditions described in Section 2 of NEI 12-06. The calculation which analyzed this strategy concludes that the containment parameters of pressure and temperature remain well below the respective UFSAR Section 3.8.2.2.2 design limits of 13.5 psig and 250°F for more than 7 days. From its review of the evaluation, the staff noted that the required actions to maintain containment integrity and required instrumentation functions have been developed, and are summarized below.

3.4.1 Phase 1

TVA's containment analysis shows that there are no Phase 1 actions required.

3.4.2 Phase 2

Approximately 60 hours into the event, the containment analysis recommends running one Containment Air Return Fan for about 10 minutes. This operation ensures the ice condenser doors open and enhanced flow through the ice condenser is achieved, furthering benign containment conditions for more than 7 days following the ELAP event.

As stated in TVA's FIP, the subject Containment Air Return Fans are available to operate after the 6.9 kV and 480 V Shutdown Electrical distribution systems are repowered by the pre-staged, 6.9 kV FLEX DGs. Action Items 8 and 9 in Attachment 1A (both the Flood and Non-Flood Sequence of Events Timelines) of TVA's FIP, show that the subject repowering procedure is expected to begin at 1.5 hours into the event and be completed by 3.5 hours into the event. This timeline supports the planned use of the Containment Air Return Fans at 60 hours following the event. These same Action Items 8 and 9 will also provide the ability to repower the hydrogen igniters as a defense-in-depth measure to ensure continued containment integrity.

As a potential alternative, if required, TVA also stated in its FIP that the onsite 6.9 kV FLEX DGs also provide the ability to recover operation of the Lower Compartment Coolers (LCCs) for containment temperature control. Cooling water to the LCCs could be provided by diesel powered FLEX pumps feeding the ERCW system headers.

3.4.3 Phase 3

TVA's containment analysis shows the continued employment of the Phase 2 strategy is sufficient to maintain containment parameters far below their design limits for more than 7 days. As such, there are no specific Phase 3 actions required.

3.4.4 Staff Evaluations

3.4.4.1 Availability of Structures, Systems, and Components

NEI 12-06 provides guidance that the baseline assumptions have been established on the presumption that other than the loss of the ac power sources and normal access to the UHS, installed equipment that is designed to be robust with respect to design-basis external events is assumed to be fully available. Installed equipment that is not robust is assumed to be unavailable. Below are the baseline assumptions for the availability of SSCs for maintaining containment functions at Watts Bar during an ELAP caused by a BDBEE.

3.4.4.1.1 Plant SSCs

Watts Bar utilizes an ice condenser, pressure suppression containment. UFSAR Section 6.2.1.2 states that the containment consists of a steel containment vessel and a separate Shield Building enclosing an annulus. The steel containment vessel is a freestanding, welded structure with a vertical cylinder, hemispherical dome, and a flat circular base. The entire containment structure is designed to seismic Category 1 requirements. Table 6.2.1-13 of the UFSAR shows that the net free volume of the containment is 1,171,012 ft^3.

As stated above, TVA's mitigation strategy employs the use of one of the two, 100 percent capacity, Containment Air Return Fans approximately 60 hours following an ELAP event. UFSAR Section 6.8.1 states that the primary purpose of the Containment Air Return Fan system is to enhance the ice condenser heat removal operation by circulating air from the upper containment to the lower compartment, through the ice condenser, and then back to the upper compartment. Additionally, UFSAR Section 6.8.2 states that the Containment Air Return Fan System is an engineered safety feature and meets the qualification requirements for seismic Category I; therefore, in accordance with NEI 12-06, it is considered to be available equipment following an ELAP event.

3.4.4.1.2 Plant Instrumentation

TVA stated in its FIP that containment pressure and temperature monitoring will be available from instruments that are powered from the 125 Vdc Vital Batteries. These batteries are stated to have an 8-hour life following employment of TVA's load shed procedure. Furthermore, Action Items 2 and 3 in Attachment 1A of TVA's FIP state that the 480 V FLEX DGs are planned to be deployed and operating within 1 hour following the ELAP event. These 480 V FLEX DGs will provide power to the 125 Vdc battery chargers through the 120 Vac Vital Inverter.

TVA's FIP also states that, during a flood event scenario, the ability to monitor containment temperature using permanently installed plant equipment will cease when the flood waters enter the technical support center inverter or battery rooms. However, in accordance with NEI 12-06, Section 5.3.3, TVA has developed a method and corresponding procedural guidance to obtain containment temperature readings locally, if needed, using a portable device.

The applicable cases of TVA's containment evaluation, LTR-ISENG-14-1, Revision 0, show that the design limits for pressure and temperature (13 psig and 250°F, respectively) are not challenged for over 7 days following an ELAP event.

3.4.4.2 Thermal-Hydraulic Analyses

The NRC staff reviewed LTR-ISENG-14-1, Revision 0, Containment Pressures and Temperatures at Watts Bar Units 1 and 2 During an ELAP, Calculated with MAAP 4.07. The staff noted that the calculation contained four cases of interest in evaluating the behavior of the containment during an ELAP event. (Two other cases were run in the analysis to benchmark the model and to establish "no RCS make up" results.)

Cases 2b, 3, and 3a, which were all analyzed for a 72-hour coping period, show that the containment response to an ELAP event is a very slow moving transient. The calculation stipulates that, because the internal compartments of the containment are not airtight, there is leakage between them which results in very low differential pressures across the compartment boundaries. As such, the ice doors do not open and the normal flow pattern expected following a design-basis loss of coolant accident does not occur.

Case 2b analyzed a scenario where the FLEX strategies for core cooling are employed and no other actions are taken to actively remove heat from the containment. At the end of the 72-hour analytical duration, the calculation showed that containment pressure was less than 20 psia, which is well below the UFSAR Section 3.8.2.2.2 design limit of 28.2 psia. Additionally, Case 2b showed that the maximum containment vessel temperature was approximately 155°F at the end of the 72-hour analysis period, which is well below the 250°F UFSAR Section 3.8.2.2.2 design limit. The calculation further extrapolated the results at 72 hours to predict an approximate time when the design limits may be reached. It was concluded that an additional 72 hours (144 hours total from the time of the ELAP event) would be available for mitigation activities to commence before reaching a design limit.

Case 3 analyzed a scenario where power was restored to one Containment Air Return Fan, and the fan was activated and allowed to run continuously from hour 60 to hour 72 following the ELAP event. The calculation showed that the effect of the fan quickly reduced both the containment pressure and temperature because the flow from the fan caused the ice doors to open. However, the calculation also concluded that the rate at which the ice was melting significantly increased by continuous operation of the fan, and the ice in the containment would be depleted approximately 36 hours after the 72-hour period of analysis (108 hours total). Considering the positive and negative effects of running one Containment Air Return Fan as shown by Case 3, TVA's FLEX strategy evolved and is based on Case 3a. Case 3a analyzes the effects of repowering and operating one Containment Air Return Fan at the 60-hour mark for a duration of 10 minutes. The calculation states:

> While the dramatic drop of Case 3 does not occur (the net pressure drop is only on the order of 1.5 psi), there is a significant benefit in that after the fan "bump" the pressure is no longer increasing, it is stable. This means that, given the trend around 72 hours, there is no foreseeable time at which the design limit will be reached.

The calculation goes on to state that extrapolating the containment vessel temperature rate of increase results in reaching the 250°F design limit approximately 30 days after the 72-hour period of analysis and, utilizing the rate of ice melt for extrapolation, the ice in the containment is not depleted for an additional 107 hours beyond the 72-hour analysis period.

Case 4 was a sensitivity analysis which was performed to evaluate the behavior of the containment during an ELAP if the ice condenser bypass leakage areas were significantly reduced. The sensitivity case resulted in containment behavior very similar to Case 2b. The calculation concluded that, with the bypass leakage areas reduced, there was enough differential pressure which developed to open the lower compartment ice doors. As such, the ice mass is engaged early in the event to reduce the containment heat up and pressurization. Consistent with the other cases, the containment conditions at 72 hours were used to extrapolate pressure, temperature, and ice melt to their respective limits. The Case 4 extrapolated results showed the containment pressure reaching its limit at approximately 8 days after the 72-hour analysis period; the temperature did not reach its limit until approximately 9 days after the 72-hour analysis period; and, the ice mass was not depleted until approximately 7.5 days following the 72-hour analysis period.

During an ELAP, the containment heat up and pressurization is driven by the leakage of the RCP Seals. In TVA's containment calculation, the RCP seal leakage modeling used in the Cases described above was constructed to follow the FLEX actions which were being proposed to maintain core cooling. These included starting a SIP 5 hours after the start of the ELAP and then replacing this pump with a 40 gpm portable pump 9 hours after the start of the ELAP. Both pumps are controlled based on pressurizer level per the Watts Bar FLEX procedures.

TVA's analysis in LTR-ISENG-14-1 shows that if the ice condenser bypass leakage areas are large enough that the lower compartment ice doors do not open and no mitigation actions are taken (Case 2b), the earliest a containment limit would be reached is approximately 144 hours following an ELAP event. It also shows that, if the ice condenser bypass leakage areas are very small such that the differential pressure between the compartments builds to a sufficient magnitude to open the lower ice doors and no other mitigation actions are taken (Case 4), the earliest an action would be required (because the ice is depleted) is approximately 10.5 days following an ELAP event. Furthermore, the calculation shows that TVA's proposed FLEX strategy of repowering a Containment Air Return Fan at approximately 60 hours and operating it for about 10 minutes (Case 3a) maintains the containment pressure indefinitely below the design limit and the containment temperature below the design limit for over 33 days following an ELAP event. The ice mass will be depleted under these conditions in approximately 180 hours after the ELAP event, but, as previously shown, this has a minimal effect on the containment pressure or temperature even after the ice is depleted. Additionally, TVA's proposed strategy may be employed any time after the FLEX DGs are placed in service, which is stated to occur within 3.5 hours following an ELAP.

The NRC staff review of this document did not identify any discrepancies. In addition, if TVA implements their strategy appropriately and consistent with its FIP, the integrity of containment should be maintained.

3.4.4.3 FLEX Pumps and Water Supplies

In its FIP, TVA stated that at approximately 60 hours into the event the containment analysis recommends a 10 minute run of a Containment Air Return Fan to ensure ice condenser doors open and enhanced flow through the ice condenser and benign containment conditions for a significant period of time past 72 hours after the ELAP event is declared. TVA also stated that the onsite 6.9 kV FLEX DGs also provide the ability to recover operation of LCCs for containment temperature control, if required. TVA explained that the cooling water would be provided to the LCCs by deployed diesel powered LP FLEX pumps feeding the ERCW system headers.

The staff noted that providing cooling water to the LCCs is only for a short period of time and may be necessary five days after the declaration of the ELAP event. The staff noted that at this time additional staffing will be available and additional off-site resources, such as a LP FLEX pump and a mobile purification unit, will be available to provide cooling water to the LCCs. Furthermore, the availability of additional staffing and off-site resources should not impact TVA's

FLEX strategies or time and equipment constraints for maintaining core cooling, SFP inventory and RCS inventory.

3.4.4.4 Electrical Analyses

TVA has performed a containment analysis based on the boundary conditions described in Section 2 of NEI 12-06. Based on the results of this analysis, required actions to ensure maintenance of containment integrity and required instrumentation function have been developed. However, there are no Phase 1 actions that are required. At approximately 60 hours into the event the containment analysis recommends a 10 minute run of a Containment Air Return Fan. This operation ensures ice condenser doors open and enhanced flow through the ice condenser and benign containment conditions for a significant period of time past 72 hours. The licensee confirmed that the DGs have the necessary capacity to support running the fan. The onsite 6.9 kV FLEX DGs also provide the ability to recover operation of LCCs for containment temperature control, if required. Cooling water would be provided to the LCCs by deployed diesel powered LP FLEX Pumps feeding the ERCW system headers and alignment of the ERCW system to maximize efficient usage of available cooling water.

Additionally, the 6.9 kV FLEX DGs can power the hydrogen igniters through the 480 V shutdown power distribution system, if required. The 480 V FLEX DGs can also be aligned to provide power to the hydrogen igniter supply transformers, if required. Repowering the 6.9 kV and 480 V Shutdown Electrical distribution system provides the ability to operate Containment Air Return Fans and other containment ventilation components (i.e., LCCs), if required.

The protection structures for the 6.9 kV FLEX DGs and the 480 V FLEX DGs and the associated power distribution systems are protected from the five external hazards, as described in Section 3.6.

3.4.5 Conclusions

Based on this evaluation, the NRC staff concludes that TVA has developed guidance that, if implemented appropriately, should maintain or restore containment functions following a BDBEE consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.5 Characterization of External Hazards

Sections 4 through 9 of NEI 12-06, Revision 0 provides the methodology to identify and characterize the applicable BDBEEs for each site. In addition, NEI 12-06 provides a process to identify potential complicating factors for the protection and deployment of equipment needed for mitigation of site-specific BDBEEs leading to an ELAP and loss of normal access to the UHS.

Characterization of the applicable hazards for a specific site includes the identification of realistic timelines for the hazard, characterization of the functional threats due to the hazard, development of a strategy for responding to events with warning, and development of a strategy for responding to events without warning.

TVA reviewed the Watts Bar site against NEI 12-06 and determined that FLEX equipment should be protected from the following hazards: seismic; external flooding; severe storms with high winds; snow, ice and extreme cold; and extreme high temperatures.

References to external hazards within the licensee's mitigating strategies and this safety evaluation are consistent with the guidance in NEI-12-06 and the related interim staff guidance in Revision 0 to JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events." Coincident with the issuance of the order, on March 12, 2012 (ADAMS Accession No. ML12053A340), the NRC staff issued a Request for information Pursuant to Title 10 of the *Code of Federal Regulations* Part 50, Section 50.54(f) (hereafter referred to as the 50.54(f) letter), which requested that licensees reevaluate the seismic and flooding hazards at their sites using updated hazard information and current regulatory guidance and methodologies. The NRC staff has requested Commission guidance related to the relationship between the reevaluated flooding hazards provided in responses to the requests for information and the requirements for Order EA-2-049 and related rulemaking to address beyond-design-basis external events (see COMSECY-14-0037, Integration of Mitigating Strategies for Beyond-Design-Basis External Events and the Reevaluation of Flooding Hazards," dated November 21, 2014). The NRC staff acknowledges in COMSECY-14-0037 that licensees may need to revise mitigating strategies developed for Order EA-12-049 if the Commission directs that the pending mitigation of beyond-design-basis events rulemaking include a requirement for mitigating strategies to address the reevaluated hazards provided in response to the requests for information made pursuant to 10 CFR 50.54(f). The NRC staff did not request that the Commission consider making a requirement for mitigating strategies capable of addressing the reevaluated flooding hazards be immediately imposed and thereby require licensees revise the plans and modifications developed using existing guidance for implementing Order EA-12-049. The Commission was deliberating on this matter at the time of this safety evaluation. The NRC staff is reviewing and inspecting licensees' implementation of Order EA-12-049, including Watts Bar, using the existing guidance documents pending a Commission response to COMSECY-14-0037.

The characterization of the specific external hazards for Watts Bar is discussed below. In addition, Sections 3.5.1 and 3.5.2 summarizes TVA's activities to address the 50.54(f) seismic and flooding reevaluations.

3.5.1 Seismic

In the FIP, TVA stated that seismic hazards are applicable to the Watts Bar site. The current licensing basis SSE is 0.18g horizontal and 0.12g vertical rock accelerations, as documented in the updated final safety analysis report (UFSAR), Sections 2.5.2.4 and 2.5.2.7.

As mentioned above, the NRC issued a 50.54(f) letter that required facilities to reevaluate the site's seismic hazard (i.e., NTTF Recommendation 2.1). In addition, the 50.54(f) letter requested that licensees submit, along with the hazard evaluation, an interim evaluation and actions planned or taken to address the reevaluated hazard where it exceeds the current design-basis. By letter dated March 31, 2014 (ADAMS Accession No. ML14098A478), TVA subsequently reevaluated the Ground Motion Response Spectra (GMRS) based upon the most recent seismic data and methodologies and determined that the existing SSE does not envelop the new GMRS at low frequencies for Watts Bar. Per the 50.54(f) letter, TVA stated that this liability along with the recognized challenge to perform NTTF Recommendation 2.1 required risk evaluations, via either Seismic Margins Assessment (SMA) or Seismic probabilistic risk assessment. The risk evaluation is being addressed in the Electric Power Research Institute (EPRI) initiative referred to as the Augmented Approach (EPRI Report 3002000704), which was endorsed by the NRC by letter dated May 7, 2013 (ADAMS Accession No. ML13114A949). The Augmented Approach, in addition to allowing more time to complete the site-specific seismic risk evaluations, requires plants to address the increase in seismic susceptibility of FLEX equipment. The Augmented Approach ensures that FLEX-credited equipment (both currently installed and new) would retain function during and after a beyond-design-basis seismic event using seismic margins assessment criteria, by calculating a High Confidence of Low Probability of Failure (HCLPF) seismic capacity and comparing that to the seismic demand of a Review Level Ground Motion (RLGM), capped to two times the SSE from 1 to 10 Hertz. TVA stated that the Watts Bar FLEX credited equipment is designed to achieve a HCLPF capacity based on a seismic RLGM demand equal to twice the SSE.

As the Watts Bar seismic reevaluation activities are completed, TVA will enter appropriate issues into the corrective action program. TVA has appropriately screened in this external hazard and identified the hazard levels for reasonable protection of the FLEX equipment.

3.5.2 Flooding

During the audit review, TVA stated that Watts Bar is designed as a "wet" site and buildings are allowed to flood. All equipment required to maintain the plant safely during all flooding events, including the design basis flood, is either designed to operate submerged, is located above the maximum flood level, or is otherwise protected.

TVA evaluated Watts Bar flood hazards to design-basis flood conditions, as described in UFSAR Section 2.4. The types of events TVA evaluated to determine the worst potential flood included (1) probable maximum storm on the total watershed and critical sub-water sheds including seasonal variations and potential consequent dam failures and (2) dam failures in a postulated SSE with concurrent flood conditions. TVA stated that the maximum plant site flood level from any cause is Elevation 739.2 ft (still reservoir). This elevation would result from the probable maximum storm. Coincident wind wave activity results in wind waves of up to 2.2 ft (crest to trough). Wind wave run up on the 4:1 slopes approaching the DG Building reaches Elevation 741.6 ft. Wind wave run-up on the critical wall of the intake pumping station reaches Elevation 741.7 ft. and wind wave run-up on the walls of the Auxiliary, Control and Shield Buildings reaches Elevation 741.0 ft. Site grade level is Elevation 728ft.

UFSAR Section 2.4.3.6 states that the safety-related facilities, systems, and equipment located in the containment structure are protected from flooding by the Shield Building structure with those accesses and penetrations below the maximum flood level designed and constructed as watertight elements. USFAR Section 2.4.3.6 states that the DG Buildings to the north and the pumping station to the southeast of the main building complex must be protected from flooding to assure plant safety. The DG Building's operating floors are at elevation 742.0 ft. UFSAR Section 2.4.14.2.3 states that the intake pumping station is designed to retain full functional capability to maintain cooling of plant loads.

TVA determined that a specific analysis of the Tennessee River flood levels resulting from ocean front surges and tsunamis is not required because of the inland location of the plant. Snow melt and ice jam considerations are also unnecessary because of the temperate zone location of the plant. Flood waves from landslides into upstream reservoirs required no specific analysis, in part because of the absence of major elevation relief in nearby upstream reservoirs and because the prevailing thin soils offer small slide volume potential compared to the available detention space in reservoirs. Seiches pose no flood threats because of the size and configuration of the lake and the elevation difference between normal lake level and plant grade.

Similar to the seismic hazard reevaluation request, the NRC staff required facilities to reevaluate the site's flooding hazard. By letter dated March 12, 2015 (ADAMS Accession No. ML15071A262), TVA submitted its Flood Hazard Reevaluation Report for Watts Bar. The reevaluation concluded that the local intense precipitation, flooding from rivers and streams, and flooding from combined effects of PMF and wind are not bounded by the current design-basis for Watts Bar. Consistent with Enclosure 2 of the March 12, 2012, letter, TVA implemented interim actions to address the higher flooding levels relative to the current licensing basis. In addition, TVA will complete an Integrated Assessment and a report will be submitted by March 12, 2017.

As the Watts Bar flooding reevaluation activities are completed, TVA will enter appropriate issues into the corrective action program. TVA has appropriately screened in this external hazard and identified the hazard levels for reasonable protection of the FLEX equipment.

3.5.3 High Winds

NEI 12-06, Section 7, provides the screening process for evaluation of high wind hazards. This screening process considers the hazard due to hurricanes and tornadoes. The first part of the evaluation of high wind challenges is determining whether the site is potentially susceptible to different high wind conditions to allow characterization of the applicable high wind hazard. The second part is the characterization of the applicable high wind threat.

The screening for high wind hazards associated with hurricanes should be accomplished by comparing the site location to NEI 12-06, Figure 7-1 (Figure 3-1 of U.S. NRC, "Technical Basis for Regulatory Guidance on Design Basis Hurricane Wind Speeds for Nuclear Power Plants, NUREG/CR-7005, December, 2009); if the resulting frequency of recurrence of hurricanes with wind speeds in excess of 130 mph exceeds 10^{-6} per year, the site should address hazards due to extreme high winds associated with hurricanes.

The screening for high wind hazard associated with tornadoes should be accomplished by comparing the site location to NEI 12-06, Figure 7-2, from U.S. NRC, "Tornado Climatology of the Contiguous United States," NUREG/CR-4461, Rev. 2, February 2007; if the recommended tornado design wind speed for a 10^{-6} per year probability exceeds 130 mph, the site should address hazards due to extreme high winds associated with tornadoes.

TVA stated that Watts Bar is susceptible to hurricanes as the plant site is within the contour lines shown in Figure 7-1 of NEI 12-06. In addition, it was determined that the Watts Bar site has the potential to experience damaging winds caused by a tornado exceeding 130 mph.

Figure 7-2 of NEI 12-06 indicates a maximum wind speed of 200 mph for Region 1 plants, including Watts Bar. Therefore, high-wind hazards are applicable to the Watts Bar site. TVA has appropriately screened in the high wind hazard and characterized the hazard in terms of wind velocities

3.5.4 Snow, Ice, and Extreme Cold

TVA referenced UFSAR Section 2.3.2.2 to determine the mean temperatures at Watts Bar, which have been in the low 40s °F in the winter. Extreme minima temperatures recorded were -20 °F at Decatur, Tennessee and -10 °F at Chattanooga, Tennessee in the winter.

TVA stated that Watts Bar site is above the 35th parallel; therefore, the FLEX strategies must consider the hindrances caused by extreme snowfall with snow removal equipment, as well as the challenges that extreme cold temperature may present.

Regarding applicability of ice storms, TVA stated that the Watts Bar site is not a Level 1 or 2 region as defined by Figure 8-2 of NEI 12-06; therefore, the FLEX strategies must consider the hindrances caused by ice storms.

In summary, based on the available local data and Figures 8-1 and 8-2 of NEI 12-06, the Watts Bar site does experience significant amounts of snow, ice, and extreme cold temperatures; therefore, the hazard is screened in. TVA has appropriately screened in the hazard and characterized the hazard in terms of expected temperatures.

3.5.5 Extreme Heat

TVA stated that the mean temperatures at the Watts Bar site can reach the upper 70s °F in the summer. Extreme maxima temperature recorded was 108 °F at Decatur, Tennessee and 106 °F at Chattanooga, Tennessee in the summer. Therefore, for selection of FLEX equipment, TVA considered the Watts Bar site maximum expected temperatures in their specification, storage, and deployment requirements, including ensuring adequate ventilation. TVA has appropriately screened in the high temperature hazard and characterized the hazard in terms of expected temperatures.

3.5.6 Conclusions

Based on the evaluation above, the NRC staff concludes that TVA has developed a characterization of external hazards that is consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.6 Planned Protection of Phase 2 FLEX Equipment

In its revised OIP dated February 7, 2014, TVA stated, in part, that its Phase 2 equipment will include three diesel driven (Dominator) LP FLEX pumps used to pressurize the ERCW headers, three diesel driven (Triton) floating booster pumps used to supply the LP FLEX pumps, and two diesel driven IP FLEX pumps used for core cooling makeup and SFP makeup during non-flood events. The staff noted the LP FLEX pumps used to pressurize the ERCW header also support SFP make-up strategies. During the audit review, TVA clarified that three 480 V HP FLEX pumps will be located on Auxiliary Building elevation 692' and will be used to supply makeup to the RCS during flood and non-flood events. There will also be two 480 V motor driven IP FLEX pumps located on Auxiliary Building elevation 737' used for core cooling makeup during a flood event and as back-ups to the diesel driven IP pumps during non-flood events. In addition, there are two Mode 5 and 6 IP FLEX pumps located on auxiliary building elevation 692' that can serve as back-ups to the elevation 737' motor driven IP FLEX pumps. Lastly, two 6.9 kV FLEX DGs are pre-staged inside the FESB and two 480 V FLEX DGs are pre-staged in a protected structure on the roof of the Auxiliary Building.

3.6.1 Protection from External Hazards

In its FIP, TVA states that it has designed and constructed one new storage location to protect portable FLEX equipment against all five external hazards. The new building is referred to as the FESB. TVA stated that FLEX equipment will be stored or staged in the FESB or inside of site Class I structures. The revised OIP specifies that FLEX equipment will also be stored in the Auxiliary Building and on the roof of the Auxiliary Building in a protected structure. UFSAR Section 3.8.4 indicates that the Auxiliary Building is a Category I Structure. In its revised OIP, TVA stated that the protection structure on the Auxiliary Building roof: (1) will be designed to the same seismic Category I requirements as the Auxiliary Building; (2) will be above the PMF and as such is not susceptible to flooding from any source; (3) will be built to protect the DGs from Region 1 tornado, missiles and velocities as defined in NRC Regulatory Guide 1.76 Revision 1; (4) will be evaluated for snow, ice and extreme cold temperature effects and heating will be provided as required to assure no adverse effects on the FLEX equipment; and (5) will be evaluated for high temperature effects and ventilation will be provided as required to assure no adverse effects on the FLEX equipment.

Below are additional details on how FLEX equipment is protected from each of the external hazards. In summary, the NRC staff finds that TVA's proposal for use of existing Category I structures, the protected structure on the Auxiliary Building roof, and the FESB addresses the applicable external hazards and is consistent with the guidance in NEI 12-06 for protection of FLEX equipment (Section 5.3.1 – seismic, Section 6.2.3.1 – external flooding, Section 7.3.1 – severe storms with high winds, Section 8.3.1 – snow, ice and extreme cold and Section 9.3.1- extreme high temperatures).

3.6.1.1 Seismic

In TVA's FIP, it states that portable equipment required to implement the FLEX strategies will be stored/staged/pre-staged in the FESB, Auxiliary Building, intake pumping station, and 5th DG Building, which are designed for seismic loading in excess of the minimum requirements of the American Society of Civil Engineers (ASCE) 7-10.

During the audit review, TVA clarified that its FESB is designed to ASCE 7-05 with the plant's design-basis loads. The FESB is designed and built to withstand 2 times the SSE HCLPF. During the Watts Bar on-site audit, the staff reviewed and confirmed these aspects of the FESB were addressed in the design documents and design drawing authorization. In addition, the FLEX 6.9 kV distribution systems have been analyzed to survive 2 times SSE HCLPF. A protective structure has been built around the 480 V FLEX DGs, which is designed to the same Seismic Category 1 requirements as the Auxiliary Building. Seismic input for the design corresponds to the appropriate seismic accelerations at the roof of the Auxiliary Building, which provides a seismic protection of twice the SSE HCLPF.

3.6.1.2 Flooding

Portable and pre-staged equipment required to implement the FLEX strategies will be maintained in the FESB, Auxiliary Building, intake pumping station, and 5th DG Building in locations functionally above the PMF level, or in areas of pre-flood access and distribution, or will be capable of submersible operation.

An ELAP could occur at any time, therefore Watts Bar will pre-stage FLEX Flood Mode equipment based on a 25-year flood warning from the TVA's Division of Water Management, River Systems Operations Branch. TVA's River Systems Operation's procedure RVM-SOP-10.05.06, "Nuclear Notifications and Flood Warning Procedure," and Watts Bar Operation's AOI-7.01, "Maximum Probable Flood," will be revised to provide the appropriate notification and direct the pre-staging of FLEX equipment. This early notification allows for FLEX equipment to be staged without impacting resources that would be required for design-basis flood mode operation preparations.

The equipment stored in the FESB will be protected from flooding, since the building is located above the PMF elevation. The distribution system from the FESB to the EDG Building, from the kirk-key switches located in the EDG building through the 6.9 kV and 480 V safety class electrical distribution system, is designed to withstand a PMF event. In addition, the EDG Building and the protected structure on the roof of the Auxiliary Building are located above the PMF flood level.

3.6.1.3 High Winds

Portable equipment required to implement the FLEX strategies will be maintained in the FESB, Auxiliary Building, intake pumping station, and 5th DG Building, which are designed to meet or exceed the licensing basis high wind hazard for Watts Bar.

The FESB is designed and built to protect against Region 1 tornado, missiles, and velocities as defined in NRC Regulatory Guide 1.76, coupled with 360 mph wind speeds. In addition, the protected structure on the roof of the Auxiliary Building is designed to withstand Region 1 tornado, missiles, and velocities as defined in NRC Regulatory Guide 1.76, Revision 1. The electrical distribution from the FESB to the EDG building is housed in robust structures that are missile protected from the kirk-key switches located in the EDG building through the 6.9 kV and 480 V safety class electrical distribution system.

3.6.1.4 Snow, Ice, Extreme Cold and Extreme Heat

TVA designed the FESB to protect against the two hazards of 1) snow, ice and extreme cold and 2) extreme heat conditions. The FESB is provided with a standalone heating, ventilating, and air conditioning (HVAC) system to maintain the internal environment between 50°F and 100°F up to the point of ELAP. TVA evaluated the protected structure on the roof of the Auxiliary Building to protect the 480 V FLEX DGs for extreme temperature effects. TVA has provided a means to heat and ventilate the protected structure to ensure that there are no adverse effects on the FLEX equipment as a result of extreme temperatures.

The staff reviewed TVA's assessment of temperature effects on the FLEX DGs as a result of extreme temperature hazards. In draft calculation WBNAPS4-004, "Summary of Mild Environment Conditions for Watts Bar Nuclear Plant," Rev. 31, TVA identified that the minimum and maximum abnormal ambient temperatures expected at the Watts Bar site are 6 °F and 102 °F, respectively. According to TVA, the 480 V FLEX DGs can handle an ambient temperature range of 5°F to 105 °F under operating conditions at 180 kW. The 480 V FLEX DGs can operate above an ambient condition of 105 °F under de-rated loading conditions (178 kW for an ambient temperature of 108 °F). The low ambient temperature of 5 °F for the 480 V FLEX DG is based on the size of the jacket water heater. During the onsite audit, TVA informed the NRC staff that the 6.9 kV FLEX DGs will be housed in a conditioned building (i.e., FESB) that will ensure operation during extreme temperature hazards.

3.6.2 Reliability of FLEX Equipment

Section 3.2.2 of NEI 12-06 states, in part, that in order to assure reliability and availability of the FLEX equipment, the site should have sufficient equipment to address all functions at all units on-site, plus one additional spare (i.e., an N+1 capability, where "N" is the number of units on-site). It is also acceptable to have a single resource that is sized to support the required functions for multiple units at a site. In addition, it is also acceptable to have multiple strategies to accomplish a function, in which case the equipment associated with each strategy does not require an additional spare.

As indicated above, TVA provided a description of the Phase 2 equipment in its revised OIP dated February 7, 2014. Based on the number of portable FLEX pumps, FLEX DGs, and support equipment identified in TVA's revised OIP and during the audit review, the staff finds that, if implemented appropriately, TVA's FLEX strategies include a sufficient number of portable FLEX pumps for core cooling, SFP makeup and RCS makeup strategies consistent with the N+1 recommendation in Section 3.2.2 of NEI 12-06.

3.6.3 Conclusions

Based on this evaluation, the NRC staff concludes that TVA has developed guidance that, if implemented appropriately, should protect the FLEX equipment during a BDBEE consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.7 Planned Deployment of FLEX Equipment

In its FIP, TVA indicated that two heavy duty 4X4 vehicles will be available, each with a bed mounted 500 gallon fuel tank and fuel transfer pump, capable of debris removal, deployment of FLEX equipment, personnel transport and refueling diesel powered FLEX equipment. TVA also indicated that one compact track loader is available for debris clearing, one of the previously identified tow vehicles (4x4 truck) is equipped with a heavy duty front mounted 16.5 ton winch, and the other previously identified tow vehicle is mounted with a debris or snow removal plow. During the audit review, TVA stated that the compact track loaders are capable of equipment deployment, debris removal, and snow and ice removal, and will be maintained in a hardened structure to meet NEI 12-06 guidance and temperature controlled between 50 °F and 100 °F. Furthermore, during its onsite audit, TVA provided its study on "Liquefaction Induced Settlement Of Haul Roads," which indicated that a truck capable of navigating 9 inches of drop/rise will be stored in the FESB for the purpose of transporting FLEX equipment stored. The staff noted TVA's determination that the resulting settlement of 9 inches is the worst case for the haul roads and was based on the large amount of geotechnical exploration that has been done at the site, which included information/boring logs from the UFSAR, Bechtel SG Replacement Report and a recent liquefaction study for the FESB.

During the audit review, the staff noted that under the current design-basis, the flood duration time for the largest duration flood above plant grade is approximately 5 days; however, as previously noted, the minimum warning time for any flood event under TVA's current licensing basis is 27 hours. The staff noted that this provides TVA warning time for flood preparations and to begin deploying and staging Phase 2 FLEX equipment to ensure it is available when flood levels reach plant grade elevation. In addition, TVA explained that its calculated timelines assumed standard RCP seals, which does not impact deployment times for Non-Flood scenarios (diesel driven IP FLEX Pump and pre-staged 480v motor driven HP FLEX Pump) or Flood scenarios (submersible 480v motor driven HP and IP FLEX Pumps). The staff noted that deployment of FLEX equipment will be verified by formal validation and verification activities. In addition, in its letters dated October 29, 2014, and March 12, 2015, TVA stated that it is completing validation in accordance with industry guidance to assure required tasks, manual actions and decisions for FLEX strategies are feasible and may be executed within the constraints identified in the FIP for Order EA-12-049. Furthermore, validation is expected to be completed as procedures are completed and transfer of Unit 2 systems from construction to operations is completed.

The staff's review of the FLEX hose connection points for core cooling, RCS inventory control, and SFP inventory control is discussed in SE Sections 3.2.3.1.1 and 3.3.4.1.1. In summary, TVA stated in its revised OIP that FLEX hose connection points will be located within the intake pumping station, MSVV and Auxiliary Building, which are Category I structures. In addition, TVA stated in its FIP, that all FLEX equipment connection points will be designed to meet or exceed its design-basis SSE protection requirements. The staff noted that the RWST and AFWST are located outside and also include FLEX hose connection points, and TVA indicated in its FIP that the AFWST associated piping and RWST FLEX connections will be seismically qualified and protected against missiles. As previously noted, the minimum warning time for any flood event under TVA's current licensing basis is 27 hours. Therefore, with the warning time available prior to flood waters reaching plant grade elevation, TVA stated that flood condition procedures will ensure that hoses are connected before flood levels reach the FLEX connection.

As noted in the December 20, 2013 ISE, Section 3.1.4.2, the staff determined that TVA adequately addressed whether the UHS flow path could be affected by ice blockage or formation of frazil ice. In summary, with respect to ice formation on the UHS, TVA stated that since the closure of Watts Bar Dam in January 1942, ice formed only at shoreline or in protected inlets. Main channel ice has not been a problem and the lowest water temperature measured at Watts Bar Dam is 39 °F. Furthermore, an ice jam sufficient to cause plant flooding is inconceivable, since no valley restriction exists in the 1.9 mile reach below Watts Bar Dam to initiate a jam and the ice dam would need to reach at least 68 ft above the streambed to endanger the plant.

During the audit review, TVA stated that its FLEX strategy utilizes fuel stored in the safety related DG 7-day tanks and these tanks are mounted under the safety related DG building, which is seismically qualified and built to site design criteria for wind generated missile protection. The staff noted from UFSAR Section 2.4.14.2.1 that the DG Buildings have a 742' floor elevation, which is higher than the flood levels identified in UFSAR Section 2.4. Furthermore, UFSAR Section 3.8.4 identifies the DG building as a Category I structure.

TVA stated that each of the 7-day tanks contains a Technical Specification required volume of 62,000 gallons for a total volume of 248,000 gallons. TVA explained that the FLEX DGs (two 225 kVA and two 3 MW DGs) will be supplied with fuel oil directly from the safety related DG 7-day tanks. During its on-site audit, the staff observed the location of fueling lines that support TVA's FLEX equipment refueling strategy, and its review focused on the protection of the fuel oil supply pathways and refueling strategies for portable and pre-staged diesel powered equipment.

During the audit review, TVA indicated that the pre-staged FLEX DGs (two 225 kVA and two 3 MW DGs) would have a fuel consumption rate of approximately 466 gallons per hour. Based on its review of TVA's maintenance instruction for portable FLEX diesel equipment refueling, the staff noted that the fuel tank capacities for each piece of equipment was identified and that the remaining portable FLEX equipment (e.g., pumps, generators, light towers, etc.) has a fuel consumption rate of approximately 175 gallons per hour. Based on the consumption rates for TVA's pre-staged and portable FLEX equipment, the staff noted that the available on-site fuel oil will last approximately 16 days, which is conservative because it is based on all FLEX equipment operating at the same time at full load.

The staff noted that the fuel oil quality for each of the safety related DG 7-day tanks is maintained per Technical Specification SR 3.8.3.3 in accordance with its Diesel Fuel Oil Testing Program. During the audit review, TVA confirmed that the periodic monitoring of FLEX stored diesels will be performed to the same requirements as the safety related emergency diesel inventories. TVA also clarified that small equipment tanks will not be part of the monitoring process; instead, these tanks will be drained and refilled with fresh diesel every 18-24 months during routine maintenance procedures. In addition, TVA stated that all FLEX equipment will have periodic engine runs in accordance with the vendor and EPRI recommendations. Thus, based on its review, the staff finds that TVA has addressed management of fuel oil quality to ensure that the diesel FLEX equipment can be expected to be supplied with quality fuel oil.

Based on this evaluation, the NRC staff concludes that TVA has developed guidance that if implemented appropriately should allow deploying the FLEX equipment following a BDBEE consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.8 Considerations in Using Offsite Resources

During the audit review, the staff noted TVA's "SAFER Response Plan for Watts Bar Nuclear Plant," dated August 28, 2014, which contained specifics on (1) SAFER control center procedures, (2) National SAFER Response Center procedures, (3) logistics and transportation procedures, (4) staging area procedures, which includes travel routes between staging areas to the site, (5) guidance for site interface procedure development, and (6) a listing of site-specific equipment (generic and non-generic) to be deployed for FLEX Phase 3.

In addition, the staff confirmed in TVA's SAFER Response Plan the identification of Staging Areas B, C and D. Specifically, Staging Area B will be within 0.25 miles of the plant and located north of the EDG building. The staff noted that the SAFER Response Plan identifies that Staging Area B is capable of accepting helicopter cargo release. During the audit review, TVA provided the NRC staff with a site topography map that indicates Staging Area B is approximately at the 740' elevation. In addition, the staff noted that UFSAR Section 2.4.1.1 indicates that the EDG Building is at the 742' elevation, which is above the design-basis flooding levels, thus ensuring that Staging Area B is viable for off-site resources delivered from the NSRCs in response to an ELAP event. Furthermore, Staging Area C will be located at Rockford Municipal Airport, which is approximately 25 flying miles (33 driving miles) from the site. During the audit review, the staff noted in TVA's response plan that there are diverse driving routes from Staging Area C to the site that include the use of state road Highway 58 or 27, which travels east and west of the Tennessee River, respectively. Finally, Staging Area D will be located at Cleveland Regional Jetport, which is approximately 25 flying miles (43 driving miles) from the site. TVA confirmed that plant access of offsite resources may be accomplished by large transportation equipment or helicopter from any one of the three staging areas. The staff also noted that TVA's SAFER Response Plan contained procedures and checks to ensure that pre-planned travel routes from the staging areas to the site are accessible, otherwise contingencies are to be developed. Based on TVA's selection of staging areas and ability to transport offsite equipment via diverse options (i.e., routes and transportation method), the staff finds that TVA has addressed potential impacts to the region surrounding the site following an BDBEE in accordance with considerations in utilizing off-site resources in NEI 12-06 Sections 5.3.4, 6.2.3.4, 7.3.4 and 8.3.4. The staff noted that the description of Staging Areas B, C and D in the Watts Bar FIP are consistent with those described during the audit and SAFER response plan.

By letter dated September 26, 2014 (ADAMS Accession No. ML14265A107), the staff issued its staff assessment of the NSRCs established in response to Order EA-12-049. In its assessment, the staff concluded that SAFER has procured equipment, implemented appropriate processes to maintain the equipment, and developed plans to deliver the equipment needed to support site responses to BDBEEs, consistent with NEI 12-06 guidance; therefore, the staff concluded in its assessment that licensees can reference the SAFER program and implement their SAFER Response Plans to meet the Phase 3 requirements of Order EA-12-049.

During the audit review, TVA confirmed that Watts Bar will reference and utilize the NSRCs to meet the Phase 3 requirements of the order; however, TVA indicated that Watts Bar will receive the Phase 3 480 V DG from one of two NSRCs and the 6.9 kV DG from Sequoyah Nuclear Plant (Sequoyah). During a teleconference on November 26, 2014, the NRC staff requested that TVA clarify its Phase 3 strategy (i.e., can the 480 V DGs indefinitely cope for an ELAP; due to the close proximity of Watts Bar and Sequoyah, how can TVA assure that the Sequoyah 6.9 kV DGs will be available during an external event; etc.). TVA clarified that they can indefinitely cope on its phase 2 strategy with the pre-staged, onsite 480 V and 6.9 kV DGs; however, the 480 V DGs pre-staged (Phase 2) and the 480 V DGs being delivered from either

NSRC are capable of powering the critical loads to indefinitely cope for an ELAP. The 6.9 kV DGs pre-staged and at Sequoyah are for redundancy and will be used to re-power existing plant equipment. Therefore, the NRC staff finds that Watts Bar Phase 3 strategy to receive the 480 V DGs from the NSRCs and 6.9 kV DGs from Sequoyah acceptable, since the 480 V DGs can indefinitely cope for an ELAP and the 6.9 kV DGs from Sequoyah provide diversity in Watts Bar strategy.

Based on this evaluation, the NRC staff concludes that TVA has developed guidance that if implemented appropriately should allow utilization of offsite resources following a BDBEE consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.9 Habitability and Operations

3.9.1 Equipment Operating Conditions

Loss of Ventilation

Following a BDBEE and subsequent ELAP event, plant HVAC in occupied areas and areas containing permanent plant and FLEX mitigation strategy equipment will be lost. Per NEI 12-06, FLEX mitigation strategies must be capable of execution under the adverse conditions (unavailability of normal plant lighting, ventilation, etc.) expected following a BDBEE resulting in an ELAP. The primary concern with regard to ventilation is the heat buildup which occurs with the loss of forced ventilation in areas that continue to have heat loads. TVA performed a loss of ventilation analysis to quantify the maximum steady state temperatures expected in specific areas related to FLEX mitigation strategy implementation to ensure the environmental conditions remain acceptable for personnel habitability and within equipment qualification limits.

During the audit, the staff reviewed TVA's evaluation (FLEX Implementation HVAC ELAP Analysis SL-01240, Revision 0) for the temperature response in areas that contain FLEX equipment for an ELAP event during the summer season when outside air temperatures are the highest. The staff noted that assessing the temperature response for an ELAP event during the summer season is bounding for the three other seasons. The staff noted that the equipment areas assessed by TVA include those that are credited and desired for its FLEX strategies. The equipment areas credited by TVA's FLEX strategies include the area for the CCW pumps, SIPs and boric acid tanks, the positive displacement pump room, which contains the HP and IP FLEX pumps (modes 5 and 6) - elevation 692', the Auxiliary Building vent room, which contains the IP FLEX pump – elevation 737', the TDAFWP room, Main Control room, Shutdown Board rooms, EDG building, 5th DG building, FESB, and intake pumping station.

TVA's evaluation concluded that temperatures remain within acceptable limits based on conservative input heat load assumptions for all areas with no actions being taken to reduce heat load or to establish either active or passive ventilation (e.g., portable fans, open doors, etc.). In the case of the TDAFW pump rooms, SIPs rooms, and the positive displacement pumps rooms (location of the HP FLEX Pumps), doors will be opened and left opened to facilitate natural circulation and ensure that the temperatures remain within the acceptable range for equipment and personnel. These doors will remain open to support pump operation. However, no action is required until 24 hours into an ELAP event since TVA's Vital Battery room, Shutdown Board room, Main Control room, and TDAFWP room HVAC studies determined that ventilation is not required until 24 hours into the ELAP event; at which point, doors can be propped open (natural circulation) and monitored periodically, if needed.

In addition, TVA provided calculation MDQ000360201300272, Revision 0, "WBNP ELAP Transient Temperature Analysis," which verified that electrical equipment relied upon as part of the Watts Bar mitigation strategy for an ELAP as a result of a BDBEE will not be adversely affected by increases in temperature as a result of loss of HVAC. TVA's analysis modeled four cases for the control and auxiliary buildings that contain equipment necessary and/or desired for coping with emergency plant functions during a loss of HVAC as a result of a BDBEE. The first case considered summer-time responses with no compensatory actions taken. The second case analyzed the impact of opening doors between modeled spaces at 4 hours with all other conditions the same as Case 1. The third case analyzed the impact of modeling fans starting after 24 hours for various rooms with all other conditions the same as Case 2. The fourth case analyzed the impact of replacing the emergency incandescent lights in the Main Control room with LEDs with all other conditions the same as Case 3. The calculation also included a separate analysis of the TDAFWP rooms.

In the draft calculation, TVA referenced TVA calculation GENSTP3-001, R000, "Upper Boundary Temperature for Mild Environments Related to Environmental Qualification of Electrical Equipment," which included results for electrical equipment used at nuclear power plants. While the NRC staff did not review this calculation, TVA noted that the reference calculation concluded that electrical equipment could experience temperature excursions up to 140 °F for 24 hours followed by a period of 120 °F for an indefinite period or slow ramp to 135 °F followed by a period of 100 days at 135 °F. TVA identified that the only exception area was for the switchgear and motor control centers, which may require current limitations above 104 °F. TVA concluded that the low voltage circuit breakers and switchgear can withstand 140 °F ambient conditions on a continuous basis while carrying 80 percent of rated load.

For each of the cases described above, TVA's calculation demonstrated that temperatures would remain below the design limits for the electrical equipment for the duration of the ELAP event. For the TDAFWP rooms, TVA stated that the room temperature would reach 126.6 °F by the end of an ELAP event. This temperature is acceptable for the first 24 hours but would need to be reduced afterwards. As stated above, TVA noted that a temperature reduction could be achieved by opening the doors to the rooms.

In addition, the staff noted that seven hours after the declaration of the ELAP event TVA plans to monitor TDAFWP room, Main Control room, Shutdown Board room, Vital Battery Board room and SFP area for ventilation needs and if required, verify 6.9 kV FLEX DG loading and restore selected heating, ventilation and air conditioning systems to service.

Based on this evaluation, the NRC staff concludes that TVA has developed guidance that if implemented appropriately should be able to execute Watts Bar FLEX mitigation strategies under the adverse conditions following a BDBEE consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

Hydrogen Gas Accumulation in Vital Battery Rooms

The staff also reviewed TVA's draft analysis, EPM-RIU-112288, "125V DC Vital Battery Rooms Ventilation," to verify that hydrogen gas accumulation in the 125 V Vital Battery rooms will not reach combustible levels while HVAC is lost during an ELAP as a result of a BDBEE. TVA's analysis considered hydrogen gas generation rates provided by the battery manufacturer (C&D Technologies) during an equalize charge, worst-case maximum temperatures (104 °F and 110 °F), and isolation from the existing HVAC system (i.e., HVAC not operating and tornado dampers closed). Given these factors, TVA's analysis concluded that the hydrogen gas accumulation in the 125 Vdc Vital Battery rooms would reach 2 percent (design basis limit) in 1.76 days at 110 °F room temperature and 2.33 days at 104 °F room temperature.

Based on its review of the analysis, TVA concluded that hydrogen accumulation in the 125 Vdc Vital Battery rooms should not reach the combustibility limit for hydrogen (4 percent) during an ELAP as a result of a BDBEE since it is assumed that power will be restored to the vital battery room HVAC systems within the calculated times before hydrogen gas accumulation reaches 2 percent in the 125 Vdc Vital Battery rooms. The NRC staff did not identify any discrepancies with the analysis.

3.9.2 Personnel Habitability

In its FIP, TVA stated that a loss of ventilation analyses was performed to quantify the maximum steady state temperatures expected in specific areas related to FLEX mitigation strategy implementation to ensure the environmental conditions remain acceptable for personnel habitability and within equipment qualification limits (FLEX Implementation HVAC ELAP Analysis SL-01240, Revision 0). TVA also stated that the areas identified for all phases of execution of the FLEX mitigation strategy activities are the Main Control room, Shutdown Board rooms, Auxiliary Building, TDAFWP rooms, EDG Building, 5th DG Building, FESB and intake pumping station. TVA further explained that the HVAC study for the Vital Battery room and Shutdown Board room, Main Control room and TDAFWP room determined that ventilation is not required until 24 hours into ELAP event, at which point it can be monitored periodically, if needed.

The staff noted that TVA's evaluation conservatively assumed that no actions were being taken to reduce heat load or to establish either active or passive ventilation (e.g., portable fans, open doors, etc.). In addition, the staff noted that seven hours after the declaration of the ELAP event TVA plans to monitor TDAFWP room, Main Control room, Shutdown Board room, Vital Battery Board room and SFP area for ventilation needs and if required, verify 6.9 kV FLEX DG loading and restore selected heating, ventilation and air conditioning systems to service. Furthermore, in its FIP, TVA stated that for both flood and non-flood events doors to rooms where systems and/or components are in service or in operation should be blocked open to facilitate natural ventilation (i.e., Vital Battery rooms, TDAFWP rooms, SIP rooms).

TVA stated in its FIP that backup control stations were installed to provide instrument air/nitrogen supplied control capability for the operator to manipulate the SG atmospheric relief valves and auxiliary feedwater level control valves. Furthermore, TVA stated that these stations are located in the shutdown board rooms, elevation 757', above the probable maximum flood elevation. The staff noted that UFSAR Section 3 indicates that the Shutdown Board rooms are located in the Auxiliary Building, which is a Class I structure. The staff noted that in addition to those backup control stations, local operation of the AFW level control valves and/or SG PORVs is possible and FLEX activities will be essentially the same as those evaluated for the current site procedure ECA-0.0, Loss of All AC Power.

In its FIP, TVA indicated that the required action is to establish ventilation in the area of the SFP and establish any equipment local to the SFP building to accomplish the coping strategies. If the air environment in the SFP area requires the building to be ventilated, doors will be opened to establish air movement and venting the SFP building. For accessibility, establishing the SFP vent and any other actions required inside the fuel handling building should be completed before boiling occurs. The staff noted during the audit review that TVA's Phase 2 SFP strategy involves two FLEX hoses that are connected, one each, to the Unit 1 and Unit 2 ERCW supply headers on the 757' elevation. The discharge ends of these hoses will either be routed all the way to the spent fuel pit, with the discharge ends positioned over the edge of the pit or connected to water cannons, positioned to discharge a water spray over the spent fuel pit. TVA's thermal-hydraulic analyses and FIP indicate that boiling occurs at approximately 18.69 hours. The staff noted that TVA's sequence of events timeline, Attachment 1A of its FIP, indicates that after six hours from event initiation operators will deploy hoses and spray nozzles as a contingency for SFP makeup and is expected to take approximately two hours for deployment.

3.9.3 Conclusions

Based on the evaluation above, the NRC staff concludes that TVA has developed guidance that, if implemented appropriately, should maintain or restore equipment and personnel habitability conditions following a BDBEE consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.10 Water Sources

3.10.1 Steam Generator Make-Up

Phase 1

During Phase 1, TVA's core cooling FLEX strategies will rely on its newly constructed AFWST. TVA stated in its FIP that the AFWST will be qualified to be robust with respect to high winds and seismic events. The staff noted that the AFWST will not be available as a water source once flood water reaches plant grade; however, TVA stated that its limiting flood event provides a 27 hour period before flood waters reach plant grade elevation. In its revised OIP, TVA stated that the AFWST will provide approximately 15 hours of inventory to the suction of the TDAFWPs for each unit before the AFWST is depleted and then the suction flow to the TDAFWP can be provided by standing water in the ERCW headers, for an additional 7 hours for Unit 1 and 4.7 hours for Unit 2. As previously discussed in SE Section 3.2.3.1.1, the staff determined that the AFWST and standing water in the ERCW header will survive a BDBEE and will be available for an ELAP/LUHS event.

If implemented appropriately and consistent with the FIP, TVA should have water sources available during Watts Bar Phase 1 core cooling strategies for SG inventory make-up. In addition, TVA's strategy should provide sufficient time for Watts Bar to begin deploying and staging Phase 2 FLEX equipment. TVA's sequence of events timeline is documented in Attachment 1A of its FIP dated October 29, 2014.

Phase 2

During Phase 2, TVA's core cooling FLEX strategies will rely on the LP FLEX pumps staged at the intake pumping station taking suction from the intake channel and discharging to the ERCW FLEX connections inside the intake pumping station, which will be used to pressurize the ERCW headers and can then be used for direct supply to the TDAFWP suction, if required. UFSAR Section 9.2.5.3 states that the intake channel is seismically qualified and a tornado cannot disrupt the water supply to the intake pumping station. During the audit review, TVA addressed the impact from the loss of a downstream dam as documented in Section 3.1.1.2 of the ISE dated December 20, 2013. In summary, TVA stated that in the assumed event of complete failure of the downstream Chickamauga Dam and with the headwater, before failure, assumed to be at normal summer level, Elevation 682.5 ft., the water surface at the site will begin to drop 3 hours after failure of the dam and will fall at a fairly uniform rate to Elevation 666.0 ft. in approximately 27 hours from failure. This time period is more than ample for initiating the release of water from the upstream Watts Bar Dam, which is also owned and operated by TVA.

TVA stated that surviving, non-seismic, clean water tanks can also be used to refill the AFWST using transfer pumps. During the audit review, the staff confirmed that TVA's procedures provide direction for use of any surviving clean water tanks on site that are available following a BDBEE.

For flood conditions, TVA's FLEX strategies rely on a LP FLEX pump taking suction from a condenser circulating water cooling tower basin with its discharge routed to a FLEX hose connection inside the 5th DG building. As previously noted, TVA would have a minimum of 27 hours before flood waters reach plant grade elevation for the current licensing basis limiting flooding event.

If implemented appropriately and consistent with its FIP, TVA should have water sources available during Watts Bar Phase 2 core cooling strategies to provide SG inventory make-up.

Phase 3

In its FIP, TVA stated that a mobile water purification system, which will be provided by the NSRC, will enable water from the Tennessee River or other raw water source to be purified and this unit would process the water source and discharge improved quality water to the AFWST. The staff noted that during flooding events, TVA can continue supplying raw water either from the condenser circulating water cooling tower basin or flood waters. During the audit, the staff reviewed TVA's SAFER Response Plan and confirmed that TVA has requested water treatment equipment from the NSRC to support its Phase 3 strategies.

If implemented appropriately and consistent with its FIP, TVA should have water sources available during Watts Bar Phase 3 core cooling strategies to provide SG inventory make-up.

3.10.2 Reactor Coolant System Inventory

Phase 1

In its FIP, TVA stated RCS inventory is a significant concern for the ELAP scenario due to the RCP seal design. Timely RCS cooldown and depressurization while holding SG pressure to greater than 300 psig ensures no nitrogen injection into the RCS from Cold Leg Accumulators. Furthermore, RCS makeup is required to compensate for the RCP seal leakage and from shrinkage due to cooldown; thus, Phase 1 RCS inventory makeup is provided from the Safety Injection System Cold Leg Accumulators. As previously discussed in SE Section 3.2.3.1.1, the staff determined that the cold leg accumulators will survive a BDBEE and will be available for an ELAP/LUHS event.

If implemented appropriately and consistent with its FIP, TVA should have water sources available during Watts Bar Phase 1 RCS makeup strategies for RCS inventory control. In addition, TVA's strategy should provide sufficient time for Watts Bar to begin deploying and staging Phase 2 FLEX equipment. TVA's sequence of events timeline is documented in Attachment 1A of its FIP.

Phase 2

During Phase 2, TVA's RCS inventory control strategies rely on the RWST as the primary source of water and the boric acid tank/boron injection tank as an alternate source of water. The staff noted that UFSAR Table 3.2-2 indicates that the RWST and boron injection tank are both seismic Category I components and are located outside and in the Auxiliary Building (Category I structure), respectively. Furthermore, UFSAR Section 3.8.4.1.3 states that a barrier wall is located around the RWST to protect the bottom three feet of the tank, which ensures storage for borated water after a postulated rupture of the tank. However, during the audit review, the staff noted that the RWST for Units 1 and 2 are not entirely protected from tornado missiles and may not have been designed for tornado wind loads. The staff noted that the volume of water retained by the 3 foot barrier wall is less than the volume necessary to support RCS injection for FLEX until off-site resources arrive with a boration skid and water purification system. The staff questioned whether TVA had sufficient protected sources of borated water to support uninterrupted RCS injection during an ELAP.

In response, TVA stated that a mobile boration unit and a water purification system will be brought from the NSRC to supply borated water to the RWST for indefinite coping. TVA also stated that sufficient borated water is available on-site to support the FLEX strategies until the off-site equipment arrives. TVA based its conclusion on the ability of the RWSTs to resist tornado missiles, intervening structures that shield the RWSTs from missile damage, procedural controls to preclude vehicles around the RWSTs, the RWSTs' ability to withstand tornado wind loads, and the existence of multiple sources of borated water onsite.

TVA performed an evaluation to demonstrate the ability of the RWSTs to withstand tornado missiles based on Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Revision 1, 2007. The staff finds the applicant's use of Regulatory Guide 1.76, Rev. 1, as an acceptable means for assessing tornado missile strikes on the RWSTs for beyond-design-basis FLEX purposes. The staff noted that Regulatory Guide 1.76

identifies a 6-inch Schedule 40 steel pipe to test penetration resistance, an automobile as a massive high-kinetic-energy missile that deforms on impact, and a 1 inch solid steel sphere to test the configuration of openings in protective barriers. TVA's design calculation for the RWSTs (TVA RIMS 891011T0163 – Design of Two Refueling Water Storage Tanks for Watts Bar Nuclear Plant, March 27, 1977) indicates that the RWSTs are fabricated from ASME SA-240, Type 304, stainless steel, with the shell thickness progressively thinning over five sections from 21/32-inch at the base to 5/16-inch at the top.

TVA evaluated the rigid missile that tests penetration resistance, a 6-inch Schedule 40 pipe that is 15 ft. long, moving at 135 feet-per-second (fps), striking normal to the surface of the RWST wall (exactly radically oriented). TVA's calculation used two separate equations to determine whether the RWSTs would be penetrated by this missile: the Stanford Research equation and Offshore Power Systems equation. TVA clarified that the Stanford Research equation is referenced in its UFSAR and used in existing calculations for design of structures to resist missile impact. The license also clarified that the Offshore Power Systems equation is a refinement of the Stanford Research equation, which used data from actual testing to develop the equation. Based on TVA's clarification of these equations, the staff finds their use to be appropriate for this evaluation of the RWSTs for beyond-design-basis FLEX purposes. TVA determined that the 3/8-inch wall thickness section of the RWSTs, which equates to a tank height of 30.4 feet, would be capable of withstanding this 6-inch Schedule 40 pipe missile. The staff noted that TVA demonstrated consistent results between the Stanford Research equation and the Offshore Power Systems equation.

TVA did not evaluate the 1-inch solid steel sphere missile defined in Regulatory Guide 1.76 for tank penetration. The staff finds this appropriate because the intent of this missile is to test the configuration of openings in protective barriers, and not to test penetration resistance. The staff noted that automobiles and other vehicles parked within the vicinity of the RWSTs may become potential large missiles during a high wind event and informed TVA of this concern. In response, TVA provided its revised abnormal operating instruction (0-AOI-8, Tornado Watch or Warning), which directs operators to ensure no vehicles are parked in the vicinity of either Unit 1 or Unit 2 RWSTs when a Tornado Watch or a Tornado Warning is issued for Rhea or Meigs county. The staff finds it appropriate that TVA will preclude automobiles and other vehicles from being within the vicinity of the RWSTs because this will remove potential large missiles that can damage the RWSTs during a high wind event. Thus, the staff also finds it appropriate that the automobile missile was not addressed by TVA's evaluation because of these provisions.

The staff noted that TVA has several sources of borated water available for RCS injection and that RCS inventory loss due to RCP leakage will decrease as the RCS is depressurized. The FLEX connections on the fuel pool cooling and cleaning system can be hosed to take suction from the Unit 1 and Unit 2 RWSTs, and discharge to the RCS via the high pressure FLEX pumps and the safety injection system; thus, either RWST can supply water to both units. TVA evaluated the amount of borated water that would be needed to support RCS injection for FLEX until off-site resources arrive and determined that the volume of borated water available in the boric acid storage tanks and a tank height of 18.3 feet from each RWST would be sufficient for approximately four days. The staff noted that there is a significant amount of margin available for additional borated water because the RWSTs have been shown to survive a missile strike up to 3/8-inch tank thickness section, which equates to a tank height of 30.4 feet.

TVA stated that the RWSTs are separated by approximately 500 feet in an east-west orientation. Furthermore, they are separated, in part, in the east-west direction by several seismic Category 1 structures that are taller than the RWSTs. Specifically, both Reactor Buildings (879.5'), the Auxiliary Building (819.75') and the Control Building (778') provide shielding and separation between the RWSTs (772.7'). The staff also noted several other structures around the RWSTs that will provide a level of protection from tornado generated missiles. For the Unit 1 RWST, these include the Tritiated Water Storage Tank to the west, the Unit 1 Primary Water Storage Tank to the north, and the Service Building to the south. For the Unit 2 RWST, these include the Unit 2 Primary Water Storage Tank to the north and the seismically qualified AFWST to the east. During a teleconference call, TVA clarified that the Tritiated Water Storage Tank and AFSWT were designed for tornado missiles. The staff considers the Category I structures between the RWSTs to provide reasonable protection and shielding for the tanks in terms of separation by large structures. Further, the other structures (e.g., surrounding tanks and service building), although not Category I structures, offer additional shielding for the RWSTs and can absorb tornado missiles before they reach the RWST(s).

Regarding tornado wind loads, TVA stated that the design calculation for the RWSTs (TVA RIMS 891011T0163) indicates that the RWSTs were designed for 100 mph wind and safe shutdown earthquake loading. This resulted in a design wind base shear of 32.9 kips and the design wind overturning moment of 691 ft-kips. In addition, the staff noted that this calculation also indicates that the RWSTs were designed for an external depressurization of 3 psi occurring in 3 seconds resulting from a tornado, which is consistent with UFSAR Section 2.3.1.3. TVA performed an evaluation accounting for 360 mph wind speed for the RWSTs based on ASCE 7-05, "Minimum Design Loads for Buildings and Other Structures," which is the code used for the design of the FESB to protect FLEX equipment. This evaluation determined a base shear of 358 kips and an overturning moment of 8,370 ft-kips caused by the 360 mph wind speed. In order to demonstrate that the RWSTs have sufficient capacity for base shear and overturning moment, TVA referenced a beyond-design-basis evaluation (CDQ 0009992012000125) associated with the seismic margins assessment performed in accordance with NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events for Severe Accident Vulnerabilities." The evaluation determined that the HCLPF of the RWSTs correspond to a base shear capacity of 5,110 kips and an overturning moment capacity of 69,300 ft-kips. Thus, TVA determined that the capacity of the tank for base shear and overturning moment is at least seven times larger than the loads induced by the 360mph wind speed. Based on (1) the margin between the base shear and overturning moment induced by the tornado wind loads compared to the corresponding capacity determined from the seismic margins assessment, and (2) the fluid forces from within the RWSTs providing for wind loading resistance, the staff finds it reasonable that the RWSTs can withstand tornado wind loads.

In summary, the staff finds it reasonable to conclude that TVA has sufficient borated water available on-site to provide RCS injection for FLEX until the boration unit and water purification system arrive from the NSRC because (1) TVA demonstrated that the tanks can withstand penetration from missiles up to a tank height of 30.4 feet, (2) TVA demonstrated that the available borated water is adequate with margin to support RCS make-up for approximately four days, (3) TVA will establish procedural controls to preclude vehicles from becoming large tornado missiles around the RWSTs, (4) TVA demonstrated that the RWSTs have the capacity to withstand tornado wind loads, and (5) the RWSTs are separated and shielded from tornado missile strikes by intervening structures (i.e., Category I structures, surrounding tanks and the service building).

The NRC staff reviewed TVA's evaluation LTR-SEE-II-14-44, Rev. 0, dated July 31, 2014, which determined that during extreme cold conditions, the RWST will approach a temperature of 32° F no earlier than 115 hours following an ELAP initiating event and that the RWST inventory (boron concentration of 3300 ppm) is soluble in water and not susceptible to precipitation at temperatures above freezing. Furthermore, TVA explained that the boric acid tanks (boron concentration of 6900 ppm) are not the primary water source for RCS inventory, are located below grade elevation inside the auxiliary building and are normally maintained in excess of the temperature for the boric acid solution to remain soluble. During the audit review, TVA also clarified that the RWST instrumentation located outside may freeze after loss of heat tracing; however, TVA determined this is not a concern because there is operator awareness of RWST inventory, the total makeup to RCS is less than RWST inventory, and FLEX strategies do not rely on the use of RWST instrumentation. The staff finds TVA has addressed the concern of heat tracing and possible boron precipitating under extreme cold conditions in its FLEX strategies.

Furthermore, in its FIP, TVA stated that for the RWST connections required during flood conditions, procedures will ensure that hoses are connected before flood levels reach the connection. As previously noted, TVA would have a minimum of 27 hours before flood waters reach plant grade elevation for the current licensing basis limiting flooding event. The staff finds it reasonable that TVA will have time to attached hoses to FLEX connections prior to flood waters reaching plant grade elevation.

If implemented appropriately and consistent with its FIP, TVA should have water sources available during Watts Bar Phase 2 RCS make-up strategies to provide RCS inventory control.

Phase 3

In its FIP dated October 29, 2014, TVA stated that a mobile water purification system, which will be provided by the NSRC, will enable water from the Tennessee River or other raw water sources to be purified. The purification system will process the water source and discharge improved quality water to the AFWST.

However, TVA's October 29, 2014 FIP did not identify a long-term boration strategy for indefinite coping. In response, TVA stated that a mobile boration unit and a water purification system will be brought from the NSRC to supply borated water to the RWST for indefinite coping. As discussed above, TVA explained that sufficient borated water is available on-site to support the FLEX strategies until the arrival of the off-site equipment. The audited information states that the mobile boration and water purification units would be placed into service within four days, which is prior to the depletion of the onsite inventory of borated coolant and would be after floodwaters recede.

If implemented appropriately and consistent with its FIP, TVA should have water sources available during Watts Bar Phase 3 core cooling strategies to provide RCS inventory control.

3.10.3 Spent Fuel Pool Inventory Control

Phase 1

The staff noted that TVA's Phase 1 SFP FLEX strategies do not rely on make-up to the SFP; thus, a water source was not identified for Phase 1.

Phase 2

During Phase 2, TVA's SFP inventory control FLEX strategies will rely on the LP FLEX pumps deployed at the intake pumping station taking suction from the intake channel and discharging to the ERCW FLEX connections inside the intake pumping station, which will be used to pressurize the ERCW headers. The staff noted that with the ERCW header pressurized, TVA's strategies involve the use of hoses to its primary and alternate connections to provide water to the SFP. SE Section 3.3.4.1 provides the staff's evaluation for TVA's primary and alternate connections for SFP inventory control. UFSAR Section 9.2.5.3 states that the intake channel is seismically qualified and a tornado cannot disrupt the water supply to the intake pumping station. TVA addressed the impact from the loss of a downstream dam as documented in Section 3.1.1.2 of the ISE dated December 20, 2013.

For flood conditions, TVA's FLEX strategies, as described in its FIP, rely on a LP FLEX pump taking suction from a condenser circulating water cooling tower basin with its discharge routed to a FLEX or B.5.b hose connections inside the 5th DG building. As previously noted, TVA would have a minimum of 27 hours before flood waters reach plant grade elevation for the current licensing basis limiting flooding event.

If implemented appropriately and consistent with its FIP, TVA should have water sources available during Watts Bar Phase 2 SFP inventory control to provide make-up to the SFP.

Phase 3

In its FIP, TVA stated that a mobile water purification system, which will be provided by the NSRC, will enable water from the Tennessee River or other raw water source to be purified. The unit will process the water source and discharge improved quality water to the AFWST. The staff noted that during flooding events, TVA can continue supplying raw water either from the condenser circulating water cooling tower basin or flood waters. During the audit process, the staff reviewed TVA's SAFER Response Plan and confirmed that TVA has requested water treatment equipment from the NSRC to support its Phase 3 strategies.

If implemented appropriately and consistent with its FIP, TVA should have water sources available during Watts Bar Phase 3 SFP strategies to provide make-up to the SFP.

3.11 Shutdown and Refueling Analyses

Order EA-12-049 requires that licensees must be capable of implementing the mitigation strategies in all modes. In general, the discussion above focuses on a BDBEE occurring during power operations. This is appropriate, as plants typically operate at power for 90 percent or more of the year. When the BDBEE occurs with the plant at power, the mitigation strategy initially focuses on the use of a pump coupled to a steam-powered turbine to provide the water initially needed for decay heat removal. If all or most of the fuel has been placed in the SFP, there may be a shorter timeline to implement the makeup of water to the SFP. However, this is balanced by the fact that if immediate cooling is not required for the fuel in the reactor vessel, the operators can concentrate on providing makeup to the SFP. TVA's analysis shows that following a full core offload to the SFP, about 30 hours are available to implement makeup before boil-off results in the water level in the SFP dropping far enough to uncover fuel assemblies, and TVA has stated that they have the ability to implement makeup to the SFP within that time.

When a plant is in a shutdown mode in which steam is not available to operate the steam-powered pump (which typically occurs when the RCS has been cooled below about 300 °F), another strategy must be used for decay heat removal. On September 18, 2013, NEI submitted to the NRC a position paper entitled "Shutdown/Refueling Modes" (ADAMS Accession No. ML13273A514), which described methods to ensure plant safety in those shutdown modes. By letter dated September 30, 2013 (ADAMS Accession No. ML13267A382), the NRC staff endorsed this position paper as a means of meeting the requirements of the order.

The position paper describes how licensees will maintain FLEX equipment either available for deployment in shutdown and refueling modes, or pre-stage certain equipment. Those plant procedures that are used to respond to loss of cooling in these modes will incorporate FLEX equipment where appropriate. The NRC staff concludes that the position paper provides an acceptable approach for demonstrating that TVAs are capable of implementing mitigating strategies in shutdown and refueling modes of operation. TVA informed the NRC staff of its plans to follow the guidance in this position paper. Based on the evaluation above, the NRC staff concludes that TVA has developed guidance that, if implemented appropriately, should maintain or restore core cooling, SFP cooling, and containment following a BDBEE in shutdown and refueling modes consistent with NEI 12-06 guidance, as endorsed, by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.12 Procedures and Training

The NRC staff reviewed TVA's loss of shutdown power procedures (ECA-0.0) and samples of its newly developed FLEX Support Instructions. The staff noted that ECA-0.0 is TVA's existing procedure for addressing loss of shutdown power and has been updated to account for an ELAP event if the shutdown board cannot be energized. The staff also noted that ECA-0.0 is the controlling procedure that declares an ELAP event. In addition, the staff noted that ECA-0.0 has been revised to direct the use of appropriate FLEX Support Instructions once an ELAP event has been declared. The staff noted that the first set of FLEX Support Instructions that are entered following the declaration of an ELAP event are associated with dc bus management/load shed and 480 V FLEX DG alignment/loading, initial assessment and FLEX equipment staging, and alternate RCS boration.

TVA stated in its FIP that to assure that FLEX response actions do not impact on design-basis flood mode preparations, FLEX Flood Mode equipment will be pre-staged based on a 25 year flood warning from TVA's River Operations Forecasting group. TVA also stated that concurrent with full FLEX implementation at Watts Bar, River Operations procedure RvM-SOP-10.05.06, "Nuclear Notifications and Flood Warning Procedure," and AOI-7.01, "Maximum Probable

Flood," have been revised to provide the notification and direct the pre-staging of FLEX equipment. TVA clarified that initial flood warning is received from TVA's River System Operations prior to a Stage 1 warning notification which will provide a minimum of 27 hours before flood waters reach grade elevation. During the audit review, TVA stated that this early notification allows for FLEX equipment to be staged prior to AOI-7 design-basis flood preparation required actions and be available in case it is needed for an ELAP event. In addition, early deployment limits the impacts on design-basis flood preparations and its resource requirements.

In its FIP, TVA stated that training plans were developed and presented for plant groups including the emergency response organization, fire, security, emergency preparedness, operations, engineering and maintenance. The training plan development was accomplished in accordance with its procedures using the Systematic Approach to Training, and has been implemented to ensure that the required licensee staff is trained prior to full implementation of Order EA-12-049. TVA also stated in its FIP that programs and controls established to assure personnel proficiency in the mitigation of beyond-design-basis events and maintaining FLEX are developed and maintained in accordance with NEI 12-06, Section 11.6.

In addition, by letter March 12, 2015, TVA stated that training for Units 1 and 2 has been completed in accordance with an accepted training process as recommended in NEI 12-06, Section 11.6.

Therefore, the staff finds that TVA has adequately addressed training associated with FLEX because a training program has been established and will be maintained in accordance with NEI 12-06, Section 11.6, and TVA committed to the completion of training associated with interaction among the Emergency Response Organization, the NSRCs and offsite FLEX staging areas by December 17, 2014.

3.13 Conclusions for Order EA-12-049

Based on the evaluations above, the NRC staff concludes that TVA has developed guidance to maintain or restore core cooling, SFP cooling, and containment following a BDBEE which, if implemented appropriately, should adequately address the requirements of Order EA-12-049.

4.0 TECHNICAL EVALUATION OF ORDER EA-12-051

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A440), TVA submitted its OIP for Watts Bar in response to Order EA-12-051. By letter dated August 2, 2013 (ADAMS Accession No. ML13204A231), the NRC staff sent a request for additional information (RAI) to TVA. TVA provided a response by letter dated September 6, 2013 (ADAMS Accession No. ML13254A065). By letters dated October 24, 2013 (ADAMS Accession No. ML13275A373), and May 15, 2014 (ADAMS Accession No. ML14128A129), the NRC staff issued an Interim Staff Evaluation, including RAIs, and an audit report to TVA. By letters dated November 22, 2013, January 10, 2014, and June 25, 2014 (ADAMS Accession Nos. ML13333B282, ML14014A137, and ML14177A526, respectively), TVA provided supplemental information. By letters dated August 28, 2013, February 28, 2014, and August 28, 2014 (ADAMS Accession Nos. ML13254A297, ML14064A238, and ML14248A484, respectively), TVA submitted six-month updates to the OIP. By letter dated March 26, 2014 (ADAMS Accession No. ML14083A620), the NRC notified all licensees and construction permit holders that the staff is conducting in-office and onsite audits of their responses to Order EA-12-051 in accordance with NRC NRR Office Instruction LIC-111, as discussed above.

TVA installed a SFP level instrumentation system designed by Westinghouse. The staff met with TVA on January 22, 2014, at the Westinghouse Electric Corporation Automation and Field Services facility in Waltz Mill, PA to observe operation of the proposed spent fuel instrumentation system in a full-scale simulated SFP environment, and to prepare for an audit of Westinghouse, LLC. On February 4, 2014, the NRC staff initiated an audit of Westinghouse, LLC (the vendor) design verification analyses and performance test results. The staff reviewed the vendor's SFP instrumentation system design specifications, calculations and analyses, test plans and test reports. This audit was concluded on April 2, 2014, and an audit report was issued on August 18, 2014 (ADAMS Accession No. ML14211A346).

By letter dated October 29, 2014 (ADAMS Accession No. ML14303A561), TVA submitted its Compliance Letter, including one open item in response to Order EA-12-051.
The open item was associated with the temperature qualification of the SFP level transmitters for seven days of operation. By letter dated December 19, 2014 (ADAMS Accession No. ML15002A202), TVA notified the NRC that a calculation has been performed to resolve the temperature qualification open item.

4.1 Levels of Required Monitoring

Attachment 2 of Order EA-12-051 states in part:

> All licensees identified in Attachment 1 to this Order shall have a reliable indication of the water level in associated spent fuel storage pools capable of supporting identification of the following pool water level conditions by trained personnel: (1) level that is adequate to support operation of the normal fuel pool cooling system [Level 1], (2) level that is adequate to provide substantial radiation shielding for a person standing on the SFP operating deck [Level 2], and (3) level where fuel remains covered and actions to implement make-up water addition should no longer be deferred [Level 3].

By letter dated September 6, 2013, on page E1-2, TVA stated that it will use the normal SFP water level at Watts Bar (749.125 feet (ft.) above mean sea level) as Level 1. Due to the physical configuration of the shared SFPs, Watts Bar elevation of 749.125 ft. is the highest possible elevation for Level 1. However, TVA's calculation determined that at this elevation, adequate Net Positive Suction Head (NPSH) for SFP cooling pumps would only exist for temperatures up to 190 °F. This elevation does not ensure NPSH protection for temperatures that exceed 190°F.

The requirement to provide operational guidance for NPSH protection during beyond-design-basis saturated conditions above 190 °F was entered in TVA's Corrective Action Program. By letter dated January 10, 2014, on page 2, TVA stated that during a BDBEE, as the temperature rises above 190°F, Watts Bar will control by procedure the throttling of pump discharge to ensure adequate NPSH. TVA also indicated the location of the valves that would require manipulation based on which train of SFP cooling being restored and described how this location would be accessed.

TVA designated Level 2 as 734.29 ft. using the first of two options described in NEI 12-02 for this level, which was 10 ft. (+/- foot) above the highest point of any fuel rack seated in the SFP. By letter dated November 22, 2013, on page E1-18, TVA provided a sketch identifying various pool elevations and SFP instrumentation levels. In this figure, TVA identified Level 2 at 734.29 ft. with the top of the SFP rack 10 ft. below at 724.29 ft.

By letter dated September 6, 2013, on page E1-2, TVA indicated that the Guided Wave Radar (GWR) system can only sense level changes above the weight attached to the sensing cable and there is a small distance above the weight that the manufacturer defines as the dead zone. On page E1-1 of the letter dated November 22, 2013, TVA indicated that level 3 would be set at 724.79 ft., in which this elevation corresponds to the top of the dead zone instead of the top of fuel storage rack. During the Westinghouse SFP instrumentation audit, the vendor indicated that the total distance above the SFP rack where level changes cannot be detected is less than one foot. By letter dated June 25, 2014, on page EA1–3 of attachment 1, TVA documented the confirmation that the unreadable distance is less than one foot from the highest point of any fuel rack seated in the SFP.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed Levels 1, 2 and 3 are consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the Order.

4.2 Evaluation of Design Features

Order EA-12-051 required that the spent fuel pool level instrumentation shall include specific design features, including specifications on the instruments, arrangement, mounting, qualification, independence, power supplies, accuracy, testing, and display. Below is the staff's assessment of the design features of Watts Bar spent fuel pool instrumentation (SFPI).

4.2.1 Design Features: Instruments

By letter dated February 28, 2013, on page E-3, TVA indicated that both instruments would consist of fixed components. Both channels would use Westinghouse SFP instrumentation solution based on GWR sensors, which functions according to the principle of Time Domain Reflectometry (TDR). Each measurement device consists of a flexible stainless-steel cable probe, suspended in the SFP from a seismic Category 1 bracket attached to the operating deck or to the raised curb at the side of the pool. The cable probe extends to nearly the top of the spent fuel racks. In addition, vendor documentation reviewed during the audit process states that there is minimum horizontal distance that must be kept between the sensing cable and any structures surrounding this cable. During the January 22, 2014 NRC staff's visit to the vendor product development facility, the staff witnessed a test performed by vendor personnel, in which a full-scale mock-up of the installation was demonstrated with one of the proposed instrument channel assemblies set up to monitor level in a 25 ft. tall open tank of water. The probe was suspended into the tank at a distance of approximately 6-8 inches (in.) from the wall of the tank. In this test, the stainless steel probe/cable assembly was lifted out of the water at a 90-degree angle (i.e., perpendicular to the simulated spent fuel pool wall) and then dropped back in. The staff noted that for the proposed weight of the probe/cable/weight assembly, and the density of the water, there was sufficient fluid resistance to completely dampen out the impact of the cable/probe assembly, such that it never came into contact with the wall of the tank.

On pages E-3 and E-4 of its February 28, 2013, letter, TVA stated that both instruments would provide continuous level indication from maximum operating level (26.6 ft. above the top of active fuel or 25.1 ft. above top of fuel storage racks) to the top of the fuel storage racks. The electronics for signal conditioning will be located inside the Unit 1 and Unit 2 upper containment access rooms.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed design, with respect to the number of channels for both of its SFPs, is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03 and adequately addresses the requirements of the Order.

4.2.2 Design Features: Arrangement

By letter dated November 22, 2013, on page E1-19, TVA illustrated that the primary instrument channel sensor is to be mounted near the northwest corner of the SFP on the wall separating the SFP and the fuel cask loading area and the backup instrument channel sensor is mounted on the opposite side of the SFP in the southeast corner. From the sensor, the primary signal cable is to be routed away from the SFP (west) to the adjacent wall and the backup signal cable is to be routed away from the SFP (east) to the adjacent wall. This arrangement results in a physical channel separation of a distance greater than the longest length of a side of the SFP.

TVA also stated on page E1-2 of the November 22, 2013, letter that additional missile protection would be accomplished by providing shielding of the signal cables within the SFP area. The cables are routed outward from the sensor brackets at the pool to the adjacent wall penetrations within trenches cut in the concrete floor. Within the trenches, the cables are to be protected by unistrut. Further protection is provided by plate steel trench covers, which are to be secured to the SFP floor using expansion anchor bolts. A 12-inch (approximate) portion of the primary signal cable which is not routed within a covered trench will be routed within a tube steel enclosure to provide shielding. The SFP walls and corners provide inherent missile protection for the level sensor cable within the pool.

TVA is extending the physical separation of the primary and backup instrument channels to the electrical portion of the system by using Class 1E-type train separation, i.e., the primary channel cables are routed as train A cables, while the backup channel cables are routed as train B cables. Further channel separation is achieved by maintaining unit separation, i.e., primary channel equipment is mounted within the Unit 1 structures, while backup channel equipment is mounted within Unit 2 structures.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed arrangement for the SFP level instrumentation, if implemented as discussed, is consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.2.3 Design Features: Mounting

By letter dated February 28, 2013, on page E-5, TVA stated that the level sensors will be mounted above the SFP and qualified by analysis to the same requirements as safety related, seismic Category I, as defined in the Watts Bar seismic design-basis. The remaining channel components and cable routing shall be mounted in accordance with the Watts Bar seismic Category I design requirements. By letter dated November 22, 2013, on page E1-3, TVA further stated that:

> All SFPIS equipment mounting is analyzed to maintain a minimum seismic capacity of high confidence of low probability of failure (HCLPF) equal to or greater than a [review level ground motion] RLGM of two times (2x) the safe-shutdown earthquake (SSE). To achieve a minimum HCLPF of 2x SSE at WBN, SFPIS SSCs are designed in accordance with plant seismic category I design requirements.
>
> The vendor has performed calculations to evaluate the structural integrity of the mounting brackets at the SFP. The model considers load combinations for the dead load, live load and seismic load on the bracket, where seismic loading is for two-times the safe shutdown earthquake (SSE). These loads are then compared to the allowable values of the applicable welds, bolts and members to determine the acceptability of the design.

On page EA1–3 of attachment 1 of the June 25, 2014, letter, TVA identified vendor documents developed to address the seismic requirements associated with the mounting device for the SFP instrumentation level sensor. This matrix contains references to the documents prepared by the vendor and reviewed by the NRC staff during the vendor audit to address the order requirements and TVA's analysis of the vendor information as it applies to their application of the SFP instrumentation.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed mounting design is consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the Order.

4.2.4 Design Features: Qualification

4.2.4.1 Augmented Quality Process

Appendix A-1 of the guidance in NEI 12-02 describes a quality assurance process for non-safety systems and equipment that is not already covered by existing quality assurance requirements. Per JLD-ISG-2012-03, the NRC staff found the use of this quality assurance process to be an acceptable means of meeting the augmented quality requirements of Order EA-12-051.

By letter dated February 28, 2013, on page E-6, TVA stated that instrument channel reliability shall be established by use of an augmented quality assurance process similar to that applied to fire protection.

If implemented appropriately, this approach is consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.2.4.2 Instrument Channel Reliability

NEI 12-02 states:

> The instrument channel reliability shall be demonstrated via an appropriate combination of design, analyses, operating experience, and/or testing of channel components for the following sets of parameters, as described in the paragraphs below:
>
> - conditions in the area of instrument channel component use for all instrument components,
> - effects of shock and vibration on instrument channel components used during any applicable event for only installed components, and
> - seismic effects on instrument channel components used during and following a potential seismic event for only installed components.

Equipment reliability performance testing was performed to (1) demonstrate that the SFP instrumentation will not experience failures during beyond-design-basis (BDB) conditions of temperature, humidity, emissions, surge, and radiation, and (2) to verify those tests envelope the Watts Bar-specific requirements.

During the vendor audit, the NRC staff reviewed vendor documents associated with testing conducted to demonstrate equipment reliability under BDB conditions. The staff reviewed the test results related to environmental qualification for the coaxial cable, probe, coupler, and pool-side bracket located inside the SFP area and outside where the level sensor electronics, sensor electronics bracket, indicators, and the electronics enclosure will be located. By letter dated August 18, 2014, the staff included a summary of the SFP instrumentation environmental qualification and reliability design documents reviewed during the audit.

By letter dated June 25, 2014, attachment 1, the vendor for the SFP instrumentation for Watts Bar captured the instrumentation test results and analysis. This matrix also contains the results from Watts Bar evaluation of the vendor information as it applies to the installation of the SFP instrumentation at their site.

The NRC staff notes that the SFP instrumentation, as designed, will envelope the conditions in the SFP instrumentation installed location for all the instrument components. The staff also notes that the impact of vibration transmitted from the SFP floor deck to the level probe would have negligible impact on the functionality of the level measurement system

In the Watts Bar October 29, 2014 (ADAMS Accession No. ML14303A561), Compliance Letter, TVA included a response for one open item for Order EA-12-051. The open item was associated with the temperature qualification of the SFP level transmitters for seven days of operation, as specified in NEI 12-02. TVA documented the temperature qualification issue in its Corrective Action Program, and by letter dated December 19, 2014 (ADAMS Accession No. ML15002A202), TVA notified the NRC that it had resolved the issue.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed instrument qualification process to be consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.2.5 Design Features: Independence

By letter dated September 6, 2013, on page E1-7, TVA stated that the primary and backup sensors will be mounted as close as practical to different corners of the SFP to take advantage of natural protection provided by spatial separation and that conduit or other means of cable protection such as routing the cable inside the wall of the pool will be utilized in the area of the SFP. TVA stated that the channels of SFP Level instruments will be powered from independent batteries maintained in a charged state by station Vital 120 Vac. In addition, TVA indicated that station Vital 120 Vac is derived from Safety Related Vital Batteries. Each channel will be maintained in a charged condition from independent Vital 120 Vac sources. The power cable to each independent SFP level channel battery will be routed and separated in accordance with site design standards for redundant channels/trains of safety related instrumentation. Outside the SFP area the conduit and cabling for both channels will be routed and separated in accordance with site design standards for redundant channels/trains of safety related instrumentation.

By letter dated November 22, 2013, on page E1-10, TVA provided further information regarding the electrical configuration and separation of the instrumentation. The power to the primary channel will be supplied from 120 Vac Vital Instrument power board 2-111, which is train A. Power to the backup channel will be supplied from 120 Vac Vital Instrument power board 2-IV, which is train B. The vital boards will be supplied by the Vital Batteries and Vital Inverters, and will be backed up by the FLEX diesel generators. Watts Bar FLEX diesel generator strategy provides two 480 V diesel generators on the roof of the Auxiliary Building to provide a direct connection to Vital Battery Chargers and two 6.9 kV diesel generators that provide an alternate approach to energize the battery chargers utilizing safety related shutdown power distribution. Cable and conduit for each channel maintain trained separation from the power source to their respective instrument enclosures, which are mounted in separate areas of the plant.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed design, with respect to instrument channel independence, is consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.2.6 Design Features: Power Supplies

Regarding power supply, on page E1-9 of the September 6, 2013, letter, TVA stated that NEI 12-06 section 3.2.1.3 initial condition 8 states "Installed electrical distribution system, including inverters and battery chargers, remain available provided they are protected consistent with current station design." The Watts Bar installed electrical distribution system, including inverters and battery chargers are fully protected and seismically mounted inside a safety related structure and above flood elevation.

By letter dated October 24, 2013, on page 2, the NRC staff requested TVA to provide the results of the calculation depicting the battery backup duty cycle requirements demonstrating that its capacity is sufficient to maintain the level indication function until offsite resource availability is reasonably assured. In an RAI response dated November 22, 2013, TVA stated that the vendor calculation concluded that the backup battery life is 96.24 hours at full charge after loss of onsite ac power based on maximum power consumption throughout the duration of the battery life.

During the vendor audit, the NRC staff reviewed the vendor's power consumption calculation for TVA's design configuration and found TVA's required battery life to be enveloped by the battery life estimate documented in the vendor's calculation. TVA documented their acceptability of the SFPI power consumption by letter dated June 25, 2014, on page EA1-4 of attachment 1.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed power supply design is consistent with NEI 12-02 guidance, as endorsed, by the JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.2.7 Design Features: Accuracy

By letter dated November 22, 2013, on page E-11, TVA stated that each instrument channel is expected to be accurate to within an estimated ±1 percent of calibrated span during normal SFP level conditions. TVA also stated that the instrument channels are expected to retain this estimated accuracy after being subjected to BDB conditions. This estimate is based on the vendor's specification documentation.

During the vendor audit, the NRC staff reviewed the vendor and plant-specific channel accuracy calculations for the primary and backup instruments and found them to be within TVA's required accuracy.

Regarding the methodology that will be used to determine that the channel requires adjustment to within the normal condition design accuracy, on page E1-11 of the November 22, 2013, letter, TVA stated that:

> Technicians will be required to perform an instrument channel calibration in the event that the instrument channel output lies outside the acceptance band

> established in the setpoint and scaling documents. The acceptance band or "as-left tolerance" is defined as the acceptable parameter variation limit above or below the desired output for a given input standard associated with the calibration of the instrument channel.
>
> The instrument channel acceptance band, which may or may not be symmetrical, is calculated using the square root of the sum of the squares (SRSS) combination of the as-left tolerance for each component comprising the instrument loop. The as-left tolerance of each component is equal to or greater than the reference accuracy of the device being calibrated, but is not so large that it could prevent or mask detection of instrument degradation or failure. Note that the SRSS method is only used for uncertainty terms that are random, independent, and posses a normal (bell-shaped) distribution; otherwise, the uncertainty term is combined through summation, either within the SRSS (for dependent terms) or outside of the SRSS (for bias and non-normally distributed terms).

Regarding the instrument's channel accuracy following a loss of power and subsequent restoration of power, TVA stated that the Guided Wave transmitter is a microprocessor based transmitter with its operating system in firmware and adjustable parameters are stored in non-volatile memory. If power is lost and later restored, the transmitter remains calibrated to its original parameters and will restore indication to actual pool level within the stated loop accuracies.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed instrument accuracy is consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.2.8 Design Features: Testing

By letter dated February 28, 2013, on page E-8, TVA stated that the full level indication of the SFP indicator will be compared to fixed marks within the SFP to validate that the transmitter zero adjustment has not drifted. TVA provided further information related to SFPI testing on page E1-13 of its November 22, 2013, letter. TVA stated that the sensor mounting design will incorporate a bracket that provides a calibrated distance to raise the sensor a known amount (12 in.). This provides a second point at which to confirm that the instrument system is performing within the channel accuracy calculation acceptance limits.

The NRC staff notes that the process described by TVA for comparing full level indication of the SFP indicators to fixed marks within the SFP and the incorporation of a bracket into the sensor mounting design that provides a calibrated distance to raise the sensor is reasonable.

On page E1-13 of the November 22, 2013, letter, TVA stated that:

> In-situ testing will be performed by loosening the hold down bolts and raising the sensor assembly until it hits the top stop (12 inches) and verifying that the indicator responds with a corresponding 12 inch change (allowed inaccuracy of change will be documented in the scaling analysis). Upon completion of

> measurement, the technician will lower the mounting bracket and re-torque the slide assembly hold down bolts.
>
> If the plant staff determined a need to confirm that the two channels are performing as expected, the two channels may be read in the shutdown board room. While the SFP is operating within design basis and at normal level, the indicators may be compared to fixed marks within the SFP by visual observation to confirm indicated level.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed SFPI design to allow for testing is consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.2.9 Design Features: Display

By letter dated November 22, 2013, on page E1-14, TVA stated that the location for the SFP level instrumentation displays was revised to have both displays located in the Electrical Board Room (EBR). TVA indicated that it had eliminated the Main Control room indicator because full compliance can be achieved by having two independent channels of indication, physically separated and both located in the EBR area.

In addition, TVA stated that the EBR is in close proximity to the Auxiliary Control room and is a mild environment. The EBR is also promptly accessible (2 minute walk) by Main Control room personnel and is not subject to the environmental conditions associated with boiling in the SFP. The route to the EBR/Auxiliary Control room area from the Main Control room will be the same route that is used during design-basis events because the route is within a safety related, seismic structure. This pathway is expected to remain intact following a seismic event. Watts Bar communications, if needed, will be by radio or telephone.

The NRC notes that the Watts Bar location for the displays will be promptly accessible to the operators as the route to this location is within a safety related, seismic structure. In addition, the operator can access this location within 2 minutes and communications with plant staff and decision makers will be available, if needed. According to TVA, this location is a mild location and will not be subject to BDB environmental conditions making it an appropriate location for the displays.

Based on the discussion above, the NRC finds that, if implemented appropriately, TVA's proposed locations for the SFPI displays, if installed at the above mentioned location, is consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.3 Evaluation of Programmatic Controls

Order EA-12-051 specified that the spent fuel pool instrumentation shall be maintained available and reliable through appropriate development and implementation programmatic controls, including training, procedures, and testing and calibration. Below is the staff's assessment of the programmatic controls of Watts Bar spent fuel pool instrumentation.

4.3.1 Programmatic Controls: Training

By letter dated February 28, 2013, on page E-8, TVA stated that training for operations and maintenance personnel is evaluated as part of the design process utilizing the Systematic Approach to Training (SAT). The SAT process will determine both the initial and continuing elements of training, if required. NEI 12-02 specifically addresses the use of SAT for training personnel in the use and the provision of alternate power to the primary and backup SFP instrument channels.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, TVA's proposed plan to train personnel in the use and the provision of alternate power to the primary and backup instrument channels, including the approach to identify the population to be trained is consistent with NEI 12-02 guidance, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.3.2 Programmatic Controls: Procedures

TVA stated, on page E-9 of its February 28, 2013, letter, that procedures will be developed using guidelines and vendor instructions to address the maintenance and operation issues associated with the new SFP instrumentation. During the audit process, the NRC staff reviewed the vendor information available to TVAs to develop procedures for maintenance, use, testing and calibration of the SFP instrumentation. The staff found the information to be adequate for this purpose.

By letter dated November 22, 2013, on page E1-16, TVA provided a list of procedures that will govern the operation of the SFP level instrumentation. This list included procedures for alternate SFP Makeup and transition from FLEX equipment, calibration, testing and operating procedures.

Based on the discussion above, the NRC finds that, if implemented appropriately, TVA's procedure development is consistent with NEI 12-02, as endorsed, by JLD-ISG-2012-03 and adequately addresses the requirements of the Order.

4.3.3 Programmatic Controls: Testing and Calibration

By letter dated November 22, 2013, on page E1-16, TVA indicated that the maintenance, testing and calibration program will be proceduralized. TVA also described the elements that will be included as part of the maintenance, testing and calibration program. For example, the elements included are: use of the vendor instruction manuals and licensee documents to develop calibration procedures for the equipment, revision of existing documents to include BDBEE instrument loop accuracies, development of detailed in-situ calibration methods for the instrumentation, vendor analysis certifying that a 2-point channel check is sufficient to maintain calibration of the full instrument range, existing work control processes such as Surveillance Instructions (SI), preventative maintenance procedures, and Work Orders to be used to perform testing and maintenance on the instrument channels and allowable channel out of service times and associated actions to be consistent with the guidance provided in NEI 12-02.

In addition, on page E1-17 of its November 22, 2013, letter, TVA discussed compensatory actions for one or both non-functioning channels. TVA stated that:

> WBN will implement a critical spare parts program for the system, taking into account the lead time and availability of spare part to provide assurance that a channel can be restored to service within 90 days. If one or both channels cannot be restored to service within 90 days, or if both channels become non-functioning, as a compensatory measure WBN will utilize 0-AOI-45, "Loss of Spent Fuel Pool Level or Cooling" during any loss of spent fuel pool level or cooling event. This instruction requires the dispatch of operators to determine the spent fuel pool level and cooling system status and investigate for the cause of leakage and to take appropriate actions to restore the spent fuel pool level and cooling.

Based on the discussion above, the NRC staff finds that if implemented appropriately, TVA's proposed testing and calibration plan is consistent with NEI 12-02, as endorsed, by JLD-ISG-2012-03, and adequately addresses the requirements of the Order.

4.4 Conclusions for Order EA-12-051

In its letter dated October 29, 2014, TVA stated that they would meet the requirements of Order EA-12-051 by following the guidelines of NEI 12-02, as endorsed, by JLD-ISG-2012-03. In the evaluation above, the NRC staff finds that if implemented appropriately, TVA has conformed to the guidelines of NEI 12-02, as endorsed, by JLD-ISG-2012-03. In addition, the NRC staff concludes that if the SFP level instrumentation is installed at Watts Bar according to TVA's proposed design, it should adequately address the requirements of Order EA-12-051.

5.0 CONCLUSION

Based on the evaluations above, the NRC staff concludes that TVA has developed guidance and proposed designs which if implemented appropriately will adequately address the requirements of Orders EA-12-049 and EA-12-051.

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Sincerely,

/RA/

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Docket Nos.: 50-390 and 50-391

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