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

October 12, 2016

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

SUBJECT: SEQUOYAH NUCLEAR PLANT, UNITS 1 AND 2 – SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 (CAC NOS. MF0864, MF0865, MF0794, AND MF0795)

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 Modifying 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. ML13063A183), Tennessee Valley Authority (TVA, the licensee) submitted its OIP for Sequoyah Nuclear Plant, Units 1 and 2 (Sequoyah) in response to Order EA-12-049. At six month intervals following the submittal of the OIP, the licensee submitted reports on its progress in complying with Order EA-12-049. These reports were required by the order, and are listed in the attached safety evaluation. 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 February 19, 2014 (ADAMS Accession No. ML14002A113), and March 3, 2015 (ADAMS Accession No. ML15033A430), the NRC issued an interim staff evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated February 11, 2016 (ADAMS Accession No. ML16049A635), TVA submitted a compliance letter and Final Integrated Plan in response to Order EA-12-049. The compliance letter stated that the licensee had achieved full compliance with Order EA-12-049.

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A011), TVA submitted its OIP for Sequoyah in response to Order EA-12-051. At six month intervals following the submittal of the OIP, the licensee submitted reports on its progress in complying with Order EA-12-051. These reports were required by the order, and are listed in the attached safety evaluation. By letters dated November 21, 2013 (ADAMS Accession No. ML13312A415), and March 3, 2015 (ADAMS Accession No. ML15033A430), the NRC staff issued an ISE and audit report, respectively, on the licensee's progress. By letter dated March 26, 2014 (ADAMS Accession No. ML14083A620), the NRC notified all licensees and construction permit holders that the staff is conducting 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 letter dated July 15, 2015 (ADAMS Accession No. ML15197A199), TVA submitted a compliance letter in response to Order EA-12-051. The compliance letter stated that the licensee had achieved full compliance with Order EA-12-051.

The enclosed safety evaluation provides the results of the NRC staff's review of TVA's strategies for Sequoyah. The intent of the safety evaluation is to inform TVA on whether or not its 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, using 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. ML15257A188). This inspection will be conducted in accordance with the NRC's inspection schedule for the plant.

If you have any questions, please contact Milton Valentin, Orders Management Branch, Sequoyah Project Manager, at 301-415-2864 or at Milton.Valentin@nrc.gov.

Sincerely,

Mandy K. Halter

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

Docket Nos.: 50-327 and 50-328

Enclosure:
Safety Evaluation

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TABLE OF CONTENTS

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

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

TENNESSEE VALLEY AUTHORITY

SEQUOYAH NUCLEAR PLANT, UNITS 1 AND 2

DOCKET NOS. 50-327 AND 50-328

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 in the United States. At Fukushima, limitations in time and unpredictable conditions associated with the accident significantly challenged attempts by the responders to preclude core damage and containment failure. During the events in 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 at U.S. commercial power reactors 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.

On March 12, 2012, 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.

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 staff requirements memorandum (SRM)-SECY-12-0025 (ADAMS Accession No. ML120690347), the NRC staff issued Orders EA-12-049 and EA-12-051.

2.1 Order EA-12-049

Order EA-12-049, Attachment 2, (ADAMS Accession No. ML12054A736) 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 cooling 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 cooling capabilities at all units on a site subject to this 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 cooling capabilities at all units on a site subject to this 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 <u>Order EA-12-051</u>

Order EA-12-051, Attachment 2, (ADAMS Accession No. ML12054A679) 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. ML13063A183), Tennessee Valley Authority (TVA, thelicensee) submitted its Overall Integrated Plan (OIP) for Sequoyah Nuclear Plant, Units 1 and 2 (Sequoyah,SQN) in response to Order EA-12-049. By letters dated August 28, 2013 (ADAMS Accession No. ML13247A286), February 28, 2014 (ADAMS Accession No. ML14064A295), August 28, 2014 (ADAMS Accession No. ML14247A644), February 27, 2015 (ADAMS Accession No. ML15064A167), and August 28, 2015 (ADAMS Accession No. ML15240A376), the licensee 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 February 19, 2014 (ADAMS Accession No. ML14002A113) and March 3, 2015 (ADAMS Accession No. ML15033A430), the NRC issued an interim staff evaluation (ISE) and an audit report on the licensee's progress. By letter dated February 11, 2016 (ADAMS Accession No. ML16049A635), the licensee reported that full compliance with the requirements of Order EA-12-049 was achieved, and submitted a Final Integrated Plan (FIP).

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 when to transition to the next phase 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 UHS. Thus, the ELAP with a loss of normal access to the UHS is used as a surrogate for a BDBEE. The initial conditions and assumptions for the analyses are stated in NEI 12-06, Section 3.2.1, and include the following:

1. The reactor is assumed to have safely shut down 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.

Both Sequoyah units are Westinghouse pressurized-water reactors (PWRs) with ice condenser containments. The FIP describes the licensee's three-phase approach to mitigate a postulated ELAP event.

At the onset of an ELAP, both reactors are assumed to trip from full power. The reactor coolant pumps (RCPs) coast down and flow in the reactor coolant system (RCS) transitions to natural circulation. Operators will take prompt actions to minimize RCS inventory losses by isolating potential RCS letdown paths. Decay heat is removed by steaming from the steam generators (SGs) through the atmospheric dump valves (ADVs) or SG safety valves, and makeup to the SGs is initially provided by the turbine-driven auxiliary feedwater (TDAFW) pumps taking suction from the condensate storage tanks (CSTs). Subsequently, the operators would begin a controlled cooldown and depressurization of the RCS by manually operating the SG ADVs. RCS inventory is a significant concern for the ELAP scenario due to the RCP seal design. Timely RCS cooldown and depressurization at 75 to 100 degrees Fahrenheit (°F) per hour will bring the units to approximately 225 pounds per square inch, gauge (psig) SG pressure. This pressure reduction will minimize reactor coolant loss due to pump seal leakage. The licensee plans to complete this cooldown within 4 hours of the start of the event. Holding SG pressure to greater than 225 psig ensures no nitrogen injection into the RCS from the cold leg accumulators (CLAs). The CLAs will provide a passive injection of 2,500-2,700 particles per million (ppm) concentration of borated water into the RCS during the initial RCS depressurization. The SGs are then maintained at this pressure while the operators restore RCS inventory using the safety injection pumps (SIPs) drawing water from the refueling water storage tanks (RWSTs).

The SIPs are powered by the one of the two 6.9 kilovolts (kV) diesel generators (DGs) pre-staged in the additional diesel generator building (ADGB). Pre-staging 6.9 kV DGs is an alternate approach to NEI 12-06 and is evaluated in Section 3.14.

Subsequently, the licensee plans a further depressurization of the SGs in order to further reduce RCS temperature and pressure. The CLAs must be isolated prior to further depressurization to prevent injection of nitrogen into the RCS. The licensee stated that a further depressurization and cooldown within 24 hours of the ELAP is required to achieve a RCS cold leg temperature of 350 °F to maintain RCP seal integrity.

The water supplies for the TDAFW pump are initially from the CSTs. The CSTs will provide a minimum of 14 hours of RCS decay heat removal, in addition to absorbing the latent heat associated with the planned RCS cooldown. Prior to emptying the CSTs, the operators will place a FLEX water transfer pump in service to refill the CSTs from clean water sources, if available. Once the CSTs are depleted, a low pressure (LP) FLEX pump, deployed at the intake pumping station (IPS), will supply river water to the suction of the TDAFW pumps.

The licensee stated that dc bus load stripping will be initiated within the first 45 minutes to ensure safety-related battery life is extended to eight hours. Following dc load stripping, the two FLEX 225 kilo-volt-amphere (kVA), 180 kilowatt electric (kWe), 480 volt alternating current (Vac) DGs (one per unit), pre-staged on the roof of the auxiliary building (AB), will be connected to power the battery chargers and through the vital inverters the 120 Vac vital instrument power system. Pre-staging the 480 Vac DGs is an alternate approach to NEI 12-06 and is evaluated in Section 3.14.

The RCS makeup and boron addition will be continued to ensure that natural circulation, reactivity control, and boron mixing is maintained in the RCS. Approximately 8.5 hours after the initiating event, the 480 volt motor driven high pressure (HP) FLEX pumps pre-staged in the AB will be available for service. These pumps would be aligned with a suction hose from RWST FLEX connections located in the AB and a discharge hose routed to the safety injection pump discharge header. An optional suction source is available from a FLEX connection on the boric acid tanks located in the AB. Pre-staging FLEX pumps is an alternate approach to NEI 12-06 and is evaluated in Section 3.14.

In addition, one of the National Strategic Alliance of FLEX Emergency Response (SAFER) Response Centers (NSRCs) will provide additional equipment to supplement and backup the on-site FLEX equipment. There are two NSRCs in the United States.

The common SFP for both units is located in the AB. The SFP will initially heat up due to the unavailability of the normal cooling system. The licensee has calculated that based on the maximum credible heat load, boiling could start as soon as 5.39 hours after the start of the event. The licensee determined that it would take approximately 27 hours for pool water level to drop to 10 feet (ft) above the fuel. Makeup water would be provided via a connection to the essential raw cooling water (ERCW) header in the AB which is pressurized by the diesel-driven LP FLEX pump deployed at the IPS. Hoses connecting to the ERCW system piping inside the AB would be routed directly to the spent fuel pool floor and provide makeup water directly into the pool. Ventilation of the generated steam is accomplished by opening doors to establish a natural draft vent path.

The licensee calculations demonstrate no actions are required to maintain the containment pressure and temperature below design limits for six days. In Phase 2, the licensee will power, if necessary, the hydrogen igniters inside containment to preclude the potential for hydrogen deflagration or detonation in the event of core damage. The igniters will be powered by a 6.9 kV DG and can be powered by a 480 Vac FLEX DGs. During Phase 3, containment cooling and depressurization would be accomplished by operating one lower compartment containment cooling fan, with water for cooling supplied by the LP FLEX pump deployed at the IPS. The containment cooling fan would be powered by a 6.9 kV DG.

Below are specific details on the licensee's strategies 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 these strategies. The NRC staff evaluated the licensee'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 loss of normal access to the UHS. Although the ELAP event 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 the licensee's core cooling strategy credits installed equipment (other than that presumed lost to the ELAP event concurrent with a loss of normal access to the UHS) 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 under ELAP conditions, two fundamental physical requirements exist: (1) a heat sink is necessary to accept the heat transferred from the reactor core to the 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, the RCS inventory should be replenished with borated coolant in order to maintain the reactor in a subcritical condition as the RCS is cooled and depressurized.

As reviewed in this section, the licensee's core cooling analysis for the ELAP with loss of normal access to the UHS event presumes that, per endorsed guidance from NEI 12-06, both units would have been operating at full power prior to the event. Therefore, the SGs may be credited as the heat sink for core cooling during the ELAP with loss of normal access to the UHS 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 the licensee to accomplish adequate core cooling during the ELAP with loss of normal access to the UHS event are discussed in further detail below. The licensee's strategy for ensuring compliance with Order EA-12-049 for conditions where one or more units are shut down or being refueled is reviewed separately in Section 3.11 of this evaluation.

3.2.1 Core Cooling Strategy and RCS Makeup

3.2.1.1 Core Cooling Strategy

3.2.1.1.1 Phase 1

The FIP states that the proposed strategy is to remove heat from the RCS by providing cooling water to the four SGs. The TDAFWP will start as designed and provide cooling through the SGs with its initial alignment to the CSTs. If the CSTs are undamaged by the initiating event, they provide 14.0 hours of cooling water per unit (240,000 gallons per CST) and if a tornado missile penetrates at the top of the CSTs' protection barrier they could provide ~ 7.5 hours of cooling water to each unit. When water from the CSTs is no longer available, suction flow to the TDAFWP can be provided by standing water in the ERCW headers for approximately 18.5 hours as a last option.

3.2.1.1.2 Phase 2

The FIP states that transition to Phase 2 is required before the TDAFWPs suction sources are depleted. When clean water sources are depleted, suction flow to the TDAFWPs can be provided by an unlimited supply of water with the LP FLEX Pumps staged at the IPS taking suction from the intake channel and discharging to four ERCW FLEX connections at the IPS. The LP FLEX Pumps will be used to pressurize the ERCW headers, which can then be used for direct supply to the TDAFWP suction, if required.

The FIP explains that that there are several options should the TDAFW not be available to provide cooling water to the SGs, which include the following:

- Once the 6.9 kV FLEX DGs are available, the motor driven auxiliary feedwater pumps (MDAFWPs) (Train A & B) could be used to relieve a TDAFWP with the suction source being the same as the TDAFWPs.

- The portable Diesel Driven Intermediate Pressure (IP) FLEX pumps deployed from the FLEX Equipment Storage Building (FESB) are staged next to the CSTs with suction from the CSTs FLEX connections and the discharge is routed via a hose to the primary connection on the TDAFWP discharge header in the West Main Steam Valve Vaults or to the alternate connection on the MDAFWPs discharge header connections in the AB.

- The 480v motor driven IP FLEX Pumps pre-staged on AB elevation 714 ft. could be placed in service. The suction source is raw water via a hose from the ERCW FLEX connections located in the AB and the discharge is to the primary and alternate FLEX connection points discussed above.

- The 480v motor driven Mode 5 & 6 IP FLEX Pumps pre-staged on AB elevation 669 ft. could be aligned and placed in service. The suction source is raw water via hose from the ERCW FLEX connections located in the AB and the discharge is to the primary and alternate FLEX connection points discussed above.

- The Diesel Driven LP FLEX Pumps (Triton and Dominators) are capable of supplying raw water to the SGs when they are depressurized to less than 150 psig (~ 105 to 115 psig). For the LP FLEX Pumps staged at the IPS, suction will be supplied by the intake channel to pressurize the ERCW system via FLEX connections at the IPS. FLEX hoses would be connected to ERCW FLEX connections on AB elevation 714 ft. and the discharge is to the primary and alternate FLEX connection points discussed above.

3.2.1.1.3 Phase 3

For Phase 3, the licensee will continue the Phase 2 coping strategies with additional assistance provided from offsite equipment/resources. A mobile water purification system provided by one of the NSRCs will enable water from the Tennessee River or other raw water source to be purified. This unit would process the water source and discharge improved quality water to the CSTs and/or other locations as required.

3.2.1.2 RCS Makeup Strategy

3.2.1.2.1 Phase 1

Under ELAP conditions, RCS inventory will tend to diminish gradually due to leakage through RCP seals and other leakage points. Furthermore, the initial RCS cooldown starting within one hour into the event would result in a significant contraction of the RCS inventory, to the extent that the pressurizer would drain and a vapor void would form in the upper head of the reactor vessel. As is typical of operating PWRs, prior to implementing the Phase 2 FLEX strategy, Sequoyah does not have a fully robust capability for active RCS makeup for Phase 1.

Sequoyah determined that sufficient reactor coolant inventory would be available throughout Phase 1 to support heat transfer to the SGs via natural circulation without crediting the active injection of RCS makeup. Emergency Contingency Action Procedure 0.0 (ECA-0.0, "Loss of All AC Power," Revision 28) directs isolation of RCS letdown pathways and verification of RCS isolation. The RCS inventory loss is assumed to be through RCP seal leakage and operational leakage. Sequoyah, Units 1 and 2 has Westinghouse-designed seals. Passive injection from the safety injection accumulators would occur as operators depressurize the RCS below the nitrogen cover gas pressure, which helps offset cooldown-induced inventory contraction and system leakage.

The Sequoyah Phase 1 strategy initiates a cooldown of the RCS within 1 hour of the initiation of the ELAP concurrent with the loss of normal access to the UHS event. The RCS is cooled down and depressurized until a SG pressure of 225 psig is reached. The minimum SG pressure of 225 psig is set to prevent nitrogen gas from the safety injection accumulators from being injected into the RCS. Cooldown and depressurization of the RCS significantly extends the expected coping time under an ELAP concurrent with loss of normal access to the UHS 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.

The licensee further indicated that, according to the core operating history specified in NEI 12-06, a sufficient concentration of xenon-135 should exist in the reactor core to ensure subcriticality throughout Phase 1, considering the planned cooldown profile. A cooldown to 225 psig in the SGs will correspond to an RCS core inlet temperature of approximately 397 °F. In addition to replenishing the RCS coolant volume, the passive injection from the nitrogen-pressurized safety injection accumulators would increase the boron concentration of the coolant in the RCS.

3.2.1.2.2 Phase 2

Per the FIP, RCS makeup is initiated within 5 hours of the ELAP concurrent with loss of normal access to the UHS event. The RWST is the preferred source of borated makeup water. Makeup will be provided to the RCS using one of the SIPs aligned through its normal injection paths into the RCS cold legs.

The RWST is protected from all natural phenomena considered under EA-12-049 except for the high wind/tornado hazard. If the RWST is unavailable, the Boric Acid Tanks (BATs) can be used. The BATs are at least 6,120 ppm boron. The SIPs can take suction from the RWSTs and inject into the RCS. At about 8.5 hours, the pre staged 480v motor driven High Pressure FLEX pumps can be available for use. The HP FLEX pumps take suction from the RWST via connections in the AB and discharge to the B train SIP discharge header. The HP FLEX pump can also take suction from the BATs to inject into the RCS. The alternate injection point for the HP FLEX pumps would be the A train SIP discharge header. A spare HP FLEX pump exists that can be aligned to replace either unit's pre staged HP FLEX pump. These pumps provide 40 gallons per minute (gpm) at 600 psig. A third flex pump, the IP FLEX pump, is available to make up to the RCS if necessary. This pump could be aligned by taking suction from the RWST or from the BATs and inject into the A or B trail SIP discharge headers. To use the pump the RCS pressure would have to be reduced to accommodate the pumping capacity (150 gpm at 350 psig). Water sources for mitigating the ELAP event are discussed further in Section 3.10 of this evaluation.

3.2.1.2.3 Phase 3

In Phase 3, the RCS makeup strategy is a continuation of the Phase 2 strategy, supplemented as needed with equipment provided by the NSRC. The NSRC will provide a high-pressure injection pump. Sequoyah is planning to receive the mobile boration skid as backup for RCS boration. The request for a mobile boration skid was entered in the licensee's corrective action program under item no. 1174445. This will allow them the ability to use the equipment to batch and inject boron as necessary. To facilitate the use of higher quality water for RCS makeup, the NRC staff expects that the licensee would begin using purification equipment from the NSRC as soon as practical considering the overall event response prioritization.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

Before the flood event, Sequoyah would receive warning of potential flood conditions. The warning time should allow for staging the FLEX equipment to prepare for potential use during the flood. Sequoyah receives 27 hours of warning prior to the flood reaching plant grade. During this time, the plant should shut down, cool down, and depressurize to meet the boration requirements.

If the plant is in Mode 1 when an ELAP occurs, the strategy would continue as described above. Prior to flood waters reaching the AB, the SIPs would be secured. The HP FLEX pumps would be aligned to take suction from the RWSTs and connected to the appropriate discharge headers. The HP FLEX pumps are capable of being operated while submerged.

3.2.3 Staff Evaluations

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

Document 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 during an ELAP caused by a BDBEE.

3.2.3.1.1 Plant SSCs

TDAFW and MDAFW Pumps

On Page E-20 of its FIP, the licensee indicates that the coping strategy is to remove heat from the RCS by providing cooling water to the four SGs initially with the TDAFW pump until the IP FLEX Pumps are available. In addition, on Page E-23 of its FIP, the licensee states that once the 6.9 kV FLEX DGs are available, the MDAFW pumps (Train A and B) could be placed in service to relieve the TDAFW pump, if required. During a flood event, the licensee indicated in its FIP that there is 27 hours of warning time, after which the TDAFW and MDAFW pumps will be submerged under floodwaters and IP FLEX Pumps will provide feedwater to the SGs. Updated Final Safety Analysis Report (UFSAR) Table 3.2.1-2 indicates that the TDAFW and MDAFW pumps are Seismic Category I components located in the AB. Sections 3.2, 3.3, and 3.5 of the UFSAR indicate that the AB is a Category I structure designed to remain functional in the design earthquake event, designed for the effects of the 300-mph rotational wind, the 60-mph translational wind and a negative differential pressure, respectively and protected against damage by tornado-driven missiles, respectively. Section 10.4.7.2 in the UFSAR explains that the safety-related portion of the Auxiliary Feedwater System is housed in the Auxiliary and Reactor Buildings and steam valve rooms. Based on the FIP and UFSAR, the staff finds that the TDAFW pump and MDAFW pump should be robust for seismic and high wind hazards and should be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3. In addition, the staff finds that the licensee should have sufficient warning time to place the IP FLEX Pumps (submersible operation capable) in service to provide core cooling when the AB is flooded.

ERCW System

On Page E-23 of its FIP, the licensee states the LP FLEX Pumps take suction from the intake channel and discharge to the ERCW FLEX connections at the IPS in order to pressurize the ERCW headers, which can then be used for direct supply to the TDAFWP suction, if required. Section 3.1.2 in the UFSAR and UFSAR Table 3.2.1-2 indicates that the ERCW System is Seismic Category I. Furthermore, UFSAR Section 9.2.2.1 states that the ERCW System is designed to supply cooling water for plant safety during either normal operation or under accident conditions. For flooding events, the ERCW headers would be pressurized with the LP FLEX Pumps staged at the Auxiliary ERCW Pumping Station. Based on the FIP and UFSAR, the staff finds that the ERCW system should be robust and is expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3. In addition, the staff finds the licensee should have sufficient warning time to place the LP FLEX Pumps in service at the Auxiliary ERCW Pumping Station to support core cooling.

Atmospheric Relief Valves

During its audit review, the staff noted that the atmospheric relief valves (ARVs) are used for plant cooldown by discharging steam to the atmosphere and that there is one ARV per steam generator. There are two ARVs are located in each of the East Main Steam Valve Room and the West Main Steam Valve Room. During its audit review, the licensee explained that the

ARVs have manual control air stations and hand wheels located above the probable maximum flood (PMF) level in the 480V shutdown board rooms. On Page E-27 of its FIP, the licensee indicates that the backup instrument air control stations for the SG ARVs have been moved to AB elevation 734 ft. above the PMF elevation 722 ft. for flood condition response as part of DCN 23192. Section 2.4A.2.2 in the UFSAR discusses plant operation during floods above grade and indicates that the secondary side steam pressure can be maintained for an indefinite time by the ARVs. Section 10.3.3 in the UFSAR indicates that the atmospheric relief valves can be adjusted by controls in the main or auxiliary control room, by manual loading station and by the relief valve handwheel as an additional backup control for each relief valve. Thus, the staff finds the ARVs can be operated during an ELAP event if air is not available to operate the relief valves. Section 3.8.4 in the UFSAR states that the west steam valve rooms are the compartments of the AB, which is a Category I structure, is protected from seismic and high wind/missile events. Based on the FIP and UFSAR, the staff finds that the ARVs should be robust and should be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Safety Injection Pumps

On Page E-41 of the FIP, the licensee states that the 6.9 kV FLEX DGs will repower a shutdown board to support the operation of the SIPs, which will provide boration and restore RCS inventory and maintain pressurizer level until the HP FLEX Pump are available. During a flood event, the licensee indicated in its FIP that there are 27 hours of warning time after which the SIPs will be submerged under floodwaters and FLEX Pumps will provide feedwater to the SGs. Section 6.3.3.12 in the UFSAR states that the Component Cooling System (CCS) supplies cooling water to the mechanical seal coolers for the SIPs and the ERCW System provides cooling water to various coolers for the SIPs. Table 3.2.1-2 in the UFSAR indicates that the SIPs and CCS equipment are Seismic Category I components located in the AB and/or the Containment Building. As previously discussed above, the AB should be a robust structure and should be protected from seismic and high wind hazards and the licensee has strategies to cope with a flood hazard. Section 3.3 and 3.5 in the UFSAR indicates the Containment Building is designed for the effects of a 300-mph rotational wind, a 60-mph translational wind, a negative differential pressure, and is protected against damage by tornado-driven missiles.
Section 2.4.2.2 in the UFSAR states that the Containment Building is protected from flooding by the shield building. Based on the FIP and UFSAR, the staff finds that the SIPs and CCS should be robust for seismic and high wind hazards and should be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3. In addition, the staff finds the licensee should have sufficient warning time to place the HP FLEX Pumps (submersible operation capable) in service to provide core cooling when the AB is flooded.

Connection Points and Water Sources

The licensee's Phase 2 and 3 core cooling FLEX strategy relies on the use of IP FLEX Pumps discharging to a primary and alternate connection point. The NRC staff's evaluation of the robustness and availability of FLEX connection points for the IP FLEX Pump is discussed in Section 3.7.3.1 of this evaluation. The licensee's Phase 1 core cooling FLEX strategy relies on the CST as the water source for the TDAFW pumps. The licensee’s Phase 2 and 3 core cooling FLEX strategy relies on the ERCW standing water and the Tennessee River as the water sources for the TDAFW pumps or the IP FLEX Pumps. The staff's evaluation of the robustness and availability of these water sources for an ELAP event is discussed in Section 3.10.1 of this evaluation.

The licensee's Phase 2 and 3 RCS Inventory Control FLEX strategy relies on the use of the HP FLEX Pumps discharging to a primary and alternate connection point. The NRC staff's evaluation of the robustness and availability of FLEX connection points for the HP FLEX Pump is discussed in Section 3.7.3.1 of this evaluation. The licensee's Phase 1 RCS Inventory Control FLEX strategy relies on the Cold Leg Accumulators as the borated water source for the RCS. The licensee's Phase 2 and 3 core cooling FLEX strategy relies on the BATs and RWST as the borated water source for the SIPs or HP FLEX Pumps. The staff's evaluation of the robustness and availability of these water sources for an ELAP event is discussed in Section 3.10.2 of this evaluation.

Equipment operation and personnel habitability during an ELAP event are addressed in Sections 3.9.1 and 3.9.2 of this evaluation, respectively.

3.2.3.1.2 Plant Instrumentation

According to the licensee's FIP, the following key parameters are credited and available, as described below, for all phases of reactor core cooling and decay heat removal strategy:

- SG Wide Range Level or Narrow Range Level with AFW Flow Indication
- SG Pressure
- CST Levels
- Core Exit Thermocouple Temperature (Until flood water enters the auxiliary instrument room. The plant would use plant procedures and hot leg temperatures to substitute for CETs if they became unavailable)
- RCS Hot Leg Temperature
- RCS Cold Leg Temperature (Until flood water enters the auxiliary instrument room. The plant would use SG pressure and plant procedures to calculate the cold leg temperature if unavailable)
- RCS Wide Range Pressure
- Pressurizer Level
- Reactor Vessel Level Indicating System
- Neutron Flux

The instrumentation available to support the licensee's strategies for core cooling and RCS inventory during the ELAP event is generally consistent with the recommendations specified in the endorsed guidance of NEI 12-06. As a result, the NRC staff considered the intent of the endorsed guidance from NEI 12-06 to be satisfied.

All FLEX portable equipment is equipped with the necessary local instrumentation to operate the equipment, and operation is detailed in the FLEX Support Instructions (FSIs).

FSI-7, "Loss of Vital Instrumentation or Control Power," includes instructions for obtaining critical parameters locally in the unlikely event that all ac and dc power is lost.

3.2.3.2 Thermal-Hydraulic Analyses

The licensee concluded that its mitigating strategy for reactor core cooling at Sequoyah would be adequate based in part on 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. This was asked 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. In the Pressurized-Water Reactor Owners Group (PWROG) Core Cooling Position Paper, which was provided in a letter dated January 30, 2013, the PWROG recommended that the reflux or boiler-condenser cooling phase be avoided because of uncertainties in operators' ability to control natural circulation following reflux boiling and the impact of the diluted pockets of water on criticality. Due to the challenge of resolving the above issues within the compliance schedule specified in Order EA-12-049, the NRC staff requested that PWR licensees 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 the (PWROG-sponsored Technical Report, PWROG-14064-P, "Application of NOTRUMP Code Results for Westinghouse Designed PWRs in Extended Loss of AC Power Circumstances," Revision 0, industry has proposed defining this coping time as the point at which the 1-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," and WCAP-17792-P, "Emergency Procedure Development Strategies for the Extended Loss of AC Power Event for all Domestic Pressurized Water Reactor 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 is discussed in greater detail in Section 3.2.3.3 of this safety evaluation (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. Further discussion of the staff's review, including conditions and limitations regarding the application of the NOTRUMP code to analysis of the ELAP event, may be found in the NRC staff's endorsement letter on this subject, dated June 16, 2015 (ADAMS Accession No. ML15061A442).

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, 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 times that would exist for specific plants.

Dominion performed a site-specific applicability review of the generic analysis in WCAP-17601 and found the overall results to be bounded by the model and inputs used in WCAP-17601 and associated analytical codes. During the audit, the NRC staff confirmed the similarity of the parameters in the reference analysis from WCAP-17601-P to the applicable values for Sequoyah, Units 1 and 2.

Based on information from WCAP-17601-P and PWROG-14027-P, reflux cooling was estimated to occur at around 16 hours for the Westinghouse four-loop reference case, assuming leakage rates for standard Westinghouse-designed RCP seals. Per its FLEX strategy, Sequoyah will begin RCS inventory makeup within 5 hours of the onset of an ELAP event using a high capacity (505 gpm) pump. The NRC staff concludes that this should provide sufficient margin to the time where reflux cooling is expected for the analyzed ELAP event.

The NRC staff's audit review found the licensee's thermal-hydraulic analysis to be in adequate conformance with applicable guidance documents (e.g., NEI 12-06, the NRC staff's endorsement letter regarding the NOTRUMP code, WCAP-17601-P, PWROG-14207-P). Therefore, based on the evaluation above, the licensee'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 (RCP) 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 Sequoyah 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., 2,250 pounds per square inch absolute (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 Sequoyah 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 Sequoyah in the first generic analysis category (i.e., Category 1) 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. The licensee provided further information which confirmed that the leakoff line hydraulic characteristics for Sequoyah are bounded by the assumed characteristics analyzed for Category 1. The analysis for Category 1 plants showed a similar coping time prior to the onset of reflux cooling as compared to the original analysis from WCAP-17601-P.

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 Sequoyah 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 Sequoyah 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 Sequoyah 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 Sequoyah 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 Sequoyah. 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 Sequoyah began using high-temperature-qualified o-rings soon after their introduction in 1991. The audited information further asserted that existing Sequoyah 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 three different RCPs at Sequoyah, Unit 1 and in two different RCPs in Unit 2. 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 Sequoyah and many other PWRs during a loss-of-seal-cooling event. In its review of the impact of these 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 Sequoyah for an extended period of time, (2) TVA intends to initiate the RCS cooldown without delay, (3) the 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 all 7228-B o-rings by Spring 2017, and henceforth to use only o-rings qualified for the maximum temperatures applicable to Sequoyah during an ELAP event. Based on these factors, the staff's audit review concluded that o-ring failure for Sequoyah during a beyond-design-basis ELAP event would not be expected.

In order to ensure that the generic Category 1 (from NSAL-14-1) leakage rates are applicable to Sequoyah, 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 1 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 1 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 Sequoyah. During the audit, the NRC staff reviewed a bounding analysis of the piping stress that could potentially occur during an ELAP event for Sequoyah. The analysis assumed a maximum pressure of 2,500 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.

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.

During the audit review, the licensee confirmed that, following the loss of seal cooling that results from the ELAP event, seal cooling would 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 seal leakage.

In addition, the NRC staff audited information associated with the more recent RCP seal leakage testing performed by AREVA. The AREVA testing showed a gradual increase in the measured first-stage seal leakage rate, which post-test inspection and analysis tied to hydrothermal corrosion of silicon nitride (likely assisted by flow erosion). Silicon nitride ceramic is used to fabricate the first-stage seal faceplates currently in operation in Westinghouse-designed RCP seals, including those at Sequoyah. Hydrothermal corrosion of silicon nitride became an audit focus area because the test data indicates that the long-term seal leakage rate could exceed the values assumed in the licensee's analysis. Academic research reviewed by the industry and NRC staff associated with this general phenomenon indicates that the corrosion rate is temperature dependent. The NRC staff understands that the PWROG is currently working to address the potential for this phenomenon to result in gradually increasing leakage rates from Westinghouse-style RCP seals.

From the limited information available regarding the recent AREVA tests, as well as several sensitivity calculations performed by the NRC staff during the audit, the NRC staff concluded that (1) the leakage rate for silicon-nitride RCP seals may be lower initially than had been predicted analytically by the PWROG's generic analysis using ITCHSEAL, (2) the RCP seal leakage rate during Phase 2 and/or Phase 3 of the ELAP event may increase beyond the long-term rate predicted analytically by the PWROG, and (3) certain aspects of the seal behavior observed in the AREVA tests did not appear consistent with the expected behavior based on models and theory that formed the basis for the WCAP and PWROG reports discussed above.

Based on these observations, the NRC staff estimated the potential effect of hydrothermal corrosion on the RCP seal leakage rate for Sequoyah, considering in particular the following relevant plant-specific considerations:

- Sequoyah plans to cooldown an hour into the event tends to reduce the rate of hydrothermal corrosion;

- Sequoyah has to consider leakage from four RCPs, it has an RCS makeup capacity that is very high as well as multiple pumps (HP FLEX pumps and IP FLEX pumps), however it may be limited by boric acid batching; and

- Within 24 hours of the ELAP event initiation, the licensee plans to cool the RCS cold leg to 350 °F or below, which should terminate the hydrothermal corrosion reaction and halt the gradual increase in leakage from the RCP seals.

The licensee's FIP states that RCS makeup would be initiated within 5 hours at a flow rate of 505 gpm. The HP FLEX pumps have a capacity of 40 gpm. This flow capacity significantly exceeds the total rate of RCS leakage expected following RCS depressurization for the analyzed ELAP event, even considering the potential impacts of hydrothermal corrosion. Thus, implementation of the licensee's mitigating strategy would lead to the RCS being refilled with liquid to the desired level control point, thereby assuring that adequate core cooling will be maintained via natural circulation. According to the NRC staff's estimate for the analyzed ELAP event, the inventory in the RWST and BATs should supply reactor inventory needs for multiple days. Subsequently, if additional RCS makeup is required from FLEX equipment to support indefinite coping, the staff expects that the flow capability of the mobile boration skid and FLEX pumps to exceed the system leakage rate.

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 Sequoyah.

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, which (according to the core operating history assumed in NEI 12-06) would;
    - initially increase above its equilibrium value following reactor trip, thereby adding negative reactivity; and
    - peak at roughly 12 hours post-trip and subsequently decay away gradually, thereby adding positive reactivity.
- The passive injection of borated makeup from nitrogen-pressurized 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 specific values for these and other factors that could influence the core reactivity balance, as assumed in the licensee's current calculations, could be affected by future changes to the core design. However, NEI 12-06, Section 11.8 states that "[e]xisting plant configuration control procedures will be modified to ensure that changes to the plant design ... will not adversely impact the approved FLEX strategies." Inasmuch as changes to the core design are changes to the plant design, the staff expects that any core design changes, such as those considered in a core reload analysis, will be evaluated to determine that they do not adversely impact the approved FLEX strategies, especially the analyses which demonstrate that recriticality will not occur during a FLEX RCS cooldown.

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 PWROG 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 event would occur under conditions similar to those for which boric acid mixing data is available. By 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 stated that Sequoyah will comply with the August 15, 2013, position paper on boric acid mixing, including the conditions imposed in the staff's corresponding endorsement letter. The NRC staff's audit review concluded that these conditions should be satisfied since (1) the licensee's analyses considered the appropriate range of RCS leakage conditions, (2) the licensee would initiate FLEX RCS makeup prior to RCS flow decreasing below the single-phase natural circulation flow rate, and (3) the licensee's plan for initiating RCS makeup would allow a one-hour delay period for boric acid mixing.

According to its FIP, TVA expects that the RCS would be refilled by approximately six 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.

The licensee 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 Sequoyah will have adequate shutdown margin following Xenon decay for an ELAP initiated at any time during the operating cycle. The licensee'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.

During the audit, the NRC staff reviewed the licensee's shutdown margin calculation. The staff requested additional detail to ensure that the Sequoyah strategy would ensure the reactor would remain subcritical throughout the event. The licensee provided additional information to show the reactor would remain shutdown. The licensee demonstrated that the boron injected into the RCS would be enough to maintain subcriticality at the initial hold temperature of 397 °F, the secondary hold temperature of 370 °F, and the final cooldown temperature of 350 °F. The SIP pump would be the initial injection pump using the RWST water to inject into the RCS. The pump would be used to restore RCS level on the pressurizer. Following the initial restore at about 8.5 hours, the HP FLEX pump would take suction from either the RWST or that BAT to inject into the RCS. This pump would be used to make up for any leakage that may occur. FLEX Support Instruction No. 8 (FSI-8) "Alternate RCS Boration," Revision 0, directs the operators to ensure that prior to the final cooldown to 350 °F, the necessary amount of boron needed is injected into the RCS to remain subcritical Xenon free. The licensee calculations showed that their ability to inject enough boron during the limiting EOL conditions allowed them to maintain margin to the boron that is required by well over 100 ppm boron.

Sequoyah will perform checks on every core reload to determine that any core design changes do not adversely impact the approved FLEX strategies, especially the analyses which demonstrate that no recriticality will occur during a FLEX RCS cooldown.

Toward the end of an operating cycle, when RCS boron concentration reaches its minimum value, some PWR licensees may need to vent the RCS to ensure that their FLEX strategies can inject a volume of borated coolant that is sufficient to satisfy shutdown margin requirements in analyzed cases where minimal RCS leakage occurs. Instruction FSI-8 includes the use of the reactor vessel head vents as the primary means for venting the RCS. 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 staff finds the use of the reactor vessel head vents preferable for the following reasons: (1) use of the smallest vent path capable of providing the required letdown is desirable, especially under ELAP with loss of normal access to the UHS 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.

For long-term boron needs, Sequoyah should have sufficient borated water available in the RWST and BATs to last multiple days into the event. The plant is planning to receive a mobile boration skid from the SAFER to mix and batch boron into the RCS indefinitely. Therefore, based on the evaluation above, the NRC staff concludes that 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

In pages E-81 through E-87 of the FIP, the licensee identified the performance criteria for the LP, IP, and HP FLEX Pumps for Phase 2 and 3 as summarized below:

LP FLEX Pumps

- Diesel driven Dominator Pump used to pressurizes ERCW Headers. 5,000 gpm at 150 psig [350 ft. Total Dynamic Head (TDH)] Diesel Driven].

- Triton Pump System - consist of two floating hydraulically driven booster pumps supplying positive suction to the Dominators). 5,000 gpm capable of 50 ft. lift.

IP FLEX Pumps

- Diesel driven FLEX Pump used for Core Cooling during non-flood events. 150 gpm at 350 psig (823 ft. TDH).
- Motor driven FLEX Pump used as backups to Diesel Driven IP FLEX Pump and Core Cooling during flood events. 150 gpm at 350 psig (823 ft. TDH).

HP FLEX Pumps

- Motor driven FLEX Pumps used for RCS Inventory Control during non-flood or flood events. 40 gpm at 600 psig (1,384 ft. TDH).

On pages E-23 through E-27 of its FIP, the licensee discusses the pre-staged, submersible, FLEX Pumps located within the AB. These FLEX Pumps include the 480v motor driven IP FLEX Pumps pre-staged on AB elevation 714 ft. and the 480v motor driven Mode 5 & 6 IP FLEX Pumps pre-staged on AB elevation 669 ft. Specifically, the HP FLEX Pumps and a spare HP FLEX Pump are located on AB elevation 669 ft. As previously discussed above, the AB is a robust structure protected from seismic and high wind hazards. Based on the FIP and UFSAR, the staff finds that the pre-staged FLEX Pumps in the AB can operate submersed during floods (i.e., IP and HP FLEX Pumps) and are protected from seismic and high wind hazards; thus, they are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

The staff noted that the performance criteria for the FLEX Phase 2 portable pumps are consistent with the FLEX Phase 3 portable pumps that support the Core Cooling and RCS inventory FLEX strategies. During the audit review, TVA provided the FLEX as-built hydraulic calculation (Sequoyah Units 1 and 2 As-Built FLEX System Fathom Model, "CN-FSE-14-48," Revision 0), which demonstrated that the LP, IP, and HP FLEX Pumps identified in the FIP are capable of providing sufficient make-up to the steam generators and RCS. The NRC staff noted that the licensee's calculation relied upon Applied Flow Technology Fathom models to create an as-built hydraulic model using FLEX strategies contained in its FIP and the purchased valve datasheets and pump curves for each FLEX valve and pump. The staff noted that licensee's calculation relied upon actual piping isometrics, FLEX valves and connections, and considered frictional losses, and hose lengths and diameters (suction and discharge) to ensure the FLEX Pumps can support each FLEX safety function. The staff noted the licensee considered various cases/scenarios and suction sources, flow paths, and discharge point to ensure the LP, IP, and HP FLEX Pumps are capable of providing the required flowrate. In addition, the staff noted that the licensee determined the simultaneous loads the LP, IP, and HP FLEX Pumps could support while still delivering the required flow rate and discharge pressure to support FLEX. The staff also noted that the licensee's calculation determined that the actual flow rates provided by the LP, IP, and HP FLEX Pumps exceed the required flow rates for each of the FLEX safety function. Therefore, the FLEX Pumps described by the licensee in its FIP are capable of providing the necessary water for the steam generators and RCS.

Based on its review, the NRC staff finds that licensee's FLEX portable pumps should be capable of supporting the licensee's FLEX strategies if implementation is performed as described in the FIP.

3.2.3.6 Electrical Analyses

The licensee's electrical strategies provide power to the equipment and instrumentation used to mitigate the ELAP and LUHS. The electrical strategies described in the FIP are practically identical for maintaining or restoring core cooling, containment, and SFP cooling, except as noted in Sections 3.3.4.4 and 3.4.4.4 of this SE.

The NRC staff reviewed the licensee's FIP, conceptual electrical single-line diagrams, summary of calculations for sizing the FLEX generators and station batteries. The staff also reviewed the licensee's evaluations that addressed the effects of temperature on the electrical equipment credited in the FIP as a result of the loss of heating, ventilation, and air conditioning (HVAC) caused by the event.

According to the licensee's FIP, the SQN plant operators would declare an ELAP following a loss of offsite power, loss of all emergency DGs, and the loss of any alternate ac power with a simultaneous loss of normal access to the UHS. In its FIP, the licensee assumes that this determination can be made in less than 1 hour after the onset of an ELAP with loss of normal access to UHS event.

The licensee's FIP defines their mitigating strategies. The licensee noted that ELAP entry conditions can be verified by control room staff. During the first phase of the ELAP event, the licensee will be relying on the installed equipment (such as station batteries) to cope until additional onsite power supplies (i.e., FLEX DGs) can be aligned and connected to the SQN electrical distribution system (Phase 2).

The SQN, Units 1 and 2 Phase 1 FLEX mitigation strategies involve relying on installed plant equipment and onsite resources, such as use of installed Class 1E station batteries, vital inverters, and the Class 1E dc electrical distribution system. These equipment are considered robust and protected with respect to applicable site external hazards since they are located within safety-related, Seismic Category 1, structures. As part of its Phase 1 FLEX mitigation strategy, the licensee will monitor containment temperature procedurally and, if necessary, reduce containment temperature to ensure that key containment instruments remain within analyzed limits for equipment qualification (see Section 3.4.4.4 for further information on the licensee's containment cooling strategy). The dc power from the station batteries will be needed in an ELAP for loads such as shutdown system instrumentation, control systems, and re-powered air-operated valves and motor operated valves (MOVs). The licensee's Phase 1 strategy includes initial station blackout (SBO) load shed that will be completed within 45 minutes following start of the event to ensure a 4-hour SBO coping duration. Procedure EA-250-1, "Load Shed of Vital Loads after Station Blackout," Revision 17, directs the plant operators to complete initial SBO load shedding for affected vital dc channels within 45 minutes following loss of power to both 6.9 kV Shutdown Boards on either Unit.

In addition, Procedure EA-250-1 requires the plant operators to complete deep load shed on vital battery within 90 minutes (1.5 hours) following the start of the ELAP event. The deep load shedding of non-essential loads would ensure that the 125 volt direct current (Vdc) vital batteries could supply power to meet at least an 8-hour coping duration and provide sufficient time to align and connect the onsite 480 Vac FLEX DGs to the SQN electrical distribution system and the vital battery chargers during an ELAP. Deep load shed also ensures the 480 Vac FLEX DGs supply to necessary loads for the 125 Vdc vital battery boards and 120 Vac vital instrument power boards to support FLEX Mitigation Strategy Response. The 125 Vdc system at SQN, Unit 1 and Unit 2 is arranged into four redundant channels (I, II, III, and IV). Two divisional loads primarily associated with Unit 1 are assigned to channels I and II, while those primarily associated with Unit 2 are assigned to channels III and IV. The non-divisional load assignments are distributed among the four channels. Each of the Division I, II, III, and IV safety-related batteries includes 60 lead-calcium cells and is manufactured by C&D Technologies (model LCUN-33) with a capacity of 2,318 ampere-hours at an eight hour discharge rate to 1.75 V per cell. The SQN dc system consists of five lead-acid-calcium batteries. The fifth vital battery (Division V) is separated from the other vital batteries and has a manual transfer switch that allows it to replace any of the other four batteries. The licensee noted and the staff confirmed that the useable station battery capacity could be extended up to eight hours by load shedding non-essential loads.

During the onsite portion of the audit, the NRC staff reviewed summary of the licensee's dc system Calculation EDQ0009992014000102, "FLEX Analysis for 125 VDC Vital Batteries," Revision 0, to verify the capability of the vital batteries to supply the required loads during the first phase of the SQN FLEX mitigation strategies plan for an ELAP as a result of a BDBEE. The licensee's analysis identified the required loads and their associated ratings (amperage (A) and minimum voltage) and loads that would be shed to ensure battery operation for at least eight hours (FLEX DG power is expected to be restored to the battery charger by this time). The methodology that the licensee used in the above calculation to determine the vital battery size/capacity for BDBEE is consistent with the Institute of Electrical and Electronics Engineers (IEEE) Standard 485-1978, "Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications."

Based on the information contained in NUREG/CR-7188, and the staff's review of the licensee's analysis, the battery vendor's capacity and discharge rates for the batteries, and the licensee's procedures, the NRC staff finds that the SQN dc systems seems to have adequate capacity and capability to power the loads required to mitigate the consequences during Phase 1 of an ELAP as a result of a BDBEE provided that necessary load shedding is completed within the times assumed in the licensee's analysis.

For Phase 2, SQN, Units 1 and 2 primary strategy includes use of the pre-staged 480 Vac, 225 kilo volt-ampere (kVA) DGs to power the vital Battery Chargers which supply power to the 125 Vdc vital battery boards (vital control power), the vital inverters to the 120 Vac vital instrument power boards (vital instrument indications) and other required loads within 1.25 hours after the event. If one of the two 480 Vac DGs become unavailable, other 480 Vac DG should be available to supply power to the above loads.

The licensee also plans to use pre-staged 6.9 kV 3 megawatt (MW) FLEX DGs to power the existing electrical distribution system as a part of their Phase 2 mitigating strategies. The 6.9 kV DG should supply power to the AFWP, the component cooling system pump (CCSP), the SIP, the RHR and ERCW motors and other Phase 2 required loads. The operators should start aligning the 6.9 kV DG at 1.5 hours to the kirk-key transfer switches located inside the Emergency Diesel Generator Building (EDGB), align the 6.9 KV Shutdown Board emergency feeder breaker, and the 6.9 kV and 480 Vac Shutdown Boards. The 6.9 kV DGs should be energized at 3.5 hours into the event to supply power to the SIP, MDAFWP, the component cooling pump, SFP cooling pump, Auxiliary Air Compressor, HP, IP and other required equipment. Procedure FSI-5.02, "6900V FLEX DG Startup and Alignment," Revision 0, provides directions to the plant operators to use the 6.9 kV DGs to energize the permanently installed 6.9 kV Shutdown Boards and plant equipment for cooling the core, spent fuel pool, and containment.

The licensee's identified the use of pre-staged DGs and pumps as an "alternative approach" from the strategies identified in NEI 12-06, Revision 0, 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. SQN plans to comply with the guidance in JLD-ISG-2012-01 and NEI 12-06 in implementing FLEX strategies for the SQN except for these alternatives. The licensee's alternative approach is discussed in detail in Section 3.14 of this SE.

The NRC staff reviewed the summary of SQN Calculation EDQ0009993013000086, "Technical Justification for Extended Station Blackout Diesel Generators," Revision 0, which confirmed that: 1) the calculated total expected loads should not exceed the capacity and capability of the 225 kVA DG; 2) the loading is within the ampacity of power cables; 3) the licensee has appropriately considered voltage drop; 4) required electrical protections and coordination are provided; 5) that the short circuit current interrupting rating of protective devices are greater than the available short circuit current; and 6) that lightening and grounding protection are adequately addressed. If one of the two 480 Vac DGs is not available, the other 480 Vac, 225 kVA DG should be available to supply power to the Battery Chargers. Based on above, the NRC staff finds that the 480 Vac FLEX DGs should have sufficient capacity and capability to supply power to the necessary loads following a BDBEE.

The NRC staff also reviewed the summary of Calculation EDN0003602014000120, "6900V 3MW Flex Generator A and B Electrical Cable System Analysis," Revision 0. This calculation analyzed the adequacy of the 6.9 kV, 3 MW DG capacity due to loading of the ERCWP, CCP, AFW pump, SIP, RHR pump, FLEX HP pump, FLEX IP pump, air return fan, CCSP, air compressor and other required equipment. The conclusion, in Section 8 of this calculation, confirmed that the 6.9 kV FLEX DGs design ratings (2750 kW (long-term rating) and 3027 kW short-term rating) bound the total maximum expected loading of 1,403.4 kW for core cooling, SFP cooling, and containment cooling. The above calculation stated that the maximum analyzed loads of 1403 kW loads included Non-Flood with one unit in Modes 1-4 and the second unit in Mode 5/6 for a time frame of T+5 hours and 20 minutes to T+24 hours. In addition, the above calculation analyzed short circuit current and cables confirming that the cables system design meets the voltage drop, motor starting, short circuit criteria and the demand placed on the system. In the FIP, the licensee stated that FLEX Procedures 0-FSI-5.03, "6.9 KV & 480 V Shutdown Board Initial FLEX Alignment," Revision 0000E, and 0-FSI-5.04, "6900V FLEX DG Plant Equipment Loading," Revision 0, provide guidelines to the plant operators for alignment of the 6.9 kV and 480 V Shutdown Boards. The procedures also provide guidelines for controlling the load placed on the 6.9 kV FLEX DGs.

The 6.9 kV, 3 MW FLEX DGs should also provide an alternate power source capability for the loads supplied by the on-site 480 Vac, 225 kVA FLEX DGs if both 480 Vac DGs are not available. If one 6.9 kV DG is not available, the other 6.9 kV DG has adequate capacity and capability to supply power to the required Phase 2 loads including loads supplied by the 480 Vac DG (such as the Vital Battery Chargers and other loads).

Based on the NRC staff's review of the licensee's calculations, FLEX Support Instructions, and conceptual single line electrical diagrams, the NRC staff finds that the alternative approach seems to be acceptable given the location of the pre-staged DGs (above the probable maximum flood level (PMF)), design of the DG structures (built to withstand design-basis earthquakes and weather events), protection and diversity of the power supply pathways, the separation and isolation of the pre-staged DGs from the Class 1E emergency diesel generators (EDGs), and availability of procedures to direct operators to align, connect, and protect associated systems and components.

The 480 Vac FLEX DGs ('A' and 'B') are pre-staged on the AB roof that is sited in a location that is above the PMF and as such is not susceptible to flooding. A robust protection structure has been built around the DGs, which is designed to the same Seismic Category I requirements as the AB. The two 6.9 kV, 3 MW FLEX DGs ('A' and 'B') are pre-staged in the ADGB 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 ADGB is a Seismic Category I structure and the 6.9 kV FLEX DGs' electrical distribution network is protected from the applicable external hazards.

In its FIP, the licensee stated that the existing Kirk-Key transfer switch connections from the EDGs would be opened then the 6.9 kV FLEX DGs would be closed to connect the existing 6.9 kV Shutdown Power distribution system to the 6.9 kV FLEX DGs for FLEX implementation and operation. These operations are performed by operating interlocked (Kirk-Key) transfer switches.

During the audit, TVA indicated that SQN plans to continue the Phase 2 coping strategies as long as Phase 2 equipment remains available. Additional assistance and equipment will be provided within 24 hours into the event from an NSRC and a 6.9 kV DG from Watts Bar to support transitioning to Phase 3, if necessary (or available in the case of the 6.9 kV DG from Watts Bar). SQN will receive four 1-MW 4160 Vac combustion turbine generators (CTGs), cables, two 4160 Vac distribution systems (to allow parallel operation of the two 1-MW 4160 Vac combustion turbine generators), and two 1100 kW, 480 Vac 3-phase CTGs from an NSRC. Once the equipment is onsite, SQN could utilize it based on the plant conditions to replace or augment FLEX Phase 2 equipment.

During a teleconference on September 8, 2016, the NRC staff requested that TVA clarify its Phase 3 strategy (i.e., can SQN indefinitely cope using the NSRC supplied 480 Vac CTGs during an ELAP; due to the close proximity of SQN and Watts Bar, how can TVA assure that the Watts Bar 6.9 kV DGs will be available during an external event; etc.). TVA clarified that SQN can indefinitely cope using its Phase 2 electrical strategy (e.g., pre-staged, onsite 480 Vac and 6.9 kV DGs). However, the NSRC supplied 480 Vac CTGs being delivered from either NSRC are capable of being deployed and power critical loads to indefinitely cope for an ELAP, if necessary. During the September 8, 2016 teleconference, TVA informed the NRC staff that it plans to stage the NSRC 480 Vac CTGs on the AB roof and that there are multiple means of separate and diverse pathways for connecting them to the SQN electrical distribution system to power required loads to indefinitely cope during an ELAP.

In the FIP, the licensee noted that each of the Phase 3 strategies will utilize common connections as used for the Phase 2 connections (if available) to prevent any compatibility issues with the offsite equipment. During the September 8, 2016 teleconference, TVA also confirmed that they would verify proper phase rotation of the NSRC supplied 480 Vac CTGs prior to powering required loads. The 6.9 kV DGs located at Watts Bar are for redundancy and would be used to re-power existing plant equipment, if available. While they may be available for use, the NRC staff does not fully credit the 6.9 kV DGs located at Watts Bar as part of the SQN Phase 3 strategy since the NRC staff did not review: 1) the robustness of the storage structure at Watts Bar to protect the DGs from applicable hazards; 2) the preventative maintenance program for the DGs; 3) the transportation routes, methods, and plans; or 3) the adequacy of the proposed staging areas and connections for the DGs at SQN. Therefore, the NRC staff finds that the SQN Phase 3 electrical strategy to utilize the 480 V CTGs from the NSRCs acceptable, since they have adequate capability and capacity for indefinitely coping with an ELAP. Additionally, the NRC staff finds that the 6.9 kV DGs from Watts Bar would provide additional redundancy to the SQN Phase 3 electrical strategy, if available.

The NRC staff's review of the licensee's electrical analyses did not identify any discrepancies.

Based on its review, the NRC staff finds that the plant batteries and the FLEX generators that the licensee plans to use should have sufficient capacity and capability to supply the necessary loads during an ELAP event.

3.2.4 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain or restore core cooling during an ELAP event consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.3 Spent Fuel Pool Cooling Strategies

NEI 12-06 Table 3-2 and Appendix D summarize an acceptable approach consisting of three separate capabilities for the SFP cooling strategies. This approach uses a portable injection source to provide the capability for 1) makeup via hoses on the refueling 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 3) spray via portable monitor nozzles from the refueling floor using a portable pump capable of providing a minimum of 200 gpm per unit (250 gpm if overspray occurs). During the event, the licensee selects the method to use based on plant conditions. This approach also requires a strategy to mitigate the effects of steam from the SFP, such as venting.

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. In 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 beyond design basis, the analysis used to provide the technical basis for time constraints associated with 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 be assumed to operate at nominal set points 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.

In 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 with water.

The ELAP causes a loss of cooling in the SFP. As a result, the pool water will heat up and eventually boil off. The licensee's response is to provide makeup water. The timing of operator actions and the required makeup rates depend on the decay heat level of the fuel assemblies in the SFP. The sections below address the response during operating, pre-fuel transfer or post-fuel transfer operations. The effect of an ELAP with full core offload to the SFP is addressed in Section 3.11. Sequoyah has one SFP, which is a reinforced concrete structure, and rests on the rock formation, shared by both units, located in the AB.

3.3.1 Phase 1

The licensee states on page E-59 of its FIP that, if the maximum possible loss of coolant through the vents due to sloshing is considered, the time to boil for the credible normal decay load is 11.65 hours and 5.34 hours for the maximum credible heat load, with an initial bulk water temperature in the pool of 127°F. The boil off rates for normal and maximum credible decay heat loads in the SFP was determined to be 43.45 gpm and 94.38 gpm, respectively. Considering no reduction in initial SFP water inventory, and starting from nominal pool level with an initial bulk water temperature of 127 °F, the time to boil off the water level to 10 ft. above the SFP racks is approximately 58.83 hours and 27.08 hours for the normal operating decay heat load and the maximum credible heat load, respectively.

The licensee stated that 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 establish any FLEX equipment local to the SFP should be completed before boil off occurs.

3.3.2 Phase 2

The licensee states on page E-61 of its FIP, that the transition to Phase 2 strategies will occur when the inventory in the SFP slowly declines due to boiling. The SFP cooling through makeup and/or spray will be provided by using the LP FLEX Pumps to pressurize the ERCW headers with raw water and then route a hose or hoses directly across the floor to the SFP from an ERCW FLEX connection to the CCS spool pieces (next to the CCS Surge Tanks) on AB elevation 734 ft. during both flood and non-flood scenarios. The licensee stated that it can provide two portable (fire-fighting type) flow/spray nozzles with a combined capacity of 500 gpm to the SFP. The licensee explained that an alternate option for SFP makeup water is from an ERCW FLEX connection located on AB elevation 714 ft. via hose deployment to a FLEX connection on the existing SFP Demineralized Water System (DWS) makeup piping located on AB elevation 714 ft., which provides makeup control when the refuel floor is not accessible.

3.3.3 Phase 3

The licensee states on page E-67 of its FIP, that the strategies described for Phase 2 can continue as long as there is sufficient inventory available to feed the strategies. Furthermore, page E-10 of the FIP states that the mobile water purification units delivered by the NSRC will provide clean water to refill the CSTs and provide for other potential needs such as clean water makeup to the SFP.

3.3.4 Staff Evaluations

3.3.4.1 Availability of Structures, Systems, and Components

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. In addition, Section 3.2.1.6 states that the initial SFP conditions are: 1) all boundaries of the SFP are intact, including the liner, gates, transfer canals, etc., 2) although sloshing may occur during a seismic event, the initial loss of SFP inventory does not preclude access to the refueling deck around the pool and 3) SFP cooling system is intact, including attached piping.

The staff reviewed the licensee's calculation on habitability on the SFP refuel floor. This calculation and the FIP indicate that boiling begins at approximately 11.65 hours during a normal, non-outage situation. The staff noted that the licensee's sequence of events timeline in the FIP indicates that operators will deploy hoses and spray nozzles as a contingency for SFP makeup within six hours from event initiation to ensure the SFP area remains habitable for personnel entry, which is in advance of the expected time to boil in the SFP.

As described in the licensee's FIP, the Phase 1 SFP cooling strategy does not require any anticipated actions. However, the licensee does establish a ventilation path to cope with temperature, humidity and condensation from evaporation and/or boiling of the SFP. The operators are directed to ensure the closure of a series of doors in Units 1 and 2 and block open another series of doors to establish a ventilation path as detailed in Attachment 2 of FSI-11, "Alternate SFP Makeup and Cooling," Revision 0. The timeline (or sequence of events) in FIP Attachment 1A indicates that one hour after the ELAP event initiation, operators will stage and align the LP FLEX Pumps at the IPS and will be completed within 3 hours of starting (or after the event initiation).

The licensee's Phase 2 and Phase 3 SFP cooling strategy involves use of the LP FLEX Pumps (or NSRC supplied pump for Phase 3), with suction from the intake channel, to pressurize the ERCW header and then use hoses from the ERCW FLEX connection in the AB to supply water to the SFP.

The staff's evaluation of the robustness and availability of the primary and secondary FLEX connections points for the FLEX pump is discussed in Section 3.7.3.1 below. Furthermore, the staff's evaluation of the robustness and availability of the intake channel for an ELAP event is discussed in Section 3.10.3.

3.3.4.1.2 Plant Instrumentation

In its FIP, the licensee stated that the instrumentation for SFP level will meet the requirements of Order EA-12-051. Furthermore, the licensee stated that these instruments will have initial local battery power with the capability to be powered from the FLEX DGs. The NRC staff's review of the SFP level instrumentation, including the primary and back-up channels, the display to monitor the SFP water level and environmental qualifications to operate reliably for an extended period are discussed in Section 4 of this safety evaluation.

3.3.4.2 Thermal-Hydraulic Analyses

On page E-59 of its FIP, the licensee provided the following information regarding the boil-off rates, time to boil and time to 10 ft. above the SFP racks for normal and maximum credible decay heat loads with an initial bulk water temperature in the pool of 127 °F:

Decay Heat Load	Boil-Off rate (gpm)	Time to Boil (hrs)	Time to 10 ft. above the SFP racks 10 ft. of top of active fuel (hrs)
Normal (w/o sloshing)	43.35	11.65	58.83
Maximum (w/o sloshing)	94.38	5.34	27.08

Calculation CN-SEE-II-13-19 indicates that for the design capabilities of the Spent Fuel Pool cooling system, which is 55 MBtu/hr (UFSAR Table 9.1.3-4), was considered for the maximum credible decay heat load and plant-specific data from its refueling outages was considered for the normal credible decay heat load. The licensee stated that access to the SFP area, as part of Phase 2, could be challenged due to environmental conditions near the pool. Therefore, the required action is to establish ventilation in this area and establish any FLEX equipment local to the SFP should be completed before boil off occurs.

In NEI 12-06, Section 3.2.1.6 states that the SFP heat load assumes the maximum design-basis heat load for the site as one of the initial SFP conditions. Based on the information in the licensee's calculation, the staff finds the licensee has considered the maximum design-basis SFP heat load for the site, consistent with NEI 12-06, Section 3.2.1.6 for a full core off-load, and finds it appropriate that the licensee used plant-specific data to determine the normal credible decay heat load.

3.3.4.3 FLEX Pumps and Water Supplies

As described in the FIP, the SFP cooling strategy relies on a FLEX pump to provide SFP makeup during Phase 2. On Page E-81 of the FIP, the licensee described the hydraulic performance criteria (e.g., flow rate, discharge pressure) for the LP FLEX Pump. The NRC staff noted that the performance criteria of a FLEX pump supplied from an NSRC for Phase 3 would allow the NSRC pump to fulfill the mission of the onsite FLEX pump if the onsite FLEX pump were to fail. As stated above, the SFP flow/spray rate of 250 gpm per unit meet the SFP makeup requirements as outlined in the previous section of this SE.

On pages E-81 through E-87 of its FIP, the licensee identifies the performance criteria for the LP FLEX Pumps for Phase 2 and 3 as summarized below:

- Diesel driven Dominator Pump used to pressurizes ERCW Headers. 5,000 gpm at 150 psig [350 ft. Total Dynamic Head (TDH)] Diesel Driven.

- Triton Pump System - consists of two floating hydraulically driven booster pumps supplying positive suction to the Dominators). 5,000 gpm capable of 50 ft. lift.

The staff noted that the performance criteria for the FLEX Phase 2 portable pumps are consistent with the FLEX Phase 3 portable pumps that support the SFP FLEX strategies. During the audit review, the licensee provided the FLEX as-built hydraulic calculation CN-FSE-14-48, which demonstrated that the LP FLEX Pumps identified in the FIP are capable of providing sufficient make-up to the SFP. The staff noted that the licensee's calculation relied upon Applied Flow Technology Fathom models to create an as-built hydraulic model using FLEX strategies contained in its FIP and the purchased valve datasheets and pump curves for each FLEX valve and pump. The licensee's calculation used actual piping isometrics, FLEX valves and connections, and considered frictional losses and hose lengths and diameters (suction and discharge) to ensure the FLEX Pumps can support each FLEX safety function.

The licensee considered various cases/scenarios, suction sources, flow paths, and discharge points to ensure the LP FLEX Pumps are capable of providing the required flowrate. In addition, the licensee considered the simultaneous loads the LP FLEX Pumps could support while still delivering the required flow rate and discharge pressure to support FLEX. The staff noted that the licensee's calculation determined that the actual flow rates provided by the LP FLEX Pumps exceeds the required flow rates for each of the FLEX safety function. Therefore, the FLEX Pumps the licensee have available are capable of providing the necessary water for the SFP. Specifically, the flow rate provided to the SFP by the LP FLEX Pumps is equal or exceeds the boil off rates of 43.45 gpm and 94.38 gpm for normal and maximum credible decay heart loads, respectively. Furthermore, the licensee demonstrated that the LP FLEX Pumps are capable of providing a combined SFP spray rate of 500 gpm consistent with NEI 12-06, Appendix D. The available water sources for these Phase 2 and 3 LP FLEX Pumps are discussed in Section 3.10.3 of this evaluation.

Based on its review, the NRC staff concludes that the licensee has demonstrated that its FLEX portable pumps should be capable of supporting the licensee's FLEX strategies if implementation is performed as described by the licensee.

3.3.4.4 Electrical Analyses

In its FIP, the licensee stated that, during Phase 1, the SFP level instruments are powered from the 120 Vac Vital Power System power, which is energized from the 125 Vdc vital batteries. The SFP level instrumentation is powered by the 125 Vdc vital Battery Chargers during Phases 2 and 3. The primary power supply to Spent Fuel Level Continuous Monitoring Loop 2 (0-LI-78-43) is from 120 Vac Vital Power Board 1-III with its individual power supply battery backup (0-BAT-78-43). The primary power supply to Spent Fuel Level Continuous Monitoring Loop 1 (0-LI-78-44) is from 120 Vac Vital Power Board 2-IV with its individual battery backup power supply (0-BAT-78-44). The 120 Vac Vital Power Boards are powered by 120 Vac Vital Inverters fed by its associated 125 Vdc Vital Battery Board.

As part of its review, the NRC staff saw a summary of the licensee's dc system Calculation EDQ000999201400102 to verify the capability of the vital batteries to supply the required loads during the first phase of the SQN FLEX mitigation strategies plan for an ELAP as a result of a BDBEE. Detailed review of the capacity of the vital batteries has been discussed in Section 3.2.3.6 of this evaluation. Based on the staff's review of the licensee's analysis and the guidance in FLEX procedures EA-250-1 and FSI-4, the NRC staff finds that the SQN dc system should have adequate capacity and capability to power the loads required to mitigate the consequences during the first phase of an ELAP as a result of a BDBEE provided that necessary load shedding is completed within the times assumed in the licensee's analysis.

For Phase 2, the SQN primary strategy includes power supply to the SFP instruments by two 480 Vac DGs. Each of the two 480 Vac, 225 kVA DGs is sized to supply power to the SFP level monitoring loops through vital battery chargers,120 Vac vital inverters and 120 Vac vital power boards. The NRC staff reviewed the summary of SQN Calculation EDQ0009993013000086, which showed that one 480 Vac, 225 kVA FLEX DG should have sufficient capacity and capability to supply power to the SFP level monitoring loop loads following a BDBEE.

In its FIP, the licensee stated that the primary strategy for SFP cooling includes use of two 6.9 kV FLEX DGs to supply power to the ERCWP, CCSP, SFP cooling pumps and other required equipment for the SFP makeup water supply.

Based on SQN Calculation EDN0003602014000120, if one 6.9 kV, 3 MW FLEX DG is not available, the other 6.9 kV FLEX DG of the same rating (3 MW) will have adequate capacity and capability available to supply power to the ERCWP, CCSP, SFP cooling pumps and other required equipment including loads supplied by the 480 Vac DG (such as vital Battery Chargers, SFP Instrument Level Loops etc.) as the capacity and capability of the 6.9 kV DGs is further discussed in Section 3.2.3.6 of this evaluation.

For Phase 3, TVA plan to continue the SQN Units 1 and 2 Phase 2 coping strategies using Phase 2 equipment. Additional assistance and equipment will be provided within 24 hours into the event from an NSRC (i.e., 480 Vac CTGs) and a 6.9 kV DG from Watts Bar to support transitioning to Phase 3, if necessary (or available in the case of the 6.9 kV DG from Watts Bar). Once the equipment is onsite, SQN could utilize it based on the plant conditions to replace or augment operating Phase 2 FLEX equipment. A detailed review of the capacity of the NSRC equipment is provided in Section 3.2.3.6 of this evaluation.

Based on its review, the NRC staff finds that the plant batteries and the FLEX generators that the licensee plans to use should have sufficient capacity and capability to supply the necessary loads during an ELAP event.

3.3.5 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain or restore SFP cooling following an ELAP consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address 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. The SQN units each have an ice condenser containment.

The licensee performed a containment evaluation, LTR-ISENG-14-2, "Containment Pressures and Temperatures for Sequoyah Units 1 and 2 during an ELAP Calculated with Modular Accident Analysis Program (MAAP) 4.07," Revision 1,which was based on the boundary conditions described in Section 2 of NEI 12-06. The calculation analyzed a few possible scenarios during an ELAP including the strategy of repowering a containment air return fan (CARF) for a short duration to enhance flow through the ice condenser. The strategy is described and proceduralized in FSI-12, "Alternate Containment Cooling," Revision 0. The calculation concludes that the containment temperature remains well below the respective FSAR Section 3.8.2.2.2 pressure and temperature limits of 12 psig at 220 °F for at least 8 days when this strategy is implemented.

Additionally, although core damage is not expected, NEI 12-06, Table 3-2, guides licensees with ice condenser containments to repower the unit's hydrogen igniters by using a portable power supply as a defense-in-depth measure to maintain containment integrity. The SQN FIP states that the hydrogen igniters can be repowered by either the 6.9 kV or the 480 Vac FLEX DGs. The Sequence of Events Timelines in the FIP show that the FLEX DGs will be available within approximately 3.5 hours following an ELAP-inducing event.

3.4.1 Phase 1

The SQN containment analysis concludes that there are no Phase 1 actions required, as the containment pressure and temperature remain below their respective limits.

3.4.2 Phase 2

Approximately 60 hours into the event, the containment analysis evaluates the strategy of running one CARF 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 eight days following the ELAP event.

As stated in TVA's FIP, the subject CARFs 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. 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 potential use of the CARFs at 60 hours following the event. These same actions to start the FLEX DGs 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

The licensee'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 eight 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

In guidance document NEI 12-06, baseline assumptions have been established on the presumption that, other than the loss of the ac power sources and loss to 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 during an ELAP.

3.4.4.1.1 Plant SSCs

Section 6.2.1.2.1 of the SQN UFSAR states that the containment consists of a containment vessel (CV) and a separate reactor shield building (RSB) enclosing the CV and annulus. The CV is a freestanding, welded steel structure with a vertical cylinder, hemispherical dome, and a flat circular base that provides primary containment. The RSB is a reinforced concrete structure similar in shape to the CV that protects the CV from external events. Section 3.8.1 of the SQN UFSAR states the RSB is a seismic category I structure in its entirety and is designed to remain functional in the event of a design-basis earthquake, a tornado, or a flood. Also, Table 6.2.1-1 of the UFSAR shows that the net free volume of the containment is 1,186,920 ft^3.

Table 3.11.1-1 of the UFSAR shows that the CARFs are engineered safety features which are required to function during and/or after an accident.

Section 9.4.8.3 of the UFSAR, states that the LCCs of the containment air cooling system are an engineered safety feature which provide the safety function of maintaining the air below a specified temperature following a High Energy Line Break, except for a LOCA.

Section 6.2.5A.1 of the UFSAR states that the hydrogen mitigation system (which contains the hydrogen igniters) is seismically mounted and will maintain functional capability under post-accident conditions. The hydrogen mitigation system is housed within the RSB which, as stated above, has also been designed to protect components against tornado loads and missiles.

Based on these UFSAR qualifications, the RSB, the CV, the CARFs, the LCCs (including the ERCW system), and the hydrogen igniters credited in the strategy are considered to be robust, as defined by NEI 12-06, and would be available following an ELAP-inducing event.

3.4.4.1.2 Plant Instrumentation

In NEI 12-06, Table 3-2, specifies that containment pressure is a key containment parameter which should be monitored by repowering the appropriate instruments. The licensee 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 eight-hour life. Furthermore, Attachment 1A of TVA's FIP states that the 480 Vac FLEX DGs are planned to be deployed and operating within approximately 1 hour following the ELAP event. These 480 Vac FLEX DGs will provide power to the 125 Vdc battery chargers through the 120 Vac Vital Inverter.

The licensee'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.

3.4.4.2 Thermal-Hydraulic Analyses

The staff reviewed LTR-ISENG-14-2, "Containment Pressures and Temperatures for Sequoyah during an ELAP Calculated with MAAP 4.07," Revision 1. The staff noted that the calculation contained three 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 three, four, and five, 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. During an ELAP, the containment heat up and pressurization is primarily driven by leakage of the RCP Seals. In the licensee's containment calculation, the RCP seal leakage modeling in the cases of interest was constructed to follow the FLEX actions to maintain core cooling. These include starting a Safety Injection Pump 5 hours after the start of the ELAP and then replacing this pump with a FLEX pump 9 hours after the start of the ELAP.

Case three analyzed a scenario in which the FLEX strategies for core cooling were employed and no other actions were taken to actively remove heat from the containment. The doors to the ice condenser, in this case, open as a result of the pressure increase from RCP seal leakage and the loss of active containment heat removal due to the ELAP. The opening of the doors allows the ice to absorb the heat and counteract the rising containment temperature and pressure. At the end of the 72-hour analytical duration, the calculation showed that containment pressure was less than 18 psia (which is well below the limit of approximately 27 psia). Additionally, case three showed that the maximum containment vessel temperature was approximately 140 °F at the end of the 72-hour analysis period which is well below the 220 °F limit.

Case four of the calculation analyzed a scenario in which there was not sufficient pressure developed to open the ice condenser doors. Leakage into the ice condenser was modeled; thus, the ice did provide some cooling, but the engagement of the ice was significantly less than the other cases. Under these conditions, as expected, the model demonstrated higher pressures and temperatures than the cases in which the ice doors opened. However, the overall magnitudes were still within the appropriate limits at the end of the 72-hour period of analysis. The calculation concluded that some mitigation act would be needed within a 6-day period following an ELAP-initiating event.

Finally, case five analyzed a scenario where power was restored to one CARF, and the fan was activated and allowed to run for 10 minutes before being turned off. The employment of the fan ensured the ice doors (assumed to be unopened until this point in time) opened to allow more effective cooling of the lower containment atmosphere. The calculation showed that the effect of the fan and ice quickly reduced both the containment pressure and temperature. When this strategy was employed, the calculation concluded that the containment conditions remained below their respective limits for at least eight days following an ELAP-initiating event.

The licensee's analysis in LTR-ISENG-14-2 concludes that, if the ice condenser doors do not open and no mitigation actions are taken (case four), a containment limit would not be reached for approximately 6 days following an ELAP event. It also shows that, if the ice condenser doors open from the expected pressure increase in containment due to RCP seal leakage and the loss of active containment heat removal (case three), containment limits would also not be reached until sometime after 6 days (when it is estimated that the ice mass will be depleted). Furthermore, the calculation shows that, if the ice condenser doors do not open due to the containment pressure, the licensee's proposed FLEX strategy of repowering a CARF at approximately 60 hours and operating it for about 10 minutes (case five), as necessary, maintains the containment atmosphere below its limits for over 8 days following an ELAP event. The employment of the strategy analyzed by case five is administratively controlled, and the licensee's proposed strategy may be employed any time after the FLEX DGs are placed in service.

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

Page E-53 of the FIP indicates that a containment analysis, Calculation LTR-ISENG-14-2, demonstrates that the containment pressure at 72 hours after ELAP event initiation is well below maximum internal pressure of 12 psig (design pressure of 10.8 psig). In addition, the highest temperature to which the containment vessel is exposed to occurs in the upper containment compartment (140 °F at 72 hours after ELAP event initiation), which is also well below the design limit of 220 °F. The pressures and temperatures are not stabilized and continue to increase, but the rate of increase is modest and conditions in the containment expected to remain benign until the ice bed in the ice condenser is depleted, which is expected to occur approximately 6 days from ELAP event initiation. The licensee explained that the 6.9 kV FLEX DGs provide the ability to support the operation of CARFs to enhance flow through the ice condenser (heat exchange), if required. Long-term containment temperature control could be provided by the operation of LCCs powered by the 6.9 kV FLEX DGs with cooling water would be provided to the LCCs by deployed LP FLEX Pumps feeding the ERCW system headers and alignment of the ERCW system.

The NRC staff noted that providing cooling water to the LCCs may be necessary approximately 6 days after the declaration of the ELAP event at which time additional staffing and off-site resources will be available. Furthermore, the availability of additional staffing and off-site resources should not impact licensee's FLEX strategies or time and equipment constraints for maintaining core cooling, SFP inventory and RCS inventory.

3.4.4.4 Electrical Analyses

The licensee 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, the licensee developed required actions to ensure maintenance of containment integrity and required instrumentation function. With an ELAP initiated, containment cooling for that unit is also lost for an extended period of time. Therefore, containment temperature and pressure will slowly increase. In its FIP, the licensee stated that there are no Phase 1 actions that are required to maintain containment functions based on the results of this analysis. Sequoyah will continue to monitor containment temperature and pressure using installed plant instruments. In its FIP, the licensee stated that SQN relies on existing installed station batteries to power critical plant instruments.

As part of its review, the NRC staff reviewed the summary of the licensee's dc system Calculation EDQ0009992014000102, to verify the capability of the vital batteries to supply the required loads during the first phase of the SQN FLEX mitigation strategies plan for an ELAP as a result of a BDBEE. Detailed review of the capacity of the vital batteries has been discussed in Section 3.2.3.6 of this evaluation. Based on its review of the above calculation and the guidance in FLEX procedures EA-250-1 and FSI-4, the NRC staff finds that the SQN dc system should have adequate capacity and capability to power the installed instruments and other required loads to mitigate the consequences during the first phase of an ELAP as a result of a BDBEE provided that necessary load shedding is completed within the times assumed in the licensee's analysis and battery coping time is 8 hours.

During Phase 2, SQN Calculation LTR-ISENG-14-2, showed that the containment pressure at T+72 hours is well below design pressure. The highest temperature to which the containment vessel is exposed to occurs in the upper containment compartment (140 °F at 72 hours) and is also well below the design limit (220 °F) with the opening of the ice condenser doors. The NRC staff reviewed the summary of the above calculation and noted that the containment environmental conditions are less severe than the SQN Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Section 50.49 Equipment Qualification temperature and pressure profiles. Based on this, the required instrumentation is expected to function during an ELAP as a result of a BDBEE.

In its FIP, the licensee stated that the primary strategy to supply power to the battery chargers, inverters, and plant instruments is by using a 480 Vac, 225 kVA FLEX DG. The NRC staff reviewed the summary of SQN Calculation EDQ0009993013000086. A detailed review of the capacity of the 480 Vac, 225 kVA FLEX DGs has been discussed in Section 3.2.3.6 of this evaluation. If one of the two 480 Vac DGs is not available, the other 480 Vac FLEX DG will be available to supply power to the battery chargers. If both 480 Vac FLEX DGs are not available, SQN mitigation strategy includes the option to use the 6.9 kV FLEX DGs to support Phase 2 loads.

During Phase 2, the SQN strategy involves use of a SIP, containment coolers, CARFs, and other required equipment. These equipment will be powered by the 6.9 kV DGs. The NRC staff reviewed the summary of Calculation EDN0003602014000120, which analyzed the adequacy of the 6.9 kV FLEX DG capacity based on the required Phase 2 equipment. Based on above, the NRC staff finds that the 6.9 kV FLEX DGs should have adequate capacity and capability to support Phase 2 Containment Functions.

The 6.9 kV FLEX DGs are capable of powering the hydrogen igniters through the 480 Vac shutdown power distribution system, if required. The 480 Vac FLEX DGs can also be aligned to provide power to the hydrogen igniter supply transformers, if required. Furthermore, repowering the 6.9 kV and 480 Vac shutdown electrical distribution system provides the ability to operate CARFs and other containment ventilation components (i.e., LCCs), if necessary.

For Phase 3, TVA plans to continue the SQN Phase 2 coping strategies using Phase 2 equipment. Additional assistance and equipment will be provided within 24 hours into the event from an NSRC (i.e., 480 Vac CTGs) and a 6.9 kV DG from Watts Bar to support transitioning to Phase 3, if necessary (or available in the case of the 6.9 kV DG from Watts Bar). Once the equipment is onsite, SQN could utilize it based on the plant conditions to replace or augment operating Phase 2 FLEX equipment. Procedure FSI-12 provides actions to establish alternate containment cooling in order to maintain containment pressure and temperature below limits during an ELAP by restoring containment coolers within 24 hours. The Phase 2 6.9 kV DGs could supply power to the containment coolers, if necessary. However, 6.9 kV DG loading will need to be checked and maintained within its limits specified in Procedure FSI-5.0.2 before loading coolers. For Phase 3, the 6.9 kV DG from Watts Bar could be used to replace a Phase 2 6.9 kV DG, if available. A detailed review of the capacity of the NSRC supplied equipment is provided in Section 3.2.3.6 of this evaluation.

Based on its review, the NRC staff finds that the plant batteries and the FLEX generators that the licensee plans to use should have sufficient capacity and capability to supply the necessary loads during an ELAP event.

3.4.5 Conclusions

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

3.5 Characterization of External Hazards

Sections 4 through 9 of NEI 12-06, Revision 0, provide 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 external hazards 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.

The licensee reviewed the plant 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. No hazard, from those described in NEI 12-06, was screened out.

References to external hazards within the licensee's mitigating strategies and this SE are consistent with the guidance in NEI-12-06 and the related interim staff guidance in JLD-ISG-2012-01 (ADAMS Accession No. ML12229A174). Coincident with the issuance of the order, on March 12, 2012 the NRC staff issued a Request for information Pursuant to 10 CFR Part 50, Section 50.54(f) (ADAMS Accession No. ML12053A340) (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 requested Commission guidance related to the relationship between the reevaluated flooding hazards provided in responses to the requested information and the requirements for Order EA-12-049 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" (ADAMS Accession No. ML14309A256). The Commission provided guidance in a SRM to COMSECY-14-0037 (ADAMS Accession No. ML15089A236). The Commission approved the staff's recommendations that licensees need to address the reevaluated flooding hazards within their mitigating strategies for BDBEEs, and that licensees may need to address some specific flooding scenarios that could significantly impact the power plant site by developing scenario-specific mitigating strategies, possibly including unconventional measures, to prevent fuel damage in reactor cores or SFPs. 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 the Commission did not require immediate imposition. In a letter to licensees dated September 1, 2015 (ADAMS Accession No. ML15174A257), the NRC staff informed the licensees that the implementation of mitigation strategies should continue as described in licensee's OIPs, and that the related NRC SEs and inspections will rely on the guidance provided in JLD-ISG-2012-01, Revision 0 and the related industry guidance in Revision 0 to NEI 12-06 (ADAMS Accession No. ML12242A378). The reevaluations may also identify issues to be entered into corrective action programs consistent with the OIPs submitted in accordance with Order EA-12-049.

By letter dated March 12, 2015, the licensee submitted its flood hazard reevaluation report (FHRR) (ADAMS Accession No. ML15071A462). The NRC staff has completed an interim review (ADAMS Accession No. ML15240A134) and the results are discussed in Section 3.5.2 below. The licensee developed its OIP for mitigation strategies in February 2013 (ADAMS Accession No. ML13063A183) by considering the guidance in NEI 12-06 and its then-current design-basis hazards. Therefore, this SE makes a determination based on the OIP and FIP, and notes the possibility of future actions by the licensee if the licensee's FHRR identifies a flooding hazard which exceeds the current design-basis flooding hazard.

Per the 50.54(f) letter, licensees were also asked to provide a seismic hazard screening and evaluation report to reevaluate the seismic hazard at their site. By letter dated March 31, 2014, the licensee submitted its seismic hazard screening report (SHSR) (ADAMS Accession No. ML14098A478). The NRC staff has completed its review and the results are discussed in Section 3.5.1 below. This SE makes a determination based on the OIP and FIP, and notes the possibility of future actions by the licensee if the licensee's SHSR identifies a seismic hazard which exceeds the current design-basis seismic hazard.

The characterization of the specific external hazards for the plant site is discussed below. In addition, Sections 3.5.1 and 3.5.2 summarize the licensee's activities to address the 50.54(f) seismic and flooding reevaluations.

3.5.1 Seismic

In its FIP, the licensee stated that seismic hazards are applicable to the site. In its SHSR, the licensee stated that per UFSAR Section 2.5.2.4, the safe shutdown earthquake (SSE) seismic criteria for the site is 0.18g peak horizontal ground acceleration and 0.12g peak ground acceleration acting vertically. It should be noted that the actual seismic hazard involves a spectral graph of the acceleration versus the frequency of the motion. Peak acceleration in the frequency range that affects structures, such as the numbers above, is often used as a shortened way to describe the hazard.

As the licensee's seismic reevaluation activities are completed, the licensee should address any safety issues by implementing appropriate corrective actions. Based on the above, the staff concludes that the licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated.

3.5.2 Flooding

In its FIP, the licensee stated that the current maximum plant site flood water level is elevation 722.0 ft. (still reservoir). This elevation would result from the rivers and streams flood causing mechanism. Coincident wind wave activity results in wind wave run up to 726.2 ft. on critical vertical external unprotected walls including the essential raw cooling water intake pumping station, auxiliary, control and shield buildings. The general plant grade near the AB which houses some FLEX equipment is elevation 705 ft. Section 2.4A.1.3 of the Sequoyah UFSAR states that the expected flood duration can be up to 6 days.

The flood hazard reevaluation concluded that the flood-causing mechanisms of local intense precipitation, flooding from rivers and streams, and flooding from combined effects of the PMF and wind are not bounded by the current design-basis for Sequoyah. Consistent with Enclosure 2 of the March 12, 2012, letter (ADAMS Accession No. ML12053A340), the licensee implemented interim actions to address the higher flooding levels relative to the current licensing basis. In addition, the licensee stated it will complete an Integrated Assessment and a report will be submitted by March 12, 2017.

During the audit process, the licensee addressed the potential impact of ground water in-leakage and any potential impacts from failure of large internal flooding sources. The licensee stated that there are no seismic hazards associated with large internal flooding sources which are not seismically robust and do not require ac power. Sequoyah is designed as a "wet" site and buildings are allowed to flood thus a loss of ac power to a sump pump would not challenge the plant's design basis. Flooding of the AB will not affect the mitigation strategies.

By letter dated September 3, 2015 (ADAMS Accession No. ML15240A134), the staff issued an Interim Staff Letter to the FHRR and concluded that the licensee's reevaluated flood hazards information is suitable for the assessment of mitigating strategies developed in response to Order EA-12-049. The NRC staff plans to issue a staff assessment documenting the basis for these conclusions at a later time.

As the licensee's flooding reevaluation activities are completed, the licensee should address any safety issues by implementing appropriate corrective actions. Based on the above, the staff concludes that the licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated.

3.5.3 High Winds

In NEI 12-06, Section 7 provides the NRC-endorsed screening process for evaluation of high wind hazards. This screening process considers the hazard due to hurricanes and tornadoes.

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 NUREG/CR-7005, "Technical Basis for Regulatory Guidance on Design Basis Hurricane Wind Speeds for Nuclear Power Plants," dated 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, Revision 2, dated February 2007; if the recommended tornado design wind speed for a 1E-6/year probability exceeds 130 mph, the site should address hazards due to extreme high winds associated with tornadoes.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee stated that Sequoyah is susceptible to hurricanes as the plant site is within the contour lines shown in Figure 7-1. It was determined the Sequoyah site has the potential to experience damaging winds caused by a tornado exceeding 130 mph. Figure 7-2 indicates a maximum wind speed of 200 mph for Region 1 plants, including Sequoyah.

Therefore, high-wind hazards are applicable to the plant site. The licensee has appropriately screened in the high wind hazard and characterized the hazard in terms of wind velocities and wind-borne missiles.

3.5.4 Snow, Ice, and Extreme Cold

As discussed in NEI 12-06, Section 8.2.1, all sites should consider the temperature ranges and weather conditions for their site in storing and deploying their FLEX equipment consistent with normal design practices. All sites outside of Southern California, Arizona, the Gulf Coast and Florida are expected to address deployment for conditions of snow, ice, and extreme cold. All sites located north of the 35th Parallel should provide the capability to address extreme snowfall with snow removal equipment. Finally, all sites except for those within Level 1 and 2 of the maximum ice storm severity map contained in NEI 12-06 Figure 8-2 should address the impact of ice storms.

The Sequoyah site is located approximately 7.5 miles northeast of Chattanooga in Hamilton County, Tennessee. In its FIP, the licensee stated that the extreme minimum temperature recorded in Chattanooga, Tennessee was -10 °F in the winter.

The licensee stated that the site is located at latitude 35° 14' N and longitude 85° 5' W. The Sequoyah site is above the 35th parallel; therefore, the FLEX strategies considered the potential hindrances caused by extreme snowfall with snow removal equipment, as well as the challenges that extreme cold temperature may present.

The Sequoyah site is not located in a Level 1 or 2 Region as defined by NEI 12-06, Figure 8-2. Therefore, the FLEX strategies must consider the hindrances caused by ice storms. The licensee concludes that the plant screens in for an assessment for snow, ice, and extreme cold hazard.

In summary, based on the available local data, and Figures 8-1 and 8-2 of NEI 12-06, the plant site does experience snow, ice, and extreme cold temperatures. Therefore, the hazards are screened in. The licensee has appropriately screened in the hazard and characterized the hazard in terms of expected temperatures.

3.5.5 Extreme Heat

In the section of its FIP regarding the determination of applicable extreme external hazards, the licensee stated that, as per NEI 12-06 Section 9.2, all sites are required to consider the impact of extreme high temperatures. The licensee stated that the extreme maximum temperature recorded in Chattanooga was 106°F in the summer and the plant site screens in for an assessment for extreme high temperature hazard.

In summary, based on the available local data and the guidance in Section 9 of NEI 12-06, the plant site does experience extreme high temperatures. The licensee 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 the licensee 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 in regard to the characterization of external hazards.

3.6 Planned Protection of FLEX Equipment

3.6.1 Protection from External Hazards

In its FIP, the licensee stated that it has designed and constructed a new storage building to protect portable FLEX equipment referred to as the FESB. The FESB is designed to protect the FLEX equipment against the external hazards described in NEI 12-06, except flooding. Other FLEX equipment will be pre-staged in existing, robust structures.

Major FLEX equipment will be stored in the FESB. This includes the diesel driven (Dominator) LP FLEX pumps with the attendant (Triton) floating booster pumps, the diesel driven IP pumps, water transfer pumps, fuel oil transfer pumps, tow vehicles equipped for debris and snow removal and a front end loader also for debris removal.

Equipment will also be pre-staged in the AB. This includes electric motor driven IP FLEX pumps (elevation 714 ft), electric motor driven Modes 5 and 6 IP FLEX pumps (elevation 669 ft), electric motor driven HP FLEX pumps (elevation 669 ft.), and the 480 Vac FLEX diesel generators pre-staged on the roof of the AB in a new protective robust enclosure. Additionally, two 6.9 kV diesel generators are pre-staged inside the existing ADGB. Lockers, storage boxes and enclosures for storing hoses, fittings and tools, required for FLEX implementation, are installed in the FESB and the ADGB. Below are additional details on how FLEX equipment is protected from each of the applicable external hazards.

3.6.1.1 Seismic

In its FIP, the licensee stated that the FLEX equipment is stored in the FESB, and pre-staged in the ADGB and AB. The ADGB and AB are seismic Category I structures. The licensee stated that the FESB is designed for seismic loading in excess of the minimum requirements of the American Society of Civil Engineers (ASCE) 7-10. The design criteria for FLEX is described, in the FIP, to be capped at 2 times the SSE from 1 to 10 hertz (of the design seismic spectra).

The 480 Vac FLEX DGs are pre-staged on the roof of the AB. A protective structure has been built around the DGs, which is designed to the same seismic Category I requirements as the AB. Seismic input for the design corresponds to the appropriate seismic accelerations at the AB roof. The licensee stated that the design provides a seismic protection of 2 times the SSE HCLPF seismic capacity.

The licensee further stated that the FLEX equipment will be stored such that it does not become a target or source of a seismic interaction from other SSCs.

3.6.1.2 Flooding

The FIP states that portable and pre-staged equipment required to implement the FLEX strategies will be maintained in the FESB, ADGB and the AB. The AB is allowed, by design, to flood and the FLEX equipment pre-staged within the AB can operate submerged or is located above the flood waters. The ADGB is protected against flooding. The new FESB is located at an elevation below the PMF flood level and is not protected against flooding. The FLEX equipment stored in the FESB will be moved upon receipt of warning of impending flood levels expected to exceed grade elevation.

Since an ELAP could occur at any time during the flood, licensee stated in its FIP that it will pre-stage FLEX equipment upon receiving warning from the TVA's Division of Water Management, River Systems Operations (RSO) Branch. The licensee's River Systems Operation's procedure RVM-SOP-10.05.06, "Nuclear Notifications and Flood Warning Procedure," and Sequoyah abnormal operating procedure (AOP)-N.03, "External Flooding," have been revised to provide the notification and to 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. Once a Stage 1 flood warning is received, the site has a minimum of 27 hours prior to flood water reaching plant grade (elevation 705 ft.) to move equipment from the FESB and deploy the equipment.

During this 27 hour period, if not prior to, based on management decision and anticipatory communication from RSO, the licensee stated that the units would be removed from service, cooled down and depressurized, borated to the required shutdown margin and aligned for flood mode operations.

A TVA procedure, CECC-EPIP-18, "Transportation and Staffing under Abnormal Conditions," is in place to pre-stage people and equipment in anticipation of inclement weather/conditions (flooding, high winds, snow and ice).

3.6.1.3 High Winds

Equipment required to implement the FLEX strategy is maintained in the FESB, ADGB, and the AB which are designed to meet or exceed the licensing basis high wind hazard for Sequoyah.

The 480 Vac FLEX DGs are pre-staged on the AB roof. The licensee stated that a protective structure has been built around the DGs, which is sited in a suitable location that is protected from tornado, missiles, and velocities as defined in NRC Regulatory Guide (RG) 1.76, Revision 1. The NRC staff requested additional information regarding the structural design of the protective structure around the DGs. The licensee provided calculation No. SQN-DC-V-48.0, "FLEX Response System," for the NRC staff to review. Calculation SQN-DC-V-48.0 described the design criteria for the protective structure. The staff reviewed portions of this calculation and was able to confirm that the protective structure, if designed and constructed as described in the calculation, should comply with the criteria in NEI 12-06 Section 7.3.1.

3.6.1.4 Snow, Ice, Extreme Cold and Extreme Heat

In its FIP, the licensee stated that the equipment stored in the FESB, ADGB, and AB is protected from extreme cold and extreme high temperature events. The licensee designed the FESB, the ADGB and the protective enclosure on the AB roof considering the effects of snow, ice, extreme cold and extreme heat conditions. The FESB is provided with a standalone HVAC system. The ADGB is provided with a heating and a ventilation system. The protective structure on the roof of the AB housing the 480 Vac FLEX DGs is provided with ventilation to ensure that there are no adverse effects on the FLEX equipment as a result of extreme high temperatures. The 480 Vac DG and the 6.9 kV diesel generators are provided with engine jacket water heaters to assure no adverse effects on the stored equipment from extreme cold conditions.

The AB is an environmentally controlled building and provides protection of the pre-staged FLEX equipment within the building from snow, ice, and extreme cold and heat effects.

3.6.2 Reliability of FLEX Equipment

The licensee stated that the following equipment will be stored in the FESB: 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 during non-flood events. In case of unavailability of one diesel driven IP FLEX pump, a submersible IP FLEX pump pre-staged in the AB can be used thereby meeting the N+1 requirement.

The licensee also stated that the following equipment will be pre-staged inside the AB; two motor driven IP FLEX pumps for core cooling during flood events, two motor driven Modes 5 and 6 IP FLEX pumps, three motor driven HP FLEX pumps for RCS makeup. In case of unavailability of one motor driven submersible IP FLEX pump, a Mode 5 and 6 submersible motor driven IP FLEX pump, also pre-staged in the AB, can be used thereby meeting the N+1 requirement.

Two 480 Vac FLEX diesel generators are pre-staged on the roof of the AB, each aligned to Unit 1 and Unit 2 respectively. In case of unavailability of one of the 480 Vac DGs, the 6.9 kV diesel generators can be connected to carry the loads thereby meeting the N+1 requirement.

Two 6.9 kV diesel generators are pre-staged inside the existing ADGB. Each DG is sized to simultaneously meet the loads for both Unit 1 and Unit 2.

In addition, support equipment consisting of two 4x4 heavy duty vehicles capable of debris and snow removal will be used for deployment of FLEX equipment, personnel transport and refueling of FLEX equipment. One compact track loader is also available for debris removal.

Based on the number of FLEX equipment identified in the FIP and during the audit review, the NRC staff finds that, if implemented appropriately, the licensee's FLEX strategies should include a sufficient number of portable FLEX pumps, FLEX DGs, and equipment for RCS makeup and boration, SFP makeup, and maintaining containment 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 the licensee 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 should adequately address the requirements of the order.

3.7 Planned Deployment of FLEX Equipment

For the core cooling strategy, which requires makeup water to the SGs, a diesel driven FLEX pump stored in the FESB would be deployed to the IPS. Floating diesel powered hydraulically driven booster pumps, which are also stored in the FESB, would be placed in the canal to feed the LP FLEX pump. The LP FLEX pump discharge is then connected, using hoses, to the ERCW header which could be aligned to feed the TDAFW pumps in both units. This method of feeding the SGs is put in place after the CSTs and other clean water sources are depleted.

If the CSTs are intact and available, the two IP FLEX pumps, stored in the FESB, will be moved next to both units CSTs. The IP pumps can be used to feed the SGs should the TDAFW pumps become unavailable.

During the flood mode, the deployment of one LP FLEX pump system to the IPS is the same as for the non-flood mode. If water levels rise and are expected to reach site grade, a second LP

FLEX pump, with its booster pumps, is deployed to the Auxiliary ERCW station, which is above the PMF level. The LP pump is staged and connected to the ERCW header in the Auxiliary ERCW station. The pump is put into service when flood waters are sufficient to provide suction to the floating booster pumps. The LP FLEX pump initially deployed to the IPS is relocated to higher ground as is the third LP FLEX pump stored in the FESB.

During the flood warning period, the submersible motor driven IP FLEX pumps pre-staged in the AB are made ready to supply ERCW water to the SGs once flood waters are expected to reach grade level.

For RCS inventory and reactivity control, three electrically-driven submersible HP FLEX pumps are pre-staged in the AB. In the non-flood mode, two HP FLEX pumps can be aligned to take suction from either the BATs or the RWST applicable to each unit and discharge into their respective SIP discharge headers. During the flood mode, the HP FLEX pump suction would be aligned to the RWST prior to losing access to the AB due to rising flood waters. The submersible pumps are powered by the FLEX DGs pre-staged on the AB roof.

For SFP cooling or containment cooling, no additional equipment needs to be deployed. For SFP cooling, the water source is the ERCW which is pressurized by the LP FLEX pumps already deployed for core cooling. Similarly, containment cooling also utilizes the ERCW headers via appropriate hose connections.

3.7.1 Means of Deployment

In its FIP, the licensee 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. One of the 4x4 tow truck vehicles is equipped with a heavy duty front mounted 16.5 ton winch, and the other tow vehicle is mounted with a debris or snow removal plow. The licensee indicated that one compact track loader is also available which is capable of clearing trees, light poles, fencing, construction materials and other miscellaneous debris. This equipment is stored in the FESB.

The LP FLEX pumps and the IP FLEX pumps are trailer mounted and would be deployed by the two 4x4 vehicles after debris removal was accomplished. The vehicles have a tow capacity of 14,000 pounds Gross Vehicle Weight (GVW).

Licensee FLEX procedures provide for manually opening the doors of the FESB for the deployment of the debris removal equipment and the FLEX equipment. The building doors can be manually opened using a come-along/chain fall in the event of loss of electric power.

3.7.2 Deployment Strategies

The mitigating strategies involve the deployment of the LP diesel driven pumps and boosters to the IPS, and IP diesel driven pump adjacent to the CSTs. Both pumps are stored in the FESB. In its FIP, the licensee indicated that pre-determined, preferred on site haul paths have been identified and have been reviewed for potential soil liquefaction. The haul paths evaluated were from the FESB to the point of deployment within the protected area (PA) and from equipment staging area "B", where the NSRC equipment will be staged prior to deployment to its final location on site. The licensee stated that the haul paths are not subject to soil liquefaction or lateral spreading and that the seismic event would not hinder deployment. All other equipment is pre-staged in the AB and ADGB, and does not need to be hauled.

The licensee also evaluated the potential for liquefaction along the deployment routes from the offsite Staging Areas C and D. The evaluation examined every route from these staging areas to the site and concluded that liquefaction could not be ruled out. Consequently the SAFER plan discussed in Section 3.8 of this evaluation provides for air transport of equipment to the site, as needed.

During the flood mode, the licensee utilizes the time from notification of potential flood to the time flood waters rise to grade level to deploy the LP FLEX pumps to the intake structures and to make the appropriate hose connections in the AB. The licensee stated that the warning time provides 27 hours to implement the FLEX strategies before flood water reach site grade level and water enters the AB. The licensee has modified the flood emergency procedure AOP-N.03 to address the potential for an ELAP event and include steps necessary to implement the FLEX strategies. FLEX strategies are implemented incrementally based on receiving an early warning, a Stage 1 warning and finally a Stage 2 warning. During the time when the site is flooded, the procedure provides for the use of boats to move personnel around the site. Access to the AERCW station will be needed to periodically monitor and refuel the FLEX LP pump deployed there.

During the audit process, the staff reviewed Sequoyah's procedure AOP-N.02, "Tornado Watch/Warning," Revision 30. The procedure covers high winds at Sequoyah and provides actions to take in preparation for potential tornados/high winds. Debris removal equipment is stored in the FESB. The LP pumps suction strainers and protocols for monitoring and ensuring the pumps do not lose suction pressure were reviewed during the on-site audit. The suction strainers will be positioned several feet below the waterline to protect the pump suction from floating debris. The licensee can monitor suction pressure and take action to clear the strainers as needed.

Access to the UHS during the flood mode is provided by staging the LP FLEX pumps at the AERCW structure with the pumps drawing suction from the rising flood waters. During the audit process the licensee stated that, in the event of complete failure of the downstream Chickamauga Dam, the water surface at the site will begin to drop within 1 hour after failure of the dam and will fall at a fairly uniform rate from normal river elevation of 681.0 ft. to elevation 641.0 ft. within approximately 60 hours from failure. The licensee will begin providing steady releases of at least 14,000 cubic ft. per second (cfs) at Watts Bar Dam within 12 hours of downstream dam failure to assure that water level recession at SQN does not drop below elevation of 641.0 ft. In the event of an ELAP with the loss of the downstream dam, a booster pumping system consisting of floating submersible source pumps that supply water to a Dominator pump would supply water to the ERCW system. The booster pumping system will be deployed in the forebay of the condenser circulating water IPS to provide raw water to the ERCW headers during this event.

The licensee also stated in its FIP, that snowmelt and ice jam considerations are also unlikely because of the geographic location of the plant.

3.7.3 Connection Points

3.7.3.1 Mechanical Connection Points

Core Cooling

Primary and Alternate Discharge connections for IP FLEX Pump:
In NEI 12-06, Table D-1 states, in part, that the performance attributes for make-up with a portable pump should include primary and alternate injection points to establish capability to inject through separate divisions/trains, i.e., should not have both connections in one division/train.

The licensee stated that in order to supply water to the suction of the IP FLEX Pumps located in the AB the existing ERCW FLEX connections on AB elevation 714 ft. have been modified to add Storz hose connections. For flood conditions, the licensee stated that procedures will ensure that hoses are deployed and connected before flood levels reach the FLEX connection. The staff noted that, during an ELAP event, hoses would be routed from the hose connections on the ERCW FLEX connections to the primary or secondary connections discussed below.

On Page E-31 of its FIP, the licensee states that the primary connection for the IP FLEX Pumps discharge is located in the West Main Steam Valve Vault (MSVV) upstream of the Level Control Valves (LCVs) on the TDAFW pump discharge piping. The licensee stated that the modifications involved adding a FLEX connection to the TDAFW pump discharge line, adding an isolation valve to the main line upstream of connection, adding an isolation valve to the new branch, and a Storz cap/adapter to the new branch. The licensee indicated that the primary connection is located inside the West MSVV, which is a safety related structure that is protected from applicable external hazards, except flooding. For flood conditions, the licensee stated that procedures will ensure that hoses are deployed and connected before flood levels reach the FLEX connection.

On Page E-33 of its FIP, the licensee states that the secondary FLEX connection for the IP FLEX Pumps discharge is located in the AB on elevation 714 ft. upstream of the LCVs on the MDAFWP discharge piping. The licensee stated that the modifications involved installing hard piping between the HPFP Train A and Train B flood mode supply piping and the MDAFWP Train A and Train B piping, adding a tee to this piping, adding isolation valves to either side of the new tee, adding isolation valves on the new branches, and a Storz caps/adapters to the new branches. The licensee indicated that the secondary connection is located inside the AB, which is a safety-related structure protected from all applicable external hazards, except flooding. For flood conditions, the licensee stated that procedures will ensure that hoses are deployed and connected before flood levels reach the FLEX connection.

Section 10.4.7.2.2 in the UFSAR, indicates that the safety-related portion of the Auxiliary Feedwater System is partially housed in the main steam valve rooms, located in the AB. As previously discussed in Section 3.2.3.1.1 of this evaluation, the AB is robust with respect to the seismic and high wind hazards. Furthermore, the licensee stated in its FIP that FLEX equipment connection points are designed to meet or exceed the design basis SSE protection requirements.

Since the FLEX connections designed to withstand a SSE are located within the West MSVV or the AB and the licensee's procedures ensure that hoses are connected before flood levels reach the connection, the staff finds that the licensee seems to have the capability of core cooling through a primary and alternate injection points to inject through separate divisions/trains. Furthermore, the staff finds that, consistent with NEI 12-06 Section 3.2.2, the primary and alternate discharge connection points were either designed, located in a safety-related structure and/or procedurally connected (i.e., flood scenario) such that at least one connection point should be available during an ELAP event.

FLEX connections to supply IP FLEX Pumps

On Page E-24 of its FIP, the licensee states that the LP FLEX Pumps staged at the IPS will take suction from the intake channel and discharge to the ERCW FLEX connections at the IPS. On FIP Page E-25, the licensee states that the LP FLEX Pumps staged at the AERCW Pumping Station will take suction from the cold water return channel and discharge to the ERCW FLEX connections located at the AERCW Pumping Station.

On Page E-32 of its FIP, the licensee states that the existing ERCW piping at the IPS has been modified to add isolation valves with Storz hose connections to allow the ERCW headers to be pressurized by the LP FLEX Pumps that will be staged near the IPS during non-flood conditions. The licensee also stated that the existing ERCW piping at the Auxiliary ERCW Pumping Station has been modified to add isolation valves with Storz hose connections to allow the ERCW headers to be pressurized by the LP FLEX Pumps that will be staged next to the ERCW Pumping Station during flood conditions.

Section 3.2 in the UFSAR indicates that the IPS is a Category I structure and is designed to remain functional in an SSE event. Also, UFSAR Section 3.3.2.1 indicates that the IPS is designed to withstand the effects of the 300-mph rotational wind, the 60-mph translational wind, and the associated negative differential pressure. In addition, UFSAR Section 3.5 indicated that the IPS is analyzed and designed to be protected against damage by tornado-driven missiles. Furthermore, the licensee stated in its FIP that FLEX equipment connection points are designed to meet or exceed the design basis SSE protection requirements.

Since the FLEX connections designed to withstand a SSE are located within the IPS (non-flood events) or the AERCW Pumping Station (flood events), the staff finds that at least one connection point should be available during an ELAP event.

RCS Inventory

Primary and Alternate Suction/Discharge connections for HP FLEX Pump:

In NEI 12-06, Table D-1, states, in part, that the performance attributes for make-up with a portable pump should include primary and alternate injection points to establish capability to inject through separate divisions/trains, i.e., should not have both connections in one division/train.

The licensee indicated that, in order to supply water to the suction of the HP FLEX Pumps located in the AB, modifications were made to the existing RWST and BAT piping. Specifically, the RWST FLEX connections involved the installation of pipe taps on the RWST supply lines to the Refueling Water Purification Pumps on AB elevation 669 ft., and the addition of isolation valves and a Storz adapter with a cap on the branch. The BAT FLEX connections involved the installation of a tee on the discharge line for the BATs and the addition of an isolation valve and a Storz adapter with a cap on the branch. For flood conditions, the licensee stated that procedures will ensure that hoses are deployed and connected before flood levels reach the FLEX connection. The staff noted that during an ELAP event hoses would be routed from the RWST and BAT FLEX connections to the primary and secondary connections discussed below.

On Pages E-41 to E-42 of its FIP, the licensee states that the HP FLEX Pumps will take suction from the RWST FLEX connections located on AB elevation 669 ft. or from the BATs FLEX connection located on AB elevation 690 ft. and with the discharge hose routed to either the B Train SIP discharge header FLEX connection (Primary) or A Train SIP discharge header (alternate).

The licensee stated that the modifications involved the installation of a weldolet, and adding two isolation valves and a hose adapter to the Train B/A SIP Discharge header. The licensee indicated that the primary and secondary connections are in the respective SIP rooms, which are located in the AB, which is a safety-related structure that is protected from all applicable external hazards except flooding. For flood conditions, the licensee stated that procedures will ensure that hoses are deployed and connected before flood levels reach the FLEX connection.

Since the FLEX connections designed to withstand a SSE are located within the AB (a Category I Structure) and the licensee's procedures ensure that hoses are connected before flood levels reach the connection, the staff finds this approach to be consistent with NEI 12-06, Table D-1. If implemented as described, the strategy should enable the licensee have RCS Inventory Control through a primary and alternate injection points to inject through separate divisions/trains. Furthermore, the staff finds this approach consistent with NEI 12-06, Section 3.2.2 because the primary and alternate discharge connection points were located in a safety-related structure and/or procedurally connected (i.e., flood scenario) such that at least one connection point should be available during an ELAP event.

SFP Makeup/Spray

<u>Primary and Alternate Connection Points</u>

In NEI 12-06, Table D-3, states, in part, that the baseline capabilities for SFP Cooling include makeup via hoses on refuel floor, spray capability via portable monitor nozzles from refueling floor, and makeup via connection to SFP cooling piping or other alternate location.

The staff noted that the LP FLEX Pumps and associated connection points that pressurize the ERCW header, which will be used as the water source to support the SFP FLEX strategies, is described in the Core Cooling section above (SE Section 3.7.3.1).

On Page E-61 of its FIP, the licensee indicates that the primary method for SFP cooling through makeup and/or spray will be from an ERCW FLEX connection at the ERCW to CCS spool pieces, via the installation of adapters with Storz hose connections, on AB elevation 734 ft. through hose or hoses routed directly across the floor to the SFP. The licensee indicated that the primary method involves the discharge of the hose directly into the SFP for makeup or to spray nozzles for SFP spray and is not impacted by floodwaters. The licensee also stated that an alternate option for SFP makeup, which does not require access to the refueling floor, is from an ERCW FLEX connection located on AB elevation 714 ft. via a hose deployed to a FLEX connection on the existing SFP Demineralized Water System makeup piping also located on AB elevation 714 ft. The licensee explained that the FLEX connection installed a tee to the SFP Demineralized Water System makeup line and added isolations valves and a Storz cap/adapter. The modifications that added FLEX connections to the ERCW headers on AB elevation 714 ft. are described in the Core Cooling section above.

Since the FLEX connections designed to withstand a SSE are located within the AB and the primary method is not impacted by floodwaters, the staff finds the available connection points in the licensee's SFP Cooling FLEX strategies are consistent with NEI 12-06, Table D-3. In addition, the staff finds consistent with NEI 12-06, Section 3.2.2, at least one connection point (primary or alternate discharge) should be available during an ELAP event.

3.7.3.2 Electrical Connection Points

In its FIP, the licensee stated that FLEX equipment and connection points are designed to meet or exceed SQN design-basis SSE protection requirements. The FIP described primary and alternate power supply connections and routing/alignment for flood and non-flood events.

For the 480 Vac FLEX DGs, two fused distribution panels provide power to the required loads. Each 480 Vac FLEX DG fuse panel provides connections to two vital battery chargers. Each fuse distribution panel provides connection capability to the 480 Vac Shutdown Power distribution system's 480 Vac Reactor MOV Boards with the ability to close Cold Leg Accumulator Isolation Valves during cooldown, if required. In an ELAP event, 'A' 480 Vac FLEX DG would supply power to 125 Vdc Vital Battery Chargers I and III and 'B' 480 Vac FLEX DG would supply power to 125 Vdc Vital Battery Chargers II and IV.

To connect the existing 6.9 kV Shutdown Power distribution system to the 6.9 kV FLEX DGs for FLEX implementation and operation, the existing Kirk-Key transfer switch connections from the EDGs would be opened and then closed from the 6.9 kV FLEX DGs. These operations are performed by operating interlocked (Kirk-Key) Transfer Switches 1A-A, 1B-B, 2A-A, or 2B-B. The installed electrical connection points for the 6.9 kV FLEX DGs are from the DGs integral output connection panel through conduits within the ADGB to underground conduits located on the outside of the ADGB to the Kirk-Key transfer switches located in the EDG Building. From these transfer switches through the normal safety-related distribution network to the designated 6.9 kV Shutdown Board emergency feeder breaker. The 6.9 kV FLEX DG 'A' is assigned to power 1A-A and 2B-B 6.9 kV Shutdown Boards and 6.9 kV FLEX DG 'B' is assigned to power 1B-B and 2B-B 6.9 kV Shutdown Boards. The 'A' 6.9 kV FLX DG would supply both 1A-A and 2A-A 6.9 kV Shutdown Boards through their respective Kirk-Key disconnect switches and shutdown board emergency feeder breaker. The 'B' 6.9 kV FLEX DG would supply 1B-B and 2B-B 6.9 kV Shutdown Boards. The electrical conduits meet seismic Class I requirements for safety-related and quality-related structures.

Attachment 1 of the FIP describes the primary and alternate paths to supply power to the Unit 1 and 2 HP pumps for flood and non-flood events and SQN, Units 1 and 2, IP for a flood event. A primary non-flood alignment example for the Unit 1 HP pump includes the 6.9 kV FLEX DG A through a EDG transfer switch, a 6.9kV shutdown board, a 6.9 kV/480Vac Step down Transformer, a 480Vac shutdown board, 480Vac C&A Vent board to Unit 1 HP Pump. An alternate flood alignment example for the Unit 2 IP pump includes 6.9 kV FLEX DG A through a EDG transfer switch, a 6.9kV shutdown board, a 6.9 kV/480Vac Step down Transformer, a 480Vac shutdown board, 480Vac C&A Vent board to Unit 1 IP Pump used for Unit 2.

During the audit, TVA indicated that SQN plans to continue the Phase 2 coping strategies as long as Phase 2 equipment remains available. Additional assistance and equipment will be provided within 24 hours into the event from an NSRC and a 6.9 kV DG from Watts Bar to support transitioning to Phase 3, if necessary (or available in the case of the 6.9 kV DG from Watts Bar). SQN will receive four 1-MW 4160 Vac combustion turbine generators (CTGs), cables, two 4160 Vac distribution systems (to allow parallel operation of the two 1-MW 4160 Vac combustion turbine generators), and two 1100 kW, 480 Vac 3-phase CTGs from an NSRC. Once the equipment is onsite, SQN could utilize it based on the plant conditions to replace or augment FLEX Phase 2 equipment.

During a teleconference on September 8, 2016, the NRC staff requested that TVA clarify its Phase 3 strategy (i.e., can SQN indefinitely cope using the NSRC supplied 480 Vac CTGs during an ELAP; due to the close proximity of SQN and Watts Bar, how can TVA assure that the Watts Bar 6.9 kV DGs will be available during an external event; etc.). TVA clarified that SQN can indefinitely cope using its Phase 2 electrical strategy (e.g., pre-staged, onsite 480 Vac and 6.9 kV DGs). However, the NSRC supplied 480 Vac CTGs being delivered from either NSRC are capable of being deployed and power critical loads to indefinitely cope for an ELAP, if necessary. During the September 8, 2016 teleconference, TVA informed the NRC staff that it plans to stage the NSRC 480 Vac CTGs on the AB roof and that there are multiple means of separate and diverse pathways for connecting them to the SQN electrical distribution system to power required loads to indefinitely cope during an ELAP.

In the FIP, the licensee noted that each of the Phase 3 strategies will utilize common connections as used for the Phase 2 connections (if available) to prevent any compatibility issues with the offsite equipment. During the September 8, 2016 teleconference, TVA also confirmed that they would verify proper phase rotation of the NSRC supplied 480 Vac CTGs prior to powering required loads. The 6.9 kV DGs located at Watts Bar are for redundancy and would be used to re-power existing plant equipment, if available. Therefore, the NRC staff finds that the SQN Phase 3 electrical strategy to utilize the 480 V CTGs from the NSRCs and 6.9 kV DGs from Watts Bar acceptable, since the 480 Vac CTGs have adequate capability and capacity for indefinitely coping with an ELAP. Additionally, the NRC staff finds that the 6.9 kV DGs from Watts Bar would provide additional redundancy to the SQN Phase 3 electrical strategy, if available.

3.7.4 Accessibility and Lighting

The licensee evaluated the lighting available for traveling to, and from, the various areas necessary to implement the FLEX mitigation strategies, make required piping and electrical connections, operating electrical disconnects and breakers, monitoring instrumentation monitoring and component manipulation. The licensee stated in its FIP that, in an ELAP event, initial lighting for the main control room and shutdown board room areas is provided by the 125 Vdc powered emergency lighting system. This system utilizes light-emitting diode (LED) light bulbs. The auxiliary control room access and egress routes and areas that must be attended for safe shutdown operations are provided with 8-hour Appendix R emergency battery lighting (EBL) units. These Appendix R lighting units were upgraded to LED bulbs, which provide extended battery life. These emergency lights are designed and periodically tested under the plant's preventive maintenance program to ensure the battery pack will provide a minimum of eight-hours of lighting with no external ac power sources.

The licensee stated that the tasks for implementing the FLEX mitigation strategies are similar to tasks previously walked down for B.5.b and Appendix R safe shutdown operations. Licensee determined that the Appendix R emergency lights provide adequate lighting for all interior travel pathways needed to access the connection points.

Once the 6.9 kV FLEX DGs repower the 6.9 kV shutdown boards and the 480 volt shutdown powered distribution system, the standby lighting system can be repowered from the reactor MOV boards supplying lighting and placing the 125 Vdc powered emergency lighting system back in a standby mode.

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. Therefore, the diesel powered FLEX pumps and generators are outfitted with lights that are powered from their respective diesels to support connection and operation. In addition to the lights installed on the portable diesel powered FLEX equipment, portable diesel generator powered light stanchions, battery powered light packs, and small generators to provide power and battery charging capability are available to be deployed to support fading light or night time operations. A stock of flashlights and head lights is available to further assist the staff responding to an ELAP.

3.7.5 Access to Protected and Vital Areas

In procedure 0-TI-DXX-000-922.3, "Diverse and Flexible Coping Strategies (FLEX) Program Basis", Revision 0, the licensee stated that SQN Site Security has written contingency plans and procedures to handle the postulated loss of security boundary equipment. These procedures also provide for the movement of required emergency equipment and personnel through the security boundaries should any or all portions of the system become inoperable.

3.7.6 Fueling of FLEX Equipment

In its FIP, the licensee stated that the major portable FLEX equipment needing periodic refueling are the diesel driven LP FLEX pumps, with their booster pump, deployed to the IPS (or in the case of rising flood waters to the AERCW), the IP FLEX pumps deployed near the CSTs, the 6.9 kV diesels located in the ADGB, and the 480 Vac DGs pre-staged on the roof of the AB. The licensee stated that all portable diesel driven equipment is stored with their fuel tanks full and ready for deployment. The method for refueling each diesel powered piece of equipment is described in procedure 0-TI-DXX-000-922.3, "Diverse and Flexible Coping Strategies (FLEX) Program Basis," Revision 0, posted on the licensee's ePortal.

The portable LP and IP FLEX pumps are refueled using the two 4x4 vehicles each equipped with a 500 gallon diesel fuel oil tank, a transfer pump, and hoses. These vehicles are stored fueled in the FESB and ready for deployment. The LP FLEX pump requires refueling approximately every 8 hours. The FLEX floating booster pump requires refueling approximately every 7 hours and the IP FLEX pump which is deployed next to the CST during the non-flood mode requires refueling approximately every 8.5 hours.

The 6.9 kV diesel generators are refueled from the safety-related 7-day emergency DG tanks or the fuel oil storage tanks. The DGs are located in the AEDG building which is near the EDG building. The 7-day tanks are mounted under the safety-related EDG building, which is a seismically qualified building and built to site design criteria for wind generated missile protection. There are four 7-day tanks each holding 62,000 gallons of diesel fuel oil. The EDGB is located at elevation 722 ft. The 6.9 kV DGs are equipped with 2800 gallon day tanks. The fuel is transferred from the 7-day tanks using the fuel transfer pumps in the EDG room and temporary hoses.

The truck mounted 500 gallon tanks that will be used to refuel the deployed LP and IP FLEX pumps will also be refilled from the 7-day tanks. Portable electric motor driven fuel transfer pumps are used to transfer fuel oil from the 7-day tanks to the truck mounted 500 gallon tanks. There are two portable fuel transfer pumps and they are stored in the ADGB.

The 480 Vac DGs pre-staged on the AB roof are each equipped with a 180 gallon day tank. The DGs are provided with an initial fill of fuel oil to provide 10 hours of operation. The day tanks are refilled from an 8,000 gallon fuel oil storage tank, with integral fuel oil transfer pumps, located on grade level on the south side of Unit 2. These fuel oil transfer pumps are powered by the 480 Vac FLEX DGs. When needed, the fuel oil hose and power supply connections will be made. Maintaining the day tanks will require manual operator action to start the fuel transfer pumps and stop the pumps once the day tanks are full. The DGs be manually refueled approximately every eight hours. The 8,000 gallon tank is normally empty, but is filled upon receiving a flood warning from River Operations.

In its fourth 6 month update (ADAMS Accession No. ML15064A167), the licensee stated that, based on the estimated total fuel consumption rate of all deployed equipment, there is enough fuel on site for seven days of operation.

3.7.7 Conclusions

The NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should allow deployment of the FLEX equipment following a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.8 Considerations in Using Offsite Resources

3.8.1 Sequoyah SAFER Plan

The industry has collectively established off-site capabilities to support FLEX Phase 3 equipment needs via the Strategic Alliance for FLEX Emergency Response (SAFER) Team. The SAFER Team consists of Pooled Equipment Inventory Company (PEICo) and AREVA Inc., and it provides FLEX Phase 3 management and deployment plans through contractual agreements with every nuclear operating company in the United States. In its FIP, the licensee stated that they have established an agreement with the SAFER/NSRC team in accordance with Section 12 of NEI 12-06.

There are two NSRCs (Memphis area and Phoenix area) established to support nuclear power plants if a BDBEE occurs at a site. Each NSRC holds five sets of equipment, four of which will be able to be fully deployed to the plant when requested. The fifth set allows removal of equipment from availability to conduct maintenance cycles. In addition, the plant's FLEX equipment hose and cable end fittings are standardized with the equipment supplied from the NSRC.

The FIP states that communications will be established between SQN and the SAFER/NSRC team and required equipment moved to the site as needed. First arriving equipment, as established in the "SAFER Response Plan for Sequoyah Nuclear," will be delivered to the site within 24 hours from the initial request. Once the equipment arrives onsite, SQN will utilize it based on plant conditions and need. Details for activation, delivery, and operational capability of the Phase 3 equipment can be found in the "SAFER Response Plan for Sequoyah Nuclear." The NRC staff reviewed, in part, the information in the SAFER Response Plan referred in the SQN FIP. The Plan provides a timeline for implementation and describes the responsibilities between the SAFER team and the site response team. The SAFER Response Plan is the basis document to execute Phase 3 of the FLEX strategies.

By letter dated September 26, 2014 (ADAMS Accession No. ML14265A107), the NRC staff issued its staff assessment of the NSRCs established in response to Order EA-12-049. In its assessment, the staff concluded that the SAFER team 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 could reference the SAFER program and implement their SAFER Response Plans to meet the Phase 3 requirements of Order EA-12-049.

During the audit, TVA indicated that SQN plans to continue the Phase 2 coping strategies as long as Phase 2 equipment remains available. Additional assistance and equipment will be provided within 24 hours into the event from an NSRC and a 6.9 kV DG from Watts Bar to support transitioning to Phase 3, if necessary (or available in the case of the 6.9 kV DG from Watts Bar). SQN will receive four 1-MW 4160 Vac combustion turbine generators (CTGs), cables, two 4160 Vac distribution systems (to allow parallel operation of the two 1-MW 4160 Vac combustion turbine generators), and two 1100 kW, 480 Vac 3-phase CTGs from an NSRC. Once the equipment is onsite, SQN could utilize it based on the plant conditions to replace or augment FLEX Phase 2 equipment.

During a teleconference on September 8, 2016, the NRC staff requested that TVA clarify its Phase 3 strategy (i.e., can SQN indefinitely cope using the NSRC supplied 480 Vac CTGs during an ELAP; due to the close proximity of SQN and Watts Bar, how can TVA assure that the Watts Bar 6.9 kV DGs will be available during an external event; etc.). TVA clarified that SQN can indefinitely cope using its Phase 2 electrical strategy (e.g., pre-staged, onsite 480 Vac and 6.9 kV DGs). However, the NSRC supplied 480 Vac CTGs being delivered from either NSRC are capable of being deployed and power critical loads to indefinitely cope for an ELAP, if necessary. During the September 8, 2016 teleconference, TVA informed the NRC staff that it plans to stage the NSRC 480 Vac CTGs on the AB roof and that there are multiple means of separate and diverse pathways for connecting them to the SQN electrical distribution system to power required loads to indefinitely cope during an ELAP.

In the FIP, the licensee noted that each of the Phase 3 strategies will utilize common connections as used for the Phase 2 connections (if available) to prevent any compatibility issues with the offsite equipment. During the September 8, 2016 teleconference, TVA also confirmed that they would verify proper phase rotation of the NSRC supplied 480 Vac CTGs prior to powering required loads. The 6.9 kV DGs located at Watts Bar are for redundancy and would be used to re-power existing plant equipment, if available. Therefore, the NRC staff finds that the SQN Phase 3 electrical strategy to utilize the 480 V CTGs from the NSRCs and 6.9 kV DGs from Watts Bar acceptable, since the 480 Vac CTGs have adequate capability and capacity for indefinitely coping with an ELAP. Additionally, the NRC staff finds that the 6.9 kV DGs from Watts Bar would provide additional redundancy to the SQN Phase 3 electrical strategy, if available.

3.8.2 Staging Areas

In general, up to four staging areas for NSRC supplied Phase 3 equipment are identified in the SAFER Plans for each reactor site. These are a Primary (Area C) and an Alternate (Area D), which are offsite areas for receipt of ground transported or airlifted equipment from the SAFER centers in Phoenix, Arizona or Memphis, Tennessee. From Staging Areas C and/or D, a near- or on-site Staging Area B is established for interim staging of equipment prior to it being transported to the final location for implementation in Phase 3 at Staging Area A. For SQN, the Alternate Staging Area D is the Chattanooga Airport (Lovell Field), located 28 driving miles from SQN. Staging Area C is the Cleveland Regional Jetport located 52 driving miles from SQN. Staging Area B is the Sequoyah Training Center upper parking lot.

The use of helicopters to transport equipment is recognized as a potential need within the Sequoyah SAFER Plan and is provided for.

3.8.3 Conclusions

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

3.9 Habitability and Operations

3.9.1 Equipment Operating Conditions

3.9.1.1 Loss of Ventilation and Cooling

During the audit, the staff reviewed document SL-012415, "Sequoyah Nuclear Plant - FLEX Implementation HVAC ELAP Analysis," 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 the equipment areas assessed by TVA include those that are credited and desired for its FLEX strategies, which include the following:

- Spent Fuel Pit Cooling Pumps

- Component Cooling Pumps
- Safety Injection Pumps
- PD Pump Rooms with HP and IP FLEX Pumps in Service
- Aux Bldg Ventilation Rooms with IP FLEX Pump in Service
- TDAFW Pumps
- MDAFW Pumps
- Boric Acid Tanks
- Air Compressors Located in the Refueling Room A13

On page E-73 of the FIP, the licensee stated that the licensee's HVAC calculation 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, Safety Injection Pumps rooms, and the PD Pumps rooms (location of the HP FLEX Pumps) the pump room doors will be opened and left open to facilitate natural circulation and ensure that the temperatures remain within the acceptable range for equipment and personnel. FSI-5.01, "Initial Assessment and Flex Equipment Deployment," Revision 0, and FSI-08, "Alternate RCS Boration," Revision 0, provide procedural guidance to block open doors for the TDAFW Pump room and SI Pump room, respectively. In addition, the staff noted that Attachment 3, "Area Temperature Monitoring," of FSI-5.01 directs monitoring of several areas including the TDAFW Pump rooms, Safety Injection Pumps rooms, and the PD Pumps rooms at least every 12 hours and to report any temperatures that exceed the minimum or maximum limits outlined in the FSI.

Based on the expected temperature response in the areas identified above, procedural guidance in the licensee's FSIs for establishing natural circulation and temperature monitoring, the staff finds it reasonable that the FLEX equipment should be available to support an ELAP event.

Electrical - Following a BDBEE and subsequent ELAP, 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 with loss of normal access to the UHS.

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. The licensee performed analysis SL-012415, to quantify the maximum steady state temperatures expected in specific areas related to FLEX mitigation strategy implementation to ensure the environmental conditions remain acceptable within equipment design qualification limits.

The areas identified for all phases of execution of the FLEX mitigation strategy activities are the Main Control Room (MCR), Shutdown Board Rooms, AB, Turbine Driven Auxiliary Feedwater Pump (TDAFWP) rooms, MDAFW, CCS Pump rooms, PD Pump rooms, and Containment. The licensee evaluated these areas to determine the temperature profiles following an ELAP with loss of normal access to the UHS event.

TDAFWP room - The licensee's analysis in the Calculation MDQ0009992013000085, "SQN ELAP Transient Temperature Analysis," Revision 1, determined that the analyzed room temperature 72 hours after event initiation (116 °F) remains within acceptable limits based on conservative 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 FIP, the licensee stated that as part of its mitigation strategy, the pump room doors will be opened and left open to facilitate natural circulation to provide further assurance that the temperatures remain within the electrical equipment design limit and to support pump operation. The FIP identified actions for non-flood and flood events to monitor ventilation in the TDAFWP room at approximately seven hours after the start of the ELAP event. If required, operators will verify 6.9 kV FLEX DG loading and restore selected HVAC systems to service. Based on its review of SL-012415, the NRC staff identified that no action is required until 24 hours into an ELAP event, at which point doors can be propped open for natural circulation and monitored periodically. Based on the above and that temperatures remaining below 120 °F (the temperature limit, as identified in NUMARC-87-00, for electronic equipment to be able to survive indefinitely), the staff finds that the equipment in the TDAFWP rooms should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

MDAFW and CCS Pump room/area – During an ELAP event MDAFW and CCS Pumps installed in the same room/area would be energized by the 6.9 kV FLEX DGs. The NRC Staff reviewed the summary of Calculation SL-012415. Table 5.1 of this analysis shows that the maximum expected room/area temperature will be 132.1 °F 72 hours after the event. In the FIP, the licensee stated that the 6.9 kV FLEX DGs can repower select ventilation equipment if needed and if loading permits. Furthermore, additional Phase 3 equipment from NSRC will be available approximately 24 hours after the licensee notifies the NSRC. In addition, the above calculation referenced a TVA Calculation, GENSTP3-001, "Upper Boundary Temperature for Mild Environments Related to Environmental Qualification of Electrical equipment," Revision 000, which concluded that the electrical equipment such as low voltage circuit breakers and switchgears can withstand 140 °F ambient conditions on a continuous basis while carrying 80 percent of rated loads. Low voltage circuit breakers and switchgears are typically designed to carry a maximum of 80 percent loads. Based on above, the NRC staff finds that the licensee's evaluation of the MDAFW and CCS Pump Room/area temperature provides assurance that the electrical equipment in the room/area should remain functional due to loss of ventilation during an ELAP.

SI Pump Room – The 6.9 kV FLEX DGs will supply electric power to the 480 Vac SI Pump motor. The NRC staff reviewed the summary of Calculation SL-012415, for expected room temperature and electrical equipment operation. This analysis shows that the worst case expected room temperature will be 140 °F at 72 hours after event initiation. Figure 6.2 of the above calculation showed that room peak temperature reaches 140 °F when the SI Pump runs for a short period (20 minutes) at 5.5 hours into the transient, and again for 5 minutes at 8 hours and then temperature remains below 113 °F for up to 72 hours. In the FIP, the licensee stated that if required, operators will verify 6.9 kV FLEX DG loading and energize selected HVAC systems to cool the SI pump rooms to the acceptable temperature limit that will support electrical equipment operation. The licensee's mitigation strategy includes opening the SI Pump room at 5.5 hours and will be left open to facilitate natural circulation. In addition, the above calculation referenced TVA Calculation, GENSTP3-001, which concluded that the electrical equipment such as low voltage circuit breakers and switchgears can withstand 140 °F ambient conditions on a continuous basis while carrying 80 percent of rated loads. Low voltage circuit breakers and switchgears are typically designed to carry a maximum of 80 percent loads. Based on above, the NRC staff finds that the licensee's evaluation of the SI Pump Room temperature provides assurance that the electrical equipment in the SI Pump room should remain functional due to loss of ventilation during an ELAP.

PD Pump Rooms (with HP and IP FLEX Pumps in Service) – The staff reviewed the summary of Calculation SL-012415. Table 5.1 of this calculation shows that the expected temperature in this pump room will be 110 °F. In the FIP, the licensee stated that the PD Pump room doors will be opened and left open to facilitate natural circulation to lower the temperature and cool the room. Based on temperatures remaining below 120 °F (the temperature limit, as identified in NUMARC-87-00, for electronic equipment to be able to survive indefinitely), the staff finds that the electrical equipment in the PD Pump rooms should remain functional due the loss of ventilation as a result of an ELAP event.

MCRs – In the FIP, the licensee stated that the temperature in the MCR have been evaluated to determine the temperature profiles following an ELAP with loss of normal access to the UHS event. Calculation MDQ0009992013000085 concluded that temperatures should remain within acceptable limits based on conservative heat load assumptions with no actions being taken to reduce heat load or to establish either active or passive ventilation (e.g., portable fans, open doors, etc.). The NRC staff reviewed the summary of Calculation MDQ0009992013000085. Figure 7.6 of this calculation showed that the MCR temperature would reach 116 °F after 24 hours and 130 °F 72 hours into the event. The evaluation also determined that by only opening doors 4 hours into the event during the summer-time would result in temperatures of 113 °F after 24 hours and 126 °F after 72 hours. Installation of portable ventilation after 24 hours would result in a temperature of 111 °F after 72 hours. The licensee's mitigating strategy also included monitoring ventilation needs for the MCRs at approximately seven hours after the start of an ELAP event. If required, operators will verify 6.9 kV FLEX DG loading and restore selected HVAC systems to cool the MCRs that will ensure that the electrical and electronic equipment within the MCR area remain functional.

The 125 Vdc Shutdown Battery Board Rooms I, II, III, IV, and 6.9 kV and 480 V Shutdown Board Rooms A and B - The NRC staff reviewed the summary of Calculation MDQ0009992013000085, which showed that under worst case summer conditions (Case 1 (with no actions)) the maximum expected room temperature for the Division II 125 Vdc Board Room I, II, III, and IV will be < 110 °F 72 hours after event initiation. Figure 7.2 of the above calculation shows that the maximum temperatures in the 6.9 kV and 480 Vac Shutdown Board Rooms A and B will be less than 102 °F. The licensee's mitigating strategy includes monitoring ventilation needs for these rooms approximately seven hours after the start of the ELAP event. In the FIP, the licensee stated that if necessary, operators will verify 6.9 kV FLEX DG loading and restore selected HVAC systems to service to cool these rooms to the acceptable temperature limit and to support electrical equipment operations. Based on the above and that the temperatures remain below 120 °F (the temperature limit, as identified in NUMARC-87-00, for electronic equipment to be able to survive indefinitely), the NRC staff finds that the electrical equipment in the 125 Vdc Shutdown Battery Board Rooms and 6.9 kV and 480 Vac Shutdown Board Rooms will remain functional due to a loss of ventilation as a result of an ELAP event.

The 125 Vdc Battery Rooms I, II, III, IV - The NRC staff reviewed the summary of Calculation SL-TVA-3014. Figure 7.5 of this calculation showed the vital battery room temperature profile in the AB. Case 1 (with no actions) determined that the maximum expected room temperatures should remain under 104.7 °F (in the 125 Vdc vital Battery Room IV) 61 hours into the event. Division I, II, III, vital Battery Room temperatures should remain below 95 °F for 72 hours.

The qualification testing performed by C&D Technologies demonstrated the ability to perform under elevated operating temperature environments. The testing results indicate that the battery cells should perform as required in excess of 200 days under an estimated 122 °F.

The elevated temperature also has an impact by increasing the charging current required to maintain the float charging voltage set by the charger. The elevated charging current will in turn increase cell water loss through an increase in gassing. Based on this, periodic water addition may be required or the float charging voltage reduced per the guidance contained in the C&D Technologies vendor manual. If battery cell plate uncovery were to occur, failure issues associated with plates being exposed would involve the potential development of sulfation and a subsequent reduction in capacity. If loss or failure of a battery string were to occur, the battery charger should have the capability to carry the anticipated loads indefinitely provided ac power remains available to power the charger.

In the FIP, the licensee stated that the vital battery room doors will be blocked open to allow for natural ventilation to cool the rooms. Furthermore, the SQN mitigation strategy includes monitoring of ventilation needs in the battery rooms starting at seven hours into the event and if needed, battery room HVAC powered from the 6.9 kV FLEX DGs can be energized which will lower and maintain the room temperature to the acceptable limit. Based on above, the NRC staff concludes that the vital batteries in the battery rooms should remain functional during a loss of ventilation during ELAP.

Other areas - In the FIP, the licensee referenced TVA Calculation GENSTP3-001, which analyzed the impact of higher temperature during ELAP on the design qualification of electrical equipment used at nuclear power plants. This calculation determined that electrical and electronic equipment/components (cables, splices, limit switches, motor operated valves, sensors and transmitters, electronic components) 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. The licensee identified that the only exception area at SQN was for the switchgear and motor control centers, which may require current limitations above 104 °F. Based on its evaluation, the licensee 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. Based on above, the NRC staff finds that the licensee's evaluation provides assurance that the electrical equipment in the expected environment should remain functional.

Containment – Refer to Section 3.4.4.4 of this SE for the NRC staff's evaluation of the licensee's mitigating strategy for maintaining containment temperature within design limit of credited instrumentation and equipment.

Based on its review, the NRC staff finds that the licensee has demonstrated that the electrical equipment relied upon as part of the SQN plant mitigation strategy for an ELAP as a result of a BDBEE should not be adversely affected by increases in temperature as a result of loss of HVAC given that the licensee performs the compensatory measures described above.

3.9.1.2 Loss of Heating

The FIP indicates that the RWST (boron concentration of 2,500-2,700 ppm) and BATs (boron concentration of 6,120-6,990 ppm) are borated water sources used to support the FLEX RCS Inventory Control Strategies. UFSAR Section 9.3.4.2.5 indicates that the BATs, which are located in the AB, contain a boric acid solution with a solubility limit reached at 58 °F. Furthermore, the UFSAR states that this temperature is sufficiently low and that the normally expected ambient temperatures within the AB will maintain boric acid solubility. The staff noted that the solubility limit for the RWST will be reached at approximately 32 °F and the licensee's Technical Specifications requires a minimum RWST temperature of 60 °F. Based on the temperature within the AB, the solubility limit of the BATs and the time frame in which the BATs will be needed for RCS makeup, the staff finds it reasonable that boron precipitation of the BATs during extreme cold conditions should not be an issue. Based on the minimum required RWST temperature, the solubility limit of the RWST, and the time frame in which the RWST will be needed for RCS makeup, the staff finds reasonable that boron precipitation of the RWST during extreme cold conditions should not be an issue.

FSI-5.01 contains cautions to operators regarding freeze protection actions and compensatory measures that support existing procedures such as 0-PI-OPS-000-006.0, "Freeze Protection," and M/AI-27, "Freeze Protection." Furthermore, Attachment 4, "Freeze Protection Considerations," of FSI-5.01 contains guidance to install temporary heat tracing/heated covering, draining water from equipment and hoses, reenergizing existing tanks heaters and staging portable heaters. Based on the procedural guidance provided in FSI-5.01, the staff finds reasonable that extreme cold conditions should not impact the use of FLEX equipment during an ELAP event.

The staff believes that the impact on the performance of the vital batteries, based on low temperatures, should be minimal. The vital batteries are located within the AB interior such that outside air temperature would not impact battery performance. In addition, during battery discharge the battery will be producing heat that will keep electrolyte temperature above the room temperature. Operator should monitor these temperature and take actions, as necessary.

3.9.1.3 Hydrogen Gas Control in Vital Battery Rooms

The NRC staff reviewed the licensee's evaluation of hydrogen accumulation in the vital battery rooms. In the FIP, the licensee stated that off gassing of hydrogen from batteries is only a concern when batteries are charging. As such, battery room doors and other doors around the battery rooms will be blocked open to facilitate natural circulation. According to the licensee, natural circulation of air will prevent accumulation of hydrogen in the battery rooms. Furthermore, the SQN mitigation strategy includes monitoring of ventilation needs in the battery rooms starting at seven hours into the event and if needed, battery room HVAC powered from the 6.9 kV FLEX DGs can be energized which will lower and maintain hydrogen concentration below the combustibility limit for hydrogen (4 percent). Based on above, the NRC staff finds that hydrogen concentration level in the battery rooms should remain below combustibility limit if the licensee mitigation strategies are implemented as described above.

3.9.2 Personnel Habitability

3.9.2.1 Main Control Room

The licensee's habitability evaluation for the MCR is documented in calculation MDQ0009992013000085. The staff noted that the licensee's evaluation considered different scenarios during a summer-time response such as no operator actions, opening up doors to the MCR and installation of portable ventilation. The evaluation determined the summer-time response with no compensatory actions taken in the MCR would result in temperatures of 116 °F after 24 hours and 130 °F after 72 hours. The evaluation also determined that only opening doors at four hours during the summer-time would result in temperatures of 113 °F after 24 hours and 126 °F after 72 hours and that installation of portable ventilation after 24 hours would result in a temperature of 111 °F after 72 hours. The licensee explained that its calculation used a measured heat load during normal operation for the MCR, which the staff finds conservative because the heat load during an ELAP would be significantly reduced due many heat sources being de-energized during a loss of AC power.

During the audit review, the licensee performed an assessment documented as "Impacts of Extreme Heat, Cold, Ice and Snow During a ELAP and Implementation of FLEX Strategies to Mitigate" (W50 152905 004). This assessment outlined challenges and presented strategies to ensure successful deployment of FLEX mitigation equipment by providing protection for both the equipment and personnel. Specifically, for the MCR the licensee stated that the following actions should take place to remediate the increasing temperatures in the MCR:

- Block open MCR doors
- Utilize portable ventilation fans
- Ensure drinking water is readily available
- Place priority to ensure MCR ventilation is provided
- Rotation of personnel
- Breaks may be taken in inner rooms, buildings or areas of air movement outside

In addition, the staff noted that Attachment 3 of FSI-5.01 directs monitoring of the MCR at least every 12 hours and to report any temperatures that exceed the minimum or maximum temperature limits of 50 °F and 104 °F, respectively.

Based on the licensee's assumption, the expected temperature response in the MCR, guidelines to cope with extreme high temperatures in the MCR and temperature monitoring in the MCR, the staff finds it is reasonable that the MCR should remain habitable during an ELAP event.

3.9.2.2 Spent Fuel Pool Area

On page E-59 of the FIP, the licensee states that, with no reduction of coolant inventory due to sloshing from a seismic event, the time for the SFP to boil is 11.77 hours for the normal credible decay heat load and 5.39 hours for maximum credible heat load with an initial bulk water temperature in the pool of 127 °F. The licensee explained that, if the maximum possible loss of coolant through the vents due to sloshing is considered, the time to boil for the credible normal decay load is 11.65 hours and 5.34 hours for the maximum credible heat load with an initial bulk water temperature in the pool of 127 °F.

The staff noted that the licensee's sequence of events timeline in the FIP indicates that operators will deploy hoses and spray nozzles as a contingency for SFP makeup within six hours from event initiation to ensure the SFP area remains habitable for personnel entry and that the duration of the work would be two hours. Procedure FSI-11, provides caution to operators regarding steam and condensation from SFP boiling that may cause access and equipment problems in other parts of the plant. FSI-11 also provides procedural guidance to operators on specific doors to be blocked open to establish a passive steam vent path.

Based on time to boil in the SFP during normal non-outage scenarios, and the cautions and procedural guidance to open doors in FSI-11, the staff finds reasonable that operators should be able to safely enter the area of the SFP to establish a vent path and begin deploying FLEX equipment.

3.9.2.3 Other Plant Areas

TDAFW Pump Room

The licensee's habitability evaluation for the TDAFW Pump room is documented in Calculation SL-012415. The licensee's assessment relied upon a previous calculation that determined the room temperatures under normal, LOCA, and SBO conditions. The licensee stated that the final temperature of the TDAFW pump room is 116.0 °F for SBO conditions and that the room temperature response during SBO conditions is considered to be the same during ELAP conditions. Thus, the results of this previous SBO calculation can be extended to apply to the 72-hour ELAP scenario. The staff finds it reasonable that the temperature response for the TDAFW Pump room during an SBO could be the same as for the ELAP because the heat loads in this room during both scenarios are expected to be the same. The staff noted that FSI-5.01 provides procedural guidance to block open the TDAFW Pump room doors during an ELAP event, which will enhance cooling within the room. In addition, the staff noted that Attachment 3 of FSI-5.01 directs monitoring of the TDAFW Pump rooms at least every 12 hours and to report any temperatures that exceed the minimum or maximum temperature limits of 50 °F and 135 °F, respectively. Based on the expected temperature response in the TDAFW pump rooms and procedural guidance in FSI-5.01 to open the room doors, the staff finds reasonable that operators should be able to safely enter this room for local manual initiation/operation of TDAFW pump, if needed.

Manual operation of Atmospheric Relief Valves

During its audit review, the licensee indicated that ARVs have hand wheels located in the 480V shutdown board rooms. The licensee's habitability evaluation for the 480V Shutdown Board Rooms A & B is documented in calculation MDQ0009992013000085. The staff noted that the licensee's evaluation considered different scenarios during a summer-time response such as no operator actions, opening up doors, and installation of portable ventilation to the 480V Shutdown Board Rooms A & B. The evaluation determined that, in all scenarios assessed, the temperature in the 480V Shutdown Board Rooms A & B after 72 hours did not exceed 100 °F. Based on the expected temperature response in the 480V Shutdown Board Rooms A & B, the staff finds reasonable that operators should be able to safely enter this area to operate the ARV hand wheels when manual control air stations are not available.

3.9.3 Conclusions

The NRC staff concludes that the licensee 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 should adequately address the requirements of the Order.

3.10 Water Sources

3.10.1 Steam Generator Make-Up

Phase 1

On page E-20 of the FIP, the licensee indicates that, during Phase 1, the initial alignment of the TDAFWP suction is to the CSTs. The licensee explained that, if the CSTs are undamaged by the initiating event, the CSTs should provide 14.0 hours of cooling water for each unit. If a missile or missiles generated by the initiating event penetrated at the top of the CSTs' protection barrier, the CSTs could still provide approximately 7.5 hours of cooling water. The FIP indicates that the CSTs have been hardened for missile protection (partially) and seismically qualified per licensee documents DCN 23191 and DCN 23376, respectively. When water from the CSTs is no longer available, operators must open valves to provide water from the ERCW system. Suction flow to the TDAFWP can be provided by standing water in the ERCW headers for approximately 18.5 hours as a last option. UFSAR Section 3.2.2.3 and UFSAR Table 3.2.2-2 indicates that ERCW piping is Safety Class C and designed to Seismic Category I, respectively. UFSAR Section 9.2.2.3 indicates that the ERCW system and piping is not impacted by tornado winds and missiles.

Based on the information provided in the FIP and UFSAR, the CST and ERCW system piping are considered to be robust and should be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3. If implemented appropriately and consistent with the FIP, the licensee should have an adequate source of water available during the Phase 1 core cooling and have sufficient time for operators to deploy and stage Phase 2 FLEX equipment.

Phase 2

The licensee indicated that it will preferably use any surviving, non-seismic, clean water tanks to provide makeup to the CSTs using deployed diesel driven transfer pumps, hoses and installed FLEX connections. The staff noted that the LP FLEX Pumps staged by the IPS will take suction from the intake channel. UFSAR Sections 2.5.6.1.2 and 2.5.6.2.2 indicates that the side slopes in the forebay area are Category I slopes and are constructed to remain stable for the most critical design conditions (like the occurrence of a SSE coincident with a sudden drawdown of the reservoir water level). During its audit, the licensee stated that, in the assumed event of complete failure of Chickamauga Dam, the water surface at the site will begin to drop within 1 hour after failure of the dam and will fall at a fairly uniform rate. The licensee indicated that TVA will begin providing steady releases at Watts Bar Dam within 12 hours of downstream dam failure to assure that water level recession at the site does not drop below Elevation 641.0 ft.

Based on the licensee's expected response to ensure adequate water level at the site after a failure of a downstream dam, the procedural interface guidance in NEI 12-06 Section 5.3.3 should be addressed.

Based on the information provided in the FIP and UFSAR, water contained in the intake channel and Tennessee River should be available during an ELAP event consistent with initial conditions in NEI 12-06, Section 3.2.1.3. If implemented appropriately and consistent with the FIP, the licensee should have an adequate source of water available during the Phase 2 core cooling and have sufficient time for the arrival of off-site equipment from the NSRC.

Phase 3

On page E-37 of its FIP, the licensee indicates that a mobile water purification system supplied by the NSRC will enable water from the Tennessee River or other raw water source to be purified. The staff confirmed in Section 7 of the SAFER Response Plan (AREVA Document No. 38-9233750-000, "SAFER Response Plan for Sequoyah Nuclear Plant") that a water purification equipment should be requested from the NSRC. If implemented appropriately and consistent with the FIP, the licensee should have an adequate source of water available during the Phase 3 core cooling.

3.10.2 Reactor Coolant System Make-Up

Phase 1

On page E-39 of its FIP, the licensee states that Phase 1 RCS makeup is provided from the Safety Injection System Cold Leg Accumulators. Table 3.2.1-2 in the UFSAR indicates that the cold leg accumulators are located in the Containment Building and are Seismic Category I components.

Section 3.3.2.1 in the UFSAR indicates the Containment Building is designed for the effects of the 300 mph rotational wind, the 60 mph translational wind and the associated negative differential pressure. Section 3.5 in the UFSAR indicated that the Containment Building is analyzed and designed to be protected against damage by tornado-driven missiles. Section 2.4.2.2 in the UFSAR states that the Containment Building is protected from flooding by the shield building.

Based on the information provided in the FIP and UFSAR, the Cold Leg Accumulators are considered to be robust and should be available at the start of an ELAP event consistent with the initial conditions in NEI 12-06, Section 3.2.1.3. If implemented appropriately and consistent with the FIP, the licensee should have a sufficient source of water available during Phase 1 to maintain RCS inventory in order to maintain natural circulation cooling and control reactivity in the core.

Phase 2

The licensee indicates in its FIP, that the borated water sources for Phase 2 RCS makeup is provided by the RWST and the BATs. Table 3.2.1-2 in the UFSAR indicates that the BATs are Seismic Category I components located in the AB. As previously discussed above, the AB is a robust structure and is protected from seismic and high wind hazards. Table 3.2.1-2 in the

UFSAR indicates that the RWST is a Seismic Category I component that is located outside. Sections 3.8.4.1.4 and 6.2.1.3.11 in the UFSAR indicates that the RWST includes a storage basin around the tank to retain a minimum of 20,000 gallons of borated water in the event the tank is ruptured.

In response to the staff's questions regarding whether 20,000 gallons of borated water was sufficient for the long-term response to an ELAP event for each unit, the licensee assessed the ability of the RWSTs to survive a beyond design basis flood and high wind hazard.

The licensee performed a finite element analysis to demonstrate that the RWSTs are robust and capable of withstanding the loads associated with a beyond-design-basis flood and high wind hazard. The RWSTs were assessed to understand the necessary RWST level required to maintain anchorage integrity as a function flood depth and flow velocity. The analysis also included the effects of hydrodynamic drag, wave action, and debris impact. Since the licensee's evaluation limits the RWST minimum level when compared to the flood elevation, during its audit, the licensee provided documentation that the volume level in the RWST is equal to or above the flood elevation for the during of the event. The RWSTs were also assessed for the combined effects of tornado winds and atmospheric pressure drop consistent with RG 1.76, Revision 1 and it was determined that the tanks, including anchorage, are capable of withstanding the applied loads. Furthermore, the tanks were assessed for their resistance to perforation from the 6" schedule 40 pipe and automobile missiles defined in RG 1.76, Revision 1. The staff noted the licensee evaluated two tank heights (i.e., base of tank and top of tank) to bound the potential for localized penetrating effect, and a global deflection of the tank and tearing effect from the anchorage (i.e., overturning). In the four scenarios (i.e., each missile at both tank heights), the licensee determined that the tank would not be perforated and that the tanks anchorage was adequate with respecting to overturning.

Based on the licensee's evaluation, the staff finds it reasonable that the RWSTs are robust for the high wind and flood hazards because the tanks were shown to withstand loadings associated for each event, including resisting perforation from high wind and flood debris missiles.

Consistent with NEI 12-06 Sections 3.2.1.3 and 3.2.2.5, the staff finds that the BATs and RWSTs are robust per the FIP and UFSAR, and are adequate borated water sources should be available during an ELAP to support the FLEX mitigation strategy during Phase 2 until the arrival of off-site equipment from the NSRC.

Phase 3

During the audit process, the licensee indicated that a mobile boration skid will be requested to be delivered by the NSRC. The licensee indicated that the mobile boration unit can supply 1000-gallon batches of borated water and will be transferred via 60 gpm pumps provided by the NSRC to each unit's RWST. The licensee entered this request for the mobile boration skid in their corrective action program (CR #1174445). The staff noted that the mobile boration skid will provide long term boration for an indefinite amount of time in conjunction with the mobile purification unit. As previously discussed, the mobile water purification unit should enable water from the Tennessee River or other raw water source to be purified and subsequently used in the mobile boration skid. If implemented appropriately and consistent with the FIP, the licensee should have an adequate source of borated water available during Phase 3 RCS inventory makeup.

3.10.3 Spent Fuel Pool Make-Up

Phase 1, 2, and 3

As discussed in Section 3.3 of this SE, assuming the normal operating decay heat load, the time for the SFP water level to boil off to 10 ft. above the SFP racks is approximately 58.83 hours after a SSE seismic event. The licensee explained that SFP cooling through makeup and/or spray will be provided by using LP FLEX Pumps providing raw water to the ERCW system piping and headers. The staff's review of the robustness and availability of the intake channel and the ERCW system piping and headers are discussed in Section 3.10.1 of this SE.

Based on the information provide in the FIP and UFSAR, water contained in the intake channel and Tennessee River should be available during an ELAP event, which is consistent with the initial conditions in NEI 12-06, Section 3.2.1.3. If implemented appropriately and consistent with the FIP, the licensee should have an adequate source of water available during the SFP cooling Phases 1, 2 and 3. This source of water should provide sufficient time for deploying and staging Phase 2 FLEX equipment and for the arrival of off-site equipment from the NSRC.

3.10.4 Containment Cooling

Phase 1, 2 and 3

On page E-53 of its FIP, the licensee indicates that pressures and temperatures within the Containment Building are not stabilized and continue to increase during an ELAP event. However, the conditions in the containment are expected to remain benign until the ice bed is depleted, which is expected to occur approximately 6 days from the event initiation. The licensee also stated that the long-term containment temperature control could be provided by the operation of LCCs powered by the 6.9 kV FLEX DGs and cooling water would be provided to the LCCs by the LP FLEX Pumps feeding the ERCW system piping and headers. The staff's review of the robustness and availability of the intake channel and the ERCW system piping and headers were discussed previously in Section 3.10.1 of this SE.

Based on the information provided in the FIP and UFSAR, water contained in the intake channel and Tennessee River should be available during an ELAP event consistent with NEI 12-06, Section 3.2.1.3. If implemented appropriately and consistent with the FIP, the licensee should have an adequate time to provide cooling to the Containment Building with the support from Phase 2 FLEX equipment and off-site resources and equipment from the NSRC.

3.10.5 Conclusions

The NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain satisfactory water sources following a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

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 an ELAP occurring during power operations. This is appropriate, as plants typically operate at power for 90 percent or more of the year. When the ELAP occurs with the plant at power, the mitigation strategy initially focuses on the use of the steam-driven TDAFW pump to provide the water initially needed for decay heat removal. If the plant has been shut down and all or most of the fuel has been removed from the RPV and 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. The licensee's analysis shows that following a full core offload to the SFP, about 27 hours are available to implement makeup before boil-off results in the water level in the SFP dropping up to 10 ft. above the SFP racks, and the licensee 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 and allow operators to release steam from the SGs (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 provides guidance to licensees for reducing shutdown risk by incorporating FLEX equipment in the shutdown risk process and procedures. Considerations in the shutdown risk assessment process include maintaining necessary FLEX equipment readily available and potentially pre-deploying or pre-staging equipment to support maintaining or restoring key safety functions in the event of a loss of shutdown cooling. The NRC staff concludes that the position paper provides an acceptable approach for demonstrating that the licensees are capable of implementing mitigating strategies in shutdown and refueling modes of operation. The FIP states that Sequoyah follows the guidance in this position paper.

Based on the information above, the licensee 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 should adequately address the requirements of the order.

3.12 Procedures and Training

In its FIP, the licensee stated that procedures and guidance to support deployment and implementation, including interfaces to Emergency Operating Procedures, special event procedures, AOPs, and System Operating Procedures, have been developed in accordance with NEI 12-06, Revision 0, Section 11.4. The PWROG has generated guidelines in order to assist utilities with the development of site-specific procedures to cope with an ELAP. Sequoyah is a participant in the PWROG project PA-PSC-0965 and has implemented FSIs in a timeline to support the implementation of FLEX for Unit 1 and Unit 2 licensed operation.

The proposed implementation strategy aligns with the procedure hierarchy described in NEI 12-06 in that actions that maneuver the plant are contained within the typical controlling procedure, and the FSIs are implemented as necessary to maintain the key safety functions of core cooling, spent fuel cooling and containment in parallel with the controlling procedure actions. The overall approach is symptom–based, meaning that the controlling procedure actions and FSIs are implemented based upon actual plant conditions. The licensee stated that Sequoyah will continue participation in PA-PSC-0965 and will update plant procedures to maintain consistency with the PWROG program.

The FIP also states that TVA Nuclear Power Group has included in procedure CECC EPIP - 3, "Operations Duty Specialist Procedure for Alert, Site Area Emergency or General Emergency" a notification of the NSRC to arrange for delivery and deployment of off-site equipment and sufficient supplies of commodities. Additionally, flood preparation procedure AOP-N.03, "External Flooding," and RvM-SOP-10.05.06, "Nuclear Notifications and Flood Warning Procedure," has been modified to include the FLEX strategies to be implemented during the early warning, Stage 1 and 2 warnings issued by River Operations.

In its FIP, the licensee stated that training plans have been developed for plant groups such as the emergency response organization (ERO), Fire, Security, Emergency Preparedness (EP), Operations, Engineering, and Maintenance. The training plan development was accomplished in accordance with Sequoyah procedures using the Systematic Approach to Training, and has been implemented to ensure that the required Sequoyah staff is trained prior to implementation of FLEX. Also, Attachment 2, "Milestone Schedule," of the FIP outlines completion dates for implementation of FLEX related training and FLEX strategy guidelines, FLEX support instructions, and maintenance procedures.

Based on the information provided in the FIP, the NRC staff concludes that the licensee has developed procedures and training guidance associated with FLEX that, if implemented appropriately, seems to be in accordance with the guidance in NEI 12-06, Section 11.6.

3.13 Maintenance and Testing of FLEX Equipment

As a generic issue, NEI submitted a letter to the NRC dated October 3, 2013 (ADAMS Accession No. ML13276A573), which included EPRI Technical Report 3002000623, "Nuclear Maintenance Applications Center: Preventive Maintenance Basis for FLEX Equipment." By letter dated October 7, 2013 (ADAMS Accession No. ML13276A224), the NRC endorsed the use of the EPRI report and the EPRI database as providing a useful input for licensees to use in developing their maintenance and testing programs. In its FIP, the licensee stated that they have implemented the maintenance and testing template in accordance with the industry letter.

The FIP states that the FLEX mitigation equipment has been initially tested (or other reasonable means used) to verify performance conforms to the FLEX requirements. Additionally, the FIP states that SQN has implemented the maintenance and testing template issued by EPRI, where applicable. The template was developed to meet the FLEX guidelines established in NEI 12-06, Revision 0, Section 11.5.

After reviewing the licensee's programs, the NRC staff finds that the licensee has developed guidance for equipment maintenance and testing activities associated with FLEX equipment that, if implemented as described, seems to be in accordance with the guidance in NEI 12-06, Section 11.5.

3.14 Alternatives to NEI 12-06, Revision 0

3.14.1 Pre-staging of FLEX Equipment

In its FIP for Sequoyah, the licensee stated to be using two 6.9 kV DGs pre-staged in the ADGB. Also, there are two FLEX 225 kW, 480 Vac DGs (one per unit), pre-staged on the AB roof. In addition, a 480 volt motor driven HP FLEX pump is pre-staged in the AB. These are powered through the existing electrical distribution system as a part of the mitigation strategy integrated plan. Pre-staging FLEX equipment is an alternate approach to NEI 12-06. This alternative is proposed 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 generators and diesel driven pumps to accomplish an ELAP event mitigation.

During the audit, the staff was able to confirm that all pre-staged locations are protected from the applicable external hazards. The 6.9 kV DGs and the HP FLEX pump are inside the ADGB. The 480 Vac DGs are inside a protection structure designed using the same criteria used for the ADGB. The staff was also able to review load and sizing calculations and found no issues. Pre-staging of FLEX equipment is an acceptable alternative as it would save time on mobility and deployment of the mitigation strategies.

In conclusion, the NRC staff finds that although the guidance of NEI 12-06 has not been met, if these alternatives are implemented as described by the licensee, the proposed strategies should meet the requirements of the order.

3.15 Conclusions for Order EA-12-049

Based on the information above, the NRC staff concludes that the licensee 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 Feb 28, 2013 (ADAMS Accession No. ML13063A011), the licensee submitted its OIP for Sequoyah in response to Order EA-12-051. By letter dated July 17, 2013 (ADAMS Accession No. ML13198A354), the NRC staff sent a request for additional information (RAI) to the licensee. The licensee provided a response by letter dated August 16, 2013 (ADAMS Accession No. ML13235A007). By letter dated November 21, 2013 (ADAMS Accession No. ML13312A415), the NRC staff issued an ISE. By letter dated March 3, 2015 (ADAMS Accession No. ML15033A430), the NRC issued an audit report on the licensee's progress.

By letters dated August 28, 2013 (ADAMS Accession No. ML13247A291), February 28, 2014 (ADAMS Accession No. ML14064A181), August 28, 2014 (ADAMS Accession No. ML14248A478), and February 27, 2015 (ADAMS Accession No. ML15064A168), the licensee submitted four 6- month status reports for the Integrated Plan. The Integrated Plan describes the strategies and guidance to be implemented by the licensee for the installation of reliable SFP level instrumentation which will function following a BDBEE, including modifications necessary to support this implementation, pursuant to Order EA-12-051. By letter dated July 16, 2015 (ADAMS Accession No. ML15197A199), the licensee reported that full compliance with the requirements of the order was achieved.

The licensee has installed a SFP level instrumentation system designed by Westinghouse (WEC). The NRC staff reviewed the vendor's SFP level instrumentation system design specifications, calculations and analyses, test plans, and test reports. The staff issued an audit report on August 18, 2014 (ADAMS Accession No. ML14211A346).

The staff performed an onsite audit to review the implementation of SFP level instrumentation related to Order EA-12-051. The scope of the audit included verification of (a) site's seismic and environmental conditions enveloped by the equipment qualifications, (b) equipment installation met the requirements and vendor's recommendations, and (c) program features met the requirements. By letter dated March 3, 2015 (ADAMS Accession No. ML15033A430), the NRC issued an audit report on the licensee's progress. Refer to Section 2.2 above for the regulatory background for this section.

4.1 Levels of Required Monitoring

In its OIP (ADAMS Accession No. ML13063A011) and RAI response letter (ADAMS Accession No. ML13235A007), the licensee defined Level 1 as elevation 726.12 ft., Level 2 as elevation 710.94 ft., and Level 3 as elevation 701.94 ft. The licensee also provided a sketch depicting the three levels in its RAI response (ADAMS Accession No. ML13235A007). Level 1, as defined, maintains adequate net positive suction head for the SFP cooling pump. Level 2 is 10 ft. above the top of the spent fuel rack at elevation 700.94 ft. Level 3 is one foot above the top of the spent fuel rack to accommodate a small dead zone above the bottom of the level instrument probe. The staff finds that Level 3, as defined, and the whole instrument span is consistent with the guidance. Further basis for the NRC staff decision is documented in the ISE (ADAMS Accession No. ML13312A415).

Based on the discussion above, the NRC staff finds that the licensee's proposed Levels 1, 2 and 3 are consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2 Evaluation of Design Features

Order EA-12-051 required that the SFP level instrumentation shall include specific design features, including specifications on the instruments, arrangement, mounting, qualification, independence, power supplies, accuracy, testing, and display. Refer to Section 2.2 above for the requirements of the order in regards to the design features. Below is the staff's assessment of the design features of the SFP level instrumentation.

4.2.1 Design Features: Instruments

In its OIP (ADAMS Accession No. ML13063A011), the licensee indicated that both instruments would consist of fixed components. Both channels would use Westinghouse SFP instrumentation solution based on Guided Wave Radar sensors, which functions according to the principle of Time Domain Reflectometry. 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 (ADAMS Accession No. ML14211A346) states that there is minimum horizontal distance that must be kept between the sensing cable and any structures surrounding this cable. During the 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 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.

In its OIP (ADAMS Accession No. ML13063A011), SQN stated that both instruments would provide continuous level indication from maximum operating level (27.2 ft. above the top of active fuel or 25.8 ft. above top of fuel storage racks) to the top of the fuel storage racks. The electronics for signal conditioning will be located inside closed rooms A12 and A14 on the north and south sides of the spent fuel pool, respectively, as noted during the NRC staff on-site audit and documented in sketch provided as attachment 2 of enclosure 2 in the July 15, 2015 compliance letter (ADAMS Accession No. ML15197A199).

Based on the discussion above, the NRC staff finds that the number of channels and measurement range for its SFP seems to be consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.2 <u>Design Features: Arrangement</u>

The NRC staff reviewed the RAI response later submitted as part of the July 15, 2015 compliance letter (ADAMS Accession No. ML15197A199), during the onsite audit which included a sketch of the AB at elevation 734 ft. The sketch shows the instrument locations in the pool, transmitter locations in the A12 and A14 rooms adjacent to the pool (opposite sides) and the battery/electronics/display locations in rooms A06 and A20, located in the north-west and south-west corners of the Aux Building, adjacent to the Control Room. The instruments are in the north-east and south-west corners of the SFP. Conduit routing maintains maximum separation and makes good use of recesses and corners to provide additional protection. Details of the sketch were confirmed during the on-site audit. The NRC staff noted that there is sufficient channel separation within the SFP area between the primary and back-up level instruments, sensor electronics, and routing cables to provide reasonable protection against loss of indication of SFP level due to missiles that may result from damage to the structure over the SFP.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed arrangement for the SFP level instrumentation seems to be consistent with

NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.3 Design Features: Mounting

In responses to RAI #2, #3, and #4 in Enclosure 2 of the July 15, 2015, compliance letter, the licensee described the design of the bracket in sufficient detail to demonstrate that the bracket will support proper operation of the level instrument. The licensee also described the basis for the seismic capacity including the basis used to determine the potential hydrodynamic loading effects. Also, a complete list of WEC and TVA supporting calculations were provided. The licensee supplied further information in Attachment 1 of the July 1, 2015, letter as noted in the RAI responses.

During the on-site audit, the NRC staff reviewed the hydrodynamic (sloshing) analysis. The staff reviewed the WEC document CN-SEE-II-13-9, Revision 0, dated April 14, 2014, "Determination of the Time to Boiling the Sequoyah Units 1 & 2 Spent Fuel Pool after an Earthquake." The licensee credited the WEC generic sloshing analysis (WEC reference number LTR-SEE-II-13-47, Revision 0, dated January 15, 2014), reviewed during the WEC vendor audit (ADAMS Accession No. ML14211A346). The WEC sloshing analysis provides plant specific sloshing evaluation results which confirms that water will not slosh onto the deck nor significantly impact the probe mounting bracket. The NRC staff also walked down the mounting point locations at and near the SFP. The equipment was partially installed at the time of the audit and installed equipment appeared to be mounted as described.

Based on the discussion above, the NRC staff finds that the licensee's proposed mounting design seems to be consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

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 (ADAMS Accession No. ML13063A011), the licensee stated that instrument channel reliability shall be established by use of an augmented quality assurance process similar to that described in NEI 12-02.

If implemented appropriately, this approach is consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.4.2 Instrument Channel Reliability

NEI 12-02 states the following:

> 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 plant-specific requirements.

The qualification testing for the SFP level instrumentation was performed by WEC. The test methods and test results were reviewed by the NRC staff as part of the WEC vendor audit. The results of the audit are documented in the Westinghouse vendor audit report (ADAMS Accession No. ML14211A346).

The licensee documented the equipment qualification in RAI #5 and #6 responses in Enclosure 2 and Attachment 1 of the July 15, 2015, compliance letter (ADAMS Accession No. ML15197A199). The licensee included the WEC test results, as well as the specific conditions at the locations for the instrument, transmitter and display electronics with supporting WEC and the licensee's document numbers. Overall, the license's documents were consistent with the guidance for equipment qualification.

The NRC staff noted issues in two specific areas during the on-site audit at SQN; the BDB temperature in the rooms A12 and A14 housing the level sensor electronics and the susceptibility for electromagnetic interference of the instrument probe between the mounting bracket and the surface of the water.

During the on-site audit at SQN, the NRC staff reviewed calculation NDQ0000782014000106 Revision 001, dated September 23, 2014, "Beyond Design Basis Dose Evaluation for Spent Fuel Pool Level Instrumentation." The calculation includes temperature and humidity analysis in Appendix 4. The staff noted that the source term for the calculation was conservative, assuming that the SFP was full (2091 fuel assemblies). The staff observed that the equipment locations assumed in the calculation were consistent with the installed locations.

While reviewing the heat up analysis, the NRC staff observed the projected 7-day temperature for the transmitter locations exceeded the qualified temperature. The staff observed the current calculation contained unnecessary conservatism, including not opening doors to cooler adjacent areas. The licensee stated the calculation was being revised to address the oversight and provided SR 938927/PER939667 in the corrective action system to track the completion of the revised calculation. The licensee stated the following in Attachment 1, Enclosure 2 (Topic #3) of the July 15, 2015, compliance letter (ADAMS Accession No. ML15197A199):

> The BDB temperature and humidity values of 99 °F to 140 °F and 35% RH to 80% RH (for Volumes 3 and 4 up to seven days) from TVA Calculation NDQ0000782014000106 are bounded by Section 5.5 of EQ-QR-269, Revision 4, which is acceptable.

The licensee stated in Attachment 1, Enclosure 2 (Topic #22) of the July 15, 2015, compliance letter the following:

> TVA has reviewed the Westinghouse test report and found it meets requirements for radiated emissions limits and criteria B for susceptibility testing. In addition, TVA has conducted additional EMI testing (B43 140513 001) and has installed the channels such that Level A compliance exists around the transmitter and coax. Level A compliance at the probe cannot be obtained in the VHF frequency band (less than 200 MHZ), however VHF radios are being phased out from all plant organizations other than security. Security will only use VHF as a backup channel if the primary channel is unavailable, so the potential for spurious indication is extremely small and does not exist during BDBEE when low water level (NEI 12-02 level 2) exists in SFP.

Based on the discussion above, the NRC staff finds that the licensee's proposed instrument qualification process, if implemented accordingly and in accordance with the FIP, is consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.5 <u>Design Features: Independence</u>

Physical separation of the primary and backup SFP level instrumentation channels is described in Section 4.2.2, above. The NRC staff observed the equipment locations and the partially installed system during the on-site audit and found they was consistent with the sketch provided as Attachment 2 of Enclosure 2 of the July 15, 2015, compliance letter (ADAMS Accession No. ML15197A199). Electrical independence is documented in Section 4.2.6 below.

Based on the discussion above, the NRC staff finds that the instrument channel independence, is consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.6 <u>Design Features: Power Supplies</u>

SQN stated in its response to RAI #7, included in Enclosure 2 of the July 15, 2015 compliance letter, the following:

> Power to the primary channel is supplied from 120 volt AC vital instrument power board 2-IV, which is train B. Power to the backup channel is supplied from 120 volt AC vital instrument power board 1-III, which is train A. The vital boards are

> supplied by the vital batteries and vital inverters, and will be backed up by the FLEX diesel generators. SQN FLEX diesel generator strategy provides two 225 kva diesel generators on the AB roof to provide a direct connection to vital battery chargers and two 3 MW diesel generators that provide an alternate approach to energize the battery chargers utilizing safety related shutdown power distribution. This approach is described in detail in response to Order EA-12-049.

The licensee stated in its response to RAI #8 provided in Enclosure 2 of the July 15, 2015 compliance letter, that the SFP level instrumentation battery backup life is 4.22 days based on maximum power consumption.

The above description is consistent with NRC staff observations during the on-site audit. The NRC staff also noted that the on-board batteries of the SFP level instrumentation system's will independently sustain the instrumentation operation for a minimum of 4 days should vital bus, inverters, station batteries or FLEX diesels become inoperable during an ELAP.

Based on the discussion above, the NRC staff finds that the licensee's proposed power supply design seems to be consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.7 <u>Design Features: Accuracy</u>

The licensee stated in its response to RAI #9, as provided in Enclosure 2 of the July 15, 2015, compliance letter the following:

> Each instrument channel is expected to be accurate to within an estimated ±1% of calibrated span during normal spent fuel pool level conditions. 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.

The licensee stated that instrument calibration must be performed if the instrument accuracy is found to be outside the acceptance band. Also stated in responses to RAI's #9 and #20, both testing and calibration are based on WEC procedures.

The NRC staff reviewed the accuracy and vendor calibration, and test procedures during the WEC vendor audit. In document WNA-CN-00301-GEN, WEC stated that the instrumentation accuracy is +/- 3 inches. Observations made by the NRC staff during WEC vendor audit are available in the audit report (ADAMS Accession No. ML14211A346).

Based on the discussion above, the NRC staff finds that the licensee's proposed instrument accuracy is consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.8 <u>Design Features: Testing</u>

The NRC staff reviewed the instrument design and testability during the Westinghouse vendor audit (ADAMS Accession No. ML14211A346).

Additionally, the licensee stated in its response to RAI #10, provided in Enclosure 2 of the July 15, 2015 compliance letter (ADAMS Accession No. ML15197A199), the following:

> The support bracket for the level sensor cable has been designed and manufactured with a sliding section. This sliding section will be raised 12 inches for calibration verification. The manufacturer has documented that the calibration is based on a linear time delay from transmission of the radar pulse to return of reflection on the surface of the water. Manufacturer documentation provides certification that raising the sensor a fixed distance and verifying that the indicator changes by this fixed amount confirms that the transmitter is in calibration. The system is designed to enable the removal of the sensor cable from the transmitter and attach a previously certified sensor cable with an adjustable metal target to allow a detailed multipoint calibration by mounting the target at different points along the cable for troubleshooting, if necessary. Each component in the instrument channel can be replaced (transmitter included) to restore the instrument loop to service in the event a component failure occurs.
>
> In-situ testing will be performed by loosening the hold down bolts and raising the sensor assembly 12 inches and verifying that the indicator responds with a corresponding 12 inch change (allowed inaccuracy of change is 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.

Based on the discussion above, the NRC staff finds that the licensee's proposed SFP instrumentation design should allow for testing consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.9 <u>Design Features: Display</u>

The licensee stated the following in its response to RAI #11, provided in Enclosure 2 of the July 15, 2015 compliance letter (ADAMS Accession No. ML15197A199):

> A shutdown board room and the path to the shutdown board room from the MCR is a mild environment during the extended loss of alternating current power (ELAP); is promptly accessible (2 minute walk) by MCR personnel; and is not subject to the environmental conditions associated with boiling in the SFP. Communication by radio or telephone is available if needed. The route to the shutdown board room area from the MCR will be the same route that is utilized during design basis events because the route is within safety-related, seismic structures (Control Building and AB). The pathway is expected to remain intact following a seismic event.

During the on-site audit, NRC staff observed the proposed display locations and their proximity to the MCR and found they met the guidance.

Based on the discussion above, the NRC staff finds that the licensee's proposed location and design of the SFP instrumentation displays appears to be consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.3 Evaluation of Programmatic Controls

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

4.3.1 Programmatic Controls: Training

In its OIP (ADAMS Accession No. ML13063A011), the licensee stated, in part, that:

> The primary and backup instrument channels will be installed utilizing current TVA design and modification processes. 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.

Based on the discussion above, the NRC staff finds that the licensee's proposed plan to train personnel in the operation, maintenance, calibration, and surveillance of the SFP level instrumentation, including the approach to identify the population to be trained seems to be consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.3.2 Programmatic Controls: Procedures

The licensee provided a list of 10 procedures covering operation, testing, calibration and maintenance for the SFP level instrumentation systems in its response to RAI #12, provided in Enclosure 2 of the July 15, 2015 compliance letter (ADAMS Accession No. ML15197A199).

Based on the discussion above, the NRC staff finds that the licensee's procedure development seems to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.3.3 Programmatic Controls: Testing and Calibration

The licensee described, in its response to RAI #13 provided in Enclosure 2 of the July 15, 2015, compliance letter, the key elements of the SQN maintenance, calibration and testing program which include using NRC audited WEC procedure as a basis, using a two point in-situ calibration verification test and citing documents containing the loop accuracy requirements. A list of procedures was described in the response to RAI #12 of the same document, as described in Section 4.3.2 above.

The licensee stated in its response to RAI #13 provided in Enclosure 2 of the July 15, 2015, compliance letter the following:

> SQN has received information from the part supplier indicating critical spare parts for the system, and the lead time and availability of spare parts. This information will be used in conjunction the site work control process to provide assurance that a channel can be restored to service within 90 days. An operating procedure is in place to track out of service time of the SFPIS. If one or both channels cannot be restored to service within 90 days, or if both channels become non-functioning, as a compensatory measure SQN will utilize AOP-M.06, "Loss of Spent Fuel 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 the licensee's proposed testing and calibration plan seems to be consistent with NEI 12-02 guidance as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.4 Conclusions for Order EA-12-051

In its letter dated July 15, 2015, the licensee 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, the licensee's plans conform 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 Sequoyah according to the licensee's proposed design, it should adequately address the requirements of Order EA-12-051.

5.0 CONCLUSION

In August 2013 the NRC staff started audits of the licensee's progress on Orders EA-12-049 and EA-12-051. The staff conducted an onsite audit in March 2015 (ADAMS Accession No. ML15033A430). The licensee reached its final compliance date in February 2016 (ADAMS Accession No. ML16049A635), and has declared that both of the reactors are in compliance with the orders. The purpose of this safety evaluation is to document the strategies and implementation features that the licensee has committed to. Based on the evaluations above, the NRC staff concludes that the licensee has developed guidance and proposed designs which, if implemented appropriately, appears to adequately address the requirements of Orders EA-12-049 and EA-12-051. The NRC staff will conduct an onsite inspection to verify that the licensee has implemented the strategies and equipment to demonstrate compliance with the orders.

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Date: October 12, 2016

evaluation. By letters dated November 21, 2013 (ADAMS Accession No. ML13312A415), and March 3, 2015 (ADAMS Accession No. ML15033A430), the NRC staff issued an ISE and audit report, respectively, on the licensee's progress. By letter dated March 26, 2014 (ADAMS Accession No. ML14083A620), the NRC notified all licensees and construction permit holders that the staff is conducting 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 letter dated July 15, 2015 (ADAMS Accession No. ML15197A199), TVA submitted a compliance letter in response to Order EA-12-051. The compliance letter stated that the licensee had achieved full compliance with Order EA-12-051.

The enclosed safety evaluation provides the results of the NRC staff's review of TVA's strategies for Sequoyah. The intent of the safety evaluation is to inform TVA on whether or not its 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, using 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. ML15257A188). This inspection will be conducted in accordance with the NRC's inspection schedule for the plant.

If you have any questions, please contact Milton Valentin, Orders Management Branch, Sequoyah Project Manager, at 301-415-2864 or at Milton.Valentin@nrc.gov.

Sincerely,

/RA/

Mandy K. Halter, Acting Chief
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Docket Nos.: 50-327 and 50-328

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