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

March 3, 2017

Site Vice President
Waterford Steam Electric Station,
Unit 3
Entergy Operations, Inc.
17265 River Road
Killona, LA 70057-3093

SUBJECT: WATERFORD STEAM ELECTRIC STATION, UNIT 3 – 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. MF0977 AND MF0946)

Dear Sir or Madam:

On March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond Design-Basis External Events" and Order EA-12-051, "Order to Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML12054A736 and ML12054A679, respectively). The orders require holders of operating reactor licenses and construction permits issued under Title 10 of the *Code of Federal Regulations* Part 50 to modify the plants to provide additional capabilities and defense-in-depth for responding to beyond-design-basis external events, and to submit for review Overall Integrated Plans (OIPs) that describe how compliance with the requirements of Attachment 2 of each order will be achieved.

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A266), Entergy Operations, Inc. (Entergy, the licensee) submitted its OIP for Waterford Steam Electric Station, Unit 3 (Waterford) 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 November 22, 2013 (ADAMS Accession No. ML13220A402), and October 6, 2015 (ADAMS Accession No. ML15272A398), the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated July 21, 2016 (ADAMS Accession No. ML16203A321), Entergy 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. ML13063A263), Entergy submitted its OIP for Waterford 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 25, 2013 (ADAMS Accession No. ML13312A787), and October 6, 2015 (ADAMS Accession No. ML15272A398), 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 January 18, 2016 (ADAMS Accession No. ML16018A014), Entergy 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 Entergy's strategies for Waterford. The intent of the safety evaluation is to inform Entergy on whether or not its integrated plans, if implemented as described, appear to adequately address the requirements of 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 Peter Bamford, Orders Management Branch, Waterford Project Manager, at 301-415-2833 or at Peter.Bamford@nrc.gov.

Sincerely,

John P. Boska, Acting Chief
Orders Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No.: 50-382

Enclosure:
Safety Evaluation

cc w/encl: Distribution via Listserv

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

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

ENTERGY OPERATIONS, INC.

WATERFORD STEAM ELECTRIC STATION, UNIT 3

DOCKET NO. 50-382

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" [Reference 4]. 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" [Reference 5]. 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 [Reference 1]. 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," [Reference 2] to the Commission. This paper included a proposal to order licensees to implement enhanced BDBEE mitigation strategies. As directed by the Commission in staff requirements memorandum (SRM) SRM-SECY-12-0025 [Reference 3], the NRC staff issued Orders EA-12-049 and EA-12-051.

2.1 Order EA-12-049

Order EA-12-049, Attachment 2, [Reference 4] 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 alternating current (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 [Reference 6] 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" [Reference 7], endorsing NEI 12-06, Revision 0, with comments, as an acceptable means of meeting the requirements of Order EA-12-049, and published a notice of its availability in the *Federal Register* (77 FR 55230).

2.2 Order EA-12-051

Order EA-12-051, Attachment 2, [Reference 5] 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 makeup 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 [Reference 8] 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" [Reference 9], 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 [Reference 10], Entergy Operations, Inc. (Entergy, the licensee) submitted its Overall Integrated Plan (OIP) for Waterford Steam Electric Station, Unit 3 (Waterford, WF3) in response to Order EA-12-049. By letters dated August 28, 2013 [Reference 11], February 28, 2014 [Reference 12], August 28, 2014 [Reference 13], February 26, 2015 [Reference 14], August 27, 2015 [Reference 15], and February 25, 2016 [Reference 16], the licensee submitted six-month updates to the OIP. By letter dated August 28, 2013 [Reference 17], 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" [Reference 35]. By letters dated November 22, 2013 [Reference 18] and October 6, 2015 [Reference 19], the NRC issued an Interim Staff Evaluation (ISE) and an audit report, respectively, on the licensee's progress. By letter dated July 21, 2016 [Reference 20], 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 a loss of normal access to the UHS. Thus, the ELAP with 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.

Waterford is a Combustion Engineering (CE) pressurized-water reactor (PWR); with a dry ambient pressure containment. The licensee's three-phase approach to mitigate a postulated ELAP event, as described in its FIP, is summarized below. The approach is somewhat different in a postulated flooding event, but the initial actions are similar.

At the onset of an ELAP the reactor is 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 to atmosphere 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 emergency feedwater (TDEFW) pump taking suction from the condensate storage pool (CSP). The initial RCS cooldown is commenced 2 hours following the event and it is completed by approximately 4 hours from the initiation of the event. The cooldown is performed to minimize RCP seal leakage, initiate safety injection tank (SIT) injection, and maintain natural circulation within the RCS. The initial plant cooldown is stopped at an RCS cold leg temperature of approximately 456 degrees Fahrenheit (°F). This RCS temperature ensures passive RCS makeup to maintain natural circulation and shutdown margin and provides an operational plateau to allow for SIT isolation during Phase 2 to preclude nitrogen injection. The RCS inventory control is maintained by minimizing RCP seal leakage and ensuring passive borated water injection from the SITs. The RCP controlled bleed-off is isolated early since the containment isolation valves fail closed on loss of power or instrument air. The RCS leakage is then primarily through the RCP seals. The passive injection of borated water from the SITs ensures adequate shutdown margin and RCS natural circulation until 17 hours from the initiation of the event, at which point RCS makeup is required.

The licensee's compliance letter dated July 21, 2016 [Reference 20], indicates that the Waterford operational staff expects to conduct a second stage of SG depressurization in order to continue reducing RCS temperature and pressure to an RCS temperature of approximately 400°F. Prior to undertaking this second stage of cooling and depressurization, operators would need to perform a number of supporting actions including: (1) placing a FLEX diesel generator (DG) into service, (2) making preparations for placing a charging pump in service for RCS makeup and boration, and (3) isolating the SITs using electrical power from FLEX generators to avoid the potential for excessive accumulator injection to the point that the nitrogen cover gas could enter the RCS.

Operators will ultimately transition the SG water supply from the TDEFW pump to the FLEX core cooling pump (FCCP) using water from an available source (CSP, wet cooling tower (WCT) basins, or refueling water storage pool (RWSP)). In addition, as noted in the FIP, the licensee eventually expects to use FLEX equipment from offsite response centers to restore shutdown cooling (SDC), the operation of which would allow RCS temperature to be reduced below 200°F.

The operators will perform dc bus load stripping within the initial two hours following event initiation to ensure safety-related battery life is extended. Following dc load stripping and prior to battery depletion, the 400-kilowatt (kW), 480 volt alternating current (Vac) FLEX DG pre-staged in a new enclosure on the roof of the Reactor Auxiliary Building (RAB) will be placed into service. This generator will be used to repower essential battery chargers within 12 hours of ELAP initiation, as well as repowering the SIT isolation valves, and one of the three charging pumps. A backup FLEX DG is stored in the "N+1" storage building.

The RCS makeup and boration will be initiated within approximately 12.5 hours of the ELAP to ensure that natural circulation, reactivity control, and boron mixing is maintained in the RCS. The RCS inventory control and long-term sub-criticality involves the use of the RWSP or boric acid makeup tank (BAMT) inventory through the repowered charging pump. Reliance on a permanently installed charging pump is an alternative approach to NEI 12-06 and is further discussed in Section 3.14.2 of this safety evaluation (SE). Suction for the charging pump will come from either the RWSP or BAMTs via existing system alignment capabilities. The charging pump is then aligned to provide makeup directly to the RCS.

The water supply for the TDEFW pump is initially from the CSP. The CSP will provide a minimum of eight hours of RCS decay heat removal, in addition to absorbing the latent heat associated with the planned RCS cooldown. Prior to depletion of the CSP, a gravity drain will be established from the WCT basins to the TDEFW pump, extending the available minimum inventory to cool down the plant and remove decay heat throughout Phase 2. In addition, a National Strategic Alliance of FLEX Emergency Response (SAFER) Center (NSRC) will provide high capacity pumps and large combustion turbine-driven generators (CTGs), which could be used to provide additional capability and redundancy for long-term core cooling.

The SFP is located in the Fuel Handling Building (FHB). Upon initiation of the ELAP event, the SFP will heat up due to the unavailability of the normal cooling system. The licensee has calculated that boiling could start as soon as 12.86 hours after the start of the event, assuming initial conditions of 120°F pool temperature and the heat load at 25 days following the previous cycle shutdown. To maintain SFP cooling capabilities, the licensee's FIP states that it would take approximately 95.5 hours for SFP water level to drop to a level at which makeup water addition should no longer be deferred. Makeup water would be provided using a component cooling water (CCW) makeup (MU) pump, repowered from the FLEX DG, via the permanently installed piping from the CCW MU pumps to the SFP. Use of an installed CCW MU pump for SFP makeup in lieu of a portable injection source is an alternative approach to NEI 12-06 and is further discussed in Section 3.14.3 of this SE. If the permanently installed piping is unavailable, makeup from the CCW MU pumps is provided using hoses routed directly to the SFP. The CCW MU pumps are designed to take suction from the CSP. As the CSP will be depleted by the time SFP makeup is required, a FLEX tie-in has been installed on CCW MU pump suction piping to allow the pump to take a suction from either the FLEX connection on the RWSP (primary) or from the WCT basins (alternate). Ventilation of the generated steam is accomplished by opening three SFP area doors (D187, D37, and D69) leading to the outside atmosphere.

For Phases 1 and 2, the licensee's calculations demonstrate that no actions are required to maintain containment pressure below design limits for over 120 hours, which is adequate time for Phase 3 implementation. During Phase 3, operators will utilize the NSRC 4160 Vac CTG to repower a containment fan cooler (CFC), a CCW pump, and the available dry cooling tower

(DCT) fans. A single CFC is capable of maintaining containment within design temperature limits for the expected FLEX heat loads indefinitely.

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. In the licensee's FIP, Reference 3.3, indicates that the FLEX plan is based upon NEI 12-06, Revision 0. Thus, the NRC staff evaluated the licensee's strategies against the NEI 12-06, Revision 0 guidance, as endorsed by the NRC.

3.2 Reactor Core Cooling Strategies

Order EA-12-049 requires licensees 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 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 with 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 coolant in the RCS, and (2) sufficient RCS inventory is necessary to transport heat from the reactor core to the heat sink via natural circulation. Furthermore, inasmuch as heat removal requirements for the ELAP event consider only residual heat, the RCS inventory should be replenished with borated coolant in order to maintain the reactor in a subcritical condition as 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, the unit 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/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/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 while the unit is shut down or being refueled is reviewed separately in Section 3.11 of this SE.

3.2.1 Core Cooling Strategy and RCS Makeup

3.2.1.1 Core Cooling Strategy

3.2.1.1.1 Phase 1

As stated in Waterford's FIP, dated July 21, 2016 [Reference 20], the heat sink for core cooling in Phase 1 would be provided by the two SGs, which would be fed simultaneously by the unit's TDEFW pump with inventory supplied from the CSP, which is robust with respect to all external hazards. The licensee calculates that the CSP water volume, at a minimum of 187,000 gallons, is sufficient to remove residual heat from the reactor for approximately 8 hours, including the sensible heat associated with the RCS cooldown to 456°F starting at 2 hours.

Following the reactor trip at the initiation of the ELAP event, steam release from the SGs to the atmosphere would be accomplished via the main steam safety valves or the SG ADVs. The SG ADVs would typically be operated by the instrument air system, which is assumed to be lost following the ELAP event. A backup nitrogen system is provided to operate the ADVs with sufficient nitrogen to provide for 10 hours of operation. Electrical power to operate the ADVs is provided by the Class 1E 125 Volts dc (Vdc) system. If these means of ADV operation are not available, Waterford's FIP states that the ADVs can be operated manually by local hand wheels or pneumatic control stations.

Waterford's Phase 1 strategy directs operators to commence a cooldown and depressurization of the RCS within 2 hours of the initiation of the ELAP/loss of normal access to the UHS event. Over a period of approximately 2 hours, the licensee would gradually cool down the RCS from post-trip conditions until a RCS cold leg temperature of 456°F is reached. A minimum RCS temperature of 456°F is set to avoid the injection of nitrogen gas from the SITs into the RCS. Cooldown and depressurization of the RCS significantly extends the expected coping time under ELAP/loss of normal access to the UHS conditions because it: (1) reduces the potential for damage to RCP seals, and (2) allows coolant stored in the nitrogen-pressurized accumulators to inject into the RCS to offset system leakage and temperature related volume loss, prolonging natural circulation.

3.2.1.1.2 Phase 2

Waterford's FIP states that the primary strategy for core cooling in Phase 2 would be to continue using the SGs as a heat sink, with SG secondary inventory being supplied by the TDEFW pump. A second cooldown will be performed after the FLEX DG is placed in service and the isolation of the SIT's is accomplished. This cooldown will be terminated at an RCS temperature of approximately 400°F, which corresponds to a SG pressure of approximately 250-260 pounds per square inch absolute (psia). Although functionality of the TDEFW pump is expected throughout Phase 2, the licensee has a pre-staged FLEX core cooling pump (FCCP) that is capable of backing up this essential function after the second stage cooldown to 400°F is completed.

According to the licensee's calculations, the CSP is capable of supplying SG makeup for approximately 8 hours. Following depletion of the CSP, water will be gravity drained from the WCT basins to the TDEFW pump suction. The available volume of the WCT basins is approximately 273,500 gallons, and will provide suction supply for an additional 30 hours.

After depletion of the WCT basins the suction of the TDEFW pump can be transferred to the RWSP. The RWSP contains approximately 420,800 gallons of borated water and is robust to all applicable external hazards. The licensee has evaluated the usage of borated water in the SGs and determined that the effect on the heat transfer performance of the SG will be negligible. The licensee has also evaluated draining the circulating water intake (CWI) piping into the CSP. The usage of the CWI piping as a water source is only credited for non-seismic, non-flood events.

The licensee's FIP states that its core cooling strategy is to rely initially on the TDEFW pump. The electrically driven FCCP that is pre-staged in the RAB can also provide makeup once the SGs are depressurized sufficiently. The pump is rated for a minimum of 250 gallons per minute (gpm) at 250 psia. The pump can take suction from the CSP, the WCT basins or the RWSP and discharge to the SGs via either a primary or alternate FLEX connection on the EFW system.

3.2.1.1.3 Phase 3

According to its FIP, Waterford's core cooling strategy for Phase 3 is a continuation of the Phase 2 strategy with additional offsite equipment and resources. In particular, the available inventory in the credited water supplies will require replenishment. An NSRC supplied water transfer pump and water treatment system is deployed to process water from the Mississippi River and provide clean water for RCS or SG makeup.

Waterford has different strategies for the staging of NSRC equipment for flood and non-flood events. During a non-flood BDBEE, the NSRC low pressure/high flow (LPHF) pump will be deployed near the Mississippi River with discharge hoses routed back to the plant. During a flood event, the NSRC LPHF pump will be staged on the RAB roof. In this case the LPHF pump will be operated in conjunction with a submersible pump to take suction on the surrounding floodwaters.

An NSRC-provided SG makeup pump can be used to provide water for continued core cooling. The pump discharge can be routed through hoses to the FLEX primary or alternate connections on the EFW piping. Suction for the pump can be provided from the water treatment system.

3.2.1.2 RCS Makeup Strategy

3.2.1.2.1 Phase 1

Following the reactor trip at the start of the ELAP/loss of normal access to the UHS event, operators will verify the isolation of RCS letdown pathways. The RCS leakage will occur through the RCP seals, but because the expected inventory loss would not be sufficient to drain the pressurizer prior to the RCS cooldown, its overall impact on the RCS behavior will be minor. Although the RCS cooldown planned for implementation between 2 and 4 hours into the event would be expected to drain the pressurizer and create a vapor void in the upper head of the reactor vessel, ample RCS volume should remain to support natural circulation flow throughout Phase 1. Likewise, there is no need to initiate boration during this period, since the reactor operating history assumed in the endorsed NEI 12-06 guidance implies that a substantial concentration of xenon-135 would be present in the reactor core. As operators depressurize the RCS, some fraction of the borated inventory from the nitrogen-pressurized SITs is expected to passively inject. Following cooldown of the RCS to 456°F, the licensee's procedures direct SIT isolation once electrical power is restored to the corresponding isolation valves via FLEX equipment. Per the Waterford FIP sequence of events, this restoration is expected to occur at approximately 12 hours after initiation of the ELAP event.

3.2.1.2.2 Phase 2

As noted above, to prevent the injection of nitrogen cover gas from the SITs, the licensee intends to temporarily halt the plant cooldown in Phase 1 at a RCS temperature of 456 °F. When electrical power is restored to the motor-operated SIT outlet valves in Phase 2, the SITs can be isolated, permitting the resumption of the plant cooldown to the target RCS temperature of 400°F. In addition, when electrical power is restored to an installed charging pump from a FLEX 480 Vac DG, additional borated coolant can be pumped into the RCS. Makeup to the RCS would also compensate for inventory contraction caused by the RCS cooldown and ongoing RCS leakage. Per the licensee's FIP, the charging pump will take suction from the BAMTs or the RWSP. The charging pump will discharge into the RCS through the normal flow path or through the alternate injection path through the high pressure safety injection (HPSI) system. According to the licensee's FIP, the charging pumps and associated piping are robust for applicable hazards.

Per the sequence of events in the licensee's FIP, requisite supporting actions are expected to be completed such that additional makeup can be commenced by approximately 12.5 hours into the ELAP event. The RCS makeup necessary to support the additional cooldown would be provided by the installed charging pumps.

3.2.1.2.3 Phase 3

According to its FIP, Waterford's core cooling strategy for Phase 3 is a continuation of the Phase 2 strategy with additional offsite equipment and resources. In particular, the available inventory in the credited water supplies will require replenishment. An NSRC supplied water transfer pump and water treatment system is deployed to process water from the Mississippi River and provide clean water for RCS or SG makeup. Water for the RCS can be borated using the NSRC-provided mobile boration skid. This water can be used to refill the RWSP.

The licensee has different strategies for the staging of NSRC equipment for flooding and non-flooding events. During a non-flooding BDBEE the NSRC LPHF pump will be deployed near the Mississippi River with discharge hoses routed back to the plant. During a flooding event the NSRC LPHF pump will be staged on the RAB roof. The LPHF pump will be operated in conjunction with a submersible pump taking suction on the surrounding floodwaters. The licensee also has the capability to deploy a FLEX water transfer pump (FWTP) stored within the RAB, to provide this function.

An NSRC-provided high pressure (HP) pump can be used as a replacement for the installed charging pumps. The HP pump can discharge through hoses to a primary or alternate connection point. The primary connection point is on the "A" HPSI pump discharge line. The alternate connection point is on the "AB" HPSI crosstie piping.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

Per its FIP, the licensee stated that the limiting flood case at Waterford is a probable maximum flood (PMF) with a flood elevation of +27.0 feet mean sea level (MSL). Waterford's FLEX strategy includes permanently pre-staging and storing one set of FLEX equipment in the Nuclear Plant Island Structure (NPIS) to ensure availability. The NPIS is a Seismic Category I structure that is designed to provide protection from external floods up to an elevation of +30 feet MSL. In accordance with NEI 12-06, additional spare FLEX equipment will be stored in the "N+1" storage building. The licensee stated that the spare FLEX equipment will be moved to the NPIS for predictable flood and hurricane events with pre-warning. For long-term persistent flooding, the licensee plans to deploy the off-site NSRC supplied Phase 3 equipment and supplies to the RAB roof via helicopter. Therefore, there are no significant variations to the core cooling strategy in the event of a flood with the exception of equipment staging and suction supply. Refer to Section 3.5.2 of this SE for further discussion on flooding.

3.2.3 Staff Evaluations

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

Guidance 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

Core Cooling – Phase 1

The licensee's FIP states that TDEFW pump automatically starts and delivers EFW flow from the CSP to the SGs following an ELAP/loss of normal access to the UHS event. In Section 2.3.4.2 of its FIP, the licensee also states that the TDEFW pump is seismically robust and most of the system is located in a structure protected from all applicable design-basis external events. Portions of the steam supply and feedwater discharge lines are routed on the roof of the RAB. However, the licensee provided an evaluation, WF-ME-15-00003, "Wind-Generated Missile Evaluation of Exposed Piping for FLEX," Revision 0, which determined that the portion of piping on the roof was reasonably protected from wind driven missiles by location, and surrounding/intervening structures, and that disabling damage was not likely from the postulated missiles. Additionally, the Waterford current licensing basis includes an NRC-approved "TORMIS" analysis which concludes that the exposed portions of this piping do not require physical protection because the probability of such a strike is adequately small.

Should it be required, Waterford procedure OP-902-005, "Station Blackout Recovery," Revision 19 directs the operators to reset, start the TDEFW pump, and take manual control if necessary. The operators will remotely adjust feed control valves to maintain SG level and control the pump initially using safety-related accumulator tanks and 125 Vdc batteries. Local operation of the valves via installed hand wheels is available if necessary.

The NRC staff performed a walk down of the RAB roof during the audit process to confirm the assumptions and protection features described in the licensee's WF-ME-15-00003 analysis. Based on the licensee's analysis description, tornado missile licensing basis, and defense-in-depth operational features, the NRC staff finds that the TDEFW pump is robust and would be expected to be available at the start of an ELAP event, consistent with NEI 12-06, Section 3.2.1.3.

The licensee plans to vent steam from the SGs by manually controlling the SG ADVs. As described in FIP Section 2.3.4.3, the ADVs are safety-related, missile protected and seismically qualified valves. The ADVs can be controlled from backup nitrogen accumulators that are fully protected, but can also be operated manually from local pneumatic stations or by hand wheel, if needed. Based on the location, design, and operational features, as confirmed during an audit walk down, NRC staff finds that the ADVs are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3. Further explanation and the NRC staff's evaluation of the robustness and availability of water sources for an ELAP event is discussed in Section 3.10 of this SE.

Core Cooling - Phase 2

The licensee's Phase 2 core cooling strategy continues to use the SGs as the heat sink. Waterford will continue to use the TDEFW pump as long as possible, and then transition to using an FCCP discharging through a primary or alternate connection point to the SGs. FLEX connection points and water sources are discussed in Sections 3.7 and 3.10 of this SE, respectively.

Core Cooling - Phase 3

The licensee's Phase 3 core cooling strategy initially relies on Phase 2 strategies with the NSRC equipment providing backup to the onsite FLEX equipment. The licensee is also planning to receive the mobile purification unit from the NSRC so they can provide clean water from the Mississippi River after the cleaner onsite sources have been depleted.

RCS Makeup - Phase 1

The licensee's Phase 1 RCS inventory control analysis and FLEX strategy relies on the ability of the installed RCP seals to limit the amount of leakage such that RCS makeup is not needed until 17 hours into the event.

RCS Makeup - Phase 2

The licensee's Phase 2 RCS inventory control strategy relies on repowering one of three installed charging pumps, taking suction from a BAMT or the RWSP, and discharging flow into the normal discharge or the HPSI lines. The staff considers the repowering of installed equipment for RCS inventory control an alternative to NEI 12-06, Revision 0. See Section 3.14 of this SE for further discussion of the acceptability of this alternative. In Section 2.3.4.5 of its FIP, the licensee states the three charging pumps are located in the RAB, which is robust for all applicable hazards, and that the charging pumps are seismically robust. Therefore, based on the FIP discussion, the NRC staff finds that the charging pumps are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3. Further explanation and the NRC staff's evaluation of the robustness and availability of the BAMT and RWSP for an ELAP event is discussed in Section 3.10.2 of this SE.

RCS Makeup - Phase 3

The licensee's Phase 3 RCS inventory strategy does not rely on any additional installed plant SSCs other than those discussed in Phase 2. However, the licensee can use the NSRC high pressure pump, along with NSRC-supplied water processing equipment, to connect to an installed HPSI connection point as a backup to the use of the installed charging pumps.

3.2.3.1.2 Plant Instrumentation

According to Waterford's FIP, the station will conduct an extended load shed on one selected train of 125 Vdc equipment. This will be completed within 2 hours after the initiation of the ELAP event. Depending on the 125 Vdc train chosen for the extended load shed, different sets of instrumentation will be available in the Main Control Room (MCR). Per the licensee's description, the following parameters and associated instruments will be relied upon to support the core cooling and RCS inventory control strategies. The following instruments are monitored from the MCR and will be available throughout the event.

- SG level (wide range and narrow range)
- SG pressure
- Neutron flux
- DC bus voltage
- RCS pressure
- Containment pressure (wide range)

Depending on the train chosen for re-energization, one of the two instruments listed below will be available for each parameter.

- Reactor vessel level or pressurizer level
- CSP level or digital voltmeter indication
- Core exit thermocouples or RCS hot-leg temperature

Installed safety-related station batteries power all of these instruments. The load shed will extend Class 1E station battery life to a minimum of 12.5 hours. A pre-staged FLEX 400 kW DG will repower a battery charger within 12 hours from the ELAP event initiation to maintain power to the instrumentation necessary for the success of the strategy.

The licensee's FIP states that, as recommended by Section 5.3.3 of NEI 12-06, procedures have been developed to read the above instrumentation locally using portable instruments, where applicable. Guidance has been provided in a Functional Support Guideline (FSG) specified as FSG-007, "Loss of Vital Instrumentation or Control Power." This document provides guidance for obtaining alternate monitoring for the following parameters:

- SG level
- SG pressure
- RCS hot leg and cold leg temperatures

- Core exit thermocouples
- Pressurizer level and pressure
- CSP level
- Containment pressure

Furthermore, as described in its FIP, the licensee stated that FLEX equipment credited in the mitigating strategies is supplied with the instrumentation necessary to support local equipment operation.

The NRC staff review finds that the instrumentation available to support the licensee's strategies for core cooling and RCS inventory during the ELAP event is consistent with the recommendations specified in the endorsed guidance of NEI 12-06 and would be available and accessible continuously throughout the ELAP event.

3.2.3.2 Thermal-Hydraulic Analyses

The licensee's strategy relies on the ELAP event analysis performed by the Pressurized Water Reactor Owners Group (PWROG) in WCAP-17601-P, "Reactor Coolant System Response to the Extended Loss of AC Power Event for Westinghouse, Combustion Engineering and Babcock & Wilcox NSSS [Nuclear Steam Supply System] Designs," Revision 1, which uses the Combustion Engineering Nuclear Transient (CENTS) code for the evaluation of CE-designed plants such as Waterford. The CENTS code is a general-purpose thermal-hydraulic computer code that the NRC staff has previously reviewed and approved for calculating the behavior of the RCS and secondary systems of PWRs designed by CE and Westinghouse during non-loss-of-coolant accident (non-LOCA) transients. Although CENTS has been approved for performing certain design-basis non-LOCA transient analyses, the NRC staff had not previously examined its technical adequacy for performing best-estimate simulations of an 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 CENTS and other thermal-hydraulic codes used for these analyses.

Based on this review, the NRC staff questioned whether CENTS and other codes used to analyze ELAP scenarios for PWRs would provide reliable coping time predictions in the reflux or boiler-condenser cooling phase of the event because of challenges associated with modeling complex phenomena that could occur in this phase, including boric acid dilution in the intermediate leg loop seals, two-phase leakage through RCP seals, and primary-to-secondary heat transfer with two-phase flow in the RCS. 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. A specific concern arose with the use of CENTS for ELAP analysis because NRC staff reviews for previous non-LOCA applications had imposed a condition limiting the code's heat transfer modeling in natural circulation to the single-phase liquid flow regime. This condition was imposed due to the lack of benchmarking for the two-phase flow models that would become active in LOCA scenarios. Although the RCS leakage rates in an analyzed ELAP event are significantly lower than what is typically evaluated for limiting small-break LOCA scenarios, nevertheless, over the extended duration of an ELAP event, two-phase natural circulation flow may eventually be reached in the RCS, dependent upon the timing of reestablishing RCS makeup.

Based on discussions with the NRC staff, the PWROG provided a Core Cooling Position Paper [Reference 53] for NRC staff review. In that paper the PWROG recommended that the reflux or boiler-condenser cooling phase be avoided under ELAP conditions because of uncertainties in operators' ability to control natural circulation following reflux cooling and the impact of dilute 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 agreed that PWR licensees should 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. However, the PWROG's Core Cooling Position Paper did not fully address the staff's issues with CENTS, and in particular, lacked a quantitative definition for the threshold of entry into reflux cooling.

To address the NRC staff's remaining concerns associated with the use of CENTS to simulate the two-phase natural circulation flow that may occur during an ELAP for CE-designed PWRs, the PWROG submitted a white paper [Reference 54] for staff review. A revised version was later resubmitted [Reference 55]. The white paper focused on comparing several small-break LOCA simulations using the CENTS code to analogous calculations performed with the CEFLASH-4AS code, which was previously approved for analysis of design-basis small-break LOCAs under the conservative 10 CFR 50 Appendix K paradigm for CE-designed reactors. The analyses in the CENTS white paper generally showed that CENTS' predictions were similar or conservative relative to CEFLASH-4AS for key figures of merit for conditions where natural circulation is occurring in the RCS, including predictions of RCS loop flow rates and the timing of the transition to reflux cooling. The NRC staff's review of the analyses in the white paper included performing confirmatory simulations with the TRACE code. In particular, the staff's TRACE simulations generally showed reasonable agreement with the predictions of CENTS regarding the fraction of the initial RCS mass remaining at the transition to reflux cooling. Therefore, the NRC staff endorsed the approach in the PWROG's white paper as an appropriate means for applying the CENTS code to beyond-design-basis ELAP analysis, with the limitation that reliance upon CENTS is limited to the phase of the event before reflux cooling begins [Reference 56].

Quantitatively, as proposed in the PWROG's white paper, the threshold for entry into reflux cooling is defined 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) in any RCS loop. Considering this criterion relative to the RCS loop flow predictions of both the CENTS and TRACE codes, the NRC staff agreed that it provides a reasonable definition for the threshold of entering reflux cooling for the purpose of analyzing the beyond-design-basis ELAP event. Both the NRC staff and industry analysts acknowledged the adoption of this definition as a practical expedient for analyzing a slow-moving ELAP event. Inasmuch as the transition of flow in the RCS loops from natural circulation to reflux cooling is a gradual process that typically occurs over multiple hours, lacking a quantitatively defined threshold, objective and consistent treatment would not be possible. As discussed further in Section 3.2.3.4 of this SE, 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.

Applying the one-tenth flow quality criterion to the analyses completed in WCAP-17601-P, the November 20, 2013, revision of the PWROG's white paper on CENTS determined ELAP coping times prior to entering the reflux cooling mode for each CE reactor included in WCAP-17601-P. Unlike the generic calculations performed for reactors designed by other vendors, the analysis for CE plants in WCAP-17601-P was generally conducted at a plant-specific level. Waterford's site specific ELAP analysis using CENTS determined a coping time prior to entering reflux cooling of 17 hours. Provided that RCS makeup at a makeup rate of 25 gpm is provided prior to 17 hours, this should be adequate to prevent the transition to reflux cooling. The coping time is well in excess of the time at which the licensee intends to initiate RCS makeup according to its FIP (i.e., 12.5 hours at a maximum possible 44 gpm makeup capacity). The NRC staff performed confirmatory simulations with the TRACE code for Waterford using an input deck generated from a mixture of plant-specific sources and generic information applicable to CE reactors. The results of the staff's calculations indicated that approximately 33 hours should be available prior to the unit entering the reflux cooling mode, thereby confirming the appropriateness of the licensee's mitigating strategy. It should further be understood that both the simulations in WCAP-17601-P and the NRC staff's confirmatory calculations are expected to significantly underestimate the actual coping time available to Waterford because: (1) these simulations assumed an RCP seal leakage rate significantly in excess of that subsequently endorsed by the NRC staff for the Flowserve N-9000 seals installed at Waterford, and (2) no credit is taken for controlled bleed-off (CBO) isolation. As a result, the NRC staff considers the licensee's strategy for ensuring sufficient RCS makeup to avoid reflux cooling as having ample margin for mitigating the analyzed ELAP event.

Therefore, based on the evaluation above, the NRC staff concludes that the licensee's analytical approach should appropriately determine the sequence of events for reactor core cooling, including time-sensitive operator actions, and evaluate the required equipment to mitigate the analyzed ELAP event, including pump sizing and cooling water capacity.

3.2.3.3 Reactor Coolant Pump Seals

Leakage from RCP seals is among the most significant factors in determining the duration that a PWR can cope with an ELAP event prior to initiating RCS makeup. An ELAP event would interrupt cooling to the RCP seals, potentially resulting in increased leakage and the 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 variations in boric acid concentration. Along with cooldown-induced contraction 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.

Flowserve N-9000 seals are installed on the RCPs at Waterford. The N-9000 is a hydrodynamic seal that was developed by Flowserve in the 1980s. One of the design objectives for the N-9000 seal was to provide low-leakage performance under loss-of-seal-cooling conditions during events such as a station blackout. In support of its customers' efforts to address the ELAP event (which similarly involves a loss of seal cooling) in accordance with Order EA-12-049, by letter dated August 5, 2015, Flowserve, via the PWROG, provided to the NRC staff a white paper describing the seal package response to ELAP conditions [Reference 41]. The N-Seal white paper contains information regarding the expected leakage rates over the course of an ELAP event for each PWR at which Flowserve N-Seals are currently installed. The NRC staff endorsed the leakage rates described in the white paper for the beyond-design-basis ELAP event, by letter dated November 12, 2015 [Reference 42], subject to certain limitations and conditions.

During the audit, the licensee addressed the status of its conformance with the white paper. In particular, the licensee confirmed that the plant design and planned mitigation strategy for Waterford is consistent with the information assumed in the calculation performed by Flowserve, which is summarized in Table 1 of the white paper. Additionally, the peak cold-leg temperature prior to the RCS cooldown assumed in Flowserve's analysis was found to be equivalent to the saturation temperature corresponding to the lowest setpoint for main steam safety valve lift pressure. Based on its audit review, the NRC staff further considered the endorsement letter's condition on the density of the coolant leaking from the RCS to be addressed inasmuch as: (1) a conservative RCP seal leakage assumption was used for the determination of the time to enter reflux cooling, and (2) shutdown margin calculations considering maximum RCS leakage were performed on an appropriate volumetric basis.

According to measured data from Flowserve's 1988 N-Seal station blackout test, following CBO isolation at 0.5 hours, over the course of the succeeding period of 6 to 7 hours during which CBO isolation was maintained, the average seal leakage rate was slightly less than 0.05 gpm. The licensee indicated that these results are applicable to Waterford, since the FLEX strategies would isolate CBO flow within 0.5 hours of the event. Although the NRC staff agreed that it is appropriate to allow credit for demonstrated performance, during its review of the Flowserve white paper, the staff questioned the extrapolation of evidence from a limited test period of 6 to 7 hours to the indefinite coping period associated with the ELAP event. Therefore, while the NRC staff ultimately agreed with the credit Flowserve's N-Seal white paper allowed for CBO isolation in determining the short-term thermal exposure profile of seal elastomers, the staff did not endorse direct application of the average leakage rate measured with the CBO isolated in the 1988 test for an indefinite period in the absence of demonstrated long-term seal performance.

Ultimately, the plant-specific calculations performed by Flowserve in its white paper determined that Waterford's FLEX scenario does not exceed the design margin demonstrated in the 1988 station blackout test, such that increased leakage during the ELAP event due to elastomer failure or other causes is not expected. Under this condition, according to the values listed in Table 3a of the Flowserve white paper, assuming a leakage rate of 1.5 gpm per RCP prior to CBO isolation would be appropriate. Considering each unit has 4 RCPs and accounting for another 1 gpm of additional RCS leakage would result in a total RCS leakage of 7 gpm. Comparing the assumed leakage rates in the licensee's analysis to the endorsed values from the Flowserve white paper, the NRC staff determined the following:

- Comparing the assumed leakage rates in the licensee's analysis to the endorsed values from the Flowserve white paper, the NRC staff observed that the licensee's analysis for determining the threshold for entry into reflux cooling did not credit the installation of the Flowserve N-Seals. Instead, the leakage rates were based on the assumption that RCP seal leakage would occur at an initial rate of 15 gpm (i.e., the rate that excess flow check valves are closed in the CBO lines) at the RCS temperature and pressure conditions applicable when sub-cooling decreases below 50°F. Modeling RCP seal leakage in this manner was intended to envelop the potential for seal instability at low inlet sub-cooling conditions to result in "pop-open" failure. Thermal-hydraulic analysis indicates that the RCS sub-cooling margin decreases below 50°F at approximately 3 hours into the event. At this juncture, the RCS cooldown is being conducted, which results in the RCS approaching saturation because the pressurizer heaters are not powered during the ELAP event. As the RCS cooldown and depressurization continue, the leakage rate is assumed to decrease in accordance with the choked flow correlation used in the licensee's CENTS analysis. Comparing the leakage rates from the licensee's CENTS analysis, as well as confirmatory analysis performed by the NRC staff with the TRACE code (see Section 3.2.3.2 above), the NRC staff concluded that the analytically assumed leakage rates are conservative relative to the expected leakage rate for Flowserve N-9000 seals during the analyzed ELAP event.

- Regarding the licensee's shutdown margin analysis, as discussed further below, the NRC staff concluded that the maximum leakage rate analyzed by the licensee is reasonable, and that the possibility of slightly increased leakage rates would not be expected to have a significant effect on the calculated results.

Based upon the discussion above, the NRC staff concludes that the 60 gpm total system leakage rate at full system pressure assumed in the licensee's thermal-hydraulic analysis is well within the makeup capability of the licensee's FLEX strategy for the beyond-design-basis ELAP event.

3.2.3.4 Shutdown Margin Analyses

In the 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 sub-criticality 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
  - 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 that are 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 NRC 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 re-criticality will not occur during a FLEX RCS cooldown.

The NRC staff audited the licensee's shutdown margin calculations. Based upon Waterford's thermal-hydraulic calculations, the licensee concluded that adequate shutdown margin could be achieved at an RCS temperature of 400°F with no credit for pumped boration. Adequate shutdown margin in this case would be provided by the insertion of all rods and the passive injection of boron from the SITs on the initial cooldown to an RCS temperature of 456°F. Per the licensee's FIP, the SIT inventory injected into the RCS ensures that a shutdown margin of 1 percent would be achieved at an RCS temperature of 400 °F. Following the restoration of electrical power from the Phase 2 DG at approximately 12 hours, the licensee plans to isolate the SITs and restore a charging pump to provide a source of pumped boration from the BAMTs or the RWSP. Following the isolation of the SITs, in Phase 2, system depressurization will proceed to the target SG pressure of 250 to 260 psia, and RCS temperature of approximately 400 °F. Per the FIP, the restoration of the charging pump must occur prior to 17 hours after the initiation of the ELAP event to prevent the onset of reflux cooling. The licensee plans to restore RCS injection via the charging pump at 12.5 hours after the initiation of the ELAP event ensuring adequate boron mixing conditions will be maintained.

The NRC staff's audit review of the licensee's shutdown margin calculation determined that credit was taken for uniform mixing of boric acid during the ELAP event. The NRC staff had previously 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 limits intended to ensure that boric acid addition and mixing during an ELAP would occur under conditions similar to those for which boric acid mixing data is available. By letter dated January 8, 2014, [Reference 43], the NRC staff endorsed the above position paper with three conditions:

> Condition 1: The required timing and quantity of borated makeup should consider conditions with no RCS leakage and with the highest applicable leakage rate.
>
> The NRC staff's review finds that this condition is satisfied because the licensee's planned timing for establishing borated makeup acceptably considered both the maximum and minimum RCS leakage conditions expected for the analyzed ELAP event.

Condition 2: 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.

The NRC staff's review for Waterford finds that this condition is satisfied because the licensee's planned timing for establishing borated makeup would be prior to RCS flow decreasing below the expected flow rate corresponding to single-phase natural circulation for the analyzed ELAP event.

Condition 3: 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 1 hour is considered appropriate.

The NRC staff's review finds that this condition is satisfied because the licensee's planned timing for establishing borated makeup allows a 1-hour period to account for boric acid mixing; furthermore, during this 1-hour period, the RCS flow rate would exceed the single-phase natural circulation flow rate expected during the analyzed ELAP event.

The NRC staff's review concludes that the licensee's shutdown margin calculations are generally consistent with the PWROG's position paper on boron mixing, including the three additional conditions imposed in the NRC staff's endorsement letter.

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

The licensee relies on two different pumps during Phase 2 for core cooling. The licensee plans to use a FCCP to feed the SGs from the CSP or WCT Basin "A", which is cross-connected to WCT Basin "B". Also, the licensee plans to use the NSRC LPHF pump to makeup water to the WCT from flood waters or the Mississippi River, with the FLEX water transfer pump (FWTP) as the backup. Additionally, the licensee uses a FLEX internal flooding sump pump. In Section 2.3.10 of its FIP, the licensee identified the performance criteria (e.g., flow rate, discharge pressure) for the Phase 2 pumps. The NRC staff noted that the performance criteria for the FLEX Phase 3 NSRC pumps are consistent with the FLEX Phase 2 pump's capacities. See Section 3.10 of this SE for a detailed discussion of the availability and robustness of each water source.

During Phase 2, core cooling will be transferred to a pre-staged electric-driven FCCP if the TDEFW pump is no longer available. The FCCP will take suction from the CSP, WCT basins or the RWSP. A single pump provides full capability to feed all SGs and the licensee has two onsite to meet the "N+1" requirement in accordance with NEI 12-06. One pump is pre-staged in the RAB building basement and the other is trailer mounted and stored in the "N+1" storage building. In the FIP, Section 2.3.10.1 states that the FCCP is nominally rated at 250 gpm at 250 pounds per square inch gage (psig). The licensee performed calculation ECM14-005, "FLEX Core Cooling Pump Sizing," Revision 0, to determine the fluid system hydraulic performance. The NRC staff review noted that this calculation assessed different possible lineups based on such variables as suction sources, connection points and hose paths to determine the flow to ensure that the FCCP procured by the licensee would be adequate for providing injection into the SGs at the required flow rate and discharge pressure.

Additionally, the licensee relies on the NSRC LPHF pump to makeup water to the CSP, RWSP or WCT basins, with one of the two available FWTPs as a backup. The FWTPs are diesel-driven pumps that can provide a total of 400 gpm at a discharge head of 370 feet. They are trailer mounted and one is stored in the RAB and the other in the "N+1" building. The licensee performed calculation ECM14-003, "FLEX Water Transfer Pump Sizing," Revision 1, to determine the fluid system hydraulic performance. This calculation assessed different possible lineups based on such variables as suction sources, discharge points and hose paths to determine the flow to ensure that the FWTP would be adequate for providing makeup to the FLEX water sources.

Lastly, the licensee relies on a FLEX internal flooding sump pump. The licensee did an analysis of internal flooding sources, ECM15-004, "Waterford 3 FLEX Internal Flooding Calculation," Revision 0. The analysis determined that the non-seismically robust fire water storage tank piping could crack during a seismic event causing up to 62 gpm to flood the basement of the RAB. At this flow rate, the FLEX strategy would be compromised 28 hours into the event, so the licensee plans to use the FLEX internal flooding pump which has a capacity of 64 gpm. The pump is permanently staged in the RAB basement and takes a suction from the sump and operators will route the discharge to the suction of the TDEFW pump, FCCP or CCW MU pumps. The sump pump is a compressed air-driven pump, and the compressed air comes from the existing diesel-driven station blackout (SBO) compressor that is pre-staged in the RAB.

During the audit process the staff was able to confirm that flow rates and pressures evaluated in the hydraulic analyses were reflected in the FIP for the core cooling strategies based upon the above FLEX pumps and respective FLEX connections being made as directed by the FSGs. During the onsite audit, the staff also conducted a walk down of the hose deployment routes for the above FLEX pumps to confirm the evaluations of the pump staging locations, hose distance runs, and connection points as described in the above hydraulic analyses and FIP. Additionally the licensee provided calculation ECC-14-028, "FLEX Equipment Anchorage in the RAB," Revision 0, that showed the FCCP and the FWTP are seismically mounted in the RAB.

Based on the staff's review of the FLEX pumping capabilities at Waterford, as described in the above hydraulic analyses and the FIP, the licensee has demonstrated that the pre-staged and portable FLEX pumps should perform as intended to support core cooling during an ELAP caused by an external event, consistent with NEI 12-06, Section 11.2.

3.2.3.6 Electrical Analyses

The licensee's electrical strategies provide power to the equipment and instrumentation used to mitigate the ELAP and loss of normal access to the UHS. 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.

During the audit process 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, operators would declare an ELAP following a loss of offsite power, emergency diesel generators (EDGs), and any ac source. The plant's indefinite coping capability is attained through the implementation of pre-determined FLEX strategies that are focused on maintaining or restoring key plant safety functions. According to the licensee's FIP, a safety function-based approach provides consistency with, and allows coordination with, existing plant emergency operating procedures (EOPs). The FLEX strategies are implemented in support of EOPs using FSGs.

During the first phase of the ELAP event, Waterford would rely on the Class 1E station batteries to provide power to key instrumentation for monitoring parameters and power to controls for SSCs used to maintain the key safety functions (core cooling, RCS inventory control, and containment integrity). The Waterford Class 1E station batteries and associated ac and dc distribution systems are located within the RAB, which is part of the NPIS. The NPIS is a safety-related, Seismic Category I structure that provides equipment protection from all applicable external events. The Class 1E station batteries are therefore protected from the applicable extreme external hazards. The licensee's FLEX Implementing Guideline, FIG-001, "Extended Loss of AC Power," and FSG-004, "ELAP DC Bus Load Shed and Management," direct operators to conserve dc power during the event by stripping non-essential loads. Operators will strip or shed unnecessary loads to extend battery life until backup power is available. The plant operators would commence load shedding (SBO load shed) within 30 minutes on both station batteries. In order to extend battery duration to 12.5 hours a deep load shed is performed on one of the station batteries within 2 hours from the onset of an ELAP/loss of normal access to the UHS event. The preferred train is 'B', however; an 'A' train deep load shed can be performed as an alternate.

In its FIP, the licensee noted that it had followed the guidance in NEI white paper, "EA-12-049 Mitigating Strategies Resolution of Extended Battery Duty Cycles Generic Concern," [Reference 47] when calculating the duty cycle of the batteries. This paper was endorsed by the NRC [Reference 48]. In addition to the white paper, the NRC sponsored testing at Brookhaven National Laboratory that resulted in the issuance of NUREG/CR-7188, "Testing to Evaluate Extended Battery Operation in Nuclear Power Plants," in May of 2015 [Reference 49]. The testing provided additional validation that the NEI white paper method was technically acceptable. The NRC staff reviewed the licensee's battery calculations and confirmed that they had followed the guidance in the NEI white paper.

The NRC staff reviewed the licensee's dc coping calculations ECE14-004, "Battery 3A-S "A" Train Calculation for FLEX Event," Revision 1 and ECE14-005, "Battery 3B-S "B" Train Calculation for FLEX Event," Revision 1, which verified the capability of the dc system to supply power to the required loads during the first phase of the Waterford FLEX mitigation strategy plan for an ELAP as a result of a BDBEE. Waterford has two Class 1E station batteries that were manufactured by C&D Technologies. Battery 3A-S and 3B-S are model type LCUN-33 and LCR-33, respectively. The capacities of the LCUN-33 and LCR-33 batteries are 2320 ampere-hours each, with minimum cell voltage of 1.80 and 1.79 volts per cell, respectively. The licensee's evaluation identified the required loads and their associated ratings (ampere (A) and minimum required voltage) and the non-essential loads that would be shed within 30 minutes (SBO load shed) and 2 hours (deep load shed) of the start of the event to ensure battery operation for at least 12.5 hours.

Based on the staff's review of the licensee's analysis and procedures, the battery vendor's capacity and discharge rates for the Class 1E station batteries, the NRC staff finds that Waterford dc systems 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.

The licensee's Phase 2 strategy includes repowering the 480 Vac buses within 12 hours after initiation of an ELAP. The strategy will use a pre-staged and permanently installed 400 kW, 480 Vac FLEX DG located within an enclosure built on the RAB roof. The licensee has a second portable 480 Vac FLEX DG stored in the "N+1" storage building. A single Phase 2 FLEX DG would provide power to a charging pump, motor-driven FCCP, CCW MU pump, battery charger, battery room exhaust fan, fuel oil transfer pump, lighting, and the SIT isolation valves.

The NRC staff reviewed the licensee calculation ECE14-003, "FLEX Strategy – Portable Diesel Generator System Sizing," Revision 1, conceptual single line diagrams, and the separation and isolation of the FLEX DGs from the EDGs. Based on the NRC staff's review, the minimum required loads for the Phase 2 400 kW FLEX DGs are 311 kW and 307 kW for Train "A" and Train "B", respectively. Therefore, a single 400 kW FLEX DG is adequate to support the electrical loads required for the licensee's Phase 2 strategy.

If the "N" FLEX DG becomes unavailable or is out of service for maintenance, plant operators would deploy the other ("N+1") FLEX DG to support the Phase 2 strategy. The "N+1" FLEX DG is identical to the "N" FLEX DG, thus ensuring electrical compatibility and sufficient electrical capacity in an instance where substitution is required. Since the "N+1" FLEX DG is identical and interchangeable with the "N" FLEX DG, the NRC staff finds that the licensee has met the provisions of NEI 12-06, Revision 0 for spare equipment capability regarding the Phase 2 FLEX DGs, as qualified by the alternatives discussed in Section 3.14 of this SE.

For Phase 3, the licensee plans to continue the Phase 2 coping strategy with additional assistance provided from offsite equipment/resources. The offsite resources that will be provided by an NSRC includes two 1-megawatt (MW) 4160 Vac CTGs, one 1100 kW 480 Vac CTG, and distribution panels (including cables and connectors). Each portable 4160 Vac CTG is capable of supplying approximately 1 MW, but two CTGs will be operated in parallel to provide a total of approximately 2 MW. The Phase 3 4160 Vac CTGs would provide power to a CFC, low pressure safety injection pump, CCW pump, DCT fans and some loads that were powered by the Phase 2 480 Vac FLEX DG. The licensee's calculation ECE14-003, discussed above, also addresses the loading for the NSRC Phase 3 4160 Vac CTGs. The NRC staff review notes that the minimum required loads in Phase 3 are approximately 1790 kW. Based on the additional margin available for the 4160 Vac CTGs and the availability of the 1100 kW

480 Vac CTG to back up the Phase 2 FLEX DG, the NRC staff finds that the 4160 Vac and 480 Vac CTGs being supplied from an NSRC have sufficient capacity and capability to supply the required loads.

Based on its review, the NRC staff finds that the plant batteries used in the strategy should have sufficient capacity to support the licensee's strategy, and that the FLEX DGs and turbine 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 should maintain or restore core cooling and RCS inventory during an ELAP event consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, as conditioned by the alternatives discussed in Section 3.14 of this SE, and should adequately address the requirements of the order.

3.3 Spent Fuel Pool Cooling Strategies

In 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 (250 gpm if overspray occurs). During the event, the licensee selects the SFP makeup 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 must be completed within a certain period of time should be identified and a basis that the time can be reasonably met should be provided. 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 for the mitigation strategies may use nominal initial values (without uncertainties) for plant parameters, and best-estimate physics data. All equipment used for consequence mitigation may be assumed to operate at nominal setpoints and capacities. In 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 effects of an ELAP with full core offload to the SFP is addressed in Section 3.11 of this SE.

3.3.1 Phase 1

The licensee states in its FIP, that no actions are required during ELAP Phase 1 for SFP makeup because the time to boil is sufficient to enable deployment of Phase 2 equipment. The licensee will monitor SFP water level using reliable SFP level instrumentation installed per Order EA-12-051.

3.3.2 Phase 2

During Phase 2, FIP Section 2.4.2 states that operators will repower the CCW MU pumps to supply water from the either the RWSP or the WCT basin to the SFP. The CCW MU pump discharge can be routed to the SFP cooling system via installed piping (not requiring refueling floor access), or via hoses that had been pre-routed during Phase 1 from the RAB +21' elevation to the refuel floor to provide direct makeup and spray flow to the pool. Repowering installed pumps is considered an alternative to NEI 12-06, Revision 0. However, as discussed in more detail in Section 3.14.3 of this SE, the staff finds the use of the installed CCW MU pumps to provide SFP cooling at Waterford to be an acceptable alternative.

3.3.3 Phase 3

The FIP states that SFP cooling can be maintained indefinitely using the makeup strategies described in Phase 2 above. However, NSRC equipment is available during Phase 3 for SFP cooling and provide additional defense-in-depth. The NSRC will also provide additional water purification equipment to provide an indefinite clean water source.

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 time to boil calculation for the SFP. This calculation and the FIP indicate that boiling begins at approximately 13 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 to the pre-staged spray nozzles as a contingency for SFP makeup within 12 hours from event initiation while the SFP area remains habitable for personnel entry.

As described in the licensee's FIP, the licensee's Phase 1 SFP cooling strategy does not require any operator actions. However, the licensee does establish a ventilation path to cope with eventual temperature, humidity and condensation from evaporation and/or boiling of the SFP. Guideline FIG-001 directs operators to prop open external doors to the FHB prior to exceeding 12 hours into the event.

The licensee's Phase 2 and Phase 3 SFP cooling strategy involves the use of the CCW MU pumps (or an NSRC supplied pump for Phase 3), with suction from the RWSP or WCT, to supply water to the SFP. Section 2.4.4.1 of the FIP, states that the CCW MU pumps are seismically robust and protected from all applicable hazards. Based on the protection for all postulated external events provided to the CCW MU pumps and the acceptability of the licensee's alternative as described in Section 3.14.3 of this SE, the staff concludes that the necessary SSCs are provided to provide SFP cooling. The staff's evaluation of the robustness and availability of the connection points for the FLEX pump are discussed in Section 3.7.3.1 below. Furthermore, the staff's evaluation of the robustness and availability of the WCT basin for an ELAP event is discussed in Section 3.10 of this SE.

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. 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 SE.

3.3.4.2 Thermal-Hydraulic Analyses

As described in Section 2.4.7 of the FIP, the SFP will boil in approximately 13 hours assuming a normal core offload. In addition, assuming the maximum design heat load, it will boil off to the top of fuel in 28 hours from initiation of the event with no operator action.

Calculation ECS14-011, "WF3 FLEX Spent Fuel Pool Time to Boil and Boil-Off Rate," Revision 0, states that the two bounding scenarios analyzed are: (1) maximum normal operation heat load, and (2) the maximum normal/emergency refueling heat load which includes a full core offload. The heat loads, boil-off times, and makeup rates can be found in the table below.

	Heat Load	Time to boil to 10 ft from top of fuel	Makeup rate
Case 1	17.57 million Btu/hr	54.9 hrs	36.41 gpm
Case 2	60.43 million Btu/hr	16.0 hrs	125.2 gpm

Based on the Case 1 evaluation, the staff concludes that the licensee has conservatively determined a SFP makeup flow rate of at least 38 gpm that will maintain adequate SFP level above the fuel for an ELAP occurring during normal power operation. Based on Cases 1 and 2, the staff finds the licensee has considered the maximum design-basis SFP heat load, consistent with the guidance in NEI 12-06, Section 3.2.1.6.

3.3.4.3 FLEX Pumps and Water Supplies

As described in the FIP, the SFP cooling strategy relies on one of two CCW MU pumps to provide SFP makeup during Phase 2. In the FIP, Section 2.4.2 describes the hydraulic flow rate of 600 gpm for each CCW MU pump. The 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 CCW MU pump if the CCW MU pump were to fail. As stated above, either CCW MU pump can provide SFP spray flow rate of 250 gpm, which both meets and exceeds the maximum SFP makeup requirements. Furthermore, the staff finds analysis above is consistent with NEI 12-06 Section 11.2 and the FLEX equipment is capable of supporting the SFP cooling strategy and is expected to be available during an ELAP event.

3.3.4.4 Electrical Analyses

The licensee's FIP defines strategies capable of mitigating a simultaneous loss of all ac power and a loss of normal access to the UHS resulting from a BDBEE, by providing the capability to maintain or restore core cooling, containment, and SFP cooling at the Waterford site.

The NRC staff's analysis of the licensee's electrical strategies include the SFP cooling strategy. The licensee's Phase 1 strategy is to monitor SFP level using installed instrumentation (the capability of this instrumentation is described in Section 4 of this SE).

The licensee's Phase 2 strategy is to continue monitoring SFP level and repower the CCW MU pump using the 480 Vac FLEX DG. The staff reviewed licensee calculation ECE14-003 and determined that a single 480 Vac FLEX DG has sufficient capacity and capability to supply power to the CCW MU pump. During the audit process the staff confirmed that FSG-011, "Alternate SFP Makeup and Cooling," Revision 1, provides guidance for powering the CCW MU pump from a 480 Vac FLEX DG.

The licensee's Phase 3 strategy is continue with the Phase 2 strategy and use equipment supplied by an NSRC as a backup, if necessary. The NRC staff reviewed licensee calculation ECE14-003 and determined that based on the margin available, there is sufficient capacity and capability to supply the cooling systems for the SFP.

Based on its review, the NRC staff finds that the licensee's strategy is acceptable to restore or maintain SFP cooling indefinitely during an ELAP as a result of a BDBEE.

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, as conditioned by the alternatives discussed in Section 3.14 of this SE, and should adequately address the requirements of the order.

3.4 Containment Function Strategies

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. Waterford has a dry ambient pressure containment.

The licensee performed a containment evaluation ECS14-001, "WF3 FLEX Containment MAAP [Modular Accident Analysis Program] Analysis," Revision 0, which was based on the boundary conditions described in Section 2 of NEI 12-06. The calculation analyzed the licensee's strategy and concluded that the containment parameters of pressure and temperature remain well below the Updated Final Safety Analysis Report (UFSAR) [Reference 57], Section 3.8.2.3 design limits of 44 psig and 263°F. From its review of the evaluation, the NRC staff notes that the required actions to maintain containment integrity and required instrumentation functions have been developed, and are summarized below.

3.4.1 Phase 1

The Phase 1 coping strategy for maintaining containment functions only involves monitoring containment pressure using installed instrumentation, initially powered by the station batteries. No specific strategy is required to maintain containment integrity during Phase 1, 2 and 3 of an ELAP event. The FIP states that the containment pressure is monitored for the duration of the ELAP.

3.4.2 Phase 2

During Phase 2, containment temperature and pressure are expected to remain below design limits for at least 120 hours; however, containment status will be monitored. When the primary or alternate 480 Vac FLEX DG set is staged and functional, power will be available to ensure that the containment pressure instrumentation will support the monitoring function.

3.4.3 Phase 3

The licensee's Phase 3 strategy relies on using the NSRC 4160 Vac generator to repower a CFC, a CCW pump and the missile protected portions for the DCT. The CFC rejects heat to the CCW system which then transfers it to the DCT. If the DCT is not available, alternate connections on the CCW can be used with the NSRC LPHF pump to provide once through cooling.

3.4.4 Staff Evaluations

3.4.4.1 Availability of Structures, Systems, and Components

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

3.4.4.1.1 Plant SSCs

Section 3.8.2.1 of the Waterford UFSAR states that the containment is a free standing steel pressure vessel surrounded by a reinforced concrete shield building. It consists of a cylindrical steel pressure vessel with a hemispherical dome and ellipsoidal bottom and is a Seismic Category I structure. Being a Category I structure, the containment has been designed to maintain its function following a Safe Shutdown Earthquake (SSE). Additionally, Section 3.8.2.1 of the UFSAR states that the containment vessel is protected from external missiles by the shield building. The licensee stated in the Section 2.5.4 of its FIP, that the CFC, CCW and the missile protected portion of the dry cooling tower are located in the NPIS so they are protected from all applicable hazards. Additionally, UFSAR Table 3.2-1 lists those SSCs as Seismic Category I. Therefore, the staff finds that the containment and systems used to cool it are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Section 3.8.2.1 of the UFSAR shows that the net free volume of the containment is 2.68 million cubic feet. The addition of mass and energy to the containment atmosphere during an ELAP event is primarily driven by the assumed leakage from the RCP seals. The relatively small amount of heat and mass being added to the containment atmosphere coupled with the very large net free volume of the containment results in a slow-moving response. As stated above, the licensee's calculation shows that even with no mitigating actions taken to remove heat from the containment, the containment parameters of pressure and temperature remain well below the respective design limits of 44 psig and 263°F for at least 120 hours.

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's FIP states that limited MCR instrumentation would be available due to the coping capability of the station batteries and associated inverters in Phase 1, or FLEX DGs deployed in Phase 2. To account for a situation where no ac or dc power is available, the staff reviewed FSG-007, "Loss of Vital Instrumentation or Control Power," Revision 0, and confirmed that it directs operators to monitor key credited plant parameters, including containment pressure, using alternate methods.

3.4.4.2 Thermal-Hydraulic Analyses

During the audit process, the NRC staff reviewed calculation ECS14-001, Revision 0, which was based on the boundary conditions described in Section 2 of NEI 12-06. In this calculation, the licensee utilized the MAAP PWR 4.0.6 code to model the containment response to an ELAP. The main additions of heat and mass to the containment atmosphere under ELAP conditions are the ambient heat losses from the surfaces of hot equipment and the leakage of reactor coolant from the RCP seals.

Using the input described above, the containment maximum pressure and temperature at 120 hours were estimated by the NRC staff to be approximately 26.3 psia and 228°F with no operator actions taken. These values are still far below the UFSAR design parameters of 58.7 (44 psig +14.7) psia and 263°F, so the staff concludes that the licensee has adequately demonstrated that there is significant margin before a limit would be reached, and that there is sufficient time to establish long-term containment cooling via NSRC equipment.

3.4.4.3 FLEX Pumps and Water Supplies

The licensee does not plan to use any FLEX equipment to maintain containment integrity other than what has already been mentioned in this safety evaluation.

3.4.4.4 Electrical Analyses

The licensee's Phase 1 coping strategy includes monitoring containment pressure using installed equipment. Control room indication for containment pressure is available for the duration of the ELAP event. The licensee's strategy to repower instrumentation using the Class 1E station batteries is identical to what is described in Section 3.2.3.6 of this SE and is adequate to ensure continued containment monitoring.

The licensee's Phase 2 coping strategy is to continue monitoring containment pressure using installed instrumentation. The licensee's strategy to repower instrumentation using the 480 Vac FLEX DG is identical to what is described in Section 3.2.3.6 of this SE and is adequate to ensure continued availability of instrumentation needed to monitor containment pressure.

The licensee's Phase 3 coping strategy includes actions to reduce containment temperature and pressure utilizing existing plant systems restored by off-site equipment and resources. The licensee's strategy is to use the NSRC supplied 4160 Vac CTGs to repower a CFC, CCW pump, and DCT fans to restore and maintain containment cooling.

The NRC staff reviewed the licensee's calculation ECE14-003 and determined that the electrical equipment available onsite (e.g., 480 Vac FLEX DGs) supplemented with the equipment that will be supplied from an NSRC (e.g., 4160 Vac CTGs), there is sufficient capacity and capability to supply the required loads to reduce containment temperature and pressure to ensure that key components and instrumentation remain functional during an ELAP.

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 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 applicable 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; and extreme high temperatures.

References to external hazards within the licensee's mitigating strategies and this safety evaluation are consistent with the guidance in NEI-12-06 and the related NRC endorsement of NEI 12-06 in JLD-ISG-2012-01. Guidance document NEI 12-06 directed licensees to proceed with evaluating external hazards based on currently available information. For most licensees, this meant that the OIP used the current design basis information for hazard evaluation. Coincident with the issuance of Order EA-12-049, on March 12, 2012, the NRC staff issued a Request for Information pursuant to Title 10 of the *Code of Federal Regulations* Part 50, Section 50.54(f) [Reference 21] (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. Due to the time needed to reevaluate the hazards, and for the NRC to review and approve them, the reevaluated hazards were generally not available until after the mitigation strategies had been developed. The NRC staff has developed a proposed rule, titled "Mitigation of Beyond-Design-Basis Events," (hereafter called the MBDBE rule), which was published for comment in the *Federal Register* on November 13, 2015 [Reference 50]. The proposed MBDBE rule would make the intent of Orders EA-12-049 and EA-12-051 generically applicable to all present and future power reactor licensees, while also requiring that licensees consider the reevaluated hazard information developed in response to the 50.54(f) letter.

The NRC staff requested Commission guidance related to the relationship between the reevaluated flooding hazards provided in response to the 50.54(f) letter and the requirements for Order EA-12-049 and the MBDBE rulemaking (see COMSECY-14-0037, Integration of Mitigating Strategies for Beyond-Design-Basis External Events and the Reevaluation of Flooding Hazards") [Reference 44]. The Commission provided guidance in an SRM to COMSECY-14-0037 [Reference 22]. The Commission approved the staff's recommendations that licensees would 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 damage 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 [Reference 36], the NRC staff informed the licensees that the implementation of mitigation strategies should continue as described in licensee's OIPs, and that the NRC SEs and inspections related to Order EA-12-049 will rely on the guidance provided in JLD-ISG-2012-01, Revision 0, and the related industry guidance in NEI 12-06, Revision 0. The hazard reevaluations may also identify issues to be entered into the licensee's corrective action program consistent with the OIPs submitted in accordance with Order EA-12-049.

As discussed above, licensees are reevaluating the site seismic and flood hazards as requested in the NRC's 50.54(f) letter. After the NRC staff approves the reevaluated hazards, licensees will use this information to perform flood and seismic mitigating strategies assessments (MSAs) per the guidance in NEI 12-06, Revision 2, Appendices G and H [Reference 51]. The NRC staff endorsed Revision 2 of NEI 12-06 in JLD-ISG-2012-01, Revision 1 [Reference 52]. The licensee's MSAs will evaluate the mitigating strategies described in this SE using the revised seismic hazard information and, if necessary, make changes to the strategies or equipment. Licensees will submit the MSAs for NRC staff review.

The licensee developed its OIP for mitigation strategies by considering the guidance in NEI 12-06 and the site's design-basis hazards. Therefore, this SE makes a determination based on the licensee's OIP and FIP. The characterization of the applicable external hazards for the plant site is discussed below.

3.5.1 Seismic

In its FIP, the licensee described the current design-basis seismic hazard, the SSE. As described in UFSAR Section 2.5.4.9, the SSE seismic criteria for the site is one-tenth of the acceleration due to gravity (0.10g) peak horizontal ground acceleration and 0.067g 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 a certain frequency range, 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 is expected to assess the mitigation strategies to ensure they can be implemented under the reevaluated hazard conditions as will potentially be required by the proposed MBDBE rulemaking. The licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated.

3.5.2 Flooding

In the UFSAR, Section 1.2.1.2, Geography and Hydrology, describes the site as it relates to the Mississippi River:

> The site is located on the right descending bank of the Mississippi River near Taft, Louisiana. It consists of over 3,000 acres of flat land extending from the Mississippi River to the St. Charles Drainage Canal. The site includes about 7500 feet of river frontage. The plant area is raised to a final grade of +17.5 ft. [mean sea level] MSL around the Nuclear Plant Island Structure, and +14.5 ft. MSL around the Turbine Building.

Figure 1 in the FIP shows a levee between the river bank and site boundary.

In its FIP, the licensee described that the current design-basis for the limiting site flooding event is the PMF event, which has been determined to be elevation +27.0 feet (ft.) MSL. This value was determined to provide acceptable conservatism for the levee failure analyses. In the UFSAR, Section 2.4.1.1 states that all safety-related components are housed in the NPIS which is flood-protected up to +30.0 ft. MSL. The NPIS is a reinforced concrete box structure with solid exterior walls. All exterior doors and penetrations below +30.0 ft. MSL, which lead to areas containing safety-related equipment, are watertight. This design also protects the plant from the probable maximum precipitation (PMP) water level. From UFSAR Section 2.4.2.3.1, the 10 square mile PMP depths for 6, 12 and 24 hours are 30.7, 34.6 and 39.4 inches respectively (approximately a maximum of 22 ft. MSL). According to UFSAR Section 2.4.3.5, the water levels in the Mississippi River at Waterford were estimated for the following three cases: (1) a project design flood level of +24 ft. MSL, (2) a moderate Mississippi River flood coincident with the probable maximum hurricane, yielding a maximum water level of +23.7 ft. MSL, and (3) PMF, for which the maximum water level considered possible is elevation +27 ft. MSL. Thus, the limiting flood case has been determined to be the PMF with a flood level of +27 ft. MSL. According to the licensee, this limiting flood source does not need to be characterized in terms of warning time due to the chosen FLEX strategies.

In its FIP, the licensee describes that potential sources of internal flooding were reviewed for flooding impacts. In-leakage flow rates from non-robust water sources were determined to be 62 gpm. At this flood rate, the FLEX strategy could be impacted within 28 hours. In order to mitigate this flooding impact, the primary strategy is to utilize a pre-staged FLEX sump pump. As an alternate strategy, the flooding sources are to be isolated via their associated isolation valves. If internal flooding is identified following a seismic event, the FLEX air powered sump pump can be placed into service, discharging via a manifold to either the suction of the FCCP, TDEFW, or CCW MU pumps or to the WCT basin. The compressed air to run the pump will come from an existing, portable, diesel driven SBO air compressor.

As the licensee's flooding reevaluation activities are completed, the licensee is expected to assess the mitigation strategies to ensure they can be implemented under the reevaluated hazard conditions as will potentially be required by the proposed MBDBE rulemaking. 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 U.S. NRC, "Technical Basis for Regulatory Guidance on Design Basis Hurricane Wind Speeds for Nuclear Power Plants," NUREG/CR-7005, December, 2009), if the resulting frequency of recurrence of hurricanes with wind speeds in excess of 130 mph exceeds 1E-6 per year, the site should address hazards due to extreme high winds associated with hurricanes using the current licensing basis for 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, February 2007; if the recommended tornado design wind speed for a 1E-6/year probability y exceeds 130 mph, the site should address hazards due to extreme high winds associated with tornadoes using the current licensing basis for tornados or Regulatory Guide 1.76, Revision 1.

Waterford is located at 29° 59' 42" north latitude, 090° 28' 16" west longitude indicating the site is located in the 240 to 250 mph hurricane wind contour per NEI 12-06, Figure 7-1; and per NEI 12-06 Figure 7-2, the site is in Region 1, where the tornado design wind speed exceeds 200 mph. Therefore, the plant screens in for an assessment for high winds and tornados, including missiles produced by these events.

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 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 Figure 8-2 should address the impact of ice storms.

Waterford is located at 29° 59' 42" north latitude, 090° 28' 16" west longitude, just inland from the Gulf coast, outside the regional areas for sites expected to address deployment for conditions of snow, ice, and extreme cold and south of the 35th Parallel. The site is located within the region characterized by the Electric Power Research Institute (EPRI) as ice severity level 3 (NEI 12-06, Figure 8-2, Maximum Ice Storm Severity Maps), thus, the site is subject to low to medium damage to power lines and/or existence of considerable amounts of ice. In its FIP, the licensee stated that there is no significant hazard from snow or extreme cold for Waterford. However, debris and ice removal equipment is stored in the "N+1" building.

In summary, based on the site location and Figures 8-1 and 8-2 of NEI 12-06, the plant site does not experience significant amounts of snow and extreme cold temperatures; therefore, the hazard is screened out, except for ice. The NRC staff concludes that the licensee has appropriately screened this hazard.

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. Per UFSAR Section 2.3.2.1.2, on the average there are 7 days a year in the New Orleans area when the temperature rises to 95°F or higher with 102°F being the highest recorded temperature. Waterford has based its high temperature BDBEE value on the maximum expected temperatures for this site, equal to or greater than the highest record temperature. 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 should adequately address 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 for Waterford, the minimum equipment required to support the FLEX safety functions ("N" set) is permanently pre-staged within the NPIS, a seismically qualified structure robust for severe storms with high winds (including tornado wind loads and missiles), external flooding up to +30' MSL, ice, and extreme high temperatures. In its compliance letter, the licensee describes a new "N" building which is a Seismic Category I, reinforced-concrete, tornado-missile protected structure located on the RAB roof, primarily constructed for housing the "N" Phase 2 DG.

In its FIP, the licensee stated that the majority of the spare equipment is stored within the "N+1" storage building, a commercially procured storage facility designed to meet American Society of Civil Engineers (ASCE) 7-10, located south of the protected area. The "N" FLEX storage building (within the NPIS) is designed to provide protection and the ability to deploy equipment for all site hazards, whereas the "N+1" building is not. Specifically, the "N+1" storage building is not protected from the flooding hazard and severe storms and high winds as it is situated at an elevation below the PMF and it is not missile protected. In its FIP, the licensee stated that the method of storage and protection of FLEX equipment is an alternative to NEI 12-06. This is further discussed in Section 3.14.5 of this SE.

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 described that the "N" set of equipment is stored within the NPIS, a seismically qualified structure. The "N+1" storage building is a commercially procured storage facility designed to meet ASCE 7-10. During the audit process, the NRC staff reviewed the licensee's engineering design documentation to confirm that all new FLEX equipment and local, miscellaneous equipment storage boxes are seismically restrained or evaluated for sliding and rocking where necessary.

3.6.1.2 Flooding

In its FIP, the licensee described that the "N" set of equipment is stored within the NPIS, which is protected from external flooding up to 30' MSL. The PMF reaches 27' MSL. The "N+1" storage building is located south of the protected area at an elevation below the projected PMF and thus, is not protected from flooding. While the flooding strategy uses the pre-installed "N" equipment, the licensee procedurally relocates specific "N+1" FLEX equipment to the NPIS such that it is provided additional protection from the hazard if notice of an impending extreme external hazard (e.g., Mississippi River levels slowly rising to potential flood level) is available.

3.6.1.3 High Winds

In its FIP, the licensee described that the "N" set of equipment is stored within the NPIS, which is protected from severe storms and high winds. The "N+1" storage building is not protected from severe storms and high winds. While the high winds strategy uses the pre-installed "N" equipment, the licensee procedurally relocates specific "N+1" FLEX equipment to the NPIS such that it is provided additional protection from the hazard if notice of an impending extreme external hazard (e.g., hurricane) is available.

3.6.1.4 Snow, Ice, Extreme Cold and Extreme Heat

Waterford screens out of the hazards involving snow and extreme cold. In its FIP, the licensee stated that in the event that outdoor temperature is forecasted to fall below 32°F, measures are taken to protect the equipment located in the "N+1" storage building against cold weather. Along with provision of temporary heating for the "N+1" storage building interior, the measures also include provision of power to the "N+1" FLEX DG block heater. With regards to high temperatures, the "N+1" storage building ventilation consists of natural circulation through louvers.

In its FIP, the licensee described that the "N" set of equipment is stored within the NPIS, which is protected from ice and extreme high temperatures. It also states that ice removal equipment is available in the "N+1" storage building which should be available in an icing event.

3.6.2 Reliability of FLEX Equipment

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

In its FIP, the licensee describes and lists all the FLEX equipment stored in both the NPIS and "N+1" storage building. Tables 10 and 11 in the FIP also list the FLEX equipment, quantities, functional uses (e.g., core cooling, SFP) and brief performance criteria, stored in the NPIS and "N+1" storage building, respectively. These lists also include tow and debris removal vehicles, light towers, and other miscellaneous support equipment.

In its FIP, the licensee stated that spare hoses and cables are stored with the "N" set of cables and hoses within the NPIS and fully protected from all applicable external hazards. The spare length of hoses and cables consists of the greater of:

- 10 percent of the total cable or hose length
- The longest single segment of cables or hoses

Storing less than a full "N+1" set of cables and hoses is considered an alternate approach to NEI 12-06, Revision 0 and is discussed further in Section 3.14.1 of this SE.

Based on the number of FLEX pumps, FLEX DGs, and support equipment identified in the FIP and during the audit review, the NRC staff finds that, if implemented appropriately, the licensee's FLEX strategies include a sufficient number of 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. This conclusion relies on the acceptability of the proposed alternative approaches to NEI 12-06, Revision 0, which are discussed in Section 3.14 of this SE.

3.7 Planned Deployment of FLEX Equipment

In its FIP, the licensee stated that because the "N" equipment is permanently pre-staged inside the NPIS there is no credible debris/access hazard to contend with. The haul path from the "N+1" storage building is shown on Figure 1 in the FIP.

3.7.1 Means of Deployment

Tow and debris removal vehicles are included in the FIP Table 11 list of FLEX equipment stored in the "N+1" storage building. The tow vehicle is a diesel four-wheel drive pickup truck and the debris removal vehicle is a front end loader with 20 metric ton capacity. Because the site is located south of the 35th parallel the capability to address extreme snowfall with snow removal equipment is not required.

3.7.2 Deployment Strategies

In its FIP, the licensee stated that a review of available geotechnical and liquefaction assessments performed in the UFSAR (Section 2.5.4.8) and for the independent spent fuel storage installation pad indicated that the liquefaction potential of the encountered subsurface soils is low. Therefore, it is likely that the liquefaction potential is low for the soils below the "N+1" storage building site, the designated travel path and staging area "B". If equipment from the "N+1" storage building is needed, plant personnel performing "N+1" equipment deployment will have to perform an assessment of the haul path and begin debris removal to the required deployment area. The haul path assessment will also ascertain if power lines are down. If lines are down, low-voltage lines and high-voltage lines like the 230 kilovolt lines that cross the haul path near the "N+1" storage building will be verified de-energized.

In a significant flooding event the haul paths from the "N+1" storage building to all staging areas outside of the NSIP could become inundated and unpassable. In its FIP, the licensee described "triggers" for relocation of the "N+1" equipment for predictable external events with pre-warning as follows:

- If the Mississippi River level fronting the site rises to +25 feet, the "N+1" FCCP, FLEX DG, and FLEX diesel fuel transfer pump (FDFTP) should be considered for relocation to the RAB.

- If the Mississippi River level is projected to rise to +27 feet within the next 12 hours, the "N+1" FCCP should be relocated to the RAB -35' [-35 foot] elevation.

- If a greater than or equal to Category 4 hurricane warning is issued for St. Charles Parish, the "N+1" FCCP, FLEX DG, and FDFTP should be considered for relocation to the RAB.

- The FCCP should be further moved to the RAB -35' elevation prior to 12 hours before hurricane landfall.

3.7.3 FLEX Connection Points

3.7.3.1 Mechanical Connection Points

Core Cooling

In the FIP, Section 2.3.5.1 states that the primary connection point for the FCCP injects into the "A" EFW header downstream of the "A" motor-driven feed pump. The connection is on the existing EFW line that contains a hose connection and a normally shut isolation valve. As described in the UFSAR Table 3.2-1, the EFW system pumps and piping are Seismic Category I. In the FIP, the licensee stated that the primary FCCP connection is located in the RAB which is a Seismic Category I structure protected from all applicable hazards. Also, FIP Section 2.3.5.1 states that the alternate connection will connect to the discharge header of the "B" motor-driven feed pump. The licensee further states in its FIP, that the connection is also located in the RAB. Additionally, the FCCP will take suction from a connection to the RWSP or the WCT via a robust intermediate pipe and hose connections all of which are located in the RAB, which is fully protected from all applicable external hazards.

RCS Inventory Control/Makeup

There are no temporary connections for RCS makeup as the re-powered charging pumps are used to pump water from the BAMT or the RWSP using installed, permanent flow paths.

SFP Makeup

In the FIP, Section 2.4.5.1 describes the licensee's SFP makeup strategy connections. A connection located in the RAB near the CCW MU pumps allows those pumps to take suction from either the RWSP or the WCT and the discharge of the CCW MU pumps can be routed via permanently installed piping to the SFP. Furthermore, the licensee can route hoses from a connection off the discharge of the CCW MU pumps up to the refueling floor to either discharge directly to the pool or provide spray flow. As stated earlier in this safety evaluation, the CCW MU pumps and piping are Seismic Category I and located in the RAB.

Given the design and location of the primary and alternate connection points, as described in the above paragraphs, the staff finds that at least one of the connection points should be available to support core and SFP cooling via a FLEX pump during an ELAP caused by an external event, consistent with NEI 12-06 Section 3.2.2.

3.7.3.2 Electrical Connection Points

Electrical connection points are only applicable for Phases 2 and 3 of the licensee's mitigation strategies for a BDBEE.

During Phase 2, the licensee's strategy is to supply power to the necessary equipment using a combination of permanently installed and portable components. The licensee's primary strategy is to use the pre-staged and permanently installed 480 Vac FLEX DG located in the FLEX DG enclosure on the RAB roof. The licensee also has a backup portable 480 Vac FLEX DG located in the "N+1" storage building. If needed, the licensee would deploy the portable 480 Vac FLEX DG to the RAB. The seismically robust FLEX DG receptacle panel is installed in the heating and ventilation fan room in the RAB located below the FLEX DG enclosure. This receptacle panel is connected to the FLEX DG with permanent cable and conduit. The seismically designed FLEX connection panels for the 480 Vac FLEX DG have been installed near the 31A and 31B switchgear in the RAB. These connection panels are connected to the switchgear with permanent cable and conduit. Spare circuit breakers have been modified on the 480 Vac switchgear to provide power from the 480 Vac FLEX DG. During the audit process the NRC staff confirmed that the licensee performed phase rotation checks during the post modification testing for the "N" FLEX DG. The staff also confirmed that FSG-005, "Initial Assessment and FLEX Equipment Staging," Revision 1, provides direction for connecting the pre-staged permanently installed 480 Vac FLEX DG using color coded cables such that proper phase rotation is maintained.

For Phase 3, the licensee will receive two 1 MW 4160 Vac and one 1100 kW 480 Vac CTG from an NSRC. The licensee plans to restore power to 4160 Vac essential buses 3A or 3B using the NSRC supplied 4160 Vac CTGs. The NSRC supplied 4160 Vac CTGs will be staged on the east side of the RAB for the non-flooding events and placed on the RAB roof by helicopter for flooding events. The staff confirmed that FSG-005 provides direction for connecting the CTGs and ensuring proper phase rotation before attempting to power equipment from the 4160 Vac CTGs.

3.7.4 Accessibility and Lighting

In its FIP, the licensee stated that the minimum equipment required to support the FLEX safety functions ("N" set) is stored within the NPIS, therefore accessibility to the primary FLEX equipment is not a concern. The majority of the spare equipment is stored within the "N+1" storage building. According to the licensee's FIP, deployment of the "N+1" equipment is not dependent on power availability since the building equipment doors are manually operated roll-up doors.

In its FIP, the licensee stated that lighting panels for high priority areas are repowered by the Phase 2 FLEX DG. Diesel powered lighting towers are stored in the "N+1" storage building and can be deployed if available and/or required. However, the NRC staff notes that since the "N+1" storage building may not be available for all postulated events, these towers are not specifically credited for the licensee's strategy. The licensee's FIP describes other lighting features including portable flashlights and supplemental high powered light emitting diode (LED) flashlights. The portable flashlights are normal equipment supplied to station personnel and operators, and the LED flashlights are stored in local equipment boxes. During the audit process the NRC staff reviewed procedure EN-OP-115-01, "Operator Rounds," Revision 0, which requires operators to carry a flashlight. In addition the staff reviewed procedure OP-902-005, "Station Blackout Recovery," Revision 19, and noted that it provides several in-plant locations where additional portable lighting may be obtained from fire protection lockers.

3.7.5 Access to Protected and Vital Areas

The licensee's compliance letter states that security key rings are part of the standard gear/equipment of operators with duties in the plant (outside the MCR) and confirmed that there are no areas requiring access that are rendered inaccessible in the event of a loss of power. Further in its FIP, the licensee described that assistance from security is required to gain access through exterior security gates and barriers on the haul path from the "N+1" storage building to equipment staging areas that become de-energized during an event.

During the audit process, the licensee provided information allowing the NRC staff to confirm that access to protected areas will not be hindered in an ELAP scenario and that the licensee has contingencies in place to provide access to areas required for the ELAP response if the normal access control systems are without power.

3.7.6 Fueling of FLEX Equipment

In FIP Section 2.9.5, the licensee states that the "N" FLEX DG will be stored fueled with approximately 12 hours of fuel. The FLEX DG will be used to repower one of the existing diesel fuel oil transfer pumps to transfer fuel oil from the fuel oil storage tanks to the fuel oil feed tanks. From the fuel oil feed tanks, the FLEX FDFTP will be connected to a vent valve on either "A" or "B" fuel oil feed tank allowing the FDFTP to take suction and discharge to a manifold that will have connections to refuel the FLEX DG, FWTP, and SBO diesel-driven air compressor. The FDFTP is stored in the NPIS so it is protected from all applicable hazards. Though not specifically credited in the strategy, the licensee has a 500 gallon portable fuel trailer that is stored in the "N+1" building. The fuel oil storage tanks (2 total) are protected from all applicable hazards. Each storage tank has a tech spec controlled minimum supply of 39,300 gallons of fuel. The feed tanks have a minimum of 339 gallons. As specified in UFSAR Table 3.2-1, the diesel oil feed and storage tanks and the fuel oil transfer pumps are Seismic Category I and safety-related. Based on the design and location of these EDG fuel tanks and protection, the staff finds the fuel oil contents should be available to support the licensee's FLEX strategies during an ELAP event.

As stated above, fuel oil storage tanks have approximately 80,000 gallons total. In the FIP, Section 2.9.5 states that the licensee calculated that the Phase 2 FLEX equipment consumption is 0.69 gpm. Fuel consumption increases significantly when the NSRC equipment is in operation. The licensee calculated that the onsite fuel will last approximately 40 days. Given the information above, the staff concludes that the licensee should have sufficient fuel onsite for diesel-powered equipment, and that diesel-powered FLEX equipment should be refueled to ensure uninterrupted operation to support the licensee's FLEX strategies.

In the licensee's compliance letter, Attachment 2, ISE Confirmatory Item 3.2.4.9.B, Entergy states the portable FLEX equipment fuel oil will be sampled and maintained in accordance with the existing site procedures that have been modified to include the portable FLEX equipment. Also, the fuel oil storage tanks will continued to be monitored and maintained consistent with existing site procedures. Based on the continued monitoring of both the portable FLEX equipment and the existing fuel oil storage tanks, the staff concludes that the diesel fuel oil onsite should be maintained such that the diesel-driven equipment will be available during an ELAP.

3.7.7 Conclusions

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

3.8 Considerations in Using Offsite Resources

3.8.1 Waterford 3 SAFER Plan

The industry has collectively established the needed off-site capabilities to support FLEX Phase 3 equipment needs via the SAFER Team. The SAFER team consists of the Pooled Equipment Inventory Company and AREVA Inc. and provides FLEX Phase 3 management and deployment plans through contractual agreements with every commercial nuclear operating company in the United States.

There are two NSRCs, located near Memphis, Tennessee and Phoenix, Arizona, established to support nuclear power plants in the event of a BDBEE. 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.

By letter dated September 26, 2014 [Reference 23], the NRC staff issued its assessment of the NSRCs established in response to Order EA-12-049. In its assessment, the staff concluded that SAFER has procured equipment, implemented appropriate processes to maintain the equipment, and developed plans to deliver the equipment needed to support site responses to BDBEEs, consistent with NEI 12-06 guidance; therefore, the staff concluded in its assessment that licensees can reference the SAFER program and implement their SAFER Response Plans to meet the Phase 3 requirements of Order EA-12-049.

The NRC staff noted that the licensee's SAFER Response Plan contains: (1) SAFER control center procedures, (2) NSRC procedures, (3) logistics and transportation procedures, (4) staging area procedures, which include travel routes between staging areas to the site, (5) guidance for site interface procedure development, and (6) a listing of site-specific equipment (generic and non-generic) to be deployed for FLEX Phase 3.

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"), if available, which are offsite areas (within about 25 miles of the plant) utilized for receipt of ground transported or airlifted equipment from the NSRCs. From Staging Areas "C" and/or "D", the SAFER team will transport the Phase 3 equipment to the on-site Staging Area "B" for interim staging prior to it being transported to the final location in the plant (Staging Area A) for use in Phase 3. For Waterford Alternate Staging Area "D" is Houma-Terrabonne Airport. Staging Area "C" is the Livingston Parish Fair Grounds. Staging Area "B" is the plant parking lot for non-flood events. For persistent flood events, an Alternate Staging Area "B" is established on the RAB roof to receive airlifted NSRC equipment. There are multiple Staging Area "A's" within the NPIS and outside areas for individual FLEX components.

During the audit process the staff reviewed the licensee's document, "Memorandum of Understanding Between Entergy Nuclear Operations, Inc., the Louisiana's Governor's Office of Homeland Security, and the Louisiana National Guard March 2015." This document provides additional assurance, beyond the SAFER plan, that helicopter support will be available. This is especially important given the licensee's roof-based flooding strategy. In this event helicopter deliveries of supplies, personnel and NSRC equipment will be made to the RAB roof staging area.

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 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

Following a BDBEE and subsequent ELAP event at Waterford 3, ventilation that provides cooling to occupied areas and areas containing required equipment will be lost. 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 a loss of ventilation analysis to quantify the maximum steady state temperatures expected in specific areas related to FLEX implementation to ensure the environmental conditions remain acceptable and within equipment limits. The key areas identified for all phases of execution of the FLEX strategy activities are the MCR, switchgear rooms, battery rooms, RAB -35' elevation (TDEFW pump, FCCP, charging pumps, CCW MU pump), and containment.

Main Control Room

The licensee's current SBO procedures directs operators to load shed, open doors, open ceiling access panels, and open the process analog control cabinet doors within 30 minutes to maintain MCR temperatures below 110°F for the first 72 hours. During the audit process the staff reviewed ECS14-002, "WF3 FLEX Main Control Room BDBEE Heat-up Analysis," Revision 1, which modeled the transient temperature response in the MCR following an ELAP event. The calculation showed that additional doors are required to be opened within 4 hours to establish passive ventilation. In addition, a 15,000 cubic feet per minute (cfm) portable ventilation fan is required to be setup within 13 hours to maintain the MCR temperature at or below 110°F. The staff also reviewed procedure OP-902-005, "Station Blackout Recovery Procedure," Revision 19, which provides guidance for opening doors and ceiling panels in the MCR. Finally, the staff reviewed FIG-001, "Extended Loss of AC Power," Revision 0, to confirm that guidance is available for opening additional doors and setting up a portable fan to minimize MCR temperature increases after a loss of ventilation and cooling due to ELAP.

Based on temperatures remaining below 120°F (the temperature limit, as identified in NUMARC-87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," Revision 1, for electronic equipment to be able to survive indefinitely), the NRC staff finds that the electrical equipment in the MCR will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Switchgear Rooms and Vital Battery Rooms

The licensee performed ECS14-004, "WF3 FLEX Switchgear and DC Equipment Rooms BDBEE Heat-up Analysis," Revision 1, which modeled the transient temperature response in the switchgear rooms and battery rooms following an ELAP event.

Switchgear Rooms - In its FIP, the licensee stated that forced ventilation is not required to maintain equipment below the limiting component maximum ambient design temperature if doors are opened within 2 hours from the start of the ELAP event. The licensee's supporting calculation, ECS14-004, "WF3 FLEX Switchgear and DC Equipment Rooms BDBEE Heat-up Results," Revision 1, was reviewed by the NRC staff. This calculation analyzed two scenarios representing the primary and alternate electrical FLEX strategy. The first scenario analyzed the primary strategy, where switchgear 'B' equipment is repowered and remains energized throughout the event. The second scenario analyzed the alternate strategy, where switchgear 'A' equipment is repowered and remains energized throughout the event. Switchgear room 'A' and 'B' maximum temperature for the primary strategy at 120 hours is 106°F and 113°F, respectively. Switchgear room 'A' and 'B' maximum temperature for the alternate strategy at 120 hours is 118°F and 108°F, respectively. The licensee's established limit for these rooms is 122°F, according to the supporting calculation. The licensee's implementation guideline, FIG-001, provides direction for opening doors establishing passive ventilation to minimize switchgear room temperature increases after a loss of ventilation and cooling due to ELAP. The NRC staff also notes that recovery actions using equipment supplied from an NSRC may allow the licensee to reenergize HVAC equipment in the plant or take other actions to protect plant equipment from temperature extremes.

Based on the temperature remaining below the maximum allowed temperature (122°F), the NRC staff concludes that the equipment in the switchgear rooms should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Vital Battery Rooms - The 3A-S and 3B-S battery rooms are adjacent to the respective switchgear rooms so the licensee's FIP states that the heat-up evaluation results are applicable to the battery rooms. Although the licensee concludes that no room cooling is required, FSG-004 provides guidance to repower battery room exhaust fans when the 480 Vac FLEX DG is repowering the 480 Vac bus (within 12 hours).

The Waterford batteries are manufactured by C&D Technologies. By letter dated July 1, 2016, the NRC staff previously documented a review of vendor manual information for similar safety-related batteries at Millstone, Unit 2 [Reference 58]. This information includes test results that indicate that the battery cells will perform as required in excess of 200 days at temperatures up to 122°F. Based on the above, the NRC staff finds that the licensee's ventilation strategy should maintain the battery room temperature below the maximum temperature limit of the batteries, as specified by the battery manufacturer, therefore the batteries will not be adversely impacted by the loss of ventilation as a result of an ELAP event. Although the licensee plans to open doors and restore ventilation, the NRC staff notes that at elevated temperatures periodic monitoring of electrolyte level may be necessary to protect the battery since the battery may gas more at higher temperatures.

<u>RAB -35' Elevation</u>

The licensee performed ECS14-003, "WF3 FLEX Reactor Auxiliary Building -35' Elevation BDBEE Heat-up Analysis," Revision 1, which modeled the transient temperature response on the -35' elevation in the area of the RAB where the TDEFW pump and charging pumps are located.

Charging Pump Rooms - The calculation showed that the temperature inside the charging pump rooms will stay below the maximum equipment temperature limit of 150°F. The calculation also showed that ventilation would not be required for well beyond 72 hours and if the Train 'A' charging pump is utilized for RCS injection during Phase 2, a door will need to be propped open to provide passive ventilation to the room. The maximum temperature expected during the first 120 hours for charging pump rooms is 123°F. Guideline FSG-001, "Long Term Inventory Control," Revision 2, provides guidance for opening a door to provide passive ventilation if charging pump 'A' is utilized for RCS injection. The other charging pump rooms are open to the -35' elevation of the RAB and do not require any doors to be opened.

TDEFW Pump Area - The calculation showed that the temperature around the TDEFW pump area will stay below the maximum temperature limit of 120°F. The maximum temperature at 72 hours and 120 hours is projected to be 103°F and 114°F, respectively. The calculation also determined that temperature in the area will continue to rise as the event progresses beyond 120 hours. The NRC staff notes that the licensee could use the FCCPs by that time if needed. In its compliance letter [Reference 20], the licensee stated that ventilation and cooling is expected to be required after 120 hours to protect the FLEX operating equipment and that one method to reestablish room cooling in Phase 3 in this area is to repower the essential chiller and corresponding room coolers with equipment supplied by an NSRC (e.g. 4160 Vac CTGs).

Therefore, based on the charging pump rooms and TDEFW pump area remaining below 150°F and 120°F, respectively, the NRC staff finds that the electrical equipment and controls should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Containment

The licensee performed ECS14-001, "WF3 FLEX Containment MAAP Analysis," Revision 0, which modeled the transient temperature response in the containment following an ELAP event. The calculation analyzed the containment pressure and temperature response for 120 hours following an ELAP. Based on the results of this analysis, the licensee determined that without any mitigating actions taken, the containment design limits for pressure (44 psig) and temperature (264°F) are not challenged during this period. Therefore, there is adequate time for the licensee to establish containment cooling during Phase 3 by either venting containment or using the CFCs to ensure that temperature and pressure limits are not exceeded and necessary equipment, including credited instruments, located inside containment remains functional throughout the ELAP event. The licensee's FIP also indicates that containment pressure is monitored, and that procedures are in place to establish containment cooling at a setpoint (25 psia or approximately 10 psig) that provides protection against exceeding the containment temperature and pressure limits.

Based on temperature and pressure remaining below the design limits for containment, including those for required components and instrumentation, the NRC staff expects that the electrical equipment in the containment should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Based on its review of the essential station equipment required to support the FLEX mitigation strategy, which are primarily located in the MCR, switchgear rooms, battery rooms, RAB -35' elevation, and containment, the NRC staff finds that the equipment should perform their required functions at the expected temperatures as a result of loss of ventilation during an ELAP/loss of normal access to the UHS event.

3.9.1.2 Loss of Heating

In Section 2.6.4 of its FIP, the licensee states that Waterford 3 screens out for extreme cold and snow. Therefore, protection of the safety-related battery rooms for extreme low temperatures is not required for the licensee's FLEX strategy.

3.9.1.3 Hydrogen Gas Control in Vital Battery Rooms

An additional ventilation concern that is applicable to Phases 2 and 3, is the potential buildup of hydrogen in the battery rooms as a result of loss of ventilation during an ELAP event. Off-gassing of hydrogen from batteries is only a concern when the batteries are charging. In its FIP, the licensee stated that they plan to restore battery room ventilation by repowering the existing battery room exhaust fans (SVS-MFAN-0006A (B) for train "A" batteries or SVS-MFAN-0005A (B) for Train "B" batteries). The licensee also stated that by repowering only one exhaust fan, a slight negative pressure is drawn on the room, purging whatever hydrogen is generated via the normal discharge to atmosphere. Guideline FSG-004, provides guidance to repower battery room exhaust fans when the 480 Vac FLEX DGs are repowering the 480 Vac bus and the station batteries are charging.

Based on its review of the licensee's battery room ventilation strategy, the NRC staff finds that hydrogen accumulation in the Waterford vital battery rooms should not reach the combustibility limit for hydrogen (4 percent) during an ELAP as a result of a BDBEE.

3.9.2 Personnel Habitability

3.9.2.1 Main Control Room

In the FIP, Section 2.11.1 indicates that an evaluation of the temperature response inside the MCR concluded that the temperature will stay at or below 110°F assuming operators open the doors within 30 minutes into the ELAP event. Additionally, operators must place in service a 15,000 cfm portable fan within 13 hours of the start of the event. Procedure OP-902-005 directs operators to open doors and remove ceiling panels within 0.5 hours. Additionally, FIG-001 directs operators to open additional doors by 4 hours into the evolution and install the temporary ventilation fan prior to 13 hours into the event. Based on the temperature remaining below 110°F and operator actions to open the MCR doors to provide ventilation in accordance with station procedures, the staff finds that station personnel can safely occupy and perform the necessary actions to support the FLEX mitigation strategy during an ELAP event, consistent with NEI 12-06, Section 3.2.2.

3.9.2.2 Spent Fuel Pool Area

See Section 3.3.4.1.1 above for the detailed discussion of ventilation and habitability considerations in the SFP Area. In general, the licensee plans to establish passive FHB ventilation and deploy hoses before the SFP boiling affects habitability. The licensee also has the ability to add water to the SFP from the installed SFP cooling piping without accessing the refueling floor.

3.9.2.3 Other Plant Areas - RAB

The FCCP, CCW MU pumps, TDEFW pump and the charging pumps are all located on the -35' elevation of the RAB. As stated above this area generally remains below 110˚F for at least 72 hours. The "A" charging pump room is isolated from the rest of the space and rises to 123˚F; however, operators would only need to enter that room periodically or if there was a problem with the "A" charging pump and neither of the other two charging pumps were available. Further, ventilation could be restarted once the NSRC equipment is received and connected 72 hours into the event.

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

The licensee describes that available water inventory sources containing over 700,000 gallons can provide support for core cooling and heat removal for a period of 72 hours after the event after which NSRC equipment will be available to provide makeup from the Mississippi River or from surrounding flood waters.

The credited water sources for all events are as follows:

- CSP
- RWSP
- WCT Basins
- BAMTs

These are described in more detail as follows:

In Section 2.3.7.1 of its FIP, the licensee states that the Phase 2 water inventory management strategy evaluates the robust water sources that are available based on each event. The strategy for all flood events is the same: The inventory of the CSP and WCT are utilized and once they are depleted, the borated water within the RWSP is utilized to extend coping beyond 72 hours. For non-flood events, the strategy is broken down further into seismic versus non-seismic events. For non-flood, non-seismic events, the plant will cope for greater than 72 hours by gravity draining the water inventory within the CWI piping. For non-flood, seismic events, similar to the flood scenario, the available inventory from the RWSP is utilized.

Due to Waterford's unique design and classification as a wet site, Waterford has included FWTPs to provide backup water replenishment capability to the equipment provided by the NSRC should it be needed. Either of the NSRC LPHF pumps, or FWTPs can be used to replenish on-site water sources with an indefinite supply of water from the Mississippi River or surrounding flood water.

For flood events and seismic events, coping is extended beyond 72 hours by utilizing borated water within the RWSP for core cooling via the FCCP or TDEFW pump when the WCT basin inventory is exhausted. This strategy relies on hose connections between the new RWSP drain line connection and the new suction line tie-ins for the CCW MU pumps, TDEFW pump, and/or FCCP. The use of borated water for core cooling via the steam generators extends coping to greater than 72 hours, after which borated water is replenished utilizing the Phase 3 strategy relying on a combination of NSRC equipment (mobile boration unit, water treatment skid, etc.).

As stated above, for non-flood, non-seismic events, Waterford can cope for greater than 72 hours without requiring replenishment utilizing the inventory of the CSP, WCT basins, and CWI piping. Replenishment via the off-site NSRC equipment or FWTP would be necessary after 72 hours. Core cooling is maintained by supplying the SGs by way of the TDEFW pump or the FCCP, both of which can take suction from the WCT basins.

The licensee also has other available water sources that are not credited due to their non-robust design but can be used, if available, to provide additional capability in support of the strategy.

These sources of water are the condensate storage tank, the primary water storage tank, and the demineralized water storage tank.

3.10.1 Steam Generator Makeup

In its FIP, the licensee states that the CSP provides an EFW water source at the initial onset of the event. The CSP is a Seismic Category I structure located within the NPIS, therefore, it is fully protected from all applicable external events. The CSP volume is maintained at 92 percent level per technical specifications, which provides approximately 187,000 gallons of usable inventory that will last approximately 8 hours.

In FIP Section 2.3.4.8, the licensee states that the RWSP is located inside the RAB, therefore, it is fully protected from all applicable external events. The RWSP contains borated water with a minimum concentration of 2,050 parts per million boron. The borated water inventory available following a BDBEE is approximately 420,800 gallons. The RWSP is also credited as a usable source of water to makeup to the SGs for flood and seismic events. It utilizes the EFW system to supply RWSP water for core cooling via the FCCP or TDEFW pump. Use of borated water within the steam generators has been evaluated to ensure acceptable heat transfer would be maintained.

Section 2.3.4.9 of the FIP, states that the WCT basins meet the requirements in NEI 12-06 for protection from all applicable external events. While the WCT basins combine to hold a minimum 348,200 gallons, only 273,500 gallons are postulated to be available utilizing the cross-tie between the two basins (approximately 15,000 gallons below the cross-tie piping will not gravity drain) and utilizing the FLEX installed tie-in connection located on the auxiliary component cooling water (ACCW) "A" pump suction line (60,000 gallons below the high point in the suction piping is not credited). The WCT basins are seismically qualified and located within the NPIS, therefore, they are considered robust. A portion of the WCT cross-connect piping and ACCW suction line are exposed to wind-generated missiles from above. These exposed portions of piping were determined to be reasonably protected from applicable missiles by virtue of their location and the presence of intervening structures.

The licensee describes that for non-flooding and non-seismic events, the WCT basins can be refilled by gravity draining the CWI piping into the basins in Section 2.3.10.5. The CWI piping is non-seismic, non-safety-related piping that runs from the circulating water pumps at the intake platform on the Mississippi River, over the levee, and then underground to the turbine building to supply coolant to the condensers. As the piping is buried underground, the piping is protected from hurricane and tornado winds and missiles. Since the valves required to establish the gravity drain require access beyond the plant flood wall, and the CWI piping does not meet the seismic design basis, the inventory within the CWI piping is only credited for non-flood, non-seismic events.

3.10.2 Reactor Coolant System Makeup

The robust water sources for RCS makeup are the RWSP or the BAMTs. The BAMTs are safety-related and seismically qualified components as described in Section 2.3.10.6 of the FIP. These tanks are located within the RAB, therefore, they are protected against all applicable external events. The BAMTs contain highly concentrated borated water utilized for reactivity control during plant operation. The exact concentration and minimum volume requirements are dependent upon the plant mode and the status of the RWSP. Given the variable nature of the BAMTs and relatively minimal water inventory (12,300 gallons maximum combining both tanks), the FLEX borated inventory analyses are based upon use of the RWSP only. The BAMTs may be utilized for RCS makeup if available and could extend RCS makeup capability.

3.10.3 Spent Fuel Pool Makeup

The credited water sources for SFP makeup are the RWSP or the WCT basins. The CWI volume is credited for non-seismic and non-flooding events.

3.10.4 Containment Cooling

Containment cooling does not depend on using makeup water from specific water sources.

3.10.5 Conclusions

Based on the evaluation above, 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 TDEFW 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 reactor vessel 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 28 hours are available to implement makeup before boil-off results in the water level in the SFP dropping far enough to reach Level 3, the SFP level below which makeup should not be deferred any further. The sequence of events in the licensee's FIP indicates that the site will 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 TDEFW 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" [Reference 37], which described methods to ensure plant safety in those shutdown modes. By letter dated September 30, 2013 [Reference 38], 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 licensee's FIP states that Waterford will comply with the guidance in this position paper. During the audit process, the NRC staff observed that the licensee had made progress in implementing this position paper.

Based on the licensee's use of the endorsed position paper, as described in its FIP, the NRC staff concludes that 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

3.12.1 Procedures

In its FIP, the licensee described that the inability to predict actual plant conditions that require the use of FLEX equipment makes it impossible to provide specific procedural guidance. As such, the FSGs will provide guidance that can be employed for a variety of conditions. Clear criteria for entry into FSGs will ensure that FLEX strategies are used only as directed for ELAP conditions, and are not used inappropriately in lieu of existing procedures. When FLEX equipment is needed to supplement EOPs, Off-Normal Operating Procedures (OOPs), or Severe Accident Mitigation Guidelines, the relevant procedure will direct the entry into and exit from the appropriate FSG.

The FSGs will provide available, pre-planned FLEX strategies for accomplishing specific tasks in the EOPs or OOPs. The FSGs will be used to supplement (not replace) the existing procedure structure that establishes command and control for the event.

Procedural interfaces have been incorporated into Procedure OP-902-005, "Station Blackout Recovery," to the extent necessary to include appropriate reference to FSGs and provide command and control for the ELAP.

The FSGs are reviewed and validated by the involved groups to the extent necessary to ensure the strategy is feasible. Validation may be accomplished via walk-throughs or drills of the guidelines.

3.12.2 Training

In its FIP, the licensee stated that based on the guidance in NEI 12-06, Waterford's Nuclear Training Program has been revised to assure personnel proficiency in the mitigation of BDBEEs is adequate and maintained. These programs and controls were developed and have been implemented in accordance with the systematic approach to training (SAT) process.

Initial training was provided and periodic training is provided to site emergency response leaders on BDB emergency response strategies and implementing guidelines. Personnel assigned to direct the execution of mitigation strategies for BDBEEs have received the necessary training to ensure familiarity with the associated tasks, considering available job aids, instructions, and mitigating strategy time constraints.

3.12.3 Conclusions

Based on the description above, the NRC staff finds that the licensee has adequately addressed the procedures and training associated with FLEX. The procedures have been issued in accordance with NEI 12-06, Section 11.4, and a training program has been established and will be maintained in accordance with 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 [Reference 39], which included EPRI Technical Report 3002000623, "Nuclear Maintenance Applications Center: Preventive Maintenance Basis for FLEX Equipment." By letter dated October 7, 2013 [Reference 40], 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 maintenance and testing of FLEX equipment is governed by the Entergy Preventive Maintenance (PM) program. The Entergy PM program utilizes the EPRI Preventive Maintenance Basis Database as an input in development of fleet specific Entergy PM Basis Templates. Based on this, the licensee states that Entergy fleet PM program for FLEX equipment follows the guidance NEI 12-06, Section 11.5.

The Entergy PM Basis Templates include activities such as:

- Periodic static inspections
- Operational inspections
- Fluid analysis
- Periodic functional verifications
- Periodic performance validation tests

The Entergy PM Basis Templates provide assurance that stored or pre-staged FLEX equipment is being properly maintained and tested. In those cases, where EPRI templates were not available for the specific component types, PM actions were developed based on manufacturer provided information/recommendations.

Additionally, the station performs periodic facility readiness checks for equipment that is outside the jurisdiction of the normal PM program and considered a functional aspect of the specific facility (emergency planning (EP) communications equipment such as radios, batteries, battery chargers, satellite phones, etc.). These facility functional readiness checks provide assurance that the EP communications equipment outside the jurisdiction of the PM Program is being properly maintained and tested. The licensee's FIP states that the unavailability of equipment and applicable connections that directly perform a FLEX mitigation strategy for core, containment, and SFP is managed such that risk to mitigating strategy capability is minimized. According to the licensee, maintenance/risk guidance conforms to NEI 12-06 as follows:

> Portable FLEX equipment may be unavailable for 45 days provided that the site FLEX capability (N) is available.
>
> If portable equipment becomes unavailable such that the site FLEX capability (N) is not maintained, initiate actions within 24 hours to restore the site FLEX capability (N) and implement compensatory measures (e.g., repair equipment, use of alternate suitable equipment or supplemental personnel) within 72 hours.

The NRC staff notes that in addition to the FIP statements listed above, by letter dated August 28, 2014 [Reference 13], the licensee also describes its proposed storage alternative to the provisions of NEI 12-06, Revision 0, to account for the site's pre-staged equipment configuration. This alternative is discussed further in Section 3.14.5 of this SE. Based on the licensee's FIP and the description contained in the licensee's letter dated August 28, 2014, the NRC staff finds that the licensee has adequately addressed equipment maintenance and testing activities associated with FLEX equipment because a maintenance and testing program has been established consistent with NEI 12-06, Section 11.5.

3.14 Alternatives to NEI 12-06, Revision 0

3.14.1 Reduced Set of Hoses and Cables as Backup Equipment

In its FIP, the licensee describes a proposed alternative approach to the NEI 12-06, Revision 0, guidance for hoses and cables. In NEI 12-06, Section 3.2.2 states that in order to assure reliability and availability of the FLEX equipment required to meet these capabilities, the site should have sufficient equipment to address all functions at all units on-site, plus one additional spare, i.e., an "N+1" capability, where "N" is the number of units on-site. Thus, a single-unit site would nominally have at least two portable pumps, two sets of portable ac/dc power supplies, two sets of hoses and cables, etc. The NEI on behalf of the industry, submitted a letter to the NRC [Reference 45] proposing an alternative regarding the quantity of spare hoses and cables to be stored on site. The alternative proposed was that that either: (a) 10 percent additional lengths of each type and size of hoses and cabling necessary for the "N" capability plus at least one spare of the longest single section/length of hose and cable be provided, or (b) that spare cabling and hose of sufficient length and sizing to replace the single longest run needed to support any FLEX strategy. The licensee also clarified in its FIP that the spare hose and cable would be stored with the "N" equipment and therefore would be located in a protected location. The licensee's proposal is to use either of the two options contained in the NEI letter. By letter dated May 18, 2015 [Reference 46], the NRC agreed that the alternative approach is reasonable, but that the licensees may need to provide additional justification regarding the acceptability of various cable and hose lengths with respect to voltage drops, and fluid flow resistance. Based on the licensee's FIP description, the NRC staff approves this alternative as being an acceptable method of compliance with the order.

3.14.2 Use of Installed Charging Pumps

The licensee states in its FIP, that the RCS makeup strategy involves repowering installed charging pumps. However, this is inconsistent with the guidance provided in NEI 12-06, Section 3.2.2(13), which specifies portable pumps for RCS makeup. Therefore, the use of the installed charging pumps is considered an alternative to NEI 12-06. However, the staff noted that the licensee's strategy involves:

- Three 100 percent capacity, safety class 2, redundant pumps.
- One pump provides 44 gpm whereas the licensee's calculations demonstrate that only 25 gpm is required
- Diverse injection paths from any of the three charging pumps are provided through either normal charging injection piping or through HPSI piping. The "A" charging pump has additional RCS injection flow path diversity.
- Either electrical power train can be used to power two of the three installed charging pumps.

The staff finds that the licensee has a strategy to provide RCS makeup would help prevent damage to the core following a BDBEE, which meets the requirement of Order EA-12-049. Further, while the use of installed charging pumps does not meet the "portable" provisions of NEI 12-06, there is an operational timing advantage that provides some compensation for the lack of flexibility inherent with the pumps being pre-installed, in addition to the licensee's power supply and flow path diversity. Therefore, the NRC staff finds that the licensee's use of installed charging pumps is an acceptable alternative to NEI 12-06, as the licensee has demonstrated compliance with the order, and the staff concludes that the licensee could provide RCS makeup.

3.14.3 Use of Installed CCW MU Pumps for SFP Makeup

The licensee states in its FIP, that the SFP makeup strategy involves repowering installed CCW MU pumps. However, this is inconsistent with the guidance provided in NEI 12-06, Table 3-2, which specifies a portable injection source. Therefore, the use of an installed CCW MU pump is considered an alternative to NEI 12-06. However, the staff noted that the licensee's strategy involves:

- Two safety class 3 pumps
- Each pump capable of providing up to 600 gpm whereas the licensee's calculations demonstrate that only 250 gpm is required
- Diverse, installed SFP makeup flow paths are available from either CCW MU pump. Additionally, hose connections on the discharge of both pumps allow for hoses to directly be routed to the SFP for makeup or spray flow.
- Each pump is powered from different Class 1E busses.
- Capability to use the FWTP as an alternative SFP makeup source

The staff finds that the licensee has a strategy to provide SFP makeup that would help prevent damage to the fuel following a BDBEE, which meets the requirement of Order EA-12-049. Further, while the use of installed CCW MU pumps does not meet the "portable" provisions of NEI 12-06, there is an operational timing advantage that provides some compensation for the lack of flexibility inherent with the pumps being pre-installed, in addition to the licensee's power supply and flow path diversity. Therefore, the NRC staff finds that the licensee's use of installed CCW MU pumps is an acceptable alternative to NEI 12-06, as the licensee has demonstrated compliance with the order, and the staff concludes that the licensee could provide SFP makeup.

3.14.4 Use of a Pre-staged 480 Vac FLEX DG

In its FIP, the licensee stated that the electrical strategy involves pre-staging a FLEX 480 Vac DG within a new enclosure on the RAB +41' elevation. The basis for this strategy is due to the extreme external flooding potential that could challenge deployment of a portable generator from an exterior storage building. As discussed in the licensee's letter dated August 28, 2014 [Reference 13], this is considered to be an alternative method to NEI 12-06. The staff noted that the licensee's strategy to pre-stage a FLEX DG involves:

- The new FLEX DG, FLEX DG receptacle panel, and FLEX connection receptacle panels are completely independent, and physically separated from the plant electrical distribution system.
- The enclosure which houses the pre-staged FLEX DG is designed and constructed to equivalent seismic standards of the RAB, is located within the confines of the NPIS, and is located above any postulated design basis flood levels.
- The FLEX cables required to place the FLEX DG into service are stored within the RAB +21' elevation on cable spools that are seismically robust per the guidance of NEI 12-06.
- The licensee has the ability to power primary and alternate equipment from the pre-staged FLEX DG.
- The licensee has recognized the out-of-service ramifications of using a single pre-installed FLEX DG and has proposed appropriate compensatory measures (see Section 3.14.5 of this safety evaluation)

The NRC staff finds that the licensee has strategy for repowering a 480 Vac bus to supply power to equipment required to maintain or restore core cooling, containment, and SFP cooling following a BDBEE, which meets the EA-12-049 order. Further, while the use of a pre-staged DG does not meet the "portable" provisions of NEI 12-06, Sections 2.1 and 3.2.2, the licensee has provided an appropriate rationale and justification for the strategy that has been developed. Therefore, the NRC staff finds that the licensee's use of a pre-staged 480 Vac FLEX DG is an acceptable alternative to NEI 12-06.

3.14.5 Storage Configuration

According to the licensee's FIP, the storage strategy involves pre-staging "N" sets of equipment inside the NPIS, thus providing protection from a flooding, or other BDBEE event. The "N+1" storage building is located outside the NPIS and is not protected against flooding or wind driven missiles. The "N+1" storage building houses the site's debris removal equipment, as well as the deployment equipment for any portable back-up equipment stored there. As described in the NRC staff's ISE for Order EA-12-049 dated November 22, 2013 [Reference 18], the licensee's third six-month OIP update for Order EA-12-049, dated August 28, 2014 [Reference 13], and the FIP, this constitutes an alternative to the provisions of NEI 12-06. The licensee has recognized that the chosen strategy has important ramifications for the treatment of out-of-service equipment and proposed clarifying treatment in its third six-month update. Specifically, since the "N+1" equipment is both unprotected and not deployable for certain BDBEE's, the licensee has proposed that should any of the pre-staged "N" equipment be out-of-service, that actions will be initiated within 24 hours, and compensatory measures implemented within 72 hours, to restore "N" capability. According to the licensee's FIP this includes strategies to provide reasonable protection to specific "N+1" equipment for predictable external events or instances where the "N" set is unavailable for reasons other than routine maintenance and testing. As described in the licensee's letter dated August 28, 2014, this could involve temporarily moving the appropriate "N+1" equipment to a protected location within the 72 hour allowed out-of-service time.

Based on the licensee's FIP, and the licensee's third six-month update dated August 28, 2014, the NRC staff concludes that that as long as the "N" equipment out-of-service time is controlled as described by the licensee, that a strategy and program has been developed that is consistent with the provisions of NEI-12-06. Further the staff concludes that the licensee's rationale for the proposed alternative, considering the specific postulated BDBEEs for the site, is reasonable and appropriate.

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, they will meet the requirements of the order.

3.15 Conclusions for Order EA-12-049

Based on the evaluations 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 February 28, 2013 [Reference 24], the licensee submitted an OIP for Waterford in response to Order EA-12-051. By email dated August 28, 2013 [Reference 25], the NRC staff sent a request for additional information (RAI) to the licensee. The licensee provided a response by letter dated September 26, 2013 [Reference 26]. By letter dated November 25, 2013 [Reference 27], the NRC staff issued an ISE and RAI to the licensee.

By letters dated August 28, 2013 [Reference 28], February 28, 2014 [Reference 29], August 28, 2014 [Reference 30], February 26, 2015 [Reference 31], and August 27, 2015 [Reference 32], the licensee submitted 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 January 18, 2016 [Reference 34], the licensee reported that full compliance with the requirements of Order EA-12-051 was achieved.

The licensee has installed a SFP level instrumentation system designed by MOHR Test and Measurement LLC (MOHR). 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 regarding the MOHR system on August 27, 2014 [Reference 33].

The staff performed an onsite audit to review the implementation of SFP level instrumentation related to Order EA-12-051 at Waterford. The scope of this audit included verification of whether the: (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 of the order. By letter dated October 6, 2015 [Reference 19], the NRC issued an audit report on the licensee's progress.

4.1 Levels of Required Monitoring

In its OIP, the licensee identified the SFP levels of monitoring as follows:

- Level 1 corresponds to 41 feet - 6 inches plant elevation.
- Level 2 corresponds to 30 feet - 0 inches plant elevation (10 feet above the top of the fuel storage racks).
- Level 3 corresponds to 20 feet - 0 inches plant elevation (top of the fuel storage racks).

For the Level 1 designation, in its OIP, the licensee stated that Level 1 is established based on the level at which the SFP cooling pumps automatically trip. This elevation is above the point where the pumps lose suction. In its letter dated September 26, 2013 [Reference 26], the licensee further stated that the water level above the normal fuel pool cooling pumps necessary to maintain the required NPSH [net positive suction head] for saturated conditions is approximately 31 feet, 6 inches. This level is well below 41 feet 6 inches, the level at which the fuel pool cooling pumps trip automatically.

The NRC staff's assessment of the licensee selection of the SFP levels of monitoring is as follows. Per NEI 12-02, Section 2.3.1, Level 1 will be the higher of the following: (1) the water level at which suction loss occurs due to uncovering of the spent fuel cooling inlet pipe, and (2) the water level at which loss of spent fuel cooling pump NPSH occurs under saturated conditions. Waterford's designated Level 1 is above both of the above two points and therefore meets NEI 12-02. Level 2 is consistent with the first of the two NEI 12-02 options for Level 2, which is 10 feet (+/- 1 foot) above the highest point of any fuel rack seated in the SFP. Level 3 is consistent with NEI 12-02 Level 3, which is the highest point of any fuel rack seated in the SFP.

Based on the evaluation above, the NRC staff finds that the licensee's proposed Levels 1, 2 and 3 appear to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

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. Below is the staff's assessment of the design features of the SFP level instrumentation.

4.2.1 Design Features: Instruments

In its OIP, the licensee stated that the primary instrument channel (Channel A) and backup instrument channel (Channel B) are permanent, fixed channels. The instrument channels will provide level indication through the use of Guided Wave Radar (GWR) technology through the principle of Time Domain Reflectometry (TDR). The instrument provides a single continuous span from above Level 1 to within 1 foot of the top of the spent fuel racks.

In its RAI response letter dated September 26, 2013 [Reference 26], the licensee provided a sketch depicting the sensor's measurement range from 44 feet - 3 inches plant elevation to 20 feet - 9 inches plant elevation. The NRC staff notes that while the measurement range clearly covers the designated Levels 1 and 2, the licensee's sketch and associated RAI response indicates that a 21 foot elevation corresponds to the "upper limit" of Level 3, implying that Level 3 has a range. In its OIP, dated February 28, 2013, the licensee had specified Level 3 as 20 feet – 0 inches, plus or minus one foot. Therefore, the NRC staff was unable to determine the licensee's specific setpoint corresponding to Level 3. However, the staff notes that in accordance with guideline FIG-001, "Extended Loss of AC Power," Revision 2, operators will take actions to initiate water makeup prior to the SFP water level dropping below 21 feet - 0 inches plant elevation. This level is within the SFP level instruments' measurement range. Based on the licensee's procedural direction, the staff concludes that actions to initiate water makeup are not delayed unnecessarily beyond an appropriate measureable setpoint.

The NRC staff finds that the licensee's design, with respect to the number of channels and measurement range for its SFP, appears to be consistent with the intent of the NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.2 Design Features: Arrangement

In its OIP, the licensee provided a sketch depicting the SFP instrument locations and conduit routings of both primary and backup level instrument channels. In the sketch, the Channel "A" (primary) probe is located near the northeast corner of the SFP, and from there the cable is routed along the FHB east wall, north wall, and west wall toward a floor penetration to the +21' elevation, where the electronics and display located. The Channel "B" (backup) probe is located near the southwest corner of the SFP and from there the cable is routed along the FHB south wall toward a floor penetration to the +21' elevation, where the electronics and display are located. In addition, the licensee stated that [instrument] channels will be physically separated by routing instrument cables in separate conduits, trays, or raceways, locating sensors on opposite sides of the pool near the corners, etc. Physical channel separation will be maintained down through and including each channel display/processor where convergence may be allowed so that display/processors can be located in close proximity or side by side.

During the onsite audit walk down, the NRC staff noticed that the SFP level instrument's cable conduits at the 46' elevation of the FHB were installed 5" apart, for approximately 20' of conduit run. The staff was concerned that this would not meet the arrangement provisions of NRC Order EA-12-051, provision 1.2, which requires the following:

> ...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 SFP. 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.

In response to the staff's concern, as documented in its compliance letter dated January 18, 2016 [Reference 34], the licensee stated that EC [Engineering Change] 48147 ECN [Engineering Change Notice] 58881 now includes a missile shield design for protecting these conduits. The staff reviewed ECN 58881 during the audit process and confirmed that the design of the shield adequately protects the adjacent conduits. Therefore, with this installation, the staff finds that there is sufficient protection against loss of SFP level indication due to missiles that may result from damage to the structure over the SFP.

Based on the evaluation above, the NRC staff finds that the licensee's arrangement for the SFP level instrumentation, if implemented appropriately, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.3 Design Features: Mounting

For the mounting design of the SFP level instrument, in its OIP, the licensee stated that both the primary and backup system will be installed in accordance with Seismic Category I standards. In addition, the licensee stated that the probes, cables, connectors, and mounting hardware in the area of the SFP will be designed to function after the effects of seismically induced sloshing. Cables shall be routed in seismically mounted rigid metal conduit, trays, or raceways. Display/Processors shall be mounted in promptly accessible areas outside of the SFP area. In its compliance letter the licensee further stated that Calculation ECC14-003, "SFPI Probe Mounting Bracket Design," Revision 0, shows that the SFPI Probe Mounting Bracket is structurally adequate and seismically qualified.

For the SFP level probe mounting, in its letter dated September 26, 2013 [Reference 26], the licensee stated that the loading on the probe mount and probe body includes both seismic and hydrodynamic loading using seismic response spectra that bound the Waterford 3 design-basis maximum seismic loads applicable to the installation location(s). The static weight load is also accounted for but is insignificant in comparison to seismic and hydrodynamic loads. Analytic modeling is being performed by the instrument vendor using IEEE [Institute of Electrical and Electronics Engineers] 344-2004 methodology. A detailed computational SFP hydrodynamic model accounts for multi-dimensional fluid motion, pool sloshing, and loss of water from the pool. Seismic loading response of the probe and mount is separately modeled using finite element modeling software.

For the SFP level electronics equipment mounting, in its letter dated September 26, 2013 [Reference 26], the licensee stated that the indicator and battery enclosures will be mounted in the +21' elevation of the RAB wing area. The new instrument mounting components and fasteners are seismically qualified and designed as rigid components inherently resistant to vibration effects. There are no expected impacts from adjacent objects during the BDBEE or design basis earthquake requirements imposed by NEI 12-02. In its compliance letter the licensee further stated that Calculation ECC14-002, "SFPI Electrical Equipment Support Qualification," Revision 0, seismically qualifies all electrical mounting equipment.

The NRC staff review notes that the licensee's design criteria and the methodology used to estimate and test the total loading on the mounting devices, including the design-basis maximum seismic loads and the hydrodynamic loads that could result from pool sloshing was appropriate. Therefore, the staff concludes that the seismic analyses demonstrates that the SFP level instrumentation's mounting design will allow the instrument to remain functional following the maximum postulated seismic ground motion.

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

4.2.4 Design Features: Qualification

4.2.4.1 Augmented Quality Process

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

In its OIP, the licensee stated that augmented quality requirements will be applied to all components in the instrumentation channels for the following:

- design control
- procurement document control
- instructions, procedures, and drawings
- control of purchased material, equipment, and services
- inspection, testing, and test control
- inspections, test, and operating status
- nonconforming items
- corrective actions
- records
- audits

The NRC staff reviewed the licensee's augmented quality program for the SFPI system and notes that it contains all of the attributes listed in Appendix A-1 of NEI 12-02. Therefore, if implemented appropriately, the licensee's approach appears to be consistent with NEI 12-02 guidance, and should adequately address the requirements of the order.

4.2.4.2 Equipment Reliability

Section 3.4 of NEI 12-02 states, in part:

> 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 conditions of temperature, humidity, emissions, surge, and radiation, and (2) to verify those tests envelope the plant-specific requirements.

During the vendor audit [Reference 33], the NRC staff reviewed the MOHR SFP level instrumentation's qualifications and testing for temperature, humidity, radiation, shock and vibration, and seismic. During the licensee audit, the staff further reviewed the anticipated site-specific seismic, radiation, and environmental conditions to confirm that the vendor's qualification and testing were bounding. Below is the staff's assessment of the equipment reliability of Waterford SFP level instrumentation.

4.2.4.2.1 Temperature, Humidity, and Radiation

The licensee's OIP states that components in the area of the SFP will be designed for the temperature, humidity, and radiation levels expected during normal, event, and post-event conditions for no fewer than 7 days post-event or until off-site resources can be deployed by the mitigating strategies resulting from Order EA-12-049. The OIP also states that equipment located in the SFP will be qualified to withstand a total accumulated dose of an expected lifetime at normal conditions plus an accident dose at post event conditions with SFP water level within 1 foot of the top of the fuel racks in the SFP. Finally, the OIP states that the probe and cable in the SFP area are robust components that are not adversely affected by expected radiation, temperature, or humidity and the areas selected for display/processor installation are considered mild environments.

For the expected radiological conditions at the SFP area, in its compliance letter, the licensee stated that calculation ECS14-008, "Spent Fuel Pool Instrumentation Shielding Calculation," Revision 0 defines a worst case dose of approximately 2.14E5 rads to the area above the SFP. Based on the vendor analysis results, the licensee concludes that the sensitive materials in the probe head will not be challenged under the specified conditions.

Regarding the expected radiological conditions of the area where the SFP level instrument electronics equipment is located, by letter dated September 26, 2013 [Reference 26], the licensee stated that the signal processor is designed for a mild environment with radiation levels similar to background radiation. In its compliance letter, the licensee further stated that the RAB (wing area) where the new signal processor/display is mounted has a normal 40-year dose of 8.8E+1 rad. According to the Waterford UFSAR [Reference 57], Table 3.11-1, the MCR also has a normal 40-year dose of 8.8E+1 rad. Furthermore, both the RAB (wing area) and MCR are designated as mild environments in this table. Therefore, according to the licensee, this environment is acceptable and no radiation testing on the transmitter electronics was performed or required. Also according to the licensee, during a BDBEE, radiation levels in the +21' RAB (wing area) are not impacted by a reduction in SFP water level.

As for the expected temperature conditions for the area the SFP level instrument electronics equipment located, in its compliance letter the licensee stated that the SFPI panels will be located in the +21' elevation of the RAB (wing area). This area has a design temperature of 104°F during normal operation. During a BDBEE, this area will have no operating equipment besides the SFPI panels and will not be subject to the heat generated during a design-basis accident. Additionally, the doors [near] the SFPI panels will be opened during a BDBEE per FIG-001 Attachment 10. Therefore, according to the licensee, it is reasonable to conclude that conditions in this area will not exceed the sensor electronics' qualification temperature of 131°F (55 degrees Centigrade (°C)) and thus are capable of continuously performing their required function under the expected temperature conditions.

As for the expected humidity conditions of the area the SFP level instrument electronics equipment located, in its compliance letter the licensee stated that humidity on the +21' elevation of the RAB is normally regulated by the RAB HVAC system. During normal operation, the licensee states that relative humidity in the RAB areas will be 20 percent to 90 percent, with an average of 60 percent. Since humidity decreases when dry bulb temperature increases given a constant mass of water per mass of air (humidity ratio), high relative humidity [RH] conditions will not occur at the upper end of the temperature range, which is 50°F – 104°F. Therefore, the licensee concludes that the normal operating conditions are bounded by the MOHR test cases of 47°C (116.6°F), 71 percent RH and 32°C (89.6°F), 96 percent RH. During a BDBEE, the RAB HVAC system is no longer available and the doors [near] the SFPI panels will be opened to allow outside air into the +21' elevation of the RAB Wing Area. Cases of both high humidity and high temperature are considered. The highest mean monthly relative humidity is 91 percent, which occurs in both July and August. The mean monthly temperature is 79.8°F during these months. Therefore, if the SFPI display is exposed to these conditions, it is still bounded by the 32°C (89.6°F) and 96 percent RH test case from MOHR Report 1-0410-1, "MOHR EFP-IL SFPI System Temperature and Humidity Test Report," with margin and is capable of continuously performing required functions under these expected humidity conditions.

Based on the licensee's submittals, as confirmed during the onsite audit review, the NRC staff finds that the equipment qualification envelops the expected radiation, temperature, and humidity conditions during a BDBEE. Further the staff finds that the equipment environmental testing demonstrates that the SFPI should maintain its functionality during the expected BDB conditions.

4.2.4.2.2 Shock and Vibration

In its compliance letter, the licensee stated that shock and vibration analyses and documentation of applicable standards are contained in proprietary MOHR Test and Measurement LLC Reports 1-0410-5, "MOHR EFP-IL SFPI System Shock and Vibration Test Report," and 1-0410-6, "MOHR EFP-IL SFPI System Seismic Test Report". The indicator and battery enclosures will be mounted in the +21' elevation of the RAB (wing area). The equipment is not affixed or adjacent to any rotating machinery that would cause vibration effects in the area of installation. The new instrument mounting components and fasteners are seismically qualified and designed as rigid components inherently resistant to vibration effects. There are no expected impacts from adjacent objects during the BDBEE or design-basis earthquake requirements imposed by NEI 12-02. The vendor testing provided adequately addresses the requirements for general robustness of the enclosures.

Based on the licensee's FIP and vendor test reports, as confirmed during the vendor and licensee audits, the NRC staff finds that the licensee and vendor evaluations show that shock and vibration should not adversely impact the reliability of the SFP level.

4.2.4.2.3 Seismic

In its compliance letter, the licensee stated that the vendor has prepared a series of generic seismic qualification reports for the SFP level instrument which bounds Waterford 3's seismic criteria. According to the licensee, the qualification reports envelop all components of the new SFP level instrumentation required to be operational during a BDBEE and post-event. Mounting bracket design and seismic Class 1 mounting analysis are included in modification package EC-48147, "Waterford 3 Spent Fuel Pool Level Instrumentation Upgrade," Revision 0. Calculation ECC14-003, "SFPI Probe Mounting Bracket Design," Revision 0 accounts for sloshing and shows that the SFPI probe mounting bracket is structurally adequate and seismically qualified.

The NRC staff's audit review of the licensee's seismic evaluations confirmed that the equipment's seismic qualifications envelop the expected seismic conditions at Waterford during a BDBEE. Further discussion of the instrument channel's mounting design is described in Subsection 4.2.3, "Design Features: Mounting" of this evaluation.

4.2.4.2.4 Equipment Reliability – Other Considerations

Based on the licensee's compliance letter, supported by the audit confirmation, the NRC staff found the Waterford SFPI design and qualification process to be adequate. However, during the audit process the staff learned that there were incidents at other nuclear facilities, in which this vendor's SFPI equipment experienced failures of the filter coil (or choke). The staff requested that the licensee address the impact of these equipment failures at Waterford.

In its compliance letter, the licensee provided a response, in which it stated that the vendor has determined the source of the failures is a miniature surface mount common-mode choke component used on the printed circuit boards within the EFP-IL Signal Processor. Per the vendor's recommendation, the two boards have both already been replaced. The new boards have equivalent substitute components that are less susceptible to transient electrical events. The substitute components have equivalent size, mass, and solder attachment technique as the original component such that there is no impact to the system mechanical characteristics. The components demonstrate equivalent electrical performance such that EMC characteristics are not significantly changed. In the event that one or both channels become non-functioning at any point in the future, compensatory actions are covered under the plant's Technical Requirements Manual (TRM).

During the audit process, the NRC staff reviewed the modification package that addresses this issue. The modification package details the following hardware modifications:

- In-place replacement of the miniature T1 surface mount choke on the 01-EFP-IL-50001 board with an equivalent component.
- In-place replacement of the miniature T1 surface mount choke on the 01-EFP-IL-50006 board with an equivalent component.
- Incorporation of a fusible link in the 01-EFP-IL-50204 cable assembly.
- Full electrical isolation added to the 01-EFP-IL-50007 (USB [Universal Serial Bus] interface) board.

During the audit process, the NRC staff reviewed the modifications performed to address this operating experience issue with respect to equipment qualification. The staff review concludes that: (1) the temperature and humidity ratings of the replacement parts envelop the expected environmental conditions of the wing area of the RAB +21' elevation during a BDBEE, (2) there is no indication that electromagnetic emissions will adversely impact, or be introduced by, the replacement parts, and (3) the mass differences are insufficient to alter the seismic, shock, and vibration response characteristics.

Based on the evaluation above, the NRC staff finds the licensee's proposed instrument qualification process appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

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

In its OIP, the licensee stated that the primary instrument channel will be independent of the backup instrument channel. Independence is obtained by the physical separation of components between channels and a power supply that comes from separate 480 Vac buses. Each instrument channel is normally powered from 120 Vac plant power to support continuous monitoring of SFP level. The primary channel receives power from a different 480 Vac bus than the backup channel. Therefore, loss of any one 480 Vac bus does not result in loss of normal 120 Vac power for both instrument channels. The two permanently mounted instruments in the pool are physically separated.

For the SFP level instrument normal power sources, in its compliance letter the licensee further stated that Channel "A" is powered by LP 312PA, and Channel "B" is powered by LP 313PB. LP 312PA is fed power from MCC 3A311S (part of the "A" bus), and LP 313PB is fed power from MCC 3B311-S (part of the "B" bus). Thus, the loss of power supplied to the "A" bus will not result in a loss of power supplied to the "B" bus and vice versa. In addition, the licensee stated that ac power is not credited for restoring power to the instrumentation in the event of an ELAP.

Instead, external batteries will be used to supply power through the external connection ports along the bottom of the battery enclosure. This is captured in procedure FIG-001, Attachment 9.

The NRC staff review concludes that the primary instrument channel is physically and electrically independent of the backup instrument channel. Further discussion of the instrument channels' physical separation is described in Subsection 4.2.2, "Design Features: Arrangement" of this safety evaluation. With the licensee's proposed power arrangement, the electrical functional performance of each level measurement channel would be considered independent of the other channel, and the loss of one power supply would not affect the operation of other independent channel under BDB event conditions.

Based on the evaluation above, the NRC staff finds the licensee's proposed design, with respect to instrument channel independence, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.6 Design Features: Power Supplies

In its OIP, the licensee stated that each instrument channel is normally powered from 120 Vac 60 Hertz plant power to support continuous monitoring of SFP level. The primary channel receives power from a different 480 Vac bus than the backup channel. On loss of normal 120 Vac power, each channel's UPS automatically transfers to a dedicated backup battery. If normal power is restored, the channel will automatically transfer back to the normal ac power. The backup batteries are maintained in a charged state by commercial-grade uninterruptible power supplies. The batteries are sized to be capable of supporting intermittent monitoring for a minimum of 3 days of operation. This provides adequate time to allow the batteries to be replaced or until off-site resources can be deployed by the mitigating strategies resulting from Order EA-12-049. Further, an external connection permits powering the system from any portable dc source.

For the instrument battery backup duty cycle, in its compliance letter, the licensee stated that the instrument testing demonstrates the battery capacity is sufficient for 7 days of continuous operation using conservative instrument power requirements. This permanently installed battery capacity should provide sufficient time to establish a long-term power supply which the licensee indicates will be accomplished using external batteries through the connection ports along the bottom of the battery enclosure.

The NRC staff finds the licensee's proposed power supply design appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.7 Design Features: Accuracy

For the SFP level instrument design accuracy, in its OIP, the licensee stated that the absolute system accuracy is better than ± 3 inches. This accuracy is applicable for normal conditions and the temperature, humidity, chemistry, and radiation levels expected for BDBEE event conditions. The display trends and retains data when powered from either normal or backup power. The licensee stated that: (1) the system automatically swaps to available power (backup battery power or external DC source) when normal power is lost, (2) neither the source of power nor system restoration impact the instrument accuracy, and (3) previously collected data is retained.

In its letter dated September 26, 2013 [Reference 26], the licensee reiterated that instrument channel level accuracy will be ± 3.0 inches for all expected conditions. The expected instrument channel accuracy performance would be approximately ±1 percent of span (based on the sensitive range of the detector). In general relative to normal operating conditions, any applicable calibration procedure tolerances (or acceptance criterion) are planned to be established based on manufacturer's stated/recommended reference accuracy (or design accuracy). The methodology used is planned to be captured in plant procedures and/or programs.

The NRC staff noted that the MOHR instrument's design accuracies and methodology sufficient for maintaining the instrument channels to within their designed accuracies before significant drift can occur. The licensee has demonstrated that the instrument channels' accuracy is not significantly affected by postulated BDBEE conditions. If implemented properly, the instrument channels will maintain the designed accuracy following a power source change or interruption without the need of recalibration.

Based on the evaluation above, the NRC staff finds the licensee's proposed instrument accuracy appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.8 Design Features: Testing

By letter dated September 26, 2013 [Reference 26], the licensee stated that the level instrument automatically monitors the integrity of its level measurement system using in-situ capability. Deviation of measured test parameters from manufactured or as-installed configuration beyond a configurable threshold prompts operator intervention. Periodic calibration checks of the signal processor electronics to extrinsic National Institute of Standards and Technology (NIST)-traceable standards can be achieved through the use of standard measurement and test equipment. The probe itself is a perforated tubular coaxial waveguide with defined geometry and is not calibrated. It is planned to be periodically inspected electromagnetically using TDR at the probe hardline cable connector to demonstrate that the probe assembly meets its manufactured specification and visually to demonstrate that there has been no mechanical deformation or fouling. Each instrument electronically logs a record of measurement values over time in nonvolatile memory that is compared to demonstrate constancy, including any changes in pool level, such as that associated with the normal evaporative loss/refilling cycle. The channel level measurements can be directly compared to each other (i.e., regular cross-channel comparisons). The two displays are installed in close proximity to each other, thus simplifying cross channel checks. Direct measurements of SFP level may be used for diagnostic purposes if cross-channel comparisons are anomalous.

By letter dated September 26, 2013 [Reference 26], the licensee stated that performance tests (functional checks) are automated and/or semi-automated (requiring limited operator interaction) and are performed through the instrument menu software and initiated by the operator. There are a number of other internal system tests that are performed by system software on an essentially continuous basis without user intervention, but which can also be performed on an on-demand basis with diagnostic output to the display for the operator to review. Other tests such as menu button tests, level alarm, and alarm relay tests are only initiated manually by the operator. Performance checks are described in detail in the vendor operator's manual, and the applicable information is planned to be contained in plant operating procedures. Performance tests are planned to be performed periodically as recommended by the equipment vendor, for instance quarterly but no less often than the calibration interval of two years.

By letter dated September 26, 2013 [Reference 26], the licensee stated that calibration and operator performance checks are planned to be performed in a periodic scheduled fashion with additional maintenance on an as-needed basis when flagged by the system's automated diagnostic testing features. Channel calibration tests per maintenance procedures with limits established in consideration of vendor equipment specifications are planned to be performed at frequencies established in consideration of vendor recommendations.

The NRC staff noted that the SFP level instrumentation is adequately designed to provide the capability for routine testing and calibration including in-situ testing/calibration. By comparing the level reading of the instrument channels with the maximum level allowed deviation for the instrument channel design accuracy, the operators could determine if recalibration or troubleshooting is needed.

Based on the evaluation above, the staff finds the licensee's proposed SFP instrumentation design allows for testing appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.9 Design Features: Display

In its compliance letter the licensee stated that the processor/display for each channel will be located on the RAB +21' elevation in the wing area. The wing area can be approached from the MCR by descending one of two stairwells adjacent to the MCR. The primary and backup channel displays can be considered promptly accessible, because station operators can obtain SFP level data trends and report those to decision makers within 30 minutes of request. To confirm this, a simulated walk down was performed for one of the routes from the MCR to the SFPI Displays. A time of less than 5 minutes was timed during the simulated walk down. There were no apparent obstructions or lighting issues identified during the walk down, and there is adequate time margin allowing for any obstructions that may be in the path. Additionally, operators carry flashlights in case of lighting issues. The impact to habitability would be primarily from elevated temperatures, as the RAB wing area is considered a mild radiation environment. Habitability will be assured by heat stress countermeasures and rotation of personnel to the extent feasible. Personnel will not be continuously stationed at the backup display, it will be monitored periodically. The site FSGs will provide guidance for personnel to evaluate the room temperature and take actions as necessary. In addition, this area is utilized as part of the overall FLEX BDBEE strategy and habitability for that strategy bounds the activity of reading the instruments.

The NRC staff review notes that if implemented properly, the displays will provide continuous indication of SFP water level. The displays are located in seismically qualified buildings and based on the staff audit walk down, the accessibility of the display area following an ELAP event is considered acceptable.

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

4.3 Evaluation of Programmatic Controls

Order EA-12-051 specified that the SFPI 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 SFPI.

4.3.1 Programmatic Controls: Training

In its OIP, the licensee stated that the SAT will be used to identify the population to be trained and to determine both the initial and continuing elements of the required training. According to the licensee's OIP, training will be completed prior to placing the instrumentation in service. The NRC staff finds that the use of the SAT to identify the training population and to determine both the elements of the required training is in accordance with the provisions of NEI 12-02. Therefore, the licensee's proposed plan to train personnel in the operation, maintenance, calibration, and surveillance of the SFPI, including the approach to identify the population to be trained, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.3.2 Programmatic Controls: Procedures

In its OIP, the licensee stated that procedures for maintenance and testing will be developed using regulatory guidelines and vendor instructions. The BDBEE event operational guidance will also address the following:

- A strategy to ensure SFP water addition is initiated at an appropriate time consistent with the implementation of NEI 12-06.
- Restoration of non-functioning SFP level channels after an event. Restoration timing will be consistent with the emergency condition. After an event, commercially available components that may not meet all qualifications may be used to replace components to restore functionality.

In its compliance letter, the licensee further stated that the calibration and test procedures are provided in the MOHR technical manuals. The objectives are to measure system performance, determine if there is a deviation from normal tolerances, and return the system to normal tolerances. Diagnostic procedures are provided as automated and semi-automated routines in system software alerting the operator to abnormal deviation in selected system parameters such as battery voltage, 4-20 milliamp loop continuity, and TDR waveform of the transmission cable. The technical objective of the diagnostic procedures is to identify system conditions that require operator attention to ensure continued reliable liquid level measurement. Manual diagnostic procedures are also provided in the event that further workup is determined to be necessary. Maintenance procedures are provided in the technical manual. These allow a technician trained in EFP-IL system maintenance to ensure that system functionality is maintained. The licensee's compliance letter stated that a SFPI calibration procedure was being developed in accordance with vendor technical manual requirements and work orders were issued to complete the calibrations. In addition, the licensee provided a list of plant procedures related to the SFPI in the compliance letter.

The NRC staff review concludes that procedures have been established for the testing, surveillance, calibration, and operation of the primary and backup SFP level instrument channels. The staff finds that the licensee's proposed procedures appear to be consistent with NEI 12-02, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.3.3 Programmatic Controls: Testing and Calibration

In its compliance letter, the licensee stated that SFPI maintenance and testing program requirements to ensure design and system readiness have been established in accordance with Entergy's processes and procedures and in consideration of vendor recommendations to ensure that appropriate regular testing, channel checks, functional tests, periodic calibration, and maintenance is performed. Both primary and backup SFPI channels incorporate permanent installation (with no reliance on portable, post-event installation) of relatively simple and robust augmented quality equipment. Permanent installation coupled with stocking of adequate spare parts reasonably diminishes the likelihood that a single channel (and greatly diminishes the likelihood that both channels) is (are) out-of-service for an extended period of time. Control of compensatory actions for out of service SFPI channel(s) is controlled by inclusion in the plant's TRM, Section 3.13.1.

In TRM 3.13.1, the licensee includes actions for SFP level instrument out-of-service as below:

- If one instrument channel inoperable, restore the SFP level instrument within 90 days or implement compensatory measures.
- If both instrument channels inoperable, within 24 hours initiate actions to restore one of the channels and within 72 hours implement compensatory measures.

The NRC staff review concludes that the necessary controls for the testing and calibration of the primary and backup SFP level instruments are in place to maintain the instrument channels at the design accuracy. Based on the review performed during the audit process, the testing and calibration procedures appear to be consistent with the vendor recommendations. Additionally, compensatory actions for instrument channel(s) out-of-service appear to be managed consistent with the guidance in NEI 12-02.

Based on the evaluation above, the staff finds that the licensee's proposed testing and calibration plan appears to be consistent with NEI 12-02, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.4 Conclusions for Order EA-12-051

In its compliance letter dated January 18, 2016 [Reference 34], 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 Waterford 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 at Waterford in July 2015 [Reference 19]. The licensee reached its final compliance dates for Orders EA-12-049 and EA-12-051 on May 26, 2016, and November 23, 2015, respectively. The licensee has declared that the site is 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 that if implemented appropriately should 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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WATERFORD STEAM ELECTRIC STATION, UNIT 3 – SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051

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