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

December 19, 2016

Mr. Bryan C. Hanson
Senior Vice President
Exelon Generation Company, LLC
President and Chief Nuclear Officer
Exelon Nuclear
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: BYRON STATION, UNITS 1 AND 2 - SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 (CAC NOS. MF0893, MF0894, MF0872, AND MF0873)

Dear Mr. Hanson:

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. ML13060A364), Exelon Generation Company, LLC (Exelon, the licensee) submitted its OIP for Byron Station, Units 1 and 2 (Byron) 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 December 17, 2013 (ADAMS Accession No. ML13225A595), and December 17, 2014 (ADAMS Accession No. ML14336A569), the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated November 30, 2015 (ADAMS Accession No. ML15335A390), Exelon submitted a compliance letter for Byron, Unit 1 and by letter dated July 15, 2016, Exelon submitted a compliance letter for Byron , Unit 2, which included the FIP for Byron, Units 1 and 2 (ADAMS Accession No. ML16197A390). The compliance letters stated that the licensee had achieved full compliance with Order EA-12-049 for the respective unit.

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A265), Exelon submitted its OIP for Byron 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 4, 2013 (ADAMS Accession No. ML13275A305), and December 17, 2014 (ADAMS Accession No. ML14336A569), 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 December 8, 2014 (ADAMS Accession No. ML14342A965), Exelon 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 Exelon's strategies for Byron. The intent of the safety evaluation is to inform Exelon 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 John Hughey, Orders Management Branch, Byron Project Manager, at 301-415-3204 or at John.Hughey@nrc.gov.

Sincerely,

Mandy K Halter

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

Docket Nos.: 50-454 and 50-455

Enclosure:
Safety Evaluation

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

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

EXELON GENERATION COMPANY, LLC

BYRON STATION, UNITS 1 AND 2

DOCKET NOS. 50-454 AND 50-455

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 (SFPLI) 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

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(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)-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," Rev. 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, Rev. 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 SFPLI. Specific requirements of the order are listed below:

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

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

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

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

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

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

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

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

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

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

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

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

On August 24, 2012, following several NEI submittals and discussions in public meetings with NRC staff, the NEI submitted document NEI 12-02, "Industry Guidance for Compliance With NRC Order EA-12-051, To Modify Licenses With Regard to Reliable Spent Fuel Pool Instrumentation," Rev. 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, Rev. 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], Exelon Generation Company, LLC (Exelon, the licensee) submitted an Overall Integrated Plan (OIP) for Byron Station, Units 1 and 2 (Byron) 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 27, 2015 [Reference 14], August 28, 2015 [Reference 42], and February 26, 2016 [Reference 43], the licensee submitted six-month updates to the OIP. By letter dated August 28, 2013 [Reference 15], 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 33]. By letters dated December 17, 2013 [Reference 16] and December 17, 2014 [Reference 17], the NRC issued an Interim Staff Evaluation (ISE) and an audit report on the licensee's progress. By letter dated November 30, 2015 [Reference 18], the licensee reported that full compliance with the requirements of Order EA-12-049 was achieved for Byron, Unit 1. By letter dated July 15, 2016, [Reference 47] the licensee reported full compliance with the requirements of Order EA-12-049 was achieved for Byron, Unit 2 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.

Byron is a Westinghouse 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 the FIP, is summarized below.

Following the occurrence of an ELAP/loss of UHS, both reactors are assumed to trip from full power and the plants will stabilize at no-load reactor coolant system (RCS) temperature and pressure conditions with reactor decay heat removal via steam release to the atmosphere through the main steam safety valves (MSSVs) and/or the steam generator (SG) power-operated relief valves (PORVs). The reactor coolant pumps (RCPs) coast down and flow in the reactor coolant system (RCS) transitions to natural circulation. The diesel-driven auxiliary feedwater (DDAF) pump will provide flow from the condensate storage tank (CST) to the SGs to makeup for steam release. If the CST is not available, operators will align the essential service water cooling tower (SXCT), which serves as the UHS, to the DDAF pump. Operators will respond to the event in accordance with emergency operating procedures (EOPs) to confirm RCS, secondary system, and containment conditions. Operators will take prompt actions to minimize RCS inventory losses by isolating potential RCS letdown paths, verify containment isolation, reduce dc loads on the station Class 1E batteries, and establish electrical equipment alignment in preparation for eventual power restoration. Operators will re-align auxiliary feedwater (AF) flow to all SGs, establish manual control of the SG PORVs, and initiate a rapid cooldown of the RCS below the MSSV opening pressure. The cooldown will be initiated as soon as possible, resources permitting, but no later than eight hours after event initiation. Operators will maintain manual control of the AF flow to the SGs and PORVs to control steam release and the RCS cooldown rate as necessary. Water from the safety injection (SI) accumulators will provide the initial boration for reactivity control and RCS inventory addition. The RCS temperature will be maintained at approximately 410 degrees Fahrenheit (°F) by controlling SG pressure at approximately 260 pounds per square inch gauge (psig) in order to ensure maximum SI accumulator injection while preventing nitrogen injection.

The Phase 2 FLEX strategy provides an indefinite supply of water for feeding the SGs using the installed DDAF pump. A FLEX diesel generator (DG) will be deployed to power a deep well water pump to maintain inventory in the essential SXCT. The medium-pressure FLEX pump will be deployed with hoses to take a suction from the SXCT and serve as a backup source of water to the SGs. The deep well water will serve as the long-term source of water to the SGs via the SXCT and DDAF pump or via the medium-pressure FLEX pump. The RCS temperature will still be maintained at approximately 410°F by controlling SG pressure at approximately 260 psig. Subsequent longer-term inventory and boration makeup will be accomplished through the use of a high pressure FLEX pump, connected from the borated refueling water storage tank (RWST) to a primary or alternate RCS injection connection. Inventory and shutdown margin calculations indicate that the licensee needs to add 6000 gallons of RWST water to the RCS and commence makeup before 16 hours.

The Phase 3 strategy for reactor core cooling and heat removal and RCS inventory control utilizes Phase 2 connections and includes additional equipment available from the National Strategic Alliance of FLEX Emergency Response (SAFER) Response Center (NSRC) to provide backup as necessary.

The icensele addressed containment integrity following an ELAP initiated in Modes 1-4. Containment cooling is lost for an extended period of time. Therefore, containment temperature and pressure will slowly increase. The operators will verify containment isolation as directed by the EOPs. Containment status will be monitored by the main control room operators. Containment temperature and pressure design limits are not expected to be approached. The Phase 2 strategy is to continue monitoring containment temperature and pressure using installed instrumentation. The Phase 3 strategy continues the Phase 2 strategy and includes additional equipment available from the NSCR to provide backup as necessary.

The Byron SFP is a common pool designed for both Unit 1 and Unit 2. For Phase 1, the basic FLEX strategy for maintaining SFP cooling is to monitor SFP level and provide sufficient makeup water to the SFP to maintain the normal SFP level. Byron has installed the new SFP level monitoring systems to meet NRC Order EA-12-051 requirements. During Phase 2, power for the makeup function will be supplied from the FLEX DG to the refueling water purification pump to provide the primary method for SFP cooling and makeup. The RWST will be the primary source of water. Alternate SFP makeup will be from the medium-pressure FLEX pump taking a suction via hoses from the deep well water system and discharging to the SFP via monitor guns. The licensee will vent the SFP area by opening the fuel handling building trackway roll-up door. Manual actions required in the fuel handling building will be performed prior to the onset of SFP boiling and prior to reaching an adverse environment in the area. The Phase 2 strategy is to continue SFP makeup on demand using the installed refueling water purification pump powered from the FLEX DG. The alternate source of SFP makeup will continue to be via the hoses routed from the deep well water system to the medium head FLEX pump to hoses to the SFP. The Phase 3 strategy for SFP cooling utilizes Phase 2 connections and includes additional equipment available from the NSRC to provide backup as necessary.

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

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

3.2.1 Core Cooling Strategy and RCS Makeup

3.2.1.1 Core Cooling Strategy

3.2.1.1.1 Phase 1

In the FIP, Section 2.3.1 states that following the occurrence of an ELAP/loss of UHS event, natural circulation of the RCS will develop to provide core cooling. As stated in Byron's FIP, the heat sink for core cooling in Phase 1 would be provided by the four SGs, which will be fed simultaneously by the unit's DDAF pump with inventory supplied from the CST. Byron's CST has a capacity of 500,000 gallons, but is not robust to all applicable hazards. In the event that the CST is not available Byron's DDAF pump is designed to transfer its suction to the essential service water (SX) system. The SX suction source is comprised of two cooling tower basins containing approximately 306,000 gallons each. The SX system and DDAF pump are safety-related systems that are robust to all applicable hazards.

Operators will respond to the ELAP/loss of UHS event in accordance with emergency operating procedures to confirm the RCS, SG, and containment conditions are in the expected ranges. A transition to the Station Blackout Procedure will be made upon the diagnosis of the total loss of ac power. The operators re-align auxiliary feedwater flow to all SGs, establish manual control of the safety-related SG power-operated relief valves (PORVs), and initiate a rapid cooldown of the reactor coolant system to minimize inventory loss through the RCP seals.

Following the closure of the main steam isolation valves (MSIVs), as would be expected in an ELAP event, steam release from the SGs to the atmosphere would be accomplished via the SG MSSVs or PORVs. During the ELAP event the SG PORVs will be operated by means of local manual action. The licensee has provided sound powered phones in a low noise area adjacent to the MSSV rooms. Operators will be able to communicate with the control room and then enter the MSSV room to make necessary adjustments to the PORV positions. This flow path is robust with respect to all applicable hazards. Missile barriers have been added to protect the PORV local controls from wind driven missiles.

Byron'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 UHS event. Over a period of approximately 4 hours, Byron will gradually cool down the RCS from post-trip conditions until a SG pressure of 260 psig is reached. A minimum SG pressure of 260 psig is set to avoid the injection of nitrogen gas from the SI accumulators into the RCS while maximizing the injection of borated water. Cooldown and depressurization of the RCS significantly extends the expected coping time under ELAP/loss of UHS conditions because it provides for an initial addition of RCS inventory offsetting the volume lost due to system leakage and temperature related contraction, as well as providing the initial boration.

3.2.1.1.2 Phase 2

Byron'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 DDAF pump. Although functionality of the DDAF pump is expected throughout Phase 2 per the NEI 12-06 assumptions associated with the analyzed ELAP event, to satisfy provisions of the order, the licensee will pre-stage a portable medium-pressure FLEX pump that is capable of backing up this essential function. In the FIP, Section 2.3.2 states that during the Phase 2 FLEX Strategy a medium-pressure FLEX pump will be deployed near the RWST tunnel hatch with suction hoses routed to the FLEX connection in the Essential SXCT valve chamber, which is the water source to the SGs. The discharge hose of the medium-pressure FLEX pump will be routed to the primary SG FLEX connection in the B/C MSIV room or to the alternate connection in the A/D MSIV room to provide a backup source of feedwater to the SGs. This pump will be pre-staged and connected at 20 hours after the initiation of the ELAP event.

According to Byron's FIP, the supply of water in the SXCT basins can be replaced by deep well water (WW) pumps. Each of the SXCT basins has a WW pump dedicated to it. To provide an unlimited source of secondary makeup in Phase 2, a FLEX DG will power the WW pumps. These pumps will draw suction from an aquifer and refill the SXCT basins via piping routed to each basin. Byron has chemically evaluated the water supplied from the wells and calculated that the use of SX water as feedwater for the SGs will result in a gradual loss of heat transfer capabilities in the SGs. Based on these calculations Unit 1 will experience a loss of 3.5 percent and Unit 2 will experience a loss of 5.8 percent through the first 72 hours. Byron calculated that the SGs could experience a loss of up to 67 percent and still meet their heat removal requirements for 72 hours and beyond. This coping time should allow ample margin for the deployment of water treatment equipment from the NSRC in Phase 3.

In the event that the FLEX AF pump is required to backup the DDAF pump function, one of three portable diesel-driven pumps rated for a capacity of 300 gallons per minute (gpm) at 500 psig are available and stored onsite in a storage building. Byron's FIP describes the pump primary and alternate connection strategies. The connection for suction to the FLEX medium-pressure pump is configured such that either WW pump can supply water through a FLEX connection and hose. The FLEX medium-pressure pump would be located near the RWST tunnel hatch. This pump would discharge via hoses routed to a primary or secondary connection. The primary connection point is in the B/C MSIV room. The alternate connection point is located in the A/D MSIV room. The connection of hoses in the main steam tunnel will allow all four SGs to be fed from the FLEX medium-pressure pump.

3.2.1.1.3 Phase 3

Per the Byron FIP, the licensee's core cooling strategy for Phase 3 is a continuation of the Phase 2 strategy with additional offsite equipment provided from the NSRC. Core cooling will continue to be provided by the SGs with feedwater supplied by either the DDAF pump, the diesel driven FLEX medium-pressure pump, or by Phase 3 equipment provided by the NSRC. Phase 3 pumps from the NSRC can connect to the Phase 2 connection points and inject into the SGs to provide cooling. In addition, a water purification skid from the NSRC can be used to treat feedwater providing cleaner water to reduce the amount of degradation of heat transfer in the SGs.

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 UHS event, operators will isolate RCS letdown pathways and confirm the existence of natural circulation flow in the RCS. A small amount of RCS leakage will occur through the low-leakage 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 6 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, injection of the borated inventory from the nitrogen-pressurized accumulators will be maximized. Following depressurization of the SGs to 260 psig, the licensee's procedures direct accumulator isolation once electrical power is restored to the corresponding isolation valves via FLEX equipment. Per its FIP, the licensee estimated that actions to effect accumulator isolation should be completed by approximately 16 hours into the event.

3.2.1.2.2 Phase 2

In Phase 2, RCS inventory control and boration is accomplished with portable equipment from the FLEX storage building. In the course of cooling and depressurizing the SGs to a target pressure of 260 psig, a significant fraction of the accumulator liquid inventory will inject into the RCS, filling volume vacated by the thermally induced contraction of RCS coolant and system leakage. The RCS boration will commence using a portable high-pressure FLEX pump no later than 14 hours into the ELAP/loss of UHS event. With low-leakage Westinghouse Generation 3 SHIELD RCP seals installed on all RCPs, Byron calculates that FLEX RCS makeup is not necessary to prevent the loss of single-phase natural circulation for at least 58 hours into the event. Therefore, the injection of borated RCS makeup water for reactivity control will be in progress long before entry into reflux cooling becomes a concern.

The Phase 2 portable high-pressure FLEX pump has a capacity of 40 gpm at 1550 psig. The pump will be aligned to take suction from the RWST, which has a borated volume of at least 395,000 gallons. The RWST is maintained at a boron concentration of 2300 to 2500 parts per million (ppm). The FLEX high-pressure pump can be aligned to discharge through hoses to either the charging header (primary strategy) or alternate connections in the SI system. Per Byron's FIP, the FLEX high-pressure pump will be deployed and aligned within 14 hours from initiation of the ELAP event. The boration must be started within 16 hours per licensee calculations. This will allow for 2 hours margin to the time of deployment.

3.2.1.2.3 Phase 3

The Phase 3 strategy for indefinite RCS inventory control and subcriticality is simply a continuation of the Phase 2 strategy, with backup pumps and water treatment equipment supplied by the NSRC. To facilitate the use of higher quality water for RCS makeup, as necessary, the FIP states that the licensee will use water purification equipment from the NSRC to treat water that will be used for core cooling. Per the SAFER response plan, Byron will receive the mobile boration skid. With this skid, water can continue to be borated to inject into the RCS indefinitely.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

The licensee stated in its FIP, that the Byron site grade level is above the external flood water level. The water surface elevation from external flooding at the site is evaluated as approximately 160.7 ft. below the grade level based on the probable maximum flood (PMF) along Rock River, which is about 2.2 miles from the plant site. In addition, flooding from hypothetical failure of upstream dams is not a threat to the plant. The site maximum flood water level from probable maximum precipitation (PMP) on the plant area will be above the plant grade level. The licensee stated in the FIP that the FLEX storage robust building (FSRB) is constructed above the flood level. The licensee provided an assessment during the NRC audit stating that the deployment path of FLEX equipment from the FSRB will experience a maximum flood height of less than 1 ft. Based on Byron's calculation, the maximum flood height from the PMP occurs 40 minutes after the maximum rainfall and the height of the water then dissipates to several inches in less than an hour. The FLEX vehicles and trailers can successfully be deployed along the haul paths under these conditions. Therefore, there are no variations to the core cooling strategy in the event of a flood. Refer to section 3.5.2 of this safety evaluation (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

The Phase 1 FLEX strategy relies on the DDAF Pump as the motive force to provide makeup to the SGs for decay heat removal from the reactor core with a suction from the CST or the SXCT. In addition, operators take manual control of the SG PORVs for steam release to control the cooldown of the RCS.

In Byron's Updated Final Safety Analysis Report (UFSAR), Section 10.4.9.2 states that the AF system consists of two subsystems, one of which uses a pump that is directly powered by a diesel engine through a gear increaser (i.e., DDAF Pump). In the UFSAR, Table 3.2-1 indicates that the AF system is classified as Safety Category I, which is defined in UFSAR Section 3.2.1.1 as those SSCs important to safety that are designed to remain functional in the event of the safe shutdown earthquake (SSE) and other design-basis events (including tornado, PMF, and , missile impact). Based on the design of the DDAF pump and system, the staff finds this system is robust and available during an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

In the UFSAR, Section 5.2.2.5.1.2 states that the SG PORVs are installed in a Safety Category I valve room immediately outside the containment. Furthermore, FIP Section 2.7 states that missile barriers have been placed outside of the 1/2B and 1/2C MSSV rooms to protect the local controls for 1/2B and 1/2C MS PORVs to ensure they are available as a steam release path. Based on the location of the PORVs and the design of the missile barriers, the NRC staff finds that the SG PORVs, including the local controls, are robust and available during an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Consistent with the baseline capability in NEI 12-06, Table D-1, the licensee has the ability for local manual control of AF flow to the SGs and manual control of the SG PORVs to control steam release and is directed by existing plant procedures.

3.2.3.1.2 Plant Instrumentation

According to the Byron FIP, the following instrumentation will be relied upon to support the licensee's core cooling and RCS inventory control strategy. These instruments are monitored from the Control Room and will be available throughout the event.

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

- RCS pressure (wide range)
- Reactor vessel level indicating system (RVLIS)
- AF flow rate
- AF suction pressure
- Core exit thermocouples
- CST level
- Neutron monitor (PANM)
- DC bus voltage
- Containment pressure and temperature
- Pressurizer level
- SI accumulator level
- RWST level

All of these instruments are powered by installed safety-related station batteries. To prevent a loss of vital instrumentation, operators will extend battery life to a minimum of 8 hours by shedding unnecessary loads. The load shedding will be completed within 65 minutes from the initiation of the ELAP event. A FLEX DG (480 Volt alternating current (Vac)) will be deployed to repower the battery chargers within 6 hours of the ELAP event initiation. This leaves a margin of at least 2 hours prior to depletion of the associated batteries. The battery could also be energized by the opposite units dc bus using a cross-tie.

The licensee's FIP states that procedures have been developed to read the above instrumentation locally using a portable instrument, where applicable. Guidance document FLEX Support Guideline (FSG) - 7, "Loss of Vital Instrumentation or Control Power," provides the guidance for alternate monitoring.

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. Based on the information provided by the licensee, the NRC staff understands that indication for the above instruments would be available and accessible continuously throughout the ELAP event.

3.2.3.2 Thermal-Hydraulic Analyses

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

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

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

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

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

During the audit, the NRC staff evaluated a comparison of the generic analysis values from WCAP-17601-P and PWROG-14064-P to the Byron plant-specific values. The NRC staff concurred that the generic plant parameters were bounding for the analyzed event. Byron has installed low-leakage SHIELD shutdown seals; therefore, the seal leakage expected for Byron is significantly less than assumed in the generic NOTRUMP analysis case. The NRC staff concluded, based on the licensee's evaluation, that the licensee could maintain natural circulation flow in the RCS at least 58 hours for single phase and 71 hours for two-phase during the ELAP event without RCS makeup. The RCS makeup will be available per the licensee's mitigating strategy for shutdown margin at approximately 14 hours following the initiation of the ELAP event, thus, the licensee's strategy for RCS makeup provides sufficient margin to the onset of reflux cooling.

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 (RCP) Seals

Leakage from the 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, resulting in increased leakage and the potential for failure of elastomeric o-rings and other components, which could further increase the leakage rate. As discussed above, as long as adequate inventory is maintained in the RCS, natural circulation can effectively transfer residual heat from the reactor core to the SGs and limit local 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.

Per the FIP, the licensee credits Generation 3 SHIELD low leakage seals for FLEX strategies including RCS inventory control and boration. The low leakage seals limit the total RCS leak rate to no more than 5 gpm (1 gpm per RCP seal and 1 gpm of unidentified RCS leakage in accordance with Technical Specification).

The SHIELD low leakage seals are credited in the FLEX strategies in accordance with the four conditions identified in the NRC's endorsement letter of TR-FSE-14-1-P, "Use of Westinghouse SHIELD Passive Shutdown Seal for FLEX Strategies," dated May 28, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14132A128). In its FIP, the licensee describes compliance with each condition of SHIELD seal use as follows:

(1) Credit for the SHIELD seals is only endorsed for Westinghouse RCP Models 93, 93A, and 93A-1.

This condition is satisfied because, as stated in FIP, the RCPs for Byron, Unit 1 and Unit 2 are Westinghouse Model 93A.

(2) The maximum steady-state RCS cold-leg temperature is limited to 571 °F during the ELAP (i.e., the applicable main steam safety valve setpoints result in an RCS cold-leg temperature of 571 °F or less after a brief post-trip transient).

As stated in the FIP, the maximum steady-state RCP seal temperature during an ELAP response is expected to be the RCS cold leg temperature corresponding to the lowest SG safety relief valve setting of 1175 psig. This results in an RCS cold leg temperature less than 571 °F. Additional analysis indicates that even in scenarios where cold leg temperatures reach 581 °F during the first 50 minutes following the ELAP event the thermal mass of the RCP internals will cool the incoming fluid to temperatures lower than 571 °F at the seal.

(3) The maximum RCS pressure during the ELAP (notwithstanding the brief pressure transient directly following the reactor trip comparable to that predicted in the applicable analysis case from WCAP-17601-P) is as follows: For Westinghouse Models 93 and 93A-1 RCPs, RCS pressure is limited to 2250 psia; for Westinghouse Model 93A RCPs, RCS pressure is to remain bounded by Figure 7.1-2 of TR-FSE-14-1-P, Rev. 1.

The licensee has assumed in calculations that the RCS operating pressure following the trip and preceding the initial cooldown, will remain essentially constant and above 2100 per square inch absolute (psia). Allowing for the possibility of a brief pressure transient directly following the reactor trip, the NRC staff concludes that the licensee's mitigating strategy of cooling the reactor core via the MSSVs and PORVs will maintain reactor pressure within the limiting maximum pressure for Model 93A RCP seals, and as the initial cooldown and depressurization step will be completed approximately 6 hours after initiation of the ELAP event, the requirements of Figure 7.1-2 of TR-FSE-14-1-P, Rev. 1 will also be met.

(4) Nuclear power plants that credit the SHIELD seal in an ELAP analysis shall assume the normal seal leakage rate before SHIELD seal actuation and a constant seal leakage rate of 1.0 gpm for the leakage after SHIELD seal actuation.

The licensee's supporting calculations assume Westinghouse SHIELD RCP seal package leakage rate of 5 gpm per RCP for first 30 mins of the event and then a constant leakage rate of 1 gpm per RCP. An additional 1 gpm of unidentified RCS leakage rate is assumed based on maximum unidentified leakage in accordance with Byron's Technical Specifications. As noted previously, Exelon's calculation indicates that reflux cooling would not be entered for at least 71 hours into the event, even if FLEX RCS makeup flow were not provided as planned. Since Exelon's mitigating strategy directs RCS makeup to begin approximately 14 hours after event initiation, ample margin exists to accommodate the small additional volume of leakage that is expected to occur before actuation of the SHIELD seals.

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

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 subcriticality at post-trip conditions. However, as the ELAP event progresses, the shutdown margin for PWRs is typically affected by several primary factors:

- the cooldown of the RCS and fuel rods adds positive reactivity
- the concentration of xenon-135, which (according to the core operating history assumed in NEI 12-06) would
  - o initially increase above its equilibrium value following reactor trip, thereby adding negative reactivity
  - o 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 recriticality will not occur during a FLEX RCS cooldown.

During the audit, the NRC staff reviewed the licensee's shutdown margin analysis. The licensee will utilize a combination of borated water injected from the SI accumulators and borated water injected by a portable high pressure pump taking suction from the RWST to ensure that adequate shutdown margin (1 percent shutdown margin) is maintained. Primary and alternate injection pathways to the RCS cold legs are available (i.e., FLEX connections to the Chemical and Volume Control System and the SI system). The licensee determined that this strategy will provide a minimum of 6000 gallons of 2300 ppm boric acid solution to the RCS from the RWST; this available boric acid solution, in combination with the coolant injected from the SI accumulators, is sufficient to maintain at least 1 percent shutdown margin in the RCS, even as the RCS cools down and xenon decays.

Toward the end of an operating cycle, when RCS boron concentration reaches its minimum value, some PWR licensees may need to vent the RCS to ensure that their FLEX strategies can inject a volume of borated coolant that is sufficient to satisfy shutdown margin requirements. The licensee's calculations concluded that, because the RCS volume shrinks as it cools down, the required volume of boric acid solution could be injected without having to vent the RCS. In the event that it is necessary to vent the RCS, procedural direction has been provided to vent through the head vent valves, or as an alternative through the PORVs.

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 (ADAMS Accession No. ML13276A183), 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.

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.

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.

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.

During the audit review, Exelon confirmed that Byron complies with the August 15, 2013, position paper on boric acid mixing, including the above conditions imposed in the staff's corresponding endorsement letter. The NRC staff's audit review indicated that the licensee's shutdown margin calculations are generally consistent with the PWROG's position paper, 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 Phase 2 FLEX strategy relies on two different types of diesel driven portable pumps. A medium-pressure FLEX pump will be used in the backup strategy for the DDAF pump, which can be used to as a suction source to the DDAF or supply the SGs directly, following the initial cooldown. This pump has a nominal rating of 500 psig at 300 gpm and is sized to provide adequate water for reactor core cooling and heat removal. In addition, a high pressure FLEX pump, with a nominal rating of 1550 psig at 40 gpm, will be used to provide RCS makeup and boration and is sized adequately for RCS inventory and reactivity control. The NRC staff noted that the performance criteria for the FLEX Phase 3 portable pumps are consistent or exceed the FLEX Phase 2 portable pumps capacities. See Section 3.10 for detailed discussion of the availability and robustness of each water source. \

During its audit, the staff was able to confirm that flow rates and pressures evaluated in the hydraulic analyses (BYR13-144/BRW-13-0160-M, Rev. 0, "FLEX Pump Sizing and Hydraulic Analysis," dated April 2014) were reflected in the FIP for the respective SG and reactor coolant system makeup strategies based upon the above FLEX pumps being diesel driven and their respective FLEX connections being made as directed by the FSGs. In addition, the staff noted that the evaluation considered additional hose length for conservatism to account for pump deployment locations, hose bends and other hose manipulations. During the onsite audit, the staff conducted a walk down of the hose deployment routes for the above FLEX pumps and was able to confirm the evaluations of the pump staging locations, hose distance runs, and connection points are described in the above hydraulic analyses and FIP.

Based on the staff's review of the FLEX pumping capabilities, as described in the above hydraulic analyses and the FIP, the licensee has demonstrated that its medium-pressure and high pressure FLEX pumps should perform as intended to support core cooling and reactor coolant system makeup during an ELAP caused by an BDBEE, 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 the UHS (LUHS). The electrical strategies described in the FIP are practically identical for maintaining or restoring core cooling, containment, and SFP cooling, except as noted in Sections 3.3.4.4 and 3.4.4.4 of this SE.

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

During the first phase of the ELAP event, Byron 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 (reactor core cooling, RCS inventory control, and containment integrity). The Byron Class 1E station batteries and associated dc distribution systems are located within a Seismic Category I structure. The Class 1E station batteries and all credited installed electrical equipment are therefore protected from the applicable extreme external hazards. The licensee's procedures 1BCA-0.0, "Loss of All AC Power Unit 1," Rev. 205, 2BCA-0.0, "Loss of All AC Power Unit 2," Rev. 210, 1BFSG-4, "ELAP DC Bus Load Shed/Management Unit 1," Rev. 0, and 2BFSG-4, "ELAP DC Bus Load Shed/Management Unit 2," Rev. 2, 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 within 35 minutes and complete load shedding within 65 minutes from the onset of an ELAP/LUHS event.

Each unit at Byron has two Class 1E station batteries that were manufactured by C&D Technologies. The Class 1E station batteries are model LCUN-29 and LCUN-33 with a nominal 8-hour rating of 2320 ampere-hours at 1.75 Vdc.

The NRC staff reviewed the licensee's dc coping calculation BYR14-060/BRW-14-0080-E, "Unit 1(2) 125 VDC Battery FLEX Coping Calculation for Beyond Design Basis," Rev. 0, which verified the capability of the dc system to supply power to the required loads during the first phase of the Byron FLEX mitigation strategy plan for an ELAP. 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 65 minutes to ensure battery operation for at least 8 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 the Byron, Units 1 and 2, dc systems have adequate capacity and capability to power the loads required to mitigate the consequences during Phase 1 of an ELAP provided that necessary load shedding is completed within the times assumed in the licensee's analysis.

The licensee's Phase 2 strategy includes a primary and alternate strategy for repowering 480 Vac buses within 6 hours after initiation of an ELAP using portable 350-kilowatt (kW) (one per unit) 480 Vac FLEX DGs. The portable 480 Vac FLEX DGs would supply power to Byron's vital 480 Vac vital bus circuits providing continuity of key parameter monitoring and other required loads. The primary strategy would provide power to vital battery chargers, battery room exhaust fans, Main Control Room (MCR) lighting, alternate SFP cooling (refueling water purification pump), SFPLI, DDAF pump battery chargers, lights and ventilation for DDAF pumps and valve operating areas, train B diesel fuel oil transfer pumps, and safety injection accumulator isolation valves. The alternate strategy would provide power to the battery room exhaust fans, alternate SFP cooling (refueling water purification pump), SFPLI, DDAF pump battery chargers, lights and ventilation for DDAF pumps and valve operating areas, train B diesel fuel oil transfer pumps, and safety injection accumulator isolation valves.

The NRC staff reviewed licensee calculation BYR13-180, "FLEX 480V Bus Connection Equipment Sizing," Rev. 1, conceptual single line diagrams, and the separation and isolation of the FLEX DGs from the EDGs. Based on the NRC staff's review of the calculation (BYR13-180), the minimum required loads for the licensee's primary strategy on the Phase 2 350 kW FLEX DG is 190 kW for each Byron unit. The minimum required loads for the alternate strategy on the Phase 2 350 kW FLEX DGs is 82 kW for each Byron unit. Therefore, one 350 kW FLEX DG per unit is adequate to support the electrical loads required for the licensee's Phase 2 strategies.

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, Rev. 0, for spare equipment capability regarding the Phase 2 FLEX DGs.

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 four (2 per unit) 1-megawatt (MW) 4160 Vac combustion turbine generators (CTGs), two (1 per unit) 1100 kW 480 Vac CTGs, and distribution panels (including cables and connectors). The licensee plans to only connect the 480 Vac CTGs and not the 4160 Vac CTGs. Based on the additional margin available due to the higher capacity (1100 kW) of the 480 Vac CTGs as compared to the Phase 2 FLEX DGs (350 kW), the NRC staff finds that the 480 Vac CTGs being supplied from an NSRC has 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, 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 per unit (250 gpm if overspray occurs). During the event, the licensee selects the SFP makeup method 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 set points 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.

Section 3.2.1.1 in NEI 12-06, 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 and as a result, the pool water will heat up and eventually boil off. The licensee's response is to provide makeup water and the timing of operator actions and the required makeup rates depend on the decay heat level of the fuel assemblies in the SFP. The sections below address the response during operating, pre-fuel transfer or post-fuel transfer operations. The effect of an ELAP event during a full core offload in the SFP is addressed in Section 3.11.

3.3.1 Phase 1

In the FIP, Section 2.6.1 indicates that no actions are required during Phase 1 for SFP makeup because the time to boil is sufficient to deploy Phase 2 equipment. The licensee will monitor SFP water level using reliable SFP level instrumentation installed per Order EA-12-051.

The FIP indicates that for Phase 1, power can be supplied from a FLEX DG to repower the 0A Refueling Water Purification pump with suction from the refueling water storage tank to provide the primary method for SFP cooling and makeup. Furthermore, hoses for alternate SFP makeup will be routed from the medium-pressure FLEX pump through the Fuel Handling Building trackway door to the refueling floor and discharge via monitor guns. A SFP vent path will be provided by opening the Fuel Handling Building trackway roll-up door and activities requiring entry into this building will be performed prior to reaching adverse environmental conditions in the area.

3.3.2 Phase 2

In the FIP, Section 2.6.2 indicates that the Phase 2 strategy is to initiate SFP makeup on demand using the installed 0A Refueling Water Purification Pump or the medium-pressure FLEX pump via hoses routed through the Fuel Handling Building to the SFP. The licensee will have the ability monitor SFP water level using reliable SFPLI installed per Order EA-12-051 and determine when it is necessary for makeup to be provided to the SFP.

3.3.3 Phase 3

In the FIP, Section 2.6.3 indicates that the Phase 3 strategy for the site is to use Phase 2 connections and includes additional equipment available from the NSRC to provide backup as necessary.

3.3.4 Staff Evaluations

3.3.4.1 Availability of Structures, Systems, and Components

3.3.4.1.1 Plant SSCs

Condition 6 of NEI 12-06, Section 3.2.1.3, states that permanent plant equipment contained in structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles, are available. In addition, Section 3.2.1.6 states that the initial SFP conditions are: 1) all boundaries of the SFP are intact, including the liner, gates, transfer canals, etc.; 2) although sloshing may occur during a seismic event, the initial loss of SFP inventory does not preclude access to the refueling deck around the pool; and 3) SFP cooling system is intact, including attached piping.

The staff reviewed the licensee's calculation on habitability on the SFP refuel floor. This calculation and the FIP indicate that boiling begins at approximately 10.94 hours during a normal, non-outage situation. The staff noted that the licensee's sequence of events timeline in the FIP indicate that operators will deploy hoses and spray nozzles as a contingency for SFP makeup within 10.94 hours from event initiation to ensure the SFP area remains habitable for personnel entry. As described in its FIP, the licensee's Phase 1 FLEX strategy does not require any operator actions; however, the licensee does establish a ventilation path to cope with temperature, humidity and condensation from evaporation and/or boiling of the SFP. The operators are directed to open the Fuel Handling Building roll-up door to establish the ventilation path prior to reaching an adverse environment in the area.

The Phase 2 and Phase 3 FLEX strategy involves the use of the 0A Refueling Water Purification pump repowered by a FLEX diesel generator or a medium-pressure FLEX pump (or NSRC supplied pump for Phase 3), with suction from the Essential Service Water Cooling Tower, to supply water to the SFP. The discharge hose of the portable FLEX pump will be routed through the Fuel Handling Building to the edge of SFP where it will be attached to spray nozzles. The staff's evaluation of the robustness and availability of FLEX connection points for the FLEX pump is discussed in Section 3.7.3.1 below. Furthermore, the staff's evaluation of the robustness and availability of the Essential Service Water Cooling Tower for an ELAP event is discussed in Section 3.10.3.

In the UFSAR, Table 3.2-1 indicates that the Fuel Handling Building is classified as a Safety Category I structure, which is defined in UFSAR Section 3.2.1.1 as those SSCs important to safety that are designed to remain functional in the event of the SSE and other design-basis events (including tornado, PMF, and , missile impact). In addition, UFSAR Section 9.1.3.2 states that the 0A Refueling Water Purification pump, including the 3-inch suction piping from the RWSTs and the 2-inch discharge piping to the SFP, are permanently installed and classified as Safety Category I components.

The staff noted that repowering the 0A Refueling Water Purification Pump with a portable FLEX diesel generator is an alternative approach from the guidance identified in NEI 12-06, as endorsed, by the NRC in JLD-ISG-2012-01. This is due to the reliance on permanently installed component (i.e., 0A Refueling Water Purification Pump) in lieu of complete reliance on deployment and alignment of portable diesel generators and diesel driven pumps as part of ELAP event mitigation per NEI 12-06, Section 3.2.2. Based on the classification of the 0A Refueling Water Purification Pump and associated piping, and the availability of the medium-pressure FLEX pump to provide SFP make-up, the staff finds the licensee is capable of providing flexibility and diversity during a BDBEE event to provide makeup to the SFP. In addition, based the number of pieces of equipment available (i.e., one Refueling Water Purification Pump and three medium FLEX pumps) the staff finds the licensee has in excess of the recommended N and N+1 sets of equipment for SFP make-up. Therefore, the NRC staff finds that repowering the Refueling Water Purification Pump is an acceptable alternative to NEI 12-06, as the licensee has demonstrated compliance with the order, and the staff concludes that the licensee has multiple methods to provide SFP make-up.

3.3.4.1.2 Plant Instrumentation

In its FIP, the licensee stated that the instrumentation for SFP level will meet the requirements of Order EA-12-051. Furthermore, the licensee stated that these instruments will have initial local battery power with the capability to be powered from the FLEX DGs. The NRC staff's review of the SFPLI, 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. Environmental impacts on the SFPLI are discussed in Section 4.2.4.2 of this SE.

3.3.4.2 Thermal-Hydraulic Analyses

As described in calculation BYR13-240/BRW-13-0222-M, "Spent Fuel Pool Boil Off Analysis during an ELAP Event," Rev. 0, the SFP will boil in approximately 11 hours and boil off to the top of active fuel in approximately 91 hours from initiation of the event with no operator action at the maximum design heat load.

In the FIP, Section 2.6.5 states that the two bounding scenarios analyzed are: (1) maximum normal operation heat load and (2) the maximum during 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	Time to boil to top of active fuel
Case 1	32.5 million Btu/hr	10.94 hrs	90.98 hrs
Case 2	62.9 million Btu/hr	2.72 hrs	43.96 hrs

During its audit, the staff noted that licensee calculation, BYR14-129 / BRW-14-0212-M, "RWST Usage During FLEX Scenarios," Rev. 1, determined a SFP makeup flow rate of at least 67 gpm will maintain adequate SFP level above the top of active fuel for an ELAP occurring during normal power operation. Section 3.2.1.6 in NEI 12-06, states that the SFP heat load assumes the maximum design-basis heat load for the site as one of the initial SFP conditions. Consistent with this guidance in NEI 12-06, Section 3.2.1.6, the staff finds the licensee has considered the maximum design-basis SFP heat load.

3.3.4.3 FLEX Pumps and Water Supplies

As described in the FIP, the SFP cooling strategy relies on the 0A Refueling Water Purification Pump or a portable FLEX pump to provide SFP makeup during Phase 2. Section 2.6.6 in the FIP describes the hydraulic performance criteria (e.g., flow rate, discharge pressure) for the 0A Refueling Water Purification pump and portable FLEX Pump. Specifically, the 0A Refueling Water Purification pump rating is a nominal 150 psig at 100 gpm and the medium-pressure FLEX pump rating is a nominal 500 psig at 300 gpm. The staff noted that the performance criteria of a FLEX pump supplied from an NSRC for Phase 3 would be capable of fulfilling the mission of the 0A Refueling Water Purification pump or the portable FLEX Pump if either were to fail. As stated above, the SFP makeup rate of 67 gpm is bounded by the performance capabilities of the 0A Refueling Water Purification pump or the medium-pressure FLEX pump.

During its audit, the staff reviewed calculation BYR13-144/BRW-13-0160-M, "FLEX Pump Sizing and Hydraulic Analysis," Rev. 0, and noted the licensee conservatively modeled a SFP make-up rate of 500gpm discharging into the SFP through spray nozzles when determining the sizing for the medium-pressure FLEX pump. The staff noted that the rate of discharge via the spray nozzles greatly exceeds the necessary make-up rate from boil-off (i.e., 67 gpm).

Spray to the SFP is only needed if there is a leak in the SFP that lowers the water level below the level of the fuel assemblies. In NEI 12-06, Section 3.2.1.6, states that an initial SFP condition is that all boundaries of the SFP are intact; thus, the staff noted that the NEI 12-06 guidance is to have spray available is a defense-in-depth measure, and the conditions that would require this capability (i.e., draining of the SFP and uncovering of the spent fuel) are extremely unlikely due to the robust construction of the SFP as a Safety Category I structure. The licensee has the capability to deliver 500 gpm of spray to the SFP; however, the licensee's capability does not fully meet the intent of NEI 12-06, as the capability is not independent of the need to provide makeup to the SGs. As long as the DDAF pump continues to provide feedwater to the SGs, the staff noted that the licensee maintains the capability of providing 500 gpm of spray to the SFP with the medium-pressure FLEX pump as a defense-in-depth measure. The staff noted that another medium-pressure FLEX Pump (the N+1 pump) is available in the robust FLEX Storage Building, but the licensee has not developed a strategy to use two medium- pressure FLEX pumps simultaneously. However, the staff finds that the licensee has a strategy to maintain or restore SFP cooling which will prevent damage to the fuel following a BDBEE, which meets the requirement of Order EA-12-049. Therefore, the NRC staff finds that the dependence of the SFP spray flow rate on the makeup flow rate to the SGs 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 implement spray flow at 500 gpm, if necessary.

3.3.4.4 Electrical Analyses

The licensee's FIP defines strategies capable of mitigating a simultaneous loss of all ac power and 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 all units on the Byron site.

The staff performed a comprehensive analysis of the licensee's electrical strategies, which includes 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 other areas of this SE). In its FIP, the licensee stated that SFPLI contains an uninterruptible power supply that will provide power to the instrumentation for 72 hours.

The licensee's Phase 2 strategy is to continue monitoring SFP level and repower SFPLI and the refueling water purification pump using the 480 Vac FLEX DG. Procedure 0BFSG-11, "Alternate SFP Makeup and Cooling Unit 0," Rev. 2, provides guidance for powering the refueling water purification pump from the 480 Vac FLEX DG.

The licensee's Phase 3 strategy is to continue with the Phase 2 strategy and use equipment supplied by an NSRC as a backup.

The staff reviewed licensee calculation BYR13-180 and determined that the 480 Vac FLEX DGs should have sufficient capacity and capability to supply SFP instrumentation and cooling systems. The NRC staff also finds that the 480 Vac CTGs being supplied by an NSRC have adequate capacity and capability since they are of higher capacity than the FLEX DGs (1100 kW versus 350 kW).

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

The NRC staff concludes that the licensee has developed the methods for SFP makeup stated in NEI 12-06, Table D-3, with the capability for a flow rate exceeding the boil-off rate and a capability to provide 500 gpm spray flow to the SFP. However, as discussed in sections 3.3.4.1.1 and 3.3.4.3 above, the staff concludes that the licensee's capability does not fully meet the conditions of NEI 12-06, but does meet the requirements of Order EA-12-049. The NRC staff finds that these are acceptable alternatives to NEI 12-06. 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, with approved alternatives, and adequately addresses the requirements of the order.

3.4 Containment Function Strategies

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

The licensee performed a containment evaluation, BYR13-235/BRW-13-0217-M, "Containment Pressure and Temperature Response during an ELAP Event," which was based on the boundary conditions described in Section 2 of NEI 12-06. The calculation analyzed the cases in the Modular Accident Analysis Program analysis that resulted in the largest mass and energy release to the containment (i.e., greatest challenge to the design pressure and temperature limits). This analysis concluded that the containment parameters of pressure and temperature remain well below the respective design limits of 64.7 psia and 280 °F for more than 30 days. From its review of the evaluation, the NRC staff noted that the required actions to maintain containment integrity, if any, and required instrumentation functions have been developed, and are summarized below.

3.4.1 Phase 1

In the FIP, Section 2.5.1 states that following the occurrence of an ELAP/loss of UHS event, the reactor will trip and the plant will initially stabilize at no-load RCS temperature and pressure conditions. The licensee will transition to 1/2ECA-0.0, "Loss of All AC Power Unit 1 /2," upon the diagnosis of the total loss of ac power. Among the actions directed by this procedure is verification of containment isolation and monitoring containment status.

3.4.2 Phase 2

In the FIP, Section 2.5.2 states that the Phase 2 coping strategy is to continue monitoring containment temperature and pressure using installed instrumentation.

3.4.3 Phase 3

Based on the containment temperature and pressure response during an ELAP event, the staff noted the licensee has adequate time to obtain additional equipment available from the NSRC to provide support to the site. In addition, FIP Section 2.5.2 states that if any FLEX Equipment from the NSRC is required, the procedural guidance for the transition is provided in its FSGs.

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

Byron UFSAR Section 3.8.1.1 describes the containment structure as a Safety Category I structure that is constructed of a pre-stressed concrete shell structure made up of a cylinder with a shallow dome roof and flat foundation slab. The cylindrical portion is pre-stressed by a post-tensioning system consisting of horizontal and vertical tendons and the dome post-tensioning system is made up of three groups of tendons oriented 120 degrees to each other and anchored at the vertical face of the dome ring. The entire structure is lined on the inside with steel plate, which acts as a leak-tight membrane. Additionally, UFSAR Section 3.2.1.1 defines Safety Category I as those SSCs important to safety that are designed to remain functional in the event of the SSE and other design-basis events (including tornado, PMF, and missile impact). The staff finds that the containment structure is robust and is expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Byron UFSAR Table 6.2-2 indicates that the net free volume of the containment is 2.758 million cubic feet. The addition of mass and energy to the containment atmosphere during an ELAP event is driven by the assumed leakage from the RCP seals (see SE Section 3.4.4.2 for details). 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 64.7 psia and 280°F for at least 30 days.

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 control room instrumentation would be available due to the coping capability of the station batteries and associated inverters in Phase 1, or the portable diesel generators deployed in Phase 2. If no ac or dc power was available, the FIP states that key credited plant parameters, including containment pressure, would be available using alternate methods.

3.4.4.2 Thermal-Hydraulic Analyses

By letter dated August 28, 2014, the licensee stated Calculation BYR13-235/BRW-13-0217-M, "Containment Pressure and Temperature Response during an ELAP Event," determined that it will take greater than 30 days for containment pressure to exceed 54.7 psia and 13.7 days for the containment temperature to exceed 200°F. Furthermore, the calculation demonstrates that it would take greater than 30 days for the containment pressure and temperature to exceed 64.7 psia and 280°F, respectively, which are the design basis limits.

Byron FIP Section 2.3.6 states the site installed the Westinghouse Reactor Coolant Pump SHIELD® Passive Thermal Shutdown Seals (Generation III) in all four RCPs on Unit 1 and Unit 2. The staff noted that calculation BYR13-235/BRW-13-0217-M was performed prior to installation of the SHIELD RCP seals; thus, with the installation of SHIELD seals the amount of leakage into containment will be reduced, resulting in additional margin (i.e., time) before the design-basis temperature and pressure limits for the containment structure are reached.

Based on the expected containment pressure and temperature response during an ELAP event and the installation of RCP SHIELD seals, the staff finds the licensee has adequately demonstrated that there is significant time before the design-basis limit would be reached. In addition, the staff finds there is sufficient time for NSRC equipment and off-site resources to arrive to assist in restoring containment cooling.

3.4.4.3 FLEX Pumps and Water Supplies

Based on the thermal-hydraulic analyses described in SE Section 3.4.4.2, the licensee has greater than 30 days for the containment pressure and temperature to exceed 64.7 psia and 280°F, respectively, which are the design-basis limits. The staff finds it reasonable that no mitigation actions are necessary to maintain or restore containment cooling during Phases 1 or 2. In addition, the staff noted that the licensee's containment integrity strategies do not rely on the use of FLEX pumps and water sources for maintaining containment pressure or temperature below the design limits for at least 72 hours until off-site resources arrive to assist in restoring containment cooling.

3.4.4.4 Electrical Analyses

The licensee performed a containment evaluation based on the boundary conditions described in Section 2 of NEI 12-06. Based on the results of its evaluation, the licensee developed required actions to ensure that containment integrity is maintained and that required instrumentation continues to function. With an ELAP initiated, while either Byron unit is in Modes 1-4, containment cooling for that unit is also lost for an extended period of time. Therefore, containment temperature and pressure will slowly increase. Structural integrity of the reactor containment building due to increasing containment pressure will not be challenged during an ELAP event. However, with no cooling in the containment, temperatures in the containment are expected to rise and could reach a point where continued reliable operation of key instrumentation and components might be challenged. If a rise in temperature or pressure occurs that could challenge containment, procedures 1BFSG-12, "Alternate Containment Cooling Unit 1," Rev. 0 and 2BFSG-12, "Alternate Containment Cooling Unit 2," Rev. 1, provide guidance to maintain containment temperature and pressure below limits so that equipment located inside containment remains functional throughout the ELAP event.

The licensee's Phase 1 coping strategy for containment involves initiating and verifying containment isolation per procedures 1BCA-0.0, "Loss of All AC Power Unit 1," Rev. 205 and 2BCA-0.0, "Loss of All AC Power Unit 2," Rev. 210, following an ELAP/LUHS. Phase 1 also includes monitoring containment temperature and pressure using installed equipment. Control room indication for containment pressure and containment temperature is available for the duration of the ELAP/LUHS. The NRC staff reviewed the licensee's dc coping calculation (BYR14-060/BRW-14-0080-E) and determined that the Byron, Unit 1 and 2 Class 1E station batteries have adequate power to supply power to the required instrumentation to monitor containment temperature and pressure prior to transitioning to Phase 2.

The licensee's Phase 2 coping strategy is to continue monitoring containment temperature and pressure using installed instrumentation. The 480 Vac FLEX DGs will power the battery chargers, which will maintain dc bus voltage for continued availability of instrumentation needed to monitor containment temperature and pressure. The NRC staff reviewed the licensee's FLEX DG sizing calculation (BYR13-180) and determined that the 480 Vac FLEX DG have sufficient capacity and capability to supply power to the battery chargers.

The licensee's Phase 3 coping strategy is to continue monitoring containment pressure, and use NSRC supplied equipment as necessary. If necessary, an NSRC supplied 480 Vac CTG could repower the reactor containment fan cooler to provide alternate containment cooling.

Based on its review of licensee calculation BYR13-180, the NRC staff 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., 480 Vac CTGs), provides sufficient capacity and capability to supply the required loads to reduce containment temperature and pressure, if necessary, to ensure that key components including required instrumentation remain functional.

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

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; high winds; snow, ice and extreme cold; and extreme high temperatures.

References to external hazards within the licensee's mitigating strategies and this SE are consistent with the guidance in NEI-12-06 and the related 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 19] (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 44]. 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 39]). The Commission provided guidance in an SRM to COMSECY-14-0037 [Reference 20]. 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 34], 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, Rev. 0, and the related industry guidance in NEI 12-06, Rev. 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, Rev. 2, Appendices G and H [Reference 45]. The NRC staff endorsed Rev. 2 of NEI 12-06 in JLD-ISG-2012-01, Rev. 1 [Reference 46]. 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 stated that the original investigation of historical seismic activity in the Byron region determined a design SSE which is defined as the occurrence of a Modified Mercalli Intensity of VIII originating at the bedrock-soil interface at the site. Per Section 2.5 of the UFSAR), Byron determined the corresponding ground surface acceleration to be 0.21 g for the postulated SSE.

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 number 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 its FIP, the licensee stated that external flooding of the Byron site is not applicable per NEI 12-06, since Byron is considered a "Dry Site" per the Byron UFSAR. The plant grade elevation is at 869.0 feet and the grade floors of the safety related buildings are elevation 870.0 feet. The site is not subject to significant river or tsunami type flooding based on site elevation relative to Rock River elevation. The PMF along the Rock River does not affect the site, since the maximum water surface elevation is 708.3 feet, a minimum of 160.7 feet below the plant grade. A review of dam failures resulted in no challenge to the Byron Station Site.

In accordance with NEI 12-06, Rev. 0, susceptibility to external flooding is based on whether the site is a “dry” site, i.e., the plant is built above the design basis flood level. Based on NEI 12-06, “dry” sites are not required to perform a characterization of the applicable flood hazard, or address protection and deployment strategies.

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.

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, Rev. 2, February 2007. If the recommended tornado design wind speed for a 1E-6/year probability exceeds 130 mph, the site should address hazards due to extreme high winds associated with tornadoes using the current licensing basis for tornados or Regulatory Guide 1.76, Rev. 1.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee stated that the site is located at 89° 16' west and 42° 4’ north, which would not experience severe winds from hurricanes. In NEI 12-06 Figure 7-2, Recommended Tornado Design Wind Speeds for the 1E-6/year Probability Level, indicates the site is in Region 1, and is susceptible to tornado winds of 200 mph. Therefore, the plant screens in for an assessment for high winds and tornados, including missiles produced by these events

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.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee stated that per UFSAR Section 2.3.1 .2.3, Heavy Snow and Severe Glaze Storms, severe winter storms consisting of six inches of snow or more will occur on average five times per year. The possibility of freezing rain or sleet, resulting in a glaze, will occur on average two times per year. Per NEI 12-06, Byron could receive 25 inches of snow over 3 days and therefore, identifies Byron with an Ice Severity Level 5, catastrophic destruction to power lines and/or existence of extreme amounts of ice. The design-basis snow and ice load on structures, per the UFSAR, is 104 psf [pounds per square foot]. Low temperatures less than or equal to 0°F occur about 16 times per year, with an extreme low temperature of (-) 22°F.

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

3.5.5 Extreme Heat

In the section of its FIP regarding the determination of applicable extreme external hazards, the licensee stated that, for Byron, per UFSAR Section 2.3.1.1, General Climate, the annual average temperature in the Byron area as represented by Rockford Data is 48.1°F, with an extreme high of 103°F. Maximum temperatures equal to or exceeding 90°F is about 13 times per year.

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 there are two storage buildings to support FLEX strategies. The FLEX Storage Robust Building (FSRB) houses the "N" and "N+ 1" FLEX equipment, and is designed to withstand design-basis wind, tornado, and seismic (i.e. SSE as described in Section 3.5.1 of this SE) hazards as outlined in NEI 12- 06. An adjacent commercial building, constructed to American Society of Civil Engineers (ASCE) 7-10, Minimum Design Loads for Buildings and Other Structures, standards, houses non-strategic, support equipment. The commercial building will hold site equipment as well as support supplies not required by NEI 12-06. Both buildings will be located outside the protected area north of the main parking lot. In addition, the site strategy will have several strategic temporary hoses and electrical cables staged within robust structures in the plant.

Below are additional details on how FLEX equipment is protected from each of the applicable external hazards.

3.6.1.1 Seismic

As stated above, the FSRB houses the N and N+1 FLEX equipment and is designed to withstand the design-basis seismic hazard.

The licensee indicated in its FIP that FLEX equipment is secured in the FSRB with tie downs to preclude seismic interaction that could damage the equipment. Cabinets and miscellaneous items stored on cabinet shelves are located away from the FLEX equipment such that they will not damage the FLEX equipment should they fall during a seismic event.

3.6.1.2 Flooding

As previously discussed, Byron is considered a “dry” site. In addition, the FSRB is constructed above the maximum flood elevation level, therefore protection from external flooding is provided.

3.6.1.3 High Winds

In its FIP, the licensee indicated that Byron houses the N and N+1 FLEX equipment in a FSRB designed to meet the design-basis UFSAR wind speed of 360 mph and designed to withstand tornado-generated missiles. The licensee also indicated that the FRSB was oriented such that the predominant tornado path would tend to direct tornado debris away from the equipment doors.

The licensee also indicated that they constructed an adjacent building, constructed to ASCE 7-10 standards, which houses non-strategic support equipment.

3.6.1.4 Snow, Ice, Extreme Cold and Extreme Heat

In its FIP, the licensee indicated that the interior temperature of the FRSB is designed to maintain between 40°F and 100°F. The FRSB is designed to withstand the snow loading as required per NEI 12-06. The commercial building for the support equipment is designed to ASCE 7-10 standards which include design for snow and ice.

In its FIP, the licensee indicated that the FLEX equipment is qualified to operate in extreme conditions, including high and low temperatures. The FLEX pumps were procured with operational specification for ambient temperatures as high as a nominal 110°F and as low as a nominal (-) 20° F. FLEX hoses were procured with similar operational specification. FLEX DGs were procured with operational specification for ambient temperatures as high as a nominal 122°F and as low as a nominal (-) 25°F and capable of operating in rain, sleet, or snow.

3.6.1.5 Conclusions

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

3.6.2 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). Thus, a two-unit site would nominally have at least three portable pumps, three sets of portable ac/dc power supplies, three sets of hoses and cables, etc. 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.

Attachment 2 in the FIP lists the FLEX portable equipment stored onsite as well as the quantities, and functional uses, e.g., core, containment, SFP. This includes the major pumps and generators referred to in the descriptive portions of the FIP. It also includes tow and debris removal vehicles, and other miscellaneous support equipment.

In its FIP, the licensee indicated that to ensure readiness of FLEX equipment and support equipment, operators will perform periodic equipment inventory, operability testing, flow testing, leakage testing, and inspections. In addition, FLEX equipment will be administratively controlled to provide the actions to be taken during unavailability of FLEX equipment.

Based on the number of portable 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 portable FLEX pumps, FLEX DGs, and equipment for RCS makeup and boration, SFP makeup, and maintaining containment consistent with the N+1 recommendation in Section 3.2.2 of NEI 12-06.

3.7 Planned Deployment of FLEX Equipment

In its FIP, the licensee provided primary an alternate deployment routes for the Phase 2 portable FLEX equipment. Attachment 6 in the FIP depicts the deployment routes and staging areas for the FLEX equipment.

3.7.1 Means of Deployment

Tow and debris removal vehicles are included in the Attachment 2 list of FLEX equipment in the FIP. The licensee stated in its FIP that debris removal and onsite transport of Phase 2 FLEX portable equipment will be accomplished using one Ford F-750 model truck (or equivalent) equipped with a plow and two tractors equipped with buckets.

During the audit, NRC staff confirmed that the deployment path and debris removal evaluations adequately justified the site capability to deploy FLEX equipment to mitigate the applicable BDBEEs.

3.7.2 Deployment Strategies

Byron is considered a "dry" site, therefore the impact of flooding on transport paths is not considered.

In its FIP, the licensee stated that the combination of the relatively shallow amount of soil from the ground surface to the limestone shelf below, between 5 feet and 15 feet under the surface, coupled with the lack of ground water in this layer, makes liquefaction a non-issue at Byron Station.

The licensee indicated in its FIP that the FLEX tow and debris removal vehicles are capable of removing snow and/or debris from the deployment routes as a result of seismic, tornado, or snow event events. The licensee stated that any downed power lines affecting the primary route will be assessed and de-energized, as necessary, or a secondary route will be used.

In its FIP, the licensee stated that the Byron UHS does not experience frazzle ice or blockage of the intake due to low temperatures. The UHS will continue to have a heat input from the DDAF pump during Phase 1 of a BDBEE. During Phase 2, if a FLEX pump is utilized, a connection has been provided directly from the deep well water pumps that can supply the FLEX pumps. The deep well water (subterranean) supply is not susceptible to freezing.

3.7.3 Connection Points

3.7.3.1 Mechanical Connection Points

Reactor Coolant System Makeup

In the FIP, Section 2.4.2 states that hoses will be routed from the FLEX RWST connection in the RWST tunnel to provide a borated water source to the high pressure FLEX pump. During its audit, the staff noted the RWST tunnel is below grade and contains the discharge piping from the RWST. Byron UFSAR Table 3.2-1 indicates that the RWST and Tank Foundation (except for small personnel hatch cover) are Safety Category I structures, which is defined in UFSAR Section 3.2.1.1 as those SSCs important to safety that are designed to remain functional in the event of the SSE and other design-basis events (including tornado, PMF, and, missile impact). Furthermore, FIP Section 2.4.2 states that hoses will be routed from the high pressure FLEX pump to the installed FLEX primary connection on the Chemical and Volume Control System (CVCS) or to the alternate connection on the SI system. Byron UFSAR Table 3.2-1 indicates that the CVCS or SI systems serve a safety-related function are classified as Safety Category I. In addition, during its audit, the staff noted that the RCS primary and alternate connection points are located in the Auxiliary Building, which is also a Safety Category I structure.

Given the design and location of the primary and alternate discharge connection points, the staff finds that at least one of the connection points should be available to support RCS inventory control via the high pressure FLEX pump during an ELAP caused by an external event, consistent with NEI 12-06 Section 3.2.2.17. In addition, based on the design and location of the suction connection point, the staff finds that this connection should be available to support the RCS inventory control FLEX strategy during an ELAP event.

Steam Generator Makeup

In the FIP, Section 2.3.2 states that suction hose will be routed from the FLEX connection for well water in the 0A SXCT valve chamber to the medium-pressure FLEX pump to serve as a backup source of water to the SGs. Byron USFAR Table 3.2-1 indicates that the SXCT and the associated piping and valves are Safety Category I. Furthermore, FLEX hoses will be routed from the discharge of the medium-pressure FLEX pump to the primary SG connection in the B/C MSIV room to provide a backup source of feedwater. Additional FLEX hose can also be routed from connections in the Main Steam tunnel to allow feedwater to be provided to the A/D SGs; thus, allowing symmetric cooling of the RCS and RCP seals to maintain their integrity. The staff noted an alternate connection for feedwater to the SGs will be available in the A/D MSIV room for use in the event the primary connection is not available and similarly additional FLEX hose can be routed from connections in the Main Steam Tunnel to allow feedwater to be provided to the B/C SGs. Byron UFSAR Section 5.2.2.5.1.2 indicates that the MSIV room is a Safety Category I structure immediately outside the containment. Furthermore, UFSAR Table 3.2-1 indicates that the Main Steam Tunnel is a Safety Category I structure.

Given the design and location of the primary and alternate discharge connection points including the hose deployment routes, the staff finds that at least one of the connection points should be available to support decay heat removal via the medium-pressure FLEX pump during an ELAP caused by an external event, consistent with NEI 12-06 Section 3.2.2.17. In addition, based on the design and location of the suction connection point, the staff finds that this connection should be available to support the Core Cooling FLEX strategy during an ELAP event.

Spent Fuel Pool Makeup

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

In the FIP, Section 2.6.2 states SFP makeup can be initiated on demand by using the 0A Refueling Water Purification Pump with suction from the RWST via existing piping and being powered from a FLEX diesel generator. The hoses from the medium head FLEX pump can also be routed through the Fuel Handling Building from the trackway door to the refuel floor and discharge into the SFP via monitor guns. As discussed in SE Section 3.3, the licensee's SFP FLEX strategy's involves an alternative to NEI 12-06 in which a repowered 0A Refueling Water Purification Pump is used to provide make-up to the SFP without access to the refuel floor. Although the licensee's strategy does not provide makeup water via a portable pump without access to the refuel floor, the staff finds the licensee's strategy is still capable of providing makeup to the SFP without access to the refuel floor in the event the refuel floor is uninhabitable and is consistent with the purpose of the baseline capability recommended in NEI 12-06, Table D-3.

Thus, the staff finds the available connection points (including the associated hoses/spray nozzles and use of the 0A Refueling Water Purification Pump) in the licensee's SFP Cooling FLEX strategies are consistent with the baseline capabilities identified in NEI 12-06, Table D-3 and provides diversity and flexibility. In addition, the staff finds consistent with NEI 12-06, Section 3.2.2, the available connection points are protected from applicable external hazards such that there is reasonable assurance at least one connection point is available during an ELAP event.

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 that result in an ELAP.

During Phase 2, the licensee has developed a primary and alternate strategy for supplying power to equipment required to maintain or restore core cooling, containment, and SFP cooling using a combination of permanently installed and portable components. There are four (only one is required per unit) portable 480 Vac FLEX DGs provided for the licensee's Phase 2 strategy. The 480 Vac FLEX DG staging location for each unit is in its respective turbine trackway. The licensee's primary strategy is to power the 480 Vac bus 132X/232X by running temporary cables from a 480 Vac FLEX DG into the division 12/22 switchgear rooms. Connection of the temporary cables is accomplished using a bus connection device (BCD) that will be racked into Bus 132X/232X. The licensee's alternate strategy will be implemented in the event a 480 Vac FLEX DG cannot be directly connected to 480 Vac bus 132X/232X. Temporary cables will be routed from the FLEX power connection panel to provide power directly to motor control centers (MCCs) to provide power to needed equipment. A 480 Vac FLEX DG will be tied into the opposite unit's bus 132X/232X with a BCD to energize the opposite unit's division 12/22 battery charger and allow powering the unit's dc bus through the dc breaker crosstie. In its FIP, the licensee stated that the primary and alternate electrical strategies were put together under the loading premise that one unit would be implementing the primary strategy while the opposite unit would be implementing the alternate strategy. Procedures 1BFSG-5, Initial Assessment and FLEX Equipment Staging Unit 1, Rev. 1 and 2BFSG-5, Initial Assessment and FLEX Equipment Staging Unit 2, Rev. 3, provide direction for connecting 480 Vac FLEX DGs using color coded cables ensuring proper phase rotation. In addition, the licensee confirmed proper phase rotation of the FLEX DGs prior to compliance with Order EA-12-049 [Reference 48].

For Phase 3, the licensee will receive four (two per unit) 1 MW 4160 Vac and two (one per unit) 1100 kW 480 Vac CTGs from an NSRC. The licensee plans to only connect the 480 Vac CTGs and not the 4160 Vac CTGs. The NSRC supplied 480 Vac CTGs will be staged in the vicinity of the portable 480 Vac FLEX DGs and provide backup power, if necessary. Procedures 1BFSG-13, "Transition From FLEX Equipment Unit 1," Rev. 0 and 2BFSG-13, "Transition From FLEX Equipment Unit 2," Rev. 1, provide direction for connecting and verifying proper phase rotation when powering equipment from a 480 Vac CTG.

3.7.4 Accessibility and Lighting

In its FIP, the licensee stated that Appendix R lights are available in many locations within the plant, including the DDAF pump room, AF005 valve area, main control room, auxiliary building, and containment penetration areas. These lights are not robust, but may provide general area lighting that will assist the operators in execution of the site FLEX strategy. Flashlights are available to operators and will be used to illuminate specific areas or components, as needed. The licensee also indicated in its FIP that temporary lighting is established in the main control room, DDAF pump rooms, AF005 flow control area, and FLEX equipment deployment areas near the RWST tunnel hatches. Main control room lighting will also be restored after a FLEX DG powers the applicable MCC.

3.7.5 Access to Protected and Vital Areas

During the audit process, the licensee stated that during the BDBEE with an ELAP, the site security doors electronic latches will fail in the latched position. The operators currently have ample security keys within the main control room that will be used to open these doors to ensure the overall integrated strategy can be successfully executed. In addition site security will be available to assist in allowing access to the protected area and all required vital areas.

3.7.6 Fueling of FLEX Equipment

In the FIP, Section 2.10.5 states the FLEX strategy is to ensure all of the Phase 2 and Phase 3 equipment can continue to operate for the indefinite coping time required. The fuel credited is the fuel stored in the 1/2B DG Fuel Oil Storage Tanks. Byron UFSAR Table 3.2-1 and Section 9.5.4.1 indicates that the Diesel-Generator Fuel Oil Storage and Transfer System is designed to operate during and after a design-basis seismic event and is designated Safety Category I, which is defined in UFSAR Section 3.2.1.1 as those SSCs important to safety that are designed to remain functional in the event of the SSE and other design-basis events (including tornado, PMF, and, missile impact). Based on the design and location of these fuel oil storage tanks and its safety-related classification, the staff finds these tanks are robust and the fuel oil contents should be available to support the licensee's FLEX strategies during an ELAP event.

Each B Train Diesel Oil Storage Tank (one per unit) typically holds a usable volume of 96,000 gallons. As described in FIP Attachment 9, the licensee assumed that the FLEX equipment supporting both units during an ELAP event in Phase 2 (e.g., pumps, generators, transport trucks, etc.) are running simultaneously at full load and will consume approximately 221 gallons per hour of diesel fuel oil. With the available protected fuel oil on site, the total estimated run time is approximately greater than 36 days for the Phase 2 equipment. The staff finds this assumption conservative because it is not expected that all FLEX equipment will run at full load continuously from the initiation of the ELAP event because the load on the FLEX equipment is expected to decrease as the reactor cools down. During its audit, the staff confirmed that the licensee has existing contracts/agreements for obtaining fuel oil from off-site that contain contingencies for extreme external events and for an "alternate" supplier to replenish fuel oil to the site. Based on the conservative fuel oil consumption rates and the protected fuel oil volume, the staff finds the tanks are robust and the fuel oil contents should be available to support the licensee's FLEX strategies during an ELAP event and the quantity available is sufficient until off-site resources can provide fuel oil replenishment to the site.

The licensee explained that refilling portable diesel fuel tanks is proceduralized and involves filling the two 118-gallon fuel tanks mounted on the F-750 truck (or equivalent) which will then be used to fill tanks on the portable FLEX equipment. During its audit, the staff noted a modification was performed on the 1/2B Diesel Oil System allowing the transfer of the fuel into a refuel vehicle from a repowered B DG Fuel Oil Transfer pump. The staff noted that the diesel driven auxiliary feedwater pump, which supports the Phase 1 core cooling strategies, is refilled directly from the diesel fuel oil storage tanks through existing robust safety-related piping located in the Auxiliary Building and can be performed independently of the refuel operations for the portable equipment. During its onsite audit, the staff performed a walkdown and noted that it is a direct path from the fuel oil connection point in the Emergency Diesel Generator Room to the parked refueling truck. Based on the equipment available for refueling (i.e., F-750 truck and two fuel tanks), the available guidance to operators, the conservative expected run time and the duration to complete refueling operations for each piece of portable FLEX equipment, and the ease of access to the fuel oil fill connection, the staff finds it reasonable that the diesel-powered FLEX equipment will be refueled to ensure uninterrupted operation to support the licensee's FLEX strategies.

In the FIP, Section 2.18 provides details regarding the monthly, quarterly, semi-annual and annual inspections/maintenance activities that will be performed for FLEX equipment. Specifically, the staff noted that on an annual basis, fuel oil stabilizer additives will be added or fuel oil will be sampled and replace as required for FLEX equipment. The staff noted that the Technical Specifications (surveillance requirements for SR 3.8.3.2) require that fuel oil properties of fuel oil are tested in accordance with, and maintained within the limits of, the Diesel Fuel Oil Testing Program for the diesel driven auxiliary feedwater system (SR 3.7.5.8) and the Fuel Oil Storage Tanks(SR 3.8.3.2). Based on the licensee's Technical Specification requirements and preventative maintenance activities for FLEX equipment, the staff finds that the licensee has addressed management of fuel oil in the fuel oil storage tanks and the portable FLEX equipment to ensure quality fuel oil will be supplied to FLEX equipment during an ELAP event.

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 Byron 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 (PEICo) 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 21], 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 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 Byron, Alternate Staging Area D is the DeKalb Taylor Municipal Airport. Staging Area C is the Whiteside Country Airport. Staging Area B is located within the owner controlled area at the North West corner of the main employee parking lot. Staging Area A is located within the PA at the various FLEX equipment deployment locations.

Use of helicopters to transport equipment from Staging Area C to Staging Area B is recognized as a potential need within the Byron SAFER Plan and is provided for.

In its FIP, the licensee stated that temporary staging areas have been identified and details for their use in supporting Phase 3 equipment receipt, inspection and deployment to operating areas are provided in the SAFER Response Plan for Byron.

During the audit, NRC staff confirmed that transportation methods (ground/air) and the various driving routes to each of the National SAFER Response Center staging areas are contained in chapter 4 of the Byron SAFER response plan.

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 Byron, 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 licensee's FLEX strategy activities are the MCR, Auxiliary Electric Equipment Rooms (AEER), DDAF Pump Rooms, Vital Battery Rooms and Miscellaneous Electrical Equipment Rooms (MEER), and Containment.

Main Control Room

Licensee calculation BYR13-236/BRW-13-0218-M, "Control Room and Aux. Electrical Equipment Room Heat Up and Ventilation during an ELAP Event," Rev. 2, modeled the transient temperature response in the MCR following an ELAP event. The calculation showed that the expected MCR temperature will remain below 120°F if portable ventilation is established along with opening doors. Procedure 0BFSG-51, "Alternate MCR Ventilation Unit 0," Rev. 2, provides guidance for establishing portable ventilation and opening room doors to minimize MCR temperature increases after a loss of ventilation and cooling due to ELAP. Procedure 0BFSG-5, "Initial Assessment and FLEX Equipment Staging Unit 0," Rev. 4, provides guidance to shift power for the portable ventilation from the 5.5 kW FLEX DG to the 480 Vac FLEX DGs.

Based on expected room temperature 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," Rev. 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.

Auxiliary Electric Equipment Rooms

Licensee calculation BYR13-236/BRW-13-0218-M modeled the transient temperature response in the AEER following an ELAP event. The calculation showed that the time to reach the maximum allowed temperature of 122°F for Unit 1 and Unit 2 AEER is 6.7 hours and 5.15 hours, respectively. Procedure 0BFSG-51, provides guidance for establishing portable ventilation, opening room doors, and opening equipment panel doors to maintain AEER temperature within acceptable limits after a loss of ventilation and cooling due to an ELAP. The licensee expects this action to be completed within 5.15 hours

Based on procedure 0BFSG-51 providing guidance to monitor and control AEER temperature below the maximum allowed temperature (122°F), the NRC staff expects that the equipment in the AEER should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

DDAF Pump Room

During Phase 1, natural circulation of the RCS will develop to provide core cooling and the DDAF pump will provide flow from the CST or the SXCT to the steam generators to make up for steam release. The DDAF pump is relied upon for continued decay heat removal via the steam generators during Phase 1 and Phase 2, until the medium head FLEX pump can be deployed. The licensee performed analysis BYR13-234/BRW-13-0216-M, "Auxiliary FW Pump Room Temperature Analysis During an ELAP Event," Rev. 1, which modeled the transient temperature response in the DDAF pump room following an ELAP event. The licensee's analysis showed that the room temperature is maintained within acceptable limits and supplemental room cooling is not required. Although supplemental room cooling is not necessary, procedure 0BFSG-5, "Initial Assessment and FLEX Equipment Staging Unit 0," Rev. 4, provides guidance for opening room door and establishing alternate cooling to provide additional options to operators. In addition, by letter dated February 27, 2015 [Reference 14], the licensee stated that modifications were completed to provide an alternate service water supply to the DDAF pump to prevent over heating from service water recirculation. The licensee stated that necessary guidance to operators is provided to align the alternate SX supply in FSGs. Specifically, as noted in the sequence of events in the FIP, operators will complete the necessary realignment for alternate service water supply to the DDAF pump within 2 hours of the pump start to prevent overheating.

Based on the licensee's analysis for loss of ventilation for the DDAF pump, plant modifications, and procedural guidance to prevent overheating of the DDAF pump, the staff finds it reasonable that the DDAF pump should perform its required function at the expected temperatures as a result of loss of ventilation during an ELAP event.

Byron UFSAR Section 2.3.1.1 states that based on data from the meteorological station in Rockford, IL the extreme high temperature has reached a maximum of 103°F to a minimum of -22°F. Byron UFSAR Section 2.3.2.1.2 states that temperature extremes from 1974 to 1976 for the Byron site were 93.2°F and -14.7°F. By letter dated July 15, 2016 [Reference 47], the licensee stated that the FLEX low pressure pump was designed to be able to operate with an outside air temperature of 110°F. Furthermore, the FLEX medium-pressure and high pressure pump purchase specification requires a maximum operating air temperature of 110°F. Thus, the staff finds the FLEX pumps are designed to operate in extreme high temperatures and it is expected that this equipment will function during an ELAP event.

Vital Battery Rooms and MEER

Licensee calculation BYR13-237/BRW-13-0219-M, "MEER and Battery Room Conditions Following an Extended Loss of AC Power," Rev. 0, modeled the transient temperature response in the vital battery rooms and MEER rooms following an ELAP event.

Vital Battery Room - The licensee's calculation showed that the maximum normal battery room temperature is 108°F and the maximum equipment acceptance temperature in the battery room is 138°F. The Division 2 battery room temperature reaches 138°F if doors are not open between the ventilation room, MEERs, and battery rooms within 6.49 hours into the ELAP event. The division 1 battery room temperature is close to 128°F for the same time period. Procedure 0BFSG-5 provides guidance for opening doors and setting up portable ventilation. Procedure 1/2BFSG-5 provides guidance to repower battery room exhaust fans when the 480

Vac FLEX DGs are repowering the 480 Vac buses (480 Vac FLEX DG should be available within 6 hours). The licensee expects that repowering the battery room exhaust fans, opening doors, and setting up portable ventilation within 8 hours of the event should drop battery room temperature to below the normal maximum temperature of 108°F. Although the licensee plans to open doors and restore ventilation, periodic monitoring of electrolyte level may be necessary to protect the battery since the battery may gas more at higher temperatures.

Based on the above, the NRC staff finds that the licensee's ventilation strategy should lower the battery room temperature below the maximum temperature limit (122°F) of the batteries, as specified by the battery manufacturer (C&D Technologies), therefore the batteries should not be adversely impacted by the loss of ventilation as a result of an ELAP event.
The MEER (includes inverters and battery chargers) calculation showed that the maximum equipment acceptance temperature in the MEERs is 138°F, and the Division 1 and 2 MEER reach 132°F and 133°F, respectively at 8 hours. Establishing portable ventilation and opening doors before 8 hours per procedure 0BFSG-5, should drop temperature to below 108°F within 8 hours.

Based on temperatures remaining below 120°F (the temperature limit, as identified in NUMARC-87-00, Rev. 1, for electronic equipment to be able to survive indefinitely), the NRC staff finds that the electrical equipment in the MEER will not be adversely impacted by the loss of ventilation as a result of an ELAP event

Containment

Licensee calculation BYR13-235/BRW-13-0217-M, "Containment Pressure and Temperature Response During An ELAP Event," Rev. 0, modeled the transient temperature response in the containment following an ELAP event. The calculation showed that it will take greater than 30 days for containment pressure to exceed 54.7 psia and 13.7 days for the containment temperature to exceed 200°F. The calculation also showed that without any mitigating actions taken to remove heat from the containment, the containment parameters of pressure and temperature remain well below the respective design limits of 64.7 psia and 280°F for at least 30 days. If a rise in temperature or pressure occurs that could challenge containment, procedures 1BFSG-12, "Alternate Containment Cooling Unit 1," Rev. 0 and 2BFSG-12, "Alternate Containment Cooling Unit 2," Rev. 1, provide guidance to maintain containment temperature and pressure below limits so that equipment located inside containment remains functional throughout the ELAP event.

Based on containment temperature and pressure remaining below their respective design limit, the NRC staff expects that the 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, DDAF Pump Rooms, AEERs, Battery Rooms and MEERs, and Containment, the NRC staff finds that the equipment should perform their required functions at the expected temperatures as a result of a loss of ventilation during an ELAP/LUHS event.

3.9.1.2 Loss of Heating

In the FIP, Section 2.8.4 states that the impact of potential freezing due to loss of heat trace or other heat sources on its FLEX strategy was evaluated. It was determined that susceptible equipment includes the RWST, temporary hoses, and pumps deployed outside. During its audit, the staff reviewed this evaluation and noted that it would take in excess of 80 hours for the RWSTs to reach 32° F without flow. The staff finds it reasonable that extreme low

temperatures will not impact the licensee's RCS FLEX strategies because the high head FLEX pumps will have been deployed and begin taking suction from the RWSTs, which will preclude stagnant water and freezing conditions, prior to the water temperature reaching 32°F.

Furthermore, the staff noted that the licensee's evaluation determined that some FLEX hoses would freeze within minutes of no flow during extreme cold temperatures and established the necessary flow through the hoses to prevent hose freezing. During its audit and as indicated in FIP Section 2.8.4, the licensee explained that its FSGs would provide warnings to the operators that during extreme cold temperatures the suction hoses are not to be filled until the FLEX pumps are ready to run or to initiate actions to drain FLEX pumps and hoses after pump operation or to protect FLEX hoses from freezing by maintaining positive flow. Based on the procedural guidance to avoid FLEX hoses with stagnant water and to drain hoses when not in use during extreme cold temperatures, the staff finds it reasonable that extreme low temperatures will not impact the licensee's FLEX strategies.

In the UFSAR, Section 2.3.1.1 states that based on data from the meteorological station in Rockford, IL, the extreme temperatures have ranged from a maximum of 103°F to a minimum of -22°F. Section 2.3.2.1.2 in the UFSAR states that temperature extremes from 1974 to 1976 for the Byron site were 93.2°F and -14.7°F. In the FIP, Section 2.8.4 states that the FLEX Pumps were procured with an operational specification for ambient temperatures as low as a nominal -20°F.

Thus, the staff finds it reasonable that the FLEX pumps will not be impacted by extreme low temperatures and it is expected this equipment will function as designed during an ELAP event.

The impact on the performance of the vital batteries due to low temperatures is minimal. The vital batteries are located in the interior of the auxiliary building such that outside air temperature would not impact battery performance. The battery room minimum temperature acceptance criteria is 60°F. The licensee calculation BYR13-237/BRW-13-0219-M shows that the battery room temperature does not drop lower than 65°F within the first 24 hours of an ELAP. In addition, during battery discharge the battery will be producing heat which will keep electrolyte temperature above the room temperature. Therefore, the NRC staff finds that Byron vital batteries should perform their required functions as a result of loss of heating during an ELAP event.

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. The NRC staff reviewed licensee calculation BYR13-237/BRW-13-0219-M, to verify that hydrogen gas accumulation in the 125 Vdc Vital Battery rooms will not reach combustible levels while HVAC is lost during an ELAP. Off-gassing of hydrogen from batteries is only a concern when the batteries are charging. Procedure 1/2BFSG-5, 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 calculation and battery room ventilation strategy, the NRC staff finds that hydrogen accumulation in the Byron 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 2.10.2 states that the Main Control Room and Auxiliary Electric Equipment Room (AEER) heat up and ventilation during an ELAP shows the Unit 2 AEER portion of the MCR boundary reaching temperature limits first within approximately 5.15 hours. In addition, the FIP states that the Main Control Room initial actions include Emergency Procedure and plant operations that will require continuous occupancy; however, the AEER does not have initial operator actions. The FIP indicates that 0BFSG-51, "Alternate MCR Ventilation Unit 0," provides operators the necessary guidance to establish temporary alternate ventilation for the MCR, the Unit 1 AEER, and the Unit 2 AEER. In addition, by letter dated August 28, 2014, the licensee stated that habitability conditions within the MCR and other areas of the plant will be maintained with a toolbox approach limiting the impact of high temperatures with methods such as supplemental cooling, personnel rotation and/or availability of fluids. The staff noted that based on the FIP sequence of events, the licensee will begin to establish temporary ventilation to the MCR and AEER with 3-5 hours after event initiation and complete the actions prior to 5.15 hours.

Based on the procedural guidance to establish temporary ventilation prior to reach the MCR and AEER temperature limits in the expected timeframe, the staff finds it reasonable that operators can safely enter and occupy the MCR and AEER during an ELAP event. The NRC staff finds the above strategies are consistent with NEI 12-06, Section 3.2.2.11 such that station personnel can safely enter and perform the necessary actions to support the FLEX mitigation strategy, during an ELAP event.

3.9.2.2 Spent Fuel Pool Area

In the FIP, Section 2.10.2 states that the actions in the SFP area include setting up temporary hoses and spray nozzles and that these actions are performed prior to the onset of SFP boiling; thus, occupancy in the SFP area after this initial setup in not required. As discussed in SE Section 3.3, the licensee's calculation indicates that boiling begins at approximately 10.94 hours during a normal, non-outage situation. The licensee's sequence of events timeline (FIP Attachment 8) indicates that operators will deploy all hoses and make necessary connections in the Fuel Handling Building before it becomes uninhabitable between 6 to 10 hours from the onset of the ELAP event, as directed by the site's FSGs. Furthermore, FIP Section 2.6.1 states that vent path for the Fuel Handling Building will be provided by opening the trackway roll-up door. During its audit, the staff observed that the trackway roll-up door can be opened manually without the need for electric power. In addition, the staff noted once the hoses are deployed and connections established in the Fuel Handling Building, the licensee will not be required to re-enter the building.

Based on the procedural guidance to deploy hoses and open the trackway roll-up door prior to the SFP boiling during abnormal, non-outage situation, the NRC staff finds the above strategies are consistent with NEI 12-06, Section 3.2.2.11 such that station personnel can safely enter the Reactor Building (including SFP refuel floor) and perform the necessary actions to support the FLEX mitigation strategy, during an ELAP event.

3.9.2.3 Other Plant Areas

In the FIP, Section 2.3.1 indicates per existing procedures, operators are directed to take local manual control of the SG PORVs to control steam release and the RCS cool down rate. During its on-site audit, the staff performed a walkdown of the area where operators would manually operate the PORVs and noted that the hand pump mechanisms are located directly behind the exterior door to the MSIV rooms, which provides quick and easy access to the hand pump mechanisms and for operators to communicate with the control room. The staff noted that, if necessary, the exterior doors could be propped open to provide a ventilation path to cool the MSIV rooms. Thus, the staff finds it reasonable that operators can safety enter the MSIV rooms to operate the PORVs and easily exit the rooms to safety because the hand pump mechanisms are located in such close proximity to the exterior door and the a ventilation path can be created by propping open the exterior door. The NRC staff finds the above strategies are consistent with NEI 12-06, Section 3.2.2.11 such that station personnel can safely enter and perform the necessary actions to support the FLEX mitigation strategy, during an ELAP 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

3.10.1 Steam Generator Make-Up

Phase 1 and 2

In the FIP, Section 2.11.1 states that that the 500,000 gallon CST provides a non-safety grade source of water to the SGs for removing decay and sensible heat from the reactor coolant system; however, since the CSTs are not fully robust, the DDAF pump can be supplied by the SX System.

Byron UFSAR Section 3.2.1.1 defines Safety Category I as those SSCs important to safety that are designed to remain functional in the event of the SSE and other design-basis events (including tornado, probable maximum flood, operating basis earthquake - OBE, missile impact, or accident internal to the plant). Byron UFSAR Table 3.2-1 indicates that the SXCTs are Safety Category I structures and the safety-related portions of the SX System are Safety Category I components.

In the FIP, Section 2.11.1 states that for analysis purposes, the UHS cooling tower basins (2) are assumed to be maintained at a nominal 60 percent level, which corresponds to approximately 306,000 gallons of water in each basin. During its audit, the staff reviewed the licensee's calculation and noted that with no operator actions makeup to the SXCT basins must be established by approximately 8 hours. In addition, this calculation describes operator actions that can be taken to prolong the volume of water in the SXCT basin until approximately 18 hours after ELAP initiation. Consistent with NEI 12-06 Section 3.2.2.5 the staff finds that the SXCT basins are robust, and an adequate water source that should be available during an ELAP to support the FLEX mitigation strategy until make up can be provided to the SXCT basins and off-site resources arrive.

Phase 3

In the FIP, Section 2.3.2 states that the WW system will serve as the long-term source of water to the SGs via makeup to the SXCT, which is the suction source for the DDAF pump or the medium head FLEX pump. There are two WW pumps with each dedicated to one of the SXCT basins is capable of providing make up to either essential service water basin and is powered from an engineered safety feature bus associated with each tower.

Byron UFSAR Section 9.2.5.3.4 states deep well pumps and portions of the WW system that are an alternate source of makeup water to the essential service water cooling towers, have been seismically qualified for the SSE and are also protected from tornado-generated missiles by reinforced concrete enclosures.

In the FIP, Section 2.11.1 indicates that the deep well water source has a wide range of associated chemical compositions and that extended periods of operation with addition of these various water sources to the SGs will have an impact on their material. The license explained that the water supply from the SX system, with makeup from the WW pumps, is essentially unlimited by quantity, but is limited in quality; thus, the licensee performed a calculation that demonstrates that the Unit 1 and 2 SG heat transfer capabilities will be reduced by 3.5 percent and 5.8 percent, respectively, through the first 72 hours when using SX system as the water supply. The licensee stated that the SGs could lose 67 percent of their heat transfer capabilities and still meet the heat removal requirement over the first 72 hours. Based on this expected impact of raw water on the heat transfer capability of the SGs, the staff finds there is an adequate amount of time for off-site resources to arrive with the water purification skid from the NSRC to treat the site makeup water that will be used for core cooling.

Based on the (1) robust design of the WW system and the SXCT basins, (2) the available quality and volume of water in these two sources and (3) the ability to prolong the water volume in the SXCT basins via operator actions, the staff finds it reasonable that there is a sufficient amount of water for decay heat removal via the SGs and there is sufficient time for the delivery and deployment of the Phase 3 NSRC water treatment equipment to provide an indefinite supply of filtered water to support the FLEX mitigation strategy.

3.10.2 Reactor Coolant System Make-Up

Phase 1, 2 and 3

In the FIP, Section 2.11.2 states that the SI Accumulators (4 per unit) will provide the initial source of borated water (7106 gallons at 2300ppm per accumulator) for reactivity control and RCS inventory makeup and are passive components that do not require operator or control action. The FIP sequence of events indicates that the SI Accumulators must be isolated prior 16 hours from event initiation. Furthermore, the RWST provides the source of borated water during Phase 2 to the RCS via the high-pressure FLEX pump. Each unit has their dedicated RWST and contains a minimum of 395,000 gallons of useable water volume at 2400 ppm. The licensee stated that based on its evaluation, each RWST can provide at least 33.6 hours of borated water for the most demanding scenario of usage and a single RWST will not be depleted until 1,060 hours if an alternate water supply is provided to the SFP. The staff noted the RWST is used to support the SFP cooling strategies if the licensee repowers the 0A Refueling Water Purification Pump. Otherwise, the licensee has the option to use the SXCT and a portable FLEX diesel pump. As described in SE Section 3.3, the SFP water level is not expected to reach the top of active fuel during non-outage situations for at least 90 hours from the initiation of the ELAP event; thus, the staff finds it reasonable that the licensee has sufficient time to assess the conditions of the site following the BDBEE and determine if it is necessary to conserve the contents of the RWSTs to support RCS FLEX strategies.

Byron UFSAR Table 3.2-1 indicates that the SI Accumulators and the RWST and tank foundation are Safety Category I structures, which is defined in UFSAR Section 3.2.1.1 as those SSCs important to safety that are designed to remain functional in the event of the SSE and other design-basis events (including tornado, probable maximum flood, and , missile impact).

Based on the robust design of the SI Accumulators and the RWSTs and the available volume of borated water from both sources, the staff finds it reasonable that there is a sufficient amount of borated water available on-site until Phase 3 off-site resources and equipment arrive and the licensee can transition to cooling. Consistent with NEI 12-06 Sections 3.2.2.5 the staff finds that the SI Accumulators and RWSTs are robust, and an adequate water source that should be available during an ELAP to support the FLEX mitigation strategy.

3.10.3 Spent Fuel Pool Make-Up

Phase 1, 2 and 3

In the FIP, Section 2.11.3 states that the RWST will be the primary borated water source to the SFP, which will be provided by the 0A Refueling Water Purification Pump during Phase 2. In addition, the licensee states that deep well water from subterranean aquafers can provide an unlimited quantity of available water for SFP makeup, which will be provided by the medium FLEX pump via the SXCT basins. See SE Sections 3.10.1 and 3.10.2 for a detailed discussion regarding the robustness of the SXCT and RWST, respectively.

Consistent with NEI 12-06 Section 3.2.2.5 the staff finds that the RWSTs and the SXCTs are robust, and an adequate water source that should be available during an ELAP to support the FLEX mitigation strategy.

3.10.4 Containment Cooling

The licensee's calculations demonstrate that no actions are required to maintain containment pressure below design limits, thus, no direct water sources are required for containment cooling.

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 DDAF 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 pressure 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 44 hours are available to implement makeup before boil-off results in the water level in the SFP dropping far enough to uncover fuel assemblies, and the licensee has stated that they have the ability to implement makeup to the SFP within that time.

When a plant is in a shutdown mode installed plant systems cannot be relied upon to cool the core, 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 35], which described methods to ensure plant safety in those shutdown modes. By letter dated September 30, 2013 [Reference 36], 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. In its FIP, the licensee informed the NRC staff of its plans to follow 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 incorporation of the use of FLEX equipment in the shutdown risk process and procedures, 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 stated that the Byron FSGs provide clear entry criteria and include guidance that can be employed for a variety of conditions. Clear criteria for entry into FSGs facilitates the use of FLEX strategies only as directed for BDBEE conditions, and not used inappropriately in lieu of existing procedures. The Byron FSGs were developed in accordance with the PWROG guidelines. The FSGs provide available, pre-planned FLEX strategies for accomplishing specific tasks in EOPs, contingency action procedures or abnormal operating procedures. Command and control for the event is established by the existing procedure structure and the FSGs are used to supplement the plant response to mitigate the BDBEE.

In addition, the licensee indicated in its FIP that procedural interfaces have been incorporated into each unit's EOPs to the extent necessary to include appropriate reference to the FSGs and to provide command and control for an ELAP event.

3.12.2 Training

In its FIP, the licensee stated that Byron's nuclear training program has been revised to incorporate training programs regarding the mitigation of BDBEEs. These training programs were developed and have been implemented in accordance with the Systematic Approach to Training (SAT) Process. Using the SAT, initial and continuing training has been established for operations and other appropriate personnel on FLEX related procedures and strategies.

During the on-site audit, NRC staff reviewed FLEX training tasks for equipment operators (EO) and licensed operators and the currently approved Long Range Training Plan which documented planned, periodic FLEX training. The EO tasks included hands-on operation of equipment, however, FLEX portable equipment was not yet on site. The B.5.b equipment was determined to be sufficiently similar to the FLEX equipment such that previous B.5.b training could be appropriately substituted for the initial FLEX training. FLEX integrated drills, including simulator training, are included in Byron emergency plan drill and exercise evaluation criteria.

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

In the compliance letters for each unit, the licensee indicated that the equipment required to implement the FLEX strategies has been procured in accordance with NEI 12-06, Sections 11.1 and 11.2, initially tested/performance verified as identified in NEI 12-06, Section 11.5, and is available for use. Maintenance and testing will be conducted through the use of the Byron Station's Unit 1 and 2 Preventative Maintenance program such that equipment reliability is achieved. The licensee provided information [Reference 32] stating that the Byron Preventive Maintenance program was developed using sources that include INPO AP- 913 process and Electric Power Research Institute Report 3002000623 entitled, "Nuclear Maintenance Applications Center: Preventive Maintenance Basis for FLEX Equipment." [References 37 and 38]

In its FIP, the licensee provided information on activities to ensure FLEX equipment readiness to support a BDBEE, including inventory control, operability testing, flow and leak testing, inspections, and equipment out of service tracking.

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 in accordance with NEI 12-06, Section 11.5.

3.14 Alternatives to NEI 12-06, Rev. 0

3.14.1 Reduced Set of Hoses and Cables as Backup Equipment

Byron took an alternative approach to the NEI 12-06 guidance for hoses and cables [Reference 31]. Section 3.2.2 of NEI 12-06 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 40] 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 has committed to following option b) of the NEI proposal. By letter [Reference 41], 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. The NRC staff approves this alternative as being an acceptable method of compliance with the order.

3.14.2 Phase 2 Use of Permanently Installed Equipment

The NRC staff noted that repowering the 0A Refueling Water Purification Pump with a portable FLEX diesel generator to supply water to the SFP during Phase 2 is an alternative approach from the guidance identified in NEI 12-06. This is due to the reliance on permanently installed component (i.e., 0A Refueling Water Purification Pump) in lieu of complete reliance on deployment and alignment of portable diesel generators and diesel driven pumps as part of ELAP event mitigation per NEI 12-06, Section 3.2.2. However, the licensee has in excess of the recommended N and N+1 sets of equipment for SFP make-up and the licensee has demonstrated compliance with the requirements of the EA-12-049 order. Therefore, alternative has been accepted by the NRC staff as detailed in section 3.3.4.1.1 of this SE.

3.14.3 Spray Flow to the SFP

The NRC staff determined that the licensee has the capability to deliver 500 gpm of spray to the SFP (250 gpm per unit) as stated in NEI 12-06, Table D-3. However, the licensee's capability does not fully meet the intent of NEI 12-06, as the capability is not independent of the need to provide makeup to the SGs. Therefore, the licensee's approach is an alternative to NEI 12-06. Since the licensee has a strategy to maintain or restore SFP cooling which will prevent damage to the fuel following a BDBEE that meets the requirement of Order EA-12-049, this alternative has been accepted by the NRC staff as detailed in Section 3.3.4.3 of this SE.

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 22], the licensee submitted its OIP for Byron in response to Order EA-12-051. By letter dated June 7, 2013 [Reference 23] the NRC staff sent a request for additional information (RAI) to the licensee. The licensee provided a response by letter dated July 3, 2016 [Reference 24]. By letter dated November 4, 2013 [Reference 25], the NRC staff issued an ISE and RAI to the licensee. By letter dated December 17, 2014 [Reference 17], the NRC issued an audit report on the licensee's progress.

By letters dated August 28, 2013 [Reference 26], February 28, 2014 [Reference 27], and August 28, 2014 [Reference 28], the licensee submitted responses to the RAIs and 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 SFPLI, which will function following a BDBEE, including modifications necessary to support this implementation, pursuant to Order EA-12-051. By letter dated December 8, 2014 [Reference 29], the licensee reported that full compliance with the requirements of Order EA-12-051 was achieved.

The licensee has installed a SFPLI system designed by Westinghouse. The NRC staff reviewed the vendor's SFPLI system design specifications, calculations and analyses, test plans, and test reports. The staff issued an audit report on August 18, 2014 [Reference 30].

The staff performed an onsite audit to review the implementation of SFPLI related to Order EA-12-051. The scope of the audit included verification of (a) site's seismic and environmental conditions enveloped by the equipment qualifications, (b) equipment installation met the requirements and vendor's recommendations, and (c) program features met the requirements. By letter dated December 17, 2014 [Reference 17], the NRC issued an audit report on the licensee's progress. Refer to Section 2.2 above for the regulatory background for this section.

4.1 Levels of Required Monitoring

In its second six month update, the licensee stated, in part, that Level 1 is 422 ft. 0 in. based on net positive suction head requirements. The NRC staff notes this is the higher of two points for net positive suction head or uncovering the SFP cooling inlet strainer and appears to be consistent with NEI 12-02, as endorsed by the ISG.

In its OIP, the licensee stated that Level 2 would be set at plant elevation of 410 ft. 2 in., which corresponds to 10 feet above the top of the SFP fuel storage rack. The NRC notes that the licensee designated Level 2 using the first of the two options described in NEI 12-02 for Level 2.

In its OIP, the licensee stated that the SFP elevation for Level 3 is set at a plant elevation of 400 ft. 2 in., which is the top of the fuel racks. The NRC notes that this elevation is the highest point of any spent fuel storage rack seated in the SFP and appears to be consistent with NEI 12-02, as endorsed by the ISG.

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 SFPLI shall include specific design features, including specifications on the instruments, arrangement, mounting, qualification, independence, power supplies, accuracy, testing, and display. Refer to Section 2.2 above for the requirements of the order in regards to the design features. Below is the staff's assessment of the design features of the SFPLI.

4.2.1 Design Features: Instruments

In its OIP, the licensee stated that the design of the instruments will be consistent with the guidelines of the ISG and NEI 12-02. The licensee also stated that the primary and backup instrument channel level sensing components will be located and permanently mounted in the SFP. According to the licensee, the primary and backup instrument channels will provide continuous level indication over a minimum range of approximately 24 ft. 7 ½ in. from the high pool level elevation of 424 ft. 9 ½ in. to the top of the spent fuel racks at elevation 400 ft. 2 in.

The NRC staff notes that the range specified for the licensee's instrumentation will cover Levels 1, 2, and 3. The staff also confirmed the primary and backup instruments were permanently mounted during the on-site audit. The continuous indication function was verified during the Westinghouse vendor audit.

Based on the evaluation above, 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 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

The licensee provided a sketch of the equipment locations in its second six month update. The sketch shows the primary instrument mounted near the SE corner of the pool. The sensor and electronic enclosures are located in the nearby Unit 1 electrical penetration area with remote indicator cabling running up through the Unit 1 lower cable spreading room to the Unit 1 main control room. The backup instrument is mounted near the Northeast corner of the pool. The sensor and electronic enclosures are located in the nearby Unit 2 electrical penetration area with remote indicator cabling running up through the Unit 2 lower cable spreading room to the Unit 2 main control room. The staff verified the equipment locations and cable routing during the on-site audit.
The NRC staff noted that there is sufficient channel separation within the SFP area between the primary and back-up level instruments, sensor electronics, and routing cables to provide reasonable protection against loss of indication of SFP level due to missiles that may result from damage to the structure over the SFP.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed arrangement for the SFPLI 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

Byron uses a cantilever style mounting bracket bolted to the deck of the refueling floor. The mounting bracket supports a launch plate which provides mounting points for the cable conduit and the probe. The licensee provided a sketch and description of the qualification in its third 6 month update.

The staff reviewed qualification of the SFPLI during the Westinghouse vendor audit. The staff also reviewed documents LTR-SEE-II-13-47 and WNA-TR-03149 to verify the sloshing analysis for loading from sloshing pool water. The staff also reviewed document BYR10-109 to verify plant specific equipment mounting details and BYR1-056 to verify the seismic qualification of the remote display which was not supplied by Westinghouse. The staff found the licensee met the NEI 12-02 mounting and seismic qualification criteria, as described in NEI 12-02.

Based on the discussion above, the NRC staff finds that 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 are not already covered by existing quality assurance requirements. In 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 [Reference 22], the licensee stated that instrument channel reliability shall be established by use of an augmented quality assurance process similar to that described in NEI 12-02.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, this approach 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.

4.2.4.2 Instrument Channel 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.

Radiation

In its final compliance letter, the licensee stated, in part, that the instruments will be reliable during the expected environmental and radiological conditions. The staff reviewed Byron design document EC392445 as part of the audit process. The documented summarized the calculation BYR13-187, "Radiological Doses in the Vicinity of the Spent Fuel Pool at Reduced Water Level". The staff found the calculation, as described, was conducted in accordance with the NEI 12-02 guidance and the results met the NEI 12-02 criteria for equipment in each of the three locations.

Temperature

In its final compliance letter, the licensee stated, in part, that the instruments will be reliable during the expected environmental and radiological conditions. The staff reviewed temperature qualification during the Westinghouse vendor audit and the review is documented in the vendor audit report [Reference 30]. The audit report confirmed that Westinghouse qualified the probe assembly and cable to a 212^{0}F/condensing environment and the transmitter and electronics enclosure to 140^{0}F/95 percent RH environment.

The staff reviewed Byron design document EC392445 as part of the audit process. The staff confirmed that the equipment in the SFP area met the criteria of NEI 12-02, based on an assumed temperature of 212^{0}F, as stated in the guidance. The staff also confirmed the qualification of the remote indicator, transmitter, and electronics enclosure located in the Aux building, met the temperature criteria of NEI 12-02 based on its review of Byron design document EC392445000. The licensee clarified, by email dated December 2, 2016 [Reference 49], that the conditions, as stated in EC392445000 are bounding and do not exceed the qualified temperature of 140^{0}F for the transmitter and electronics enclosure located in the Auxiliary Building, Electrical Penetration Room, Environmental Zone A11.

Seismic

The staff reviewed the seismic qualification testing as part of the vendor audit and found it met the criteria of NEI 12-02 as documented in the Westinghouse vendor audit report [Reference 30]. The staff reviewed Byron specific aspects of the seismic qualifications and found they met the criteria of NEI 12-02, as documented in Section 4.2.3 of the Westinghouse report.

Vibration and Shock

The staff reviewed vibration and shock qualification during the Westinghouse vendor audit and the review is documented in the vendor audit report. The staff also reviewed Byron design document EC392445 as part of the audit process and found that Exelon met the NEI 12-02 guidance for shock and vibration.

Based on the above, the NRC staff finds that 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 Design Features: Independence

The licensee, in its second six month update [Reference 27] provided a sketch of the component locations and described the electrical separation in response to RAI-6.The staff notes that the primary instrument is powered from Unit 1 and the backup instrument is powered from Unit 2 which provides the required electrical isolation. Physical separation was verified in Section 4.2.2 of this SE.

Based on the above, the NRC staff finds that 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

Normal power supply for primary and secondary instruments is described in Section 4.2.5 of this SE. Other aspects of the power supply including on-board battery backup capabilities were reviewed and found acceptable as part of the Westinghouse vendor audit [Reference 30].

Based on the above, the NRC staff finds that 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

In its third six month update [Reference 28] the licensee stated, in part, in its RAI-7 response, that the overall accuracy for the Westinghouse based SFPLI is +/- 5.06 in. The NRC staff reviewed the Westinghouse system accuracy during the Westinghouse vendor audit and verified the accuracy at +/- 3 in. The change in accuracy noted at Byron was incurred by the addition of the remote indicators located in the MCRs that are not part of the Westinghouse provided system. The required accuracy described in NEI 12-02 is +/- 1 ft.

Based on the evaluation above, the NRC staff finds that 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

The licensee stated, in part, in its third six month update RAI-8 response that Westinghouse calibration and functional test procedures WNA-TP-04709-GEN and WNA-TP-04613-GEN are acceptable for Byron, but that it would use the alternate 2 point in-situ test methodology, documented in Westinghouse letter LTR-SFPIS-14-55 to accommodate the low profile Westinghouse supplied mounting bracket. The licensee also stated in its full compliance letter for SFPLI that it has developed operating and maintenance procedures and that those procedures have been integrated into existing procedures.

The staff reviewed the Westinghouse procedures during the Westinghouse vendor audit [Reference 30]. The staff also discussed the testing procedures during the on-site audit and confirmed the in-situ testing procedure during the SFP walkdown.

Based on the evaluation above, the NRC staff finds that the licensee's proposed SFP instrumentation design allows for testing 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

The licensee provided a sketch of the component locations in its second six month update showing the remote displays for the primary and backup SFPLIs in the Unit 1 and Unit 2 Main Control Rooms, respectively.

The staff observed the displays and the display locations during the onsite audit and confirmed they are consistent with the NEI 12-02 guidance. The staff notes that the main control rooms are explicitly identified as acceptable display locations in the NEI 12-02 guidance.

Based on the evaluation above, the NRC 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 spent fuel pool instrumentation shall be maintained available and reliable through appropriate development and implementation programmatic controls, including training, procedures, and testing and calibration. Below is the NRC staff's assessment of the programmatic controls for the spent fuel pool instrumentation.

4.3.1 Programmatic Controls: Training

In its OIP, the licensee stated that personnel performing functions associated with these SFPLI channels will be trained to perform the job specific functions. The licensee also stated that the SAT will be used to identify the population to be trained and to determine the initial and continuing elements of the required training. According to the licensee, training will be completed prior to placing the instrumentation in service.

In its full compliance letter, the licensee stated, in part, that training for the SFPLI has been completed.

The staff reviewed the OIP and the full compliance letter in regard to training and found it is consistent with the NEI 12-02 guidance.

Based on the above, the NRC staff finds that the licensee's plan to train personnel in the operation, maintenance, calibration, and surveillance of the SFPLI, 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 second six month update under RAI-13 (sic - should be RAI-12), the licensee provided a list of the procedures to be developed for the operation and maintenance of the SFPLI. The RAI response also described the objective of each procedure. The procedures listed included system inspection, calibration and test, maintenance, repair, operation and responses.

In its full compliance letter, the licensee stated that procedures have been developed and integrated with existing procedures and that site processes have been established to ensure the instruments are maintained at their design accuracy.

The staff reviewed the RAI response list of procedures and their objectives and also reviewed the full compliance letter regarding procedures. The NRC staff finds that the procedures as described are consistent with the NEI 12-02 guidance.

Based on the evaluation above, the NRC staff finds that the licensee's procedure development is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.3.3 Programmatic Controls: Testing and Calibration

Exelon stated, in part, in its SFPLI compliance letter that the maintenance and operating procedures have been developed, integrated with existing procedures, and verified. Exelon also stated, in part, in its compliance letter that site processes have been established to ensure the instruments are maintained at their design accuracy.

In its second six month update, the licensee described the channel functional tests and manual calibration tests, both of which would be carried out at regularly scheduled intervals with additional manual calibrations performed on an as-needed basis. The licensee also stated, in part, they would follow the manufacturer's recommendations. The staff previously reviewed and accepted the manufacturer's testing during the Westinghouse vendor audit [Reference 30].

Compensatory actions were described for both 1 channel and 2 channels not functioning. During the on-site audit, the staff noted that the alternate monitoring plan would be reported to the Plant Operations Review Committee within 14 days. The licensee modified the process to enter the compensatory action into the Corrective Action Program as stated, in part, in the compliance letter.

The staff reviewed the licensee's plan for testing and calibration as described in the OIP, second six moth update (RAI-11 response) and the compliance letter and found the approach is consistent with the NEI 12-02 guidance.

Based on the evaluation above, the NRC staff finds that the licensee's proposed testing and calibration plan 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.

4.4 Conclusions for Order EA-12-051

In its letter dated December 8, 2014 [Reference 29], 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 has conformed to the guidance in NEI 12-02, as endorsed by JLD-ISG-2012-03. In addition, the NRC staff concludes that if the SFPLI is installed at Byron 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 from August 18-21, 2014 [Reference 17]. The licensee reached its final compliance date on May 17, 2016, and has declared that both of the reactors are in compliance with the orders. The purpose of this SE 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.

6.0 REFERENCES

1. SECY-11-0093, "Recommendations for Enhancing Reactor Safety in the 21st Century, the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," dated July 12, 2011 (ADAMS Accession No. ML11186A950)

2. 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," dated February 17, 2012 (ADAMS Accession No. ML12039A103)

3. SRM-SECY-12-0025, "Staff Requirements – 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," dated March 9, 2012 (ADAMS Accession No. ML120690347)

4. Order EA-12-049, "Issuance of Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," March 12, 2012 (ADAMS Accession No. ML12054A736)

5. Order EA-12-051, "Issuance of Order to Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," dated March 12, 2012 (ADAMS Accession No. ML12054A679)

6. Nuclear Energy Institute document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Rev. 0, dated August 21, 2012 (ADAMS Accession No. ML12242A378)

7. 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," dated August 29, 2012 (ADAMS Accession No. ML12229A174)

8. Nuclear Energy Institute 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," Rev. 1, dated August 24, 2012 (ADAMS Accession No. ML12240A307)

9. JLD-ISG-2012-03, "Compliance with Order EA-12-051, Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," dated August 29, 2012 (ADAMS Accession No. ML12221A339)

10. Byron, Units 1 and 2, Overall Integrated Plan in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049), dated February 28, 2013 (ADAMS Accession No. ML13060A364)

11. Byron Station, Units 1 and 2, "First Six-Month Status Report of the Implementation of the Requirements of the Commission Order with Regard to Mitigation Strategies for Beyond-Design-Basis External Events (EA-12-049)", dated August 28, 2013 (ADAMS Accession No. ML13241A279)

12. Byron Station, Units 1 and 2, "Second Six-Month Status Report of the Implementation of the Requirements of the Commission Order with Regard to Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," dated February 28, 2014 (ADAMS Accession No. ML14059A425)

13. Byron, Units 1 and 2, "Third Six-Month Status Report of the Implementation of the Requirements of the Commission Order with Regard to Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," dated August 28, 2014 (ADAMS Accession No. ML14248A229)

14. Byron Station, Units 1 and 2, "Fourth Six-Month Status Report of the Implementation of the Requirements of the Commission Order with Regard to Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," dated February 27, 2015 (ADAMS Accession No. ML15058A476)

15. Letter from Jack R. Davis (NRC) to All Operating Reactor Licensees and Holders of Construction Permits, "Nuclear Regulatory Commission Audits of Licensee Responses to Mitigation Strategies Order EA-12-049," dated August 28, 2013 (ADAMS Accession No. ML13234A503)

16. NRC, Byron Station, Units 1 and 2, Interim Staff Evaluation Relating to Overall Integrated Plan in Response to Order EA-12-049 (Mitigation Strategies,) dated December 17, 2013 (ADAMS Accession No. ML13225A595)

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18. Byron Station, Unit 1 "Report of Full Compliance with March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," dated November 30, 2015 (ADAMS Accession No. ML15335A390)

19. NRC, "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," dated March 12, 2012 (ADAMS Accession No. ML12053A340)

20. SRM-COMSECY-14-0037, "Staff Requirements – COMSECY-14-0037 – Integration of Mitigating Strategies For Beyond-Design-Basis External Events and the Reevaluation of Flooding Hazards," dated March 30, 2015 (ADAMS Accession No. ML15089A236)

21. Letter from Jack R. Davis (NRC) to Joseph E. Pollock (NEI), "Staff Assessment of National SAFER Response Centers Established In Response to Order EA-12-049," dated September 26, 2014 (ADAMS Accession No. ML14265A107)

22. Byron Station, Units 1 and 2, Overall Integrated Plan in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Reliable Spent Fuel Pool Instrumentation (Order Number EA-12-051), dated February 28, 2013 (ADAMS Accession No. ML13063A265)

23. NRC, Byron Station, Units 1 and 2, Request for Additional Information Regarding Overall Integrated Plan for Reliable Spent Fuel Pool Instrumentation, dated June 7, 2013 (ADAMS Accession No. ML13134A093)

24. Byron Station, Units 1 and 2, Response to Request for Additional Information - Overall Integrated Plan in Response to Commission Order Modifying License Requirements for Reliable Spent Fuel Pool Instrumentation (Order No. EA-12-051), dated July 3, 2013 (ADAMS Accession No. ML13186A006)

25. U. S. Nuclear Regulatory Commission, Byron Station, Units 1 and 2, Interim Staff Evaluation and Request for Additional Information Regarding the Overall Integrated Plan for Implementation of Order EA-12-051, Reliable Spent Fuel Pool Instrumentation, dated November 4, 2013 (ADAMS Accession No. ML13275A305)

26. Byron Station, Units 1 and 2, First Six-Month Status Report of the Implementation of the Requirements of the Commission Order with Regard to Reliable Spent Fuel Pool Instrumentation (Order Number EA-12-051), dated August 28, 2013 (ADAMS Accession No. ML13241A239)

27. Byron Station, Units 1 and 2 Second Six-Month Status Report of the Implementation of the Requirements of the Commission Order with Regard to Reliable Spent Fuel Pool Instrumentation (Order No. EA-12-051), dated February 28, 2014 (ADAMS Accession No. ML14062A057)

28. Byron Station, Units 1 and 2 Third Six-Month Status Report of the Implementation of the Requirements of the Commission Order with Regard to Reliable Spent Fuel Pool Instrumentation (Order Number EA-12-051), dated August 28, 2014 (ADAMS Accession No. ML14248A323)

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31. E-mail from Lisa Zurawski (Exelon) to John Hughey (NRC), dated September 28, 2016 (ADAMS Accession No. ML16273A198).

32. E-mail from Lisa Zurawski (Exelon) to John Hughey (NRC), dated October 18, 2016 (ADAMS Accession No. ML16293A120).

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34. Letter from William Dean (NRC) to Power Reactor Licensees, "Coordination of Requests for Information Regarding Flooding Hazard Reevaluations and Mitigating Strategies for Beyond-Design Bases External Events," dated September 1, 2015 (ADAMS Accession No. ML15174A257).

35. NEI Position Paper: "Shutdown/Refueling Modes", dated September 18, 2013 (ADAMS Accession No. ML13273A514)

36. Letter from Jack R. Davis (NRC) to Joseph E. Pollock (NEI), regarding NRC endorsement of NEI Position Paper: "Shutdown/Refueling Modes", dated September 30, 2013 (ADAMS Accession No. ML13267A382)

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39. COMSECY-14-0037, "Integration of Mitigating Strategies for Beyond-Design-Basis External Events and the Reevaluation of Flooding Hazards," dated November 21, 2014 (ADAMS Accession No. ML14309A256)

40. Letter from Nicholas Pappas (NEI) to Jack R. Davis (NRC) regarding alternate approach to NEI 12-06 guidance for hoses and cables, dated May 1, 2015 (ADAMS Accession No. ML15126A135)

41. Letter from Jack R. Davis (NRC) to Joseph E. Pollock (NEI), regarding NRC endorsement of NEI's alternative approach to NEI 12-06 guidance for hoses and cables, dated May 18, 2015 (ADAMS Accession No. ML15125A442)

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44. U.S. Nuclear Regulatory Commission, "Mitigation of Beyond-Design-Basis Events," *Federal Register*, Vol. 80, No. 219, dated November 13, 2015, pp. 70610-70647.

45. Nuclear Energy Institute document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Rev. 2, dated December 31, 2015 (ADAMS Accession No. ML16005A625)

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48. Letter from Eric R. Duncan (NRC) to Bryan C. Hanson (Exelon), "Byron Station, Units 1 and 2, NRC Integrated Inspection Report Nos. 05000454/2015002; 05000455/2015002; and 07200068/2015001," dated July 22, 2015 (ADAMS Accession No. ML15203A984)

49. E-mail from Lisa Zurawski (Exelon) to John Hughey (NRC), dated December 2, 2016 (ADAMS Accession No. ML16340A002).

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Date: December 19, 2016

BYRON STATION, UNITS 1 AND 2 - SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 (CAC NOS. MF0893, MF0894, MF0872, AND MF0873) Dated December 19, 2016

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