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

May 10, 2017

Mr. Bryan Hanson
President and Chief Nuclear Officer
Exelon Nuclear
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: BRAIDWOOD 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. MF0895 AND MF0896)

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 BDBEEs, 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. ML13060A362), Exelon Generation Company, LLC (Exelon, the licensee) submitted its OIP for Braidwood Station, Units 1 and 2 (Braidwood) 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. ML13225A592), and May 27, 2015 (ADAMS Accession No. ML15134A459), the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated December 16, 2015 (ADAMS Accession No. ML15350A414), Exelon submitted a compliance letter for Braidwood, Unit 2 and by letter dated December 7, 2016, Exelon submitted a compliance letter for Braidwood, Unit 1, which included the final integrated plan for Braidwood (ADAMS Accession No. ML16348A053). 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. ML13059A265), Exelon submitted its OIP for Braidwood 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. ML13280A566), and May 27, 2015 (ADAMS Accession No. ML15134A459), 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 June 9, 2015 (ADAMS Accession No. ML15160A351), 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 Braidwood. 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. ML15257A444). 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, Braidwood Project Manager, at 301-415-3204 or at John.Hughey@nrc.gov.

Sincerely,

John P. Boska

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

Docket Nos.: 50-456 and 50-457

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

BRAIDWOOD STATION, UNITS 1 AND 2

DOCKET NOS. 50-456 AND 50-457

1.0 INTRODUCTION

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

On March 12, 2012, the NRC issued Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" [Reference 4]. This order directed licensees to develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool (SFP) cooling capabilities in the event of a BDBEE. Order EA-12-049 applies to all power reactor licensees and all holders of construction permits for power reactors.

On March 12, 2012, the NRC also issued Order EA-12-051, "Order Modifying Licenses With Regard to Reliable Spent Fuel Pool Instrumentation" [Reference 5]. This order directed licensees to install reliable SFP level instrumentation with a primary channel and a backup channel, and with independent power supplies that are independent of the plant alternating current (ac) and direct current (dc) power distribution systems. Order EA-12-051 applies to all power reactor licensees and all holders of construction permits for power reactors.

2.0 REGULATORY EVALUATION

Following the events at the Fukushima Dai-ichi nuclear power plant on March 11, 2011, the NRC established a senior-level agency task force referred to as the Near-Term Task Force (NTTF). The NTTF was tasked with conducting a systematic and methodical review of the NRC regulations and processes and determining if the agency should make additional improvements to these programs in light of the events at Fukushima Dai-ichi. As a result of this review, the NTTF developed a comprehensive set of recommendations, documented in SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," dated July 12, 2011 [Reference 1]. Following interactions with stakeholders, these recommendations were enhanced by the NRC staff and presented to the Commission.

On February 17, 2012, the NRC staff provided SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," [Reference 2] to the Commission. This paper included a proposal to order licensees to implement enhanced BDBEE mitigation strategies. As directed by the Commission in staff requirements memorandum (SRM)-SECY-12-0025 [Reference 3], the NRC staff issued Orders EA-12-049 and EA-12-051.

2.1 Order EA-12-049

Order EA-12-049, Attachment 2, [Reference 4] requires that operating power reactor licensees and construction permit holders use a three-phase approach for mitigating BDBEEs. The initial phase requires the use of installed equipment and resources to maintain or restore core cooling, containment and SFP cooling capabilities. The transition phase requires providing sufficient, portable, onsite equipment and consumables to maintain or restore these functions until they can be accomplished with resources brought from off site. The final phase requires obtaining sufficient offsite resources to sustain those functions indefinitely. Specific requirements of the order are listed below:

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

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

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

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

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

On August 21, 2012, following several submittals and discussions in public meetings with NRC staff, the Nuclear Energy Institute (NEI) submitted document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 0 [Reference 6] to the NRC to provide specifications for an industry-developed methodology for the development, implementation, and maintenance of guidance and strategies in response to the Mitigation Strategies order. The NRC staff reviewed NEI 12-06 and on August 29, 2012, issued its final version of Japan Lessons-Learned Directorate (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" [Reference 7], endorsing NEI 12-06, Revision 0, with comments, as an acceptable means of meeting the requirements of Order EA-12-049, and published a notice of its availability in the *Federal Register* (77 FR 55230).

2.2 Order EA-12-051

Order EA-12-051, Attachment 2, [Reference 5] requires that operating power reactor licensees and construction permit holders install reliable SFP level instrumentation. Specific requirements of the order are listed below:

> All licensees identified in Attachment 1 to the order shall have a reliable indication of the water level in associated spent fuel storage pools capable of supporting identification of the following pool water level conditions by trained personnel: (1) level that is adequate to support operation of the normal fuel pool cooling system, (2) level that is adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck, and (3) level where fuel remains covered and actions to implement 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 alternating current (ac) and direct current (dc) power distribution systems, such as portable generators or replaceable batteries. Onsite generators used as an alternate power source and replaceable batteries used for instrument channel power shall have sufficient capacity to maintain the level indication function until offsite resource availability is reasonably assured.

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

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

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

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

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

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

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

On August 24, 2012, following several NEI submittals and discussions in public meetings with NRC staff, the NEI submitted document NEI 12-02, "Industry Guidance for Compliance With NRC Order EA-12-051, To Modify Licenses With Regard to Reliable Spent Fuel Pool Instrumentation," Revision 1 [Reference 8] to the NRC to provide specifications for an industry-developed methodology for compliance with Order EA-12-051. On August 29, 2012, the NRC staff issued its final version of JLD-ISG-2012-03, "Compliance with Order EA-12-051, Reliable Spent Fuel Pool Instrumentation" [Reference 9], endorsing NEI 12-02, Revision 1, as an acceptable means of meeting the requirements of Order EA-12-051 with certain clarifications and exceptions, and published a notice of its availability in the *Federal Register* (77 FR 55232).

3.0 TECHNICAL EVALUATION OF ORDER EA-12-049

By letter dated February 28, 2013 [Reference 10], Exelon Generation Company, LLC (Exelon, the licensee) submitted an Overall Integrated Plan (OIP) for Braidwood Station, Units 1 and 2 (Braidwood) 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 22], February 26, 2016 [Reference 23] and August 26, 2016 [Reference 24], 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 36]. 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 December 16, 2015 [Reference 18], the licensee reported that full compliance with the requirements of Order EA-12-049 was achieved for Braidwood, Unit 2. By letter dated December 7, 2016 [Reference 25], the licensee reported full compliance with the requirements of Order EA-12-049 was achieved for Braidwood, Unit 1 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.

Braidwood 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/LUHS, 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 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, auxiliary feedwater (AF) can be supplied by the essential service water (SX) system. The SX system provides a protected water source backup to the CST. 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. They will also 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 AF flow to all SGs, establish manual control of the SG PORVs, and initiate a cooldown of the RCS as soon as possible, but no later than 8 hours after event initiation. Braidwood has installed the Westinghouse RCP SHIELD® Passive Thermal Shutdown Seals (SDS) (Generation III) on Units 1 and 2, which significantly reduces RCS leakage following SHIELD seal actuation. 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. In addition, the site will deploy a FLEX strategy capable of providing SG makeup. The low head FLEX pump will be used to take a suction from the UHS via a strainer and provide water to the medium head FLEX pump. The UHS will serve as the long-term source of water to the SGs via the SX and DDAF pump or via the medium head FLEX pump utilizing primary or alternate connection points.

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 require the addition of 6000 gallons of RWST water to the RCS to commence before 16 hours. A second RCS cooldown is initiated following isolation of the SI accumulators and after completion of the minimum RCS boration.

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 (SAFER) Response Center (NSRC) to provide backup as necessary. A water treatment skid from the NSRC will be used to treat site makeup water used for core cooling. A boration skid from the NSRC will be used for long-term borated makeup source.

With regard to containment integrity, containment cooling is lost for an extended period of time following an ELAP. Therefore, containment temperature and pressure will slowly increase. With the installation of the Westinghouse SDS, the amount of leakage into containment will be minimized, resulting in additional margin to reaching design basis temperature and pressure. The operators will verify containment isolation as directed by the EOPs. Containment status will be monitored by the main control room (MCR) 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 the option of using installed equipment or additional equipment available from the NSRC to reduce containment temperature and pressure, if desired.

The Braidwood SFP is a common pool designed for both Unit 1 and Unit 2. For Phase 1, the basic FLEX strategy is to monitor SFP level using the new spent fuel pool level monitoring system installed to meet NRC Order EA 12-051 requirements. A SFP vent path will be provided by opening the fuel handling building track way roll-up door. Manual actions required in the fuel handling building, which include aligning the alternate SFP make-up path, will be performed prior to SFP boiling and prior to reaching an adverse environment in the area.

The primary Phase 2 strategy for SFP cooling involves repowering the installed safety-related refueling water purification pump by reenergizing safety-related 480 volt (V) buses with a FLEX diesel generator (DG). The RWST will be used as the suction source and the discharge will use the refueling water purification pump safety-related discharge piping directly to the SFP. The alternate source of SFP makeup will be via the low head FLEX pump taking a suction from the UHS via hoses and supplying spray monitor nozzles positioned to spray into 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, Revision 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/LUHS event. Maintenance of sufficient RCS inventory, despite ongoing system leakage expected under ELAP conditions, is accomplished through a combination of installed systems and FLEX equipment. The specific means used by the licensee to accomplish adequate core cooling during the ELAP/LUHS 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

As stated in Braidwood'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. Braidwood's CST has a capacity of 650,000 gallons, but is not robust to all applicable hazards. The minimum technical specification level assures that the required useable volume of approximately 212,000 gallons is met. In the event that the CST is not available Braidwood's DDAF pump will automatically transfer its suction to the SX system. The SX suction source is comprised of an essential cooling pond that is sized to supply 30 days' worth of water. The SX system and DDAF pump are safety-related systems that are robust to all applicable hazards.

Following the closure of the main steam isolation valves, 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.

Braidwood's Phase 1 strategy directs operators to commence a cooldown and depressurization of the RCS within 2 hours of the initiation of the ELAP/LUHS event. Over a period of approximately 4 hours, Braidwood 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/LUHS 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

Braidwood'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 the licensee will pre-stage a portable medium pressure FLEX pump that is capable of backing up this essential function. This pump will be pre-staged and connected at 20 hours after the initiation of the ELAP event.

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. Braidwood's FIP describes the pump primary and alternate connection strategies. The licensee would put the Low Pressure FLEX pump by the essential cooling pond and put a suction hose into the pond. The suction hose would include a strainer to keep debris from being injected into the SG. The Low Pressure FLEX pump would discharge through hoses to the Medium Pressure FLEX pump. 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 Braidwood 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, water purification from the NSRC can be used to treat feedwater providing cleaner water to reduce the amount of degradation of heat transfer in the SGs.

Braidwood's long-term strategy in phase three is to continue to remove core heat through the steaming of the SGs with no intent to initiate shutdown cooling.

3.2.1.2 RCS Makeup Strategy

3.2.1.2.1 Phase 1

Following the reactor trip at the start of the ELAP/LUHS 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 licensee's calculations assume that over the course of the initial cooldown and depressurization RCS pressure will lower linearly with temperature to the target cooldown temperature. The RCS boration will commence using a portable high-pressure FLEX pump for each unit no later than 16 hours into the ELAP/LUHS event. With low-leakage Westinghouse Generation 3 SHIELD RCP seals installed on all RCPs, Braidwood 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 method of boration and inventory control in Phase 2 is a portable high-pressure FLEX pump with a capacity of 40 gpm at 1550 psig. The pump will be aligned to take suction from each unit's RWST, with 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).

Licensee calculations demonstrate that if the medium pressure FLEX pump is supplying the SFP, the RWST will not be depleted for 1,060 hours from the initiation of the ELAP event. 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 Braidwood'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, Braidwood will receive the mobile boration skid. With this skid, they can continue to borate water to inject into the RCS indefinitely.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

There are no variations to the licensee's strategy for an external flooding event.

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

As stated in FIP Section 2.3.1, the DDAF pump will provide flow to the SGs. This will makeup for steam released through the MSSVs and/or the SG PORVs. Each unit has one DDAF pump, and FIP Section 2.3.4.1 states that it provides 100 percent of the required AF capacity to the four SGs. The DDAF pump and its associated safety-related systems are located in the robust Auxiliary Building. As described in safety evaluation (SE) Section 3.9.2, the DDAF pump discharge valves will need to be throttled periodically. In the FIP, Section 2.3.4.4 states that these valves are air operated and fail open on loss of air. They have a manual override and can be positioned using local hand wheels. Furthermore, they are safety-related and located in the Auxiliary Building. The DDAF pump is powered by a 16 cylinder diesel engine which produces 1500 horsepower. The engine is equipped with two sets of 100 percent capacity battery banks, one of which is used to power the starting motor while half of the other bank is used for control power. Fuel for the engine is contained in an independent fuel tank containing a technical specification minimum of 420 gallons. Engine cooling is maintained by the essential service water system. Based on the safety-related classification of the DDAF system and location of the pump and support systems within the Auxiliary Building, the NRC staff finds that the DDAF pump and discharge valves are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Steam will be released from the SGs using the SG PORVs to initiate a rapid cooldown of the RCS. In the FIP, Section 2.3.1 states that the PORVs are safety-related, missile protected, and seismically qualified. They are hydraulically operated valves, and they can be manually operated via a hand pump. As described in SE Section 3.9.2, the SG PORVs are located within the MSSV room. There are two SG PORVs in each robust MSSV room; however, they are manually operated next to a non-robust, outside access door. In the FIP, Section 2.3.4.3 states that the door is designed for high winds, but not tornado winds or wind driven missiles. Therefore, the licensee is taking an alternative approach to NEI 12-06 Sections 3.2 and 3.2.1.3 for protecting the non-safety-related PORV manual operators. The licensee's alternative justification for the Unit 1 and 2 A/D MSSV rooms is that its proximity to other structures protects the access door and the manual operators. The basis for the Unit 1 and 2 B/C MSSV rooms is that the licensee will place large concrete blocks in front of the doors to protect the manual operators from design basis horizontal missiles. Based on the of the location of the SG PORVs within the robust MSSV rooms, and that the S/G PORVs are manually operated within the MSSV rooms, the NRC staff finds that the PORVs are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3. the licensee's alternative approach for protecting the PORV manual operators is discussed in SE section 3.14.3.

Phase 2

The licensee's Phase 2 core cooling strategy continues to use the SGs as the heat sink. As stated in FIP Section 2.3.2, the installed DDAF pump provides an indefinite supply of water for feeding the SGs. However, a medium head FLEX pump will also be maintained in standby as a backup to the DDAF pump. The medium head FLEX pump will be supplied water from the low head FLEX pump that takes suction from the UHS. The medium head FLEX pump discharge will be directed through primary or alternate connection points to the SGs. The licensee plans to rely on the FLEX connection points and water sources discussed in SE Sections 3.7 and 3.10, respectively.

Phase 3

The licensee's Phase 3 core cooling strategy relies on Phase 2 strategies and Phase 2 connections, with the NSRC equipment providing backup as necessary. In the FIP, Section 2.3.3 states that a water treatment skid from the NSRC will be used to treat site makeup water used for core cooling.

RCS Makeup

Phase 1

The licensee's Phase 1 RCS inventory control FLEX strategy relies on SDS (Generation III) in all four RCPs on Units 1 and 2. As stated in FIP Section 2.3.7.2, nominal RCP seal leakage occurs for the first 30 minutes followed by significantly reduced leakage due to SHIELD seal actuation. During Phase 1, the SI accumulators will inject liquid to compensate for this loss. The SI accumulators are designed to withstand the extreme hazards described in FIP Section 6.2 and are therefore robust. As described in FIP Sections 2.3.1 and 2.3.7.2 and shown in the licensee's calculation CN-LIS-15-34, to maintain inventory, no FLEX RCS makeup is needed within 58 hours of event initiation as single-phase natural circulation continues to this point. Note, however, shutdown margin calculations require the addition of borated water from the RWST to commence before 16 hours have elapsed.

Phase 2

The licensee's Phase 2 RCS inventory strategy for Braidwood will use a high head FLEX pump to supply borated water from the RWST and does not rely on any installed plant SSCs other than the installed systems with FLEX connection points and borated water sources discussed in Sections 3.7 and 3.10, respectively.

Phase 3

The licensee's Phase 3 RCS inventory strategy for Braidwood does not rely on any additional installed plant SSCs other than those discussed in Phase 2. In the FIP, Section 2.3.3 states that a boration skid from the NSRC will be used as a long-term borated water makeup source.

3.2.3.1.2 Plant Instrumentation

According to the Braidwood 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 pressure
- SG Level Narrow Range
- SG Level Wide Range
- RCS hot leg and cold leg temperatures
- RCS pressure (wide range)
- AF flow rate
- AF suction pressure
- CST level
- 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 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 following instruments will be repowered from the FLEX DG.

- Reactor vessel level indicating system (RVLIS)
- Core exit thermocouples
- Neutron monitor (PANM)

The licensee's FIP states that procedures have been developed to read the vital instrumentation locally using a portable instrument, where applicable. Guidance document FLEX Support Guideline (FSG) 1/2BwFSG-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

Per its FIP, Exelon stated that its 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 the duration that reference reactor designs could cope with an ELAP event prior to providing makeup to the RCS.

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

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

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

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

During the audit, the NRC staff evaluated a comparison of the generic analysis values from WCAP-17601-P and PWROG-14064-P to the Braidwood plant-specific values. The NRC staff concurred that the generic plant parameters were bounding for the analyzed event. Braidwood has installed low-leakage SHIELD shutdown seals; therefore, the seal leakage expected for Braidwood is significantly less than assumed in the generic NOTRUMP analysis case. The NRC staff concluded based on licensee 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 16 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 its 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 the RCS operational leakage 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 the FIP, the RCPs for Braidwood 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 MSSV 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. Per Section 2.3.8 of the FIP, additional analysis performed by the RCP seal vendor, Westinghouse, 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 [per square inch absolute]; for Westinghouse Model 93A RCPs, RCS pressure is to remain bounded by Figure 7.1-2 of TR-FSE-14-1-P, Revision 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 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, Revision 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 the 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 Braidwood'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 (BDB) 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 BDB 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:
    - initially increase above its equilibrium value following reactor trip, thereby adding negative reactivity
    - peak at roughly 12 hours post-trip and subsequently decay away gradually, thereby adding positive reactivity
- the passive injection of borated makeup from nitrogen-pressurized accumulators due to the depressurization of the RCS, which adds negative reactivity

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

The specific values for these and other factors that could influence the core reactivity balance that are assumed in the licensee's current calculations could be affected by future changes to the core design. However, NEI 12-06, Section 11.8 states that "[e]xisting plant configuration control procedures will be modified to ensure that changes to the plant design ... will not adversely impact the approved FLEX strategies." Inasmuch as changes to the core design are changes to the plant design, the NRC staff expects that any core design changes, such as those considered in a core reload analysis, will be evaluated to determine that they do not adversely impact the approved FLEX strategies, especially the analyses which demonstrate that 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 (CV) 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 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.

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 Braidwood 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 Braidwood plan relies on three different portable diesel driven pumps for each unit during Phase 2. The licensee plans to use a centrifugal low head FLEX pump in combination with a centrifugal medium head FLEX pump to provide an alternate source of feedwater to the SGs if the DDAF pump can no longer perform its function. The licensee also plans to use a positive displacement high head FLEX pump for RCS inventory and reactivity control. In Section 2.3.10 of its FIP, the licensee identified the performance criteria (e.g., flow rate, discharge pressure) for the Phase 2 portable pumps. See Section 3.10 for detailed discussion of the availability and robustness of each water source.

During Phase 2 when the DDAF pump is no longer available, SG makeup will be transferred to a low head FLEX pump (discharging to a medium head FLEX pump). This alignment is described in FIP Sections 2.3.2 and 2.3.10.1. The portable diesel driven low head FLEX pump will take suction from the UHS by means of a strainer in the lake screen house. The pump has a nominal rating of 1500 gpm at 150 psig and provides a water supply of 300 gpm to each unit, as well as 500 gpm for SFP makeup. The licensee performed calculation BRW-14-0030-M Revision 0, "Godwin Pump Suction Line Hydraulic Analysis to Support FLEX," to show the low head FLEX pump has sufficient suction capability to perform its FLEX function. The low head FLEX pump is trailer-mounted and stored in the FLEX Storage Building. Two pumps are available to satisfy the N+1 requirement.

As described in FIP Section 2.3.10.2, the portable diesel-driven medium head FLEX pump has a nominal rating of 500 gpm at 409 psig and is sized to provide adequate cooling water flow for reactor core cooling and heat removal. When needed, it will be moved to the deployment area near the RWST tunnel hatch, and its discharge will be directed to the primary or alternate plant connections within the B/C and A/D MSSV rooms. The licensee performed calculation BYR13-144/BRW-13-0160-M, Revision 2, "FLEX Pump Sizing and Hydraulic Analysis," to determine the fluid system hydraulic performance. The medium head FLEX pump is trailer-mounted and stored in the FLEX Storage Building and three are available to satisfy the N+1 requirement.

The third portable pump is a high head FLEX pump that is described in FIP Section 2.3.10.3. It has a nominal rating of 1522 psig at 40 gpm and is sized to provide for the required RCS inventory and reactivity control. When needed, it will be moved to the deployment area near the RWST tunnel hatch. It will supply borated water from the RWST and discharge through a FLEX primary connection on the B SI system or alternate connection on the B CV system. The licensee performed calculation BYR13-144/BRW-13-0160-M Revision 2, "FLEX Pump Sizing and Hydraulic Analysis," to determine the fluid system hydraulic performance. The high head FLEX pump is trailer-mounted and stored in the FLEX Storage Building and three are available to satisfy the N+1 requirement.

During the audit process, the staff was able to confirm that flow rates and pressures evaluated in the hydraulic analyses were reflected in the FIP for the respective SG and RCS makeup strategies based upon the above FLEX pumps being diesel driven and respective FLEX connections being made as directed by the FSGs. During the onsite audit, the staff conducted a walk down of the hose deployment routes for the above FLEX pumps to confirm the evaluations of the pump staging locations, hose distance runs, and connection points as described in the above hydraulic analyses and FIP.

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

3.2.3.6 Electrical Analyses

The licensee's electrical strategies provide power to the equipment and instrumentation used to mitigate the ELAP and 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 and the summary of calculations for sizing the FLEX generators and station batteries. The staff also reviewed the licensee's evaluations that addressed the effects of temperature on the electrical equipment credited in the FIP as a result of the loss of heating, ventilation, and air conditioning (HVAC) caused by the event.

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

During the first phase of the ELAP event, Braidwood 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 Braidwood 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 and guidleines 1BwCA-0.0, "Loss of All AC Power Unit 1," Revision 209, 2BwCA-0.0, "Loss of All AC Power Unit 2," Revision 206, 1BwFSG-4, "ELAP DC Bus Load Shed/Management Unit 1," Revision 2, and 2BwFSG-4, "ELAP DC Bus Load Shed/Management Unit 2," Revision 1, 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 (Phase 2). 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 Braidwood has two Class 1E station batteries that were manufactured by C&D Technologies. The Class 1E station batteries are model LCUN-33 with 2187 ampere-hours capacity when discharged to 1.81 V/cell.

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 – Common Calc - Beyond Design Basis," Revision 0, which verified the capability of the dc system to supply power to the required loads during the first phase of the Braidwood FLEX mitigation strategy plan for an ELAP as a result of a BDBEE. 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, and the battery vendor's capacity and discharge rates for the Class 1E station batteries, the NRC staff finds that the Braidwood 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 as a result of a BDBEE provided that necessary load shedding is completed within the times assumed in the licensee's analysis.

The licensee's Phase 2 strategy includes a primary and alternate strategy for repowering 480 Vac buses within 6 hours after initiation of an ELAP using three (one per unit and one for N+1) portable 350-kilowatt (kW) 480 Vac FLEX DGs. The portable 480 Vac FLEX DGs would supply power to Braidwood's 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. The primary strategy would also provide power to battery room exhaust fans, MCR lighting, alternate SFP cooling (refueling water purification pump), SFP level instrumentation, DDAF pump battery chargers, lights and ventilation for DDAF pumps and valve operating areas, train B diesel oil fuel transfer pumps, and SI accumulator isolation valves. In the event one unit's 480 Vac bus cannot be repowered and the associated battery charger is unavailable, the battery is fed from the opposite units FLEX DG and battery charger via the dc crosstie, as described in Section 2.3.11 of the licensee's FIP. The alternate strategy would provide power to the battery room exhaust fans, alternate SFP cooling (refueling water purification pump), SFP level instrumentation, DDAF pump battery chargers, lights and ventilation for DDAF pumps and valve operating areas, train B diesel oil fuel transfer pumps, and safety injection accumulator isolation valves, by separately powering the necessary MCCs.

The NRC staff reviewed licensee calculation BWR13-0182-E, "FLEX 480V Bus Connection Equipment Sizing," Revision 2, 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 (BWR13-0182-E), the minimum required loads for the licensee's primary strategy on the Phase 2 350 kW FLEX DG is 191.8 kW and 180.7 kW for Unit 1 and Unit 2, respectively. The minimum required loads for the alternate strategy on the Phase 2 350 kW FLEX DGs is 83.8 kW and 72.7 kW for Unit 1 and Unit 2, respectively. 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 DGs, 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 DGs, the NRC staff finds that the licensee has met the provisions of NEI 12-06, 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 accceptable 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 to use based on plant conditions. This approach also requires a strategy to mitigate the effects of steam from the SFP, such as venting.

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

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

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

3.3.1 Phase 1

Due to decay heat, the SFP water will gradually heat up and evaporate or boil off following a loss of SFP cooling after the ELAP occurs. As described in FIP Section 2.4 and BYR13-240/BRW-13-0222-M Revision 0, "Spent Fuel Pool Boil Off Analysis during an ELAP Event," adequate SFP inventory exists to provide radiation shielding for personnel well beyond the time of boiling. During Phase 1, operators will establish ventilation pathways in the Fuel Handling Building (FHB) by opening the FHB track way roll-up door. In addition, they will monitor level using the SFP level instrumentation installed per Order EA-12-051. Site staff will perform manual actions within the FHB to align the alternate SFP make-up flow path.

3.3.2 Phase 2

For the primary Phase 2 strategy, FIP Section 2.4.2 states that operators will repower the installed safety-related 0A Refueling Water Purification Pump by reenergizing safety-related 480 Vac buses from a FLEX diesel generator. The 0A Refueling Water Purification Pump will be supplied water from the RWST using installed safety-related piping. It will discharge directly to the SFP using existing safety-related discharge piping. This strategy does not require entry into the FHB.

In the FIP, Section 2.4.2 also describes an alternative Phase 2 strategy that uses the portable low head FLEX diesel pump staged at the UHS. This pump will discharge to the medium head

FLEX pump suction header. Discharge hoses will be routed to the SFP via the medium head FLEX pump suction header and will discharge spray flow to the SFP. The deployment of the required hoses in the FHB will be completed before the initiation of boiling in the pool.

3.3.3 Phase 3

In the FIP Section 2.4.3 states that the Phase 3 strategy is a continuation of the Phase 2 strategy but includes equipment available from the NSRC. The NSRC equipment provides backup as necessary to achieve additional defense-in-depth.

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 FIP indicates that boiling begins at approximately 10.94 hours under worst case, non-outage conditions. The staff noted that the licensee's sequence of events timeline in the FIP indicates that personnel will deploy hoses and spray nozzles as a contingency for SFP makeup within 6 to 10 hours from event initiation to ensure the SFP area remains habitable for personnel entry.

As described in the licensee's FIP, during Phase 1 the site has manual actions within the FHB, which include aligning the alternate SFP make-up flow path. In addition, the licensee establishes 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 FHB track way roll-up door to establish the ventilation path.

The licensee's primary Phase 2 SFP cooling strategy involves the use of the 0A Refueling Water Purification Pump with suction from the RWST and discharge through existing safety-related piping directly to the SFP. The licensee's alternative Phase 2 SFP cooling strategy includes the use of a portable low head FLEX diesel pump to provide spray flow. The pump will be staged at the UHS and will require discharge hoses to be routed to the SFP from the medium head FLEX pump suction header. The licensee states in Section 2.4.2 of the FIP that spray monitor nozzles and sufficient hose length required for this strategy are located in the FLEX Storage Building. The staff's evaluation of the robustness and availability of 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 UHS for an ELAP event is discussed in Section 3.10.3.

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 a permanently installed component (i.e., OA Refueling Water Purification Pump) in lieu of complete reliance on the 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 OA 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 on the number of pieces of equipment available (i.e., one Refueling Water Purification Pump and three medium head 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 SFP level instrumentation, including the primary and back-up channels, the display to monitor the SFP water level and environmental qualifications to operate reliably for an extended period are discussed in Section 4 of this safety evaluation.

3.3.4.2 Thermal-Hydraulic Analyses

As described in Section 2.4.6 of the FIP and analysis BYR13-240 / BRW-13-0222-M, "Spent Fuel Pool Boil Off Analysis During an ELAP Event," the SFP will boil in approximately 10.94 hours for the worst case SFP heat load during normal power operation (or non-outage conditions) and 2.72 hours during an outage. For the worst case SFP heat load, it will boil to a level 20 feet above the fuel 24.8 hours into the event for normal power operation and 9.8 hours into the event for an outage.

Section 2.4.6 of the FIP includes two scenarios: (1) a 1/3 core offload for non-outage conditions and (2) a full core offload during a normal refueling outage. 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 the top of active fuel	Makeup rate
Case 1	32.5 million Btu/hr	10.94 hrs	90.98	70 GPM
Case 2	62.9 million Btu/hr	2.72 hrs	43.96	127 GPM

During the audit, the staff noted that licensee calculation, BYR13-240 / BRW-13-0222-M, "RWST Usage during FLEX Scenarios," Revision 1, determined a SFP makeup flow rate of at least 70 gpm will maintain adequate SFP level above the top of active fuel for an ELAP occurring during normal power operation. In addition, as stated in FIP Section 2.4.7.1, the 0A Refueling Water Purification pump has a nominal rating of 150 gpm at 150 psig. Thus, it will provide the required SFP makeup (This pump is also described in updated final safety analyisis report (UFSAR) Section 9.1.3.). Alternatively, the low head FLEX pump is sized to provide 500 gpm to the SFP which far exceeds the required makeup rate shown in the previous table. 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 OA Refueling Water Purification Pump or a portable FLEX pump to provide SFP makeup during Phase 2. Section 2.4.7 in the FIP, describes the hydraulic performance criteria (e.g., flow rate, discharge pressure) for the OA Refueling Water Purification pump and portable FLEX Pump. Specifically, the OA Refueling Water Purification pump rating is a nominal 150 gpm at 150 psig and the low head FLEX pump rating is a nominal 1500 gpm at 150 psig. The supply from the low head FLEX pump is shared in such a manner that 300 gpm is supplied to each unit and 500 gpm is supplied to the SFP. The staff noted that the performance criteria of a FLEX pump supplied from the NSRC for Phase 3 would be capable of fulfilling the mission of the OA Refueling Water Purification pump or the portable FLEX Pump if either were to fail. As stated above, the SFP makeup rate of 70 gpm is bounded by the performance capabilities of the OA Refueling Water Purification pump or the medium-pressure FLEX pump as fed by a low pressure FLEX pump.

During its audit, the staff reviewed calculation BYR13-144/BRW-13-0160-M, "FLEX Pump Sizing and Hydraulic Analysis," Revision 2, and noted the licensee conservatively modeled a SFP make-up rate of 500 gpm discharging into the SFP through spray monitor 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., 127 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 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. Therefore, the NRC staff finds that the SFP spray flow rate is in accordance with 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. Based on the description of the FLEX equipment provided in the FIP, the staff finds the analysis is consistent with the requirements of NEI 12-06 Section 11.2 and the FLEX equipment is capable of supporting the SFP cooling strategy and is expected to be available during an ELAP event.

3.3.4.4 Electrical Analyses

The licensee's Phase 1 electrical strategy is to monitor SFP level using installed instrumentation (the capability of this instrumentation is described in other areas of this SE). In the FIP, the licensee stated that SFP level instrumentation contains an uninterruptible power supply (UPS) that will provide power to the instrumentation for 72 hours. Prior to the UPS exhaustion, the licensee plans to connect the FLEX DG to provide a continuing source of power. Procedures 1BwFSG-5, "Initial Assessment and FLEX Equipment Staging Unit 1," Revision 2 and 2BwFSG-5, "Initial Assessment and FLEX Equipment Staging Unit 2," Revision 0, provide guidance to repower the SFP level instruments from the 480 Vac FLEX DG.

The licensee's Phase 2 electrical strategy is to continue monitoring SFP level. The licensee's strategy is to also repower SFP level instrumentation and the refueling water purification pump using the 480 Vac FLEX DG. Procedure 0BwFSG-11, "Alternate SFP Makeup and Cooling Unit 0," Revision 1, provides guidance for powering the refueling water purification pump from the 480 Vac FLEX DG.

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

The staff reviewed licensee calculation BWR13-0182-E 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 to supply the loads during Phase 3 of an ELAP since they are of higher capacity (1100 kW versus 350 kW) than the FLEX DGs.

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

3.3.5 Conclusions

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

3.4 Containment Function Strategies

The industry guidance document, NEI 12-06, Table 3-2, provides some examples of acceptable approaches for demonstrating the baseline capability of the containment strategies to effectively maintain containment functions during all phases of an ELAP event. One such approach is for a licensee to perform an analysis demonstrating that containment pressure control is not challenged. The 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 50 psig 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 1/2BwCA-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

The Phase 3 coping strategy is to continue monitoring Containment temperature and pressure using installed instrumentation. 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 2.5.3 states that, if necessary, 1/2BwFSG-12, Containment Cooling, provides operators with options for restoring containment cooling to reduce containment temperature and pressure, which use existing plant systems and/or FLEX equipment.

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

Braidwood 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 posttensioning 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 safe shutdown earthquake (SSE) and other design-basis events (including tornado, probable maximum flood (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. Braidwood 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 DGs deployed in Phase 2. If no ac or dc power was available, the FIP states that key credited plant parameters, including containment pressure and containment wide range temperature, would be available using alternate methods.

3.4.4.2 Thermal-Hydraulic Analyses

In the FIP, Section 2.5.6 states that Calculation BYR13-235/BRW-13-0217-M, Containment Pressure and Temperature Response during an ELAP Event, was performed and demonstrates that it will take greater than 30 days for the containment pressure to exceed 54.7 psia and 13.7 days for the containment temperature to exceed 200°F. The staff noted that a pressure of 54.7 psia and a temperature of 200°F are FSG setpoint limits and not the design-basis limits. 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.

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 limits for pressure and temperature 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 Phase 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 maintenance of containment integrity and that required instrumentation continues to function. With an ELAP initiated, while either Braidwood 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.

The licensee's Phase 1 electrical strategy for containment involves initiating and verifying containment isolation per procedures 1BwCA-0.0 and 2BwCA-0.0. Phase 1 also includes monitoring containment pressure and temperature using installed equipment. Control room indication for containment pressure and containment wide range 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 Braidwood, Unit 1 and 2 Class 1E station batteries have adequate power to supply power to the required instrumentation to monitor containment pressure and temperature prior to transitioning to Phase 2.

The licensee's Phase 2 electrical strategy is to continue monitoring containment pressure and temperature 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 pressure and temperature. The NRC staff reviewed the licensee's FLEX DG sizing calculation (BWR13-0182-E) 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 electrical strategy is to continue monitoring containment pressure and temperature, 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 BWR13-0182-E, 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), there is 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 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 46]. 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 45]. 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 37], the NRC staff informed the licensees that the implementation of mitigation strategies should continue as described in licensee's OIPs, and that the NRC safety evaluations and inspections related to Order EA-12-049 will rely on the guidance provided in JLD-ISG-2012-01, Revision 0, and the related industry guidance in NEI 12-06, Revision 0. The hazard reevaluations may also identify issues to be entered into the licensee's corrective action program consistent with the OIPs submitted in accordance with Order EA-12-049.

As discussed above, licensees are reevaluating the site seismic and flood hazards as requested in the NRC's 50.54(f) letter. After the NRC staff approves the reevaluated hazards, licensees will use this information to perform flood and seismic mitigating strategies assessments (MSAs) per the guidance in NEI 12-06, Revision 2, Appendices G and H [Reference 40]. The NRC staff endorsed Revision 2 of NEI 12-06 in JLD-ISG-2012-01, Revision 1 [Reference 41]. The licensee's MSAs will evaluate the mitigating strategies described in this safety evaluation 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 safety evaluation 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 Braidwood Station region determined a design SSE, which is defined as the occurrence of a Modified Mercalli Intensity of VIII originating at the bedrock-till interface at the site. Per Section 2.5 of the UFSAR, Braidwood Station determined the corresponding ground surface acceleration to be 0.26 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 Braidwood Station site is not applicable per NEI 12-06, since Braidwood is considered a "Dry Site" per Braidwood UFSAR. The plant grade elevation is at 600.0 feet and the grade floor of the safety-related buildings are elevation 601.0 feet. The site is not subject to significant river or tsunami type flooding based on site elevation compared to nearby rivers. The PMF along the Kankakee River, Mason River and Granary Creek do not affect the site, since the maximum water surface elevation are 561.3, 582, and 576 feet respectively: the peak elevations are a minimum of 18 feet below the plant grade of 600 feet.

There are no dams or upstream rivers whose failure could cause flooding at the site.

In accordance with NEI 12-06, Revision 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, Revision 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, Revision 1.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee stated that the site is located at 41° 16' North latitude and 88° 13' West longitude, 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 associated with tornados, including missiles produced by these tornados. 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 four times per year.

Per NEI 12-06 (Figure 8-1), Braidwood Station is identified as an area that could receive 25 inches of snow over three days. Per NEI 12-06 (Figure 8-2), identifies Braidwood Station with an Ice Severity Level 5, catastrophic destruction to power lines and/or existence of extreme amounts of ice.

UFSAR Section 2.3.1.1, General Climate, lists the extreme low temperature in the Braidwood Station area, as represented by Peoria, Illinois, as minus 20°F. Minimum temperatures are less than or equal to 32°F about 130 times per year.

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, per UFSAR Section 2.3.1.1, General Climate, the annual average temperature in the Braidwood area as represented by Peoria, Illinois is 50.8°F, with an extreme high of 102°F. Maximum temperatures equal or exceeding 90°F is about 20 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

The licensee indicated in its FIP that the site FLEX Storage Buildings will consist of one robust building and one commercial building. The robust and commercial buildings are located adjacent to each other outside the protected area, southeast of the main parking lot. The site FLEX robust storage structure is designed to withstand design-basis wind, tornado, and seismic events as outlined in NEI 12-06. The commercial building is constructed to American Society of Civil Engineers (ASCE) 7-10 standards. In general, the robust building will contain the sites N FLEX equipment and the commercial building will contain the sites N+1 FLEX equipment. The two storage buildings do not meet the axis of separation described in NEI 12-06. As a result, Braidwood Station is taking an alternate approach to NEI 12-06, Revision 0, for protection of FLEX equipment as stated in Section 5.3.1 (seismic), Section 7.3.1 (severe storms with high winds), and Section 8.3.1 (impact of snow, ice and extreme cold). This alternate approach will be to store N sets of equipment in a fully robust building and the +1 set of equipment in a commercial building. Note that, for Braidwood Station, some of the +1 equipment will be stored in a fully robust building. Refer to Section 3.14 of this SE for the review of the alternative storage approach.

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

3.6.1.1 Seismic

The licensee indicated in its FIP that large portable FLEX equipment such as pumps and power supplies will be secured with tie-downs (minimum of two tie-down points per piece of equipment or engineering evaluation of tie-down) to preclude seismic interaction that could cause damage to the equipment. Storage cabinets and items on shelves will be located such that they will not make contact with equipment if they fall over during a seismic event.

3.6.1.2 Flooding

As previously discussed, Braidwood is considered a “dry” site. The FLEX storage buildings are located above the flood level at an elevation of 602 feet.

3.6.1.3 High Winds

As indicated in its FIP, the licensee is taking an alternate approach to FLEX equipment protection from high winds. Refer to Section 3.14, Alternatives to NEI 12-06, Revision 1, for a review of the alternative storage approach.

3.6.1.4 Snow, Ice, Extreme Cold and Extreme Heat

In its FIP, the licensee indicated that the interior temperatures of the FLEX storage buildings are designed to maintain between 40°F and 100°F. The buildings are designed to withstand the snow loading as required per NEI 12-06.

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 minus 20°F. FLEX hoses were procured with similar operational specification. FLEX cables were procured with similar operational specifications. FLEX DGs were procured with operational specification for ambient temperatures as high as a nominal 122°F and as low as a nominal minus 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, with the exception of tornado winds and missiles, and should adequately address the requirements of the order.

Refer to Section 3.14, Alternative to NEI 12-06, Revision 0, for a review of the storage protection alternative approach for tornado winds and missiles.

3.6.2 Availability 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.

Table 1 of the FIP lists the FLEX portable equipment stored onsite as well as the quantities (except for hoses and cables), 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 stated that for hoses and cables associated with FLEX equipment required for FLEX strategies, an alternate approach to meet the N+1 capability stated in Section 3.2.2 of NEI 12-06, Revision 0, has been selected. This alternative approach is discussed in Section 3.14 of the SE.

In its FIP, the licensee indicated that to ensure readiness of FLEX equipment and support equipment, operators will perform periodic maintenance and testing to verify proper function. 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, with the exception of hoses and cables. For hoses and cables, the licensee is proposing an alternative approach that is discussed in Section 3.14 of this SE.

3.7 Planned Deployment of FLEX Equipment

In its FIP, the licensee indicated that pre-determined primary and alternate deployment routes for Phase 2 portable FLEX equipment are identified in CC-BR-118-1001, Site Implementation of Diverse and Flexible Coping Strategies (FLEX) and Spent Fuel Pool Instrumentation Program, Attachment 7.

3.7.1 Means of Deployment

In its FIP in Attachment 2, the licensee provided a list of FLEX Equipment to include tow and debris removal vehicles. The licensee stated in its FIP that debris removal and onsite transport of Phase 2 FLEX portable equipment will be accomplished using one F-750 (or equivalent) equipped with a plow and two tractors equipped with buckets.

3.7.2 Deployment Strategies

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

In its FIP, the licensee indicated that the deployment of onsite FLEX equipment in Phase 2 requires that pathways between the FLEX storage building(s) and various deployment locations be clear of debris resulting from BDB events. The stored FLEX debris removal equipment includes a F750 truck with plow and two tractors. One of the tractors is equipped with a bucket and the other with forks to assist in debris removal. These vehicles will be stored within the robust FLEX building. The robust building has three vehicle access doors. The two tractors and the F750 truck will be staged behind these doors ready to deploy. The deployment of the debris removal equipment and the Phase 2 FLEX equipment from the storage building is not dependent on offsite power. The building equipment doors can be manually opened, if needed.

In its FIP, the licensee stated that 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 indicated that there is a potential for liquefaction at intermittent depths between about 6 feet to 16 feet. The induced ground settlement for the FLEX equipment paths outside the main plant area is about 1 inch. The induced ground settlement for the FLEX equipment paths in the main plant area is about 2 inches. Considering the size of the haul vehicles and the trailer loads, 1 inch to 2 inch settlement should not impose a significant impediment to FLEX equipment deployment

The licensee indicated in its FIP that deployment paths and staging areas are contained in the snow/ice removal plan. These areas will be maintained as a priority after site safety concerns are addressed. Post event snow/ice removal will be accomplished by a FLEX truck with snow plow or FLEX tractor with bucket. Additionally, the main road salt storage facility contains a large amount of salt and smaller amounts are strategically located throughout the site for winter use.

In its FIP, the licensee indicated that FLEX temporary hoses routed outside will be protected from freezing by maintaining positive flow or by draining when not in use. Operator guidance has been added to various FSGs to alert the operators to the potential freezing concern. Additional sections of FLEX hose are also available as a replacement in the event a section of the hose freezes.

In its FIP, the licensee stated that the lake (UHS) temperature trends for the last 3,600 days shows the temperature has been maintained above freezing. The SX suction in the UHS is well below the surface to protect it from surface ice blockage. The low head portable FLEX pump suction is from a temporary hose/strainer lowered into the UHS and will be below the surface to protect it from ice blockage. Additionally, a set of fire irons will be available to breakup surface ice, if necessary.

3.7.3 Connection Points

3.7.3.1 Mechanical Connection Points

Primary and Alternate SG Makeup Connections

The DDAF pump provides an indefinite supply of water for feeding the SGs in both the Phase 1 and Phase 2 strategies. However, if this pump becomes unavailable, then the medium head FLEX pump is used to supply feedwater to the SGs. The primary and alternate connections for the medium head FLEX pump are described in FIP Sections 2.3.5.1 and 2.3.5.2, respectively. The primary SG connection is located in the B/C MSSV room on the 401 foot elevation; the alternate connection is in the A/D MSSV room also at the 401 foot elevation. For the primary connection, a flexible hose will be routed from the discharge of the medium head FLEX pump to the FLEX connection on the B/C AF lines in the B/C MSSV room. The alternate FLEX connection would be to the A/D AF lines in the A/D MSSV room. In addition, the B/C and A/D AF lines have flanges in the Main Steam tunnel on the 377 foot elevation and a hose can be routed through the tunnel between these two flanges to allow one medium head FLEX pump to feed all four SGs. In the FIP, Section 2.3.5 states that the connections are above or protected from the probable maximum precipitation flood level and are protected from the external hazards described in FIP Section 2.6. These hazards include seismic, external flooding, high winds, ice, snow, extreme cold, and extreme high temperatures. In addition, the MSSV room and Main Steam tunnel are seismic Category I, missile protected areas.

RCS Inventory Control/Makeup

The high head FLEX pump provides borated water from the RWST for RCS Inventory Control/Makeup. As stated in FIP Section 2.3.5.5, the primary supply of water to this pump is through a connection installed in the RWST tunnel on the suction piping of the B SI pump. A hose is routed from this connection, through the RWST tunnel, to the high head FLEX pump suction manifold. If the RWST is not available, then a connection to the opposite unit's RWST can be made through the opposite unit's high head FLEX pump suction manifold. For RCS makeup connections, FIP Section 2.3.5.3 states that the primary connection is in the RWST tunnel and FIP Section 2.3.5.4 states that the alternate connection is in the B CV system pump room. For the primary connection, a hose will be routed from the pump through the RWST tunnel hatch to a FLEX connection on the B SI system downstream of the B SI pump. For the alternate connection, a hose will be routed from the pump through the RWST tunnel hatch, through the RWST tunnel to a FLEX connection on the B CV system downstream of the B CV pump, but to support physical and train separation from the primary connection, additional routings are also available. The discharge hose could instead be routed through the Fuel Handling Building or the opposite unit's RWST tunnel. In the FIP, Section 2.3.5.3 states that the connections in the RWST tunnel and CV pump rooms are protected from the external hazards described in FIP Section 2.6.

SFP Cooling

The primary Phase 2 strategy for SFP cooling is to repower the installed 0A Refueling Water Purification Pump and use existing safety-related suction and discharge piping to supply water from the RWST directly to the SFP. No FLEX connections are required to implement the primary strategy. For the alternate strategy, the Low head FLEX pump is staged at the UHS to provide water to the medium head FLEX pump suction header. Discharge hoses are routed from the header to provide spray flow to the SFP. As stated in FIP Section 2.4.4.2, no FLEX connections to plant systems are required to implement this strategy.

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

3.7.3.2 Electrical Connection Points

Electrical connection points are only applicable for Phases 2 and 3 of the licensee's mitigation strategies for a BDBEE 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 three (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 track way. 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. One units 480 Vac FLEX DG would be connected to the FLEX power connection panel to provide power directly to motor control centers (MCCs) to provide power to needed equipment. The other 480 Vac FLEX DG woukd 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 developed under the loading premise that one unit would be implementing the primary strategy while the opposite unit would be implementing the alternate strategy. Procedures 1BwFSG-5 and 2BwFSG-5, provide direction for connecting (primary and alternate strategy) the 480 Vac FLEX DGs. In its FIP, the licensee stated that the FLEX DG phase rotation was verified to be compatible with Braidwood Station equipment and that standard color-coded cables will be used to ensure the FLEX DG is properly connected.

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 1BwFSG-13, "Transition From FLEX Equipment Unit 1," Revision 2 and 2BwFSG-13, "Transition From FLEX Equipment Unit 2," Revision 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 indicated that Appendix R lights, although not robust, are available in many locations within the plant and 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. Temporary lighting will be established in the MCR, DDAF pump rooms, flow control valve operating area, and FLEX equipment deployment areas as directed by the initial equipment and FLEX equipment staging FSG. The MCR lighting will also be restored after a FLEX DG powers the applicable motor control center. In addition, the high and medium head FLEX pumps are equipped with external lighting that illuminates the deployment area. Figures 14, 15, and 16 of the FIP depicts the general lighting layout for the MCR, DDAF pump rooms, and the flow control valve operating area.

3.7.5 Access to Protected and Vital Areas

In its FIP, the licensee indicated that site security doors electronic latches will fail in the latched position requiring operators to open the security doors with keys located in the MCR in order to execute the FLEX strategies. In addition, site security will be available to assist in allowing access to the required vital areas.

In its FIP, the licensee indicated that vehicle access to the protected area via the vehicle access area will be manually controlled by site security, as part of the security access contingency, to allow delivery of FLEX equipment (e.g., generators, pumps) and other vehicles such as debris removal equipment into the protected area.

3.7.6 Fueling of FLEX Equipment

In the FIP, Sections 2.3.5.8 and 2.9.5, and the "Braidwood Flex Fuel Consumption Study" included in Attachment 9 of CC-BR-118-1001, Revision 1 describe the safety-related Unit 1/2 "A" and "B" Train DG Fuel Oil Storage Tanks. These tanks are underground safety-related tanks protected from external hazards. As described in Attachment 9 of CC-BR-118-1001, Revision 1, the DDAF pumps are refueled directly from the tanks but five other major pieces of FLEX equipment require mobile refueling. To accomplish the mobile refueling, a FLEX connection has been installed in both units' B DG rooms at the 401' elevation. The FLEX connection is on the discharge of the fuel transfer pumps, and hoses are routed from this connection to the Turbine Building track way door to a fuel transport vehicle. In the FIP, Section 2.3.11 states that the Train B fuel transfer pumps will be repowered from a FLEX DG. In addition, FIP Section 2.6.2 describes protection of the transfer pumps from external and internal flooding. Based on the design and location of the fuel oil storage tanks and their safety-related classification, as well as the protection of the transfer pumps from flooding and the availability of additional ones from NSRC (See FIP Section 2.9.5.), the staff finds the tanks are robust and transfer pumps should be available to supply fuel oil to support the licensee's FLEX strategies during an ELAP event.

Attachment 9 of CC-BR-118-1001 states that administrative controls ensure that the fuel oil storage tanks are filled to 95.7 percent of capacity. At this amount, the site would have at least 191,400 gallons of fuel to support continuous operation of major FLEX equipment. Attachment 9 of CC-BR-118-1001, Revision 1, is a fuel consumption study for FLEX equipment and it shows that the fuel supply capacity is adequate to provide onsite FLEX equipment with diesel fuel for more than 30 days. In addition, the site has 125,000 and 50,000 gallon storage tanks that are not robust but could be used if available. In the FIP, Sections 2.9.5 and 2.3.2 and Attachment 9 in CC-BR-118-1001, Revision 1, describe the use of procedure 0BwFSG-50, "FLEX Support Equipment Operation" for refilling tanks on FLEX equipment. It applies to filling the DDAF day tank as well as portable diesel fuel tanks. It is also used for transferring fuel oil from Train A fuel oil storage tanks to Train B. Given the information above, the licensee should have sufficient fuel onsite to support FLEX strategies that use diesel-powered equipment during an ELAP event until off-site resources are available to replenish fuel oil. In addition, based on a review of guideline 0BwFSG-50, the staff finds the licensee should be able to refuel the diesel-powered FLEX equipment to ensure uninterrupted operation and support the licensee's FLEX strategies.

In the FIP, Section 2.18.7 states that FLEX mitigation equipment is subject to initial acceptance testing and subsequent periodic maintenance and testing to verify proper operation. It also states that portable FLEX equipment is maintained under the site's Preventative Maintenance (PM) program. Section 4.5.4 of CC-BR-118-1001, Revision 1, describes the inspection intervals for FLEX equipment and includes the addition of fuel stabilizer additive or sampling the fuel and replacing as required during annual inspections. In the FIP, Section 2.9.5 describes the fuel used in FLEX equipment. It states that FLEX equipment will operate on the same type of Ultra Low Sulfur (ULS) diesel fuel. Furthermore, all fuel onsite, as well as future orders, will meet the

ULS requirement. Therefore, the staff finds that the licensee has addressed management of fuel oil quality in the fuel oil storage tanks and FLEX equipment to ensure the FLEX equipment will be supplied with quality fuel oil 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 Braidwood Generating Station 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

Equipment will be moved from an NSRC to a local assembly area, established by the SAFER team and the utility. Site primary staging area (Area C) location is the Pontiac Municipal Airport in Pontiac Illinois. The alternate staging area (Area D) location is LaSalle Nuclear Station near Marseilles Illinois. The site has approved memorandum of understanding (MOU) with Pontiac

Municipal Airport and LaSalle Nuclear Station. Primary and alternate transportation routes have been identified between these locations and the site. These routes are detailed within the sites response plan (playbook). The main transportation method will be by a heavy haul vehicle. If an accessible transportation route cannot be identified, helicopter transportation will be utilized. Communications will be established between the affected nuclear site and the SAFER team and required equipment moved to the site as needed. 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. Staging Area B is located within Braidwood Station's owner controlled area located in the northeast corner of the main employee parking lot. The FLEX buildings are located southeast of this location. The southeast corner of the contractor parking lot can be used as an alternate Staging Area B, if needed. From Staging Area B, equipment is moved to the normal vehicle access area and processed into the protected area to Staging Area A. First arriving equipment, as established during development of the nuclear site's playbook will be delivered to the site within 24 hours from the initial request. Braidwood Station's response plan (playbook) CC-BR-118-1002, Revision 1, has been developed and approved.

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 Braidwood, 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 (MEERs), 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," Revision 0, modeled the transient temperature response in the MCR following an ELAP event. The calculation showed that the MCR will take greater than 8 hours to reach 120°F. To prevent MCR temperatures from exceeding 120°F, licensee procedure 0BwFSG-51, "Alternate MCR Ventilation Unit 0," Revision 1, provides guidance for establishing portable ventilation, opening room doors, and opening MCR back panel doors. Procedure 0BwFSG-5, “Initial Assessment and FLEX Equipment Staging Unit 0,” Revision 4, provides guidance to shift power for the portable ventilation from 5.5 kW FLEX DGs to the 480 Vac FLEX DGs, if necessary.

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,” Revision 1, for electronic equipment to be able to survive indefinitely), the NRC staff expects that the equipment in the MCR should 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 the Unit 1 and Unit 2 AEER is 6.35 hours and 4.75 hours, respectively. To prevent AEER temperatures from exceeding 122°F, licensee procedure 0BwFSG-51, provides guidance for establishing portable ventilation, opening room doors, and opening energized AEER cabinet 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 4.5 hours

Based on the availability of procedure 0BwFSG-51 which provides 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.

Diesel Driven Auxiliary Feedwater Pump Room

Licensee analysis BYR13-234/BRW-13-0216-M, “Auxiliary FW Pump Room Temperature Analysis During an ELAP Event,” Revision 0, modeled the transient temperature response in the DDAF pump room following an ELAP event. In the FIP, Section 2.11.1 describes ventilation in the DDAF pump room and FIP Sections 2.3.4.1 and 2.3.4.2 describe DDAF pump cooling, including the use of an alternate SX line installed to cool DDAF engine components during a BDBEE. The licensee’s analysis showed that the DDAF pump room coolers will function adequately during an ELAP (powered by a FLEX DG) and supplemental room cooling is not required. Although supplemental room cooling is not necessary, procedure 0BwFSG-5, “Initial Assessment and FLEX Equipment Staging Unit 0,” Revision 2, provides guidance for opening room doors and establishing alternate ventilation. The licensee’s analysis uses a room temperature of 140°F in the heat transfer calculation. However, the analysis states that this temperature is extremely conservative since the FLEX bypass will bring cool water to the room coolers, noticeably improving their cooling capacity and decreasing room temperatures. In addition, the FLEX bypass will occur within 40 minutes and allow cool water to be distributed to DDAF engine components. Procedures 1BwFSG-2, “Alternate AFW/EFW Suction Source Unit 1,” Revision 1 and 2BwFSG-2, “Alternate AFW/EFW Suction Source Unit 2,” Revision 0, provide guidance to operators to align the alternate SX line.

Based on the room coolers functioning adequately, the availability of cooling water through the FLEX bypass, and the procedural guidance for alternative cooling, the NRC staff finds the DDAF pumps should remain functional 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," Revision 0, modeled the transient temperature response in the Vital Battery Rooms and MEERs 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 0BwFSG-5 provides guidance for opening doors and setting up portable ventilation, if necessary. Procedures 1BwFSG-5 and 2BwFSG-5, provide 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.

Based on the above, the NRC staff finds that the licensee's ventilation strategy (open doors and restore ventilation) 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. 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.

The licensee's calculation showed that the maximum equipment acceptance temperature in the MEERs is 138°F (includes inverters and battery chargers), and that the Division 1 and 2 MEER would reach 132°F and 133°F, respectively 8 hours into an ELAP event. The licensee's calculation also showed that by establishing portable ventilation and opening doors before 8 hours per procedure 0BwFSG-5, temperature should drop below 108°F within this timeframe.

Based on temperatures remaining below 138°F (maximum acceptance temperature limit) and the licensee's ventilation strategy, the NRC staff finds that the electrical equipment in the MEER should 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," Revision 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 1BwFSG-12, "Alternate Containment Cooling Unit 1," Revision 0 and 2BwFSG-12, "Alternate Containment Cooling Unit 2," Revision 0, provide guidance to maintain containment temperature and pressure below limits by using alternate containment spray, venting containment, repowering the reactor containment fan coolers, or externally cooling containment so that equipment located inside containment remains functional throughout the ELAP event.

Based on containment temperature and pressure remaining below their respective design limit and the licensee's alternate containment cooling strategies, 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.

Conclusion

Based on its review of the essential station equipment required to support the FLEX mitigation strategy, which are primarily located in the MCR, AEERs, DDAF Pump Rooms, Vital Battery Rooms and MEERs, and Containment, the NRC staff finds that the electrical 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 2.6.4 states that extreme low temperatures can reach - 20 °F in the Braidwood Station area with minimum temperatures less than or equal to 32 °F about 130 times per year. The licensee addresses the protection of FLEX equipment from extreme cold in FIP Section 2.7. In addition, it describes the results of its FLEX strategy evaluation for potential freezing in FIP Sections 2.7 and 2.11.2. Finally, the licensee addresses the temperature effects on battery capacity in Calculation BYR13-237 / BRW-13-0219-M, Revision 0.

In the FIP, Section 2.7 addresses the protection of FLEX equipment from extreme cold. It states that the dedicated FLEX equipment will be housed in a FLEX storage robust building and a commercial building with interior temperatures maintained between 40 °F and 100 °F. The licensee commits to Item 2 in Section 8.3.1 of NEI 12-06 which states that equipment should be maintained at a temperature within a range to ensure its likely function when called upon. The FLEX pumps were procured with an ambient temperature operational specification as low as -20 F. In addition, the licensee procured FLEX DGs with an operational specification for ambient temperatures as low as a nominal -25 °F. Therefore, the NRC staff finds the FLEX equipment is stored at a temperature significantly above its low operational specification and this should ensure its likely function when called upon consistent with Section 8.3.1 of NEI 12-06.

In the FIP, Sections 2.7 and 2.11.2 describe the potential for freezing to affect the site's FLEX strategy because some equipment is installed outside or deployed outside. The RWST vent header is heat traced and includes a vacuum relief device, but the licensee also provides direction in 0BwFSG-5, "Initial Assessment and FLEX Equipment Staging," to open the RWST hatch to ensure a vent path is maintained in the event that temperatures lower than 35° F are expected. Also, the licensee determined that the RWST could potentially reach 32 °F in 83.7 hours, but it determined boron should not precipitate before this time. Therefore, borated water would remain available as required. Calculation BYR14-130 / BRW-14-0211-M, Revision 0 also evaluates hoses. It recommends fittings be insulated in extreme cold temperatures in order to increase the time for the hoses to reach 32 °F and decrease the required flow rate. Although this recommendation is not described in FIP Sections 2.7 or 2.11.2, these sections instead specify that FLEX temporary hoses, routed outside, will be protected from freezing by maintaining positive flow or by draining when not in use. In addition, other sections of FLEX hose are available as a replacement if a section freezes. Therefore, the NRC staff finds the FLEX equipment installed or deployed outside should remain available to perform its required functions during potential freezing conditions and loss of heating.

The vital batteries are located in the interior of the auxiliary building such that outside air temperature should not adversely impact battery performance. The battery room minimum temperature acceptance criteria is 60°F. Licensee calculation BYR13-237/BRW-13-0219-M shows that the battery room temperature does not drop lower than 65°F (assuming a worst case outside temperature of -10°F) within 24 hours. The licensee expects to restore HVAC within 6 hours when the FLEX DGs restore power to the 480 Vac buses. 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 Braidwood vital batteries should perform their required functions as a result of loss of heating during an ELAP event.

Based on the information above, the NRC staff finds the station equipment required to support the FLEX mitigation strategy should perform the required functions at the expected temperatures as a result of loss of heating during an ELAP event consistent with NEI 12-06 Sections 3.2.2.12 and 8.3.2.

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 Vital 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 Class 1E station batteries are charging. Procedure 1/2BwFSG-5, provides guidance to repower battery room exhaust fans when the 480 Vac FLEX DGs are repowering the 480 Vac bus and the Class 1E 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 Braidwood 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

In the FIP, Section 2.12 states that the licensee will maintain habitability conditions within the MCR and other areas using methods such as supplemental cooling, personnel rotation, and/or availability of fluids. It identifies seven areas where local manual actions will occur to support the FLEX strategy. These areas are described in the sections that follow.

3.9.2.1 Main Control Room

In the FIP, Section 2.12 states that temporary ventilation will be setup in MCR and the AEERs. The Unit 1 and Unit 2 AEERs will not be continuously occupied but entry is required for instrument readings. The MCR will be continuously occupied.

In the FIP, Section 2.11.1 identifies temperature limits being reached within approximately 4.75 hours, and 1/2BwFSG-5, "Initial Assessment and FLEX Equipment Staging," provides guidance for operators to establish ventilation within this timeframe. Calculation BYR13-236 / BRW-13-0218-M, "Control Room and Auxiliary Electric Equipment Room Heat Up and Ventilation during an ELAP Event" calculates the times for the MCR, Unit 1 AEER, and Unit 2 AEER to reach a limit of 122 °F. The Unit 2 AEER is the first to reach the limit at 4.75 hours, but the MCR takes more than 8 hours to reach the limit. Consistent with these times and the guidance in 1/2BwFSG-5, Action Item 11 in FIP Table 4 identifies ventilation being setup between 3 and 4.5 hours following the occurrence of the BDBEE. This alternate ventilation is established using the guidance in 0BwFSG-51, "Alternate MCR Ventilation." Therefore, the licensee's strategy should establish acceptable conditions in the MCR for continuous habitability following the ELAP.

3.9.2.2 Spent Fuel Pool Area

In the FIP, Section 2.12 states that initial actions will be performed in the SFP area, but entry afterwards is not required. Initial actions include the setup of temporary hoses and spray nozzles. In addition, Phase 1 actions require a SFP vent path be established by opening the FHB track way roll-up door. Guideline 1/2BWFSG-5 states that SFP boiling may occur in 10.94 hours (2.72 hours following a full core offload). These times are calculated in Calculation BYR13-240 / BRW-13-02222-M, "Spent Fuel Pool Boil Off Analysis during an ELAP Event" and are also described in Section 3.3.4.2 of this report. Because the FHB may become inaccessible once boiling occurs, the alternate SFP makeup and the FHB vent path need to be setup prior to that time. Action Item 13 in FIP Table 4 identifies deploying hoses and connections in the FHB for alternate SFP makeup between 6 to 10 hours following the occurrence of the BDBEE. This timeframe is consistent with the calculated SFP boiling time for normal power or non-outage conditions.

3.9.2.3 Other Plant Areas

In the FIP, Section 2.12 identifies five other plant areas where local manual actions will occur; however, continuous occupancy is not required in these areas.

Diesel Driven Auxiliary Feedwater Pump Room

In the FIP, Section 2.11.1 states that supplemental room cooling is not required in the DDAF Pump Room; however, 0BwFSG-5, "Initial Assessment and FLEX Equipment Staging," does provide guidance for setting up alternate cooling as an option for operators. Calculation BYR13-234 / BRW-13-0216M, "Auxiliary FW Pump Room Temperature Analysis during an ELAP Event" shows that the room coolers will function adequately during an ELAP, and therefore, operators would be able to gain access to the pumps. In the FIP, Section 2.12 states that initial operator actions include aligning the DDAF pump suction source and aligning the alternate SX cooling water supply to the diesel engine. Other actions would include filling the day tank, monitoring pump performance, and setting up temporary ventilation.

Main Steam Safety Valve Room

The SG PORVs are located within the MSSV room. These valves may need to be manually throttled for an indefinite period of time via a hydraulic hand pump. Entry to the MSSV would only be required to make small valve position adjustments and the work would be next to an outside access door which can be opened to provide ventilation.

Miscellaneous Electric Equipment Room and Battery Room

In the FIP, Section 2.11.1 addresses the need for ventilation in the MEERs and battery rooms to preserve component availability. Calculation BYR13-237 / BRW-13-0219-M," MEER and Battery Room Conditions Following an ELAP," determines the maximum temperatures in these rooms from an initial maximum normal temperature of 108 °F. Temperature profiles from the calculations show temperatures increasing rapidly in the first hour to more than 120 °F. In the FIP, Section 2.12 states that continuous occupancy is not required in the MEERs or battery rooms; however, ventilation is needed for personnel access because of the potential for high temperatures. 0BwFSG-5 and 1/2BwFSG-5 provide guidance to operators for establishing ventilation. In addition, Calculation BYR13-237 / BRW-13-0219-M describes the use of portable fans to ensure MEER and battery room temperatures do not exceed 108 °F.

Main Steam Tunnel

Initial actions are required to route a temporary hose between the A/D and B/C MSSV rooms. The Main Steam Tunnel will have natural circulation from the Turbine Building and out through the MSSV rooms. It therefore does not require additional ventilation.

Diesel Driven Auxiliary Feedwater Pump Discharge Valve Area (AF005s)

In the FIP, Section 2.12 states that the DDAF pump discharge valves will need to be throttled periodically, and these valves are located on the 364' elevation of the Auxiliary Building. Because this area does not include components that will generate significant heat the area remains relatively cool, and therefore, does not require additional ventilation for operator access.

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

In its FIP, the licensee described the water sources for SG makeup as the non-safety grade CSTs (preferred source) with a minimum of 212,000 gallons available per unit. The CST provides a gravity flow of water to the AF system which feeds the SGs. The SX system provides a safety-related seismic category 1 backup to the CSTs to feed the SGs from the UHS. The UHS is sized to permit a minimum of 30 days of operation with no makeup and consists of an excavated essential cooling pond integral with the main cooling pond, and the piping and valves connecting the pond with the SX system pumps. The licensee's strategy prioritizes the water sources from the cleanest to the dirtiest. The first choice for makeup to the SGs is the CST. If the CST is not available the UHS will be used. Additionally, lakes adjacent to the site, such as Monster Lake, can be used as make-up water sources for the UHS. Approximately 24 hours after the event, equipment from the NSRC will begin arriving which includes water purification equipment which can be used for SG makeup.

3.10.2 Reactor Coolant System Make-Up

In its FIP, the licensee indicated that the passive SI accumulators (4 per unit) will provide the initial source of borated water for reactivity control and RCS inventory makeup. Each SI accumulator contains a nominal volume of 7,106 gallons of water with a boron concentration of 2,300 ppm. Nitrogen gas is the motive force for RCS addition from the accumulators and is sufficient to discharge each borated accumulator contents into their respective cold leg of the RCS as RCS pressure decreases below the accumulator pressure.

In its FIP, the licensee describes the RWST (one per unit) as the supply of water for makeup to the RCS. Each RWST has a usable volume of 320,600 gallons of water maintained at a nominal boron concentration of 2400 ppm. Calculations have shown that in the most demanding scenario of usage, each RWST alone will provide at least 33.6 hours of borated water. If an alternate water supply is provided to the SFP, a single RWST is not depleted until 1,060 hours.

The licensee indicated in its FIP that the RWST and the SI accumulators are designed to withstand all the applicable extreme hazards.

Approximately 24 hours after the event, equipment from the NSRC will begin arriving which includes water purification equipment which can be used for RCS makeup. In addition, the licensee has developed strategies for refilling the RWST from the boric acid storage tanks (BASTs), portable makeup skid, or by cross-tying the RWSTs.

3.10.3 Spent Fuel Pool Make-Up

In its FIP, the licensee described that the primary source of makeup to the SFP is from the RWST via a repowered safety-related refueling water purification pump and piping discharging directly to the SFP. The the alternate source of makeup to the SFP is from the UHS via the low head FLEX pump and hoses routed via the medium head FLEX pump suction manifold to the

SFP. While the RWST is a limited supply, the UHS can provide an indefinite supply of water to the SFP.

Additional equipment will be available from the NSRC to support SFP makeup activities after approximately 24 hours.

3.10.4 Containment Cooling

In its FIP, the licensee indicated that calculations demonstrate that containment temperature and pressure design limits are not expected to be approached during Phase 1 and 2, thus, no direct water sources are required for containment cooling. If required during Phase 3, containment pressure and temperature can be reduced by restoring containment cooling using existing plant systems, on-site FLEX equipment, and/or equipment available from the NSRC.

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 10 hours are available to implement makeup before boil-off results in the water level in the SFP dropping to a level of 20 feet above the 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 38], which described methods to ensure plant safety in those shutdown modes. By letter dated September 30, 2013 [Reference 39], 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. Per Section 2.16 of the FIP, the licensee stated that Braidwood Station will 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.

3.12 Procedures and Training

3.12.1 Procedures

In its FIP, the licensee indicated that the inability to predict actual plant conditions that require the use of BDB equipment makes it impossible to provide specific procedural guidance. As such, the Braidwood Station FSGs provide guidance that can be employed for a variety of conditions. Clear criteria for entry into FSGs will ensure that FLEX strategies are used only as directed for BDB external event conditions, and are not used inappropriately in lieu of existing procedures. When FLEX equipment is needed to supplement EOPs, contingency action procedures (CAs), or abnormal operating procedures (AOPs) strategies, the EOP, CA or AOP, as well as severe accident mitigation guidelines (SAMGs), or extreme damage mitigation guidelines (EDGMs), direct the entry into and exit from the appropriate FSG procedure. The licensee also stated that FLEX Strategy guidelines have been developed in accordance with PWROG guidelines. The FSGs provide available, pre-planned FLEX strategies for accomplishing specific tasks in EOPs, CAs or AOPs. The FSGs are used to supplement (not replace) the existing procedure structure that establishes command and control for the event.

In addition, the licensee indicated in its FIP that procedural interfaces have been incorporated into each unit's EOP for Loss of all ac Power and Loss of All ac Power while on Shutdown Cooling to the extent necessary to include appropriate reference to FSGs and provide command and control for the ELAP.

3.12.2 Training

In its FIP, the licensee stated that Braidwood's Nuclear Training Program has been revised to assure personnel proficiency in the mitigation of BDBEE is adequate and maintained. These programs and controls were developed and have been implemented in accordance with the Systematic Approach to Training (SAT) Process. Using the SAT, operations and other appropriate personnel received initial and will receive continuing training on FLEX related procedures and strategies.

In its FIP, the licensee stated that personnel assigned to direct the execution of mitigation strategies for BDBEEs have received the necessary training to ensure familiarity with the associated tasks, considering available job aids, instructions, and mitigating strategy time constraints. Upon SAFER equipment deployment and connection in an event, turnover and familiarization training on each piece of SAFER equipment will be provided to station operators by the SAFER deployment/operating staff.

In its FIP, the licensee stated that Emergency Response Organization (ERO) members have completed [National Academy for Nuclear Training e-Learning] NANTEL Basic FLEX

Certification. New ERO members will complete NANTEL Basic FLEX Certification. ERO decision makers have completed NANTEL Generic Advanced FLEX Certification. New ERO Decision makers will complete NANTEL Generic Advanced FLEX Certification.

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 its FIP, the licensee stated that FLEX mitigation equipment is subject to initial acceptance testing and subsequent periodic maintenance and testing to verify proper function. Portable FLEX equipment is maintained under the site's PM program. PM procedures and test procedures are based on the templates contained within the EPRI PM Basis Database. FLEX support equipment will be maintained as necessary to ensure continued reliability. The performance of the PMs and test procedures are controlled through the site work control process.

In its FIP, the licensee also stated that identified equipment deficiencies shall be entered into the corrective action program. Equipment deficiencies that would prevent FLEX equipment from performing the intended function shall be worked under the priority list in accordance with the work management process. Equipment that cannot perform its intended functions shall be declared unavailable. Unavailability shall be tracked in accordance with 0BwOS FX-1a, Administrative Action Requirement (AAR) FLEX Support Equipment.

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, Revision 0

3.14.1 FLEX Storage Building Alternative Approach

Per Section 3.6.1 of this SE, the Braidwood FLEX storage configuration utilizes two storage locations: one robust building and one commercial building. The robust and commercial buildings are located adjacent to each other outside the protected area, southeast of the main parking lot. The site FLEX robust storage structure is designed to withstand design-basis wind, tornado, and seismic events as outlined in NEI 12-06. In general, the robust building will contain the sites N FLEX equipment and the commercial building will contain the sites N+1 FLEX equipment. In NEI 12-06, Revision 0, Section 10.1, stipulates that N+1 sets of FLEX equipment be protected from all applicable BDBEEs. However, the Braidwood FLEX storage configuration does not protect N+1 sets of FLEX equipment from all applicable BDBEEs as stipulated in NEI 12-06, Revision 0, Section 10.1. As a result, Braidwood Station is taking an alternate approach to NEI 12-06, Revision 0, for protection of FLEX equipment.

In its FIP, the licensee acknowledges that the Braidwood FLEX storage configuration is an alternative to the guidance in NEI 12-06, Revision 0. The FIP also describes a reduced allowed out of service time for FLEX equipment maintenance to address the alternative FLEX storage configuration. The NRC staff notes that by letter dated December 10, 2015, NEI submitted guidance document NEI 12-06, Revision 2 [Reference 40] to the NRC for review. By letter dated January 22, 2016 [Reference 41], the NRC staff endorsed NEI 12-06, Revision 2. Guidance document NEI 12-06, Revision 2, contains modifications which resulted in NRC acceptance of the storage of backup (N+1) equipment such that it is not protected from the applicable BDBEE hazards. Section 11.5.4.b of NEI 12-06, Revision 2, contains the condition that if the site FLEX capability (N) is met, but not protected for all of the site's applicable hazards, then the allowed unavailability is reduced to 45 days (compared to the 90 day unavailability with any FLEX equipment unavailable, but with the FLEX capability (N) available and in a protected or diverse storage configuration). Although Braidwood is evaluated to NEI 12-06, Revision 0, in this SE, the licensee has committed to follow the 45 day unavailability limit consistent with NEI 12-06, Revision 2 [Reference 40]. Therefore, the NRC staff finds the Braidwood storage configuration acceptable.

The NRC staff reviewed the licensee's proposal and finds that the methods used to ensure that the primary (N) set of equipment is available, with a reduction in allowed unavailability to 45 days if any N equipment is not protected for all of the site's applicable hazards, is an acceptable alternative to the NEI 12-06, and should meet the requirements of Order EA-12-049.

3.14.2 Reduced Set of Hoses and Cables As Backup Equipment

In its FIP, the licensee describes an alternative approach to the NEI 12-06 guidance for hoses and cables. In NEI 12-06, Section 3.2.2 states that in order to assure reliability and availability of the FLEX equipment required to meet these capabilities, the site should have sufficient equipment to address all functions at all units on-site, plus one additional spare, i.e., an N+1 capability, where N is the number of units on-site. Thus, a single-unit site would nominally have at least two portable pumps, two sets of portable ac/dc power supplies, two sets of hoses and cables, etc. The NEI on behalf of the industry submitted a letter to the NRC [Reference 42] 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 the NEI proposal. By letter dated May 18, 2015 [Reference 43], the NRC agreed that the alternative approach is reasonable, but that the licensees may need to provide additional justification regarding the acceptability of various cable and hose lengths with respect to voltage drops, and fluid flow resistance. Based on the FIP description and meeting the provisions of References 42 and 43, the NRC staff approves this alternative as being an acceptable method of compliance with the order.

3.14.3 PORV Manual Hand Pump Protection Alternative Approach

In its FIP, the licensee indicated that they will be taking an alternate approach to NEI 12-06 Sections 3.2, Performance Attributes, and 3.2.1 .3, Initial Conditions. The alternate approach is for the method of protecting the permanently installed PORV manual hand pumps from all design-basis external events. The PORV hand pumps are relied upon for symmetric cool down following a BDBEE. While the PORV hand pumps are seismically mounted within robust structures, the associated access doors are non-robust and subject to tornado wind generated missiles.

Per Section 2.3.4.3 of the Braidwood FIP, the licensee detailed the structures that provide tornado missile shielding to the non-robust door including the turbine building, auxiliary building, containment and the transformer yard firewalls. In addition, large concrete blocks will be placed in front of two of the doors to provide shielding from design-basis horizontal missiles. The NRC staff considers that the intervening structures and licensee's actions to place additional shielding should provide reasonable protection from tornado generated missiles for the non-robust doors associated with the PORV hand pumps. Therefore, the NRC staff finds the alternative acceptable.

3.14.4 Using installed Refueling Water Purification Pumps to provide makeup to the SFP

As described in Section 3.3.4.1.1 of this SE, the staff noted that repowering the OA Refueling Water Purification Pump with a portable FLEX DG 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 a permanently installed component (i.e., OA Refueling Water Purification Pump) in lieu of complete reliance on the 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 OA 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 on the number of pieces of equipment available (i.e., one Refueling Water Purification Pump and three medium head FLEX pumps fed by three low head 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.

3.14.5 Conclusions for Alternatives to NEI 12-06, Revision 0

In conclusion, the NRC staff finds that although the guidance of NEI 12-06 has not been met in all respects, if the above alternatives are implemented as described by the licensee, they should 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 26], the licensee submitted its OIP for Braidwood, Units 1 and 2, in response to Order EA-12-051. By letter dated July 11, 2013 [Reference 27], the NRC staff sent a request for additional information (RAI) to the licensee. The licensee provided a response by letter dated July 31, 2013 [Reference 28]. By letter dated November 4, 2013 [Reference 29], the NRC staff issued an ISE and RAI to the licensee.

By letters dated August 28, 2013 [Reference 30], February 28, 2014 [Reference 31], August 28, 2014 [Reference 32], and February 27, 2015 [Reference 33], the licensee submitted status reports for the Integrated Plan and the RAI in the ISE. The Integrated Plan describes the strategies and guidance to be implemented by the licensee for the installation of reliable Spent Fuel Pool Level Instrumentation (SFPLI), which will function following a BDBEE, including modifications necessary to support this implementation, pursuant to Order EA-12-051. By letter dated June 9, 2015 [Reference 34], the licensee reported that full compliance with the requirements of Order EA-12-051 was achieved. By email dated February 15, 2017 [Reference 35], the licensee responded to further NRC questions.

The licensee has installed a SFPLI system designed by Westinghouse, LLC. The NRC staff reviewed the vendor's SFPLI system design specifications, calculations and analyses, test plans, and test reports during a vendor audit. The staff issued an audit report for the vendor audit on August 18, 2014 [Reference 44].

The staff performed an onsite audit to review the implementation of SFPLI related to Order EA-12-051 at Braidwood. 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 May 27, 2015 [Reference 17], the NRC issued an audit report on the licensee's progress.

4.1 Levels of Required Monitoring

Braidwood, Units 1 and 2 share a single SFP located in the FHB. The SFP is approximately 62' – 0" long by 33' – 1" wide and 41'- 0" deep.

Attachment 2 of Order EA-12-051 requires that licensees have a reliable indication of the water level in SFPs as follows:

Level 1 - level that is adequate to support operation of the normal fuel pool cooling system

Level 2 - level that is adequate to provide substantial radiation shielding for a person standing on the SFP operating deck

Level 3 - level where fuel remains covered and actions to implement make-up water addition should no longer be deferred

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

- Level 1 corresponds to the 418' - 1¾" plant elevation
- Level 2 corresponds to the 410' - 1¾" plant elevation
- Level 3 corresponds to the 400' - 1¾" plant elevation

In its OIP, the licensee also identified the top of the spent fuel rack as an elevation of 400' - 1¾" and the level instrument measuring range from 424' – 9" elevation to 400' - 1¾" elevation.

In its email dated February 15, 2017 [Reference 35], the licensee provided the revised SFP levels of monitoring based on the finalization of Calculation NED-M-MSD-041, "Available Net Positive Suction Head (NPSH) for the Spent Fuel Pit Pump," Revision 2 as follows:

- Level 1 corresponds to a plant elevation of 421' - 6"
- Level 2 corresponds to a plant elevation of 410' - 2"
- Level 3 corresponds to a plant elevation of 400' - 2"

In its email dated February 15, 2017 [Reference 35], the licensee also provided a sketch depicting the revised SFP levels of monitoring as illustrated below in Figure 1, "Braidwood SFP Levels of Monitoring."

The NRC staff noted that NED-M-MSD-041 evaluates the SFP pumps' operating levels from 424' - 2" plant elevation (low level alarm) to 421' – 6" plant elevation. The calculation notes that the SFP pumps will not function properly with the water level below 421' – 6" plant elevation (with temperature at 212°F). The calculation concludes that the SFP pumps are capable of pumping the design flow rate of 4500 gpm at a bulk pool temperature of approximately 193°F when the water level is at 424' – 2" plant elevation (low level alarm setpoint) and 187°F when the water level is at 421' – 6" plant elevation with adequate NPSH available margin. The staff's assessment of the licensee's selection of the SFP levels of monitoring is as follows.

- Level 1: Per NEI 12-02, Section 2.3.1, Level 1 will be the HIGHER of two points. The first point is the water level at which suction loss occurs due to uncovering of the spent fuel coolant inlet pipe, weir or vacuum breaker. This was identified by the licensee in its letter dated August 28, 2014 [Reference 32] as 417' - 9 ¾" plant elevation. The second point is the water level at which loss of spent fuel cooling pump net positive suction head (NPSH) occurs under saturated conditions. This was identified by the licensee as below 421' – 6" plant elevation (NED-M-MSD-041). Braidwood Level 1 (421' – 6" plant elevation) is the HIGHER of the above two points and therefore consistent with NEI 12-02.
- Level 2: Level 2 was identified by the licensee as elevation 410' – 2" plant elevation. This level is consistent with the first of the two options described in NEI 12-02 for Level 2, which is 10 feet (+/- 1 foot) above the highest point of any fuel rack seated in the SFP.

- Level 3: Level 3 was identified by the licensee as 400' – 2" plant elevation, which is above the highest point of any fuel rack seated in the SFP where fuel remains covered; and therefore, consistent with NEI 12-02.

Based on the evaluation above, the NRC staff finds that the licensee's selection of Levels 1, 2, and 3 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 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

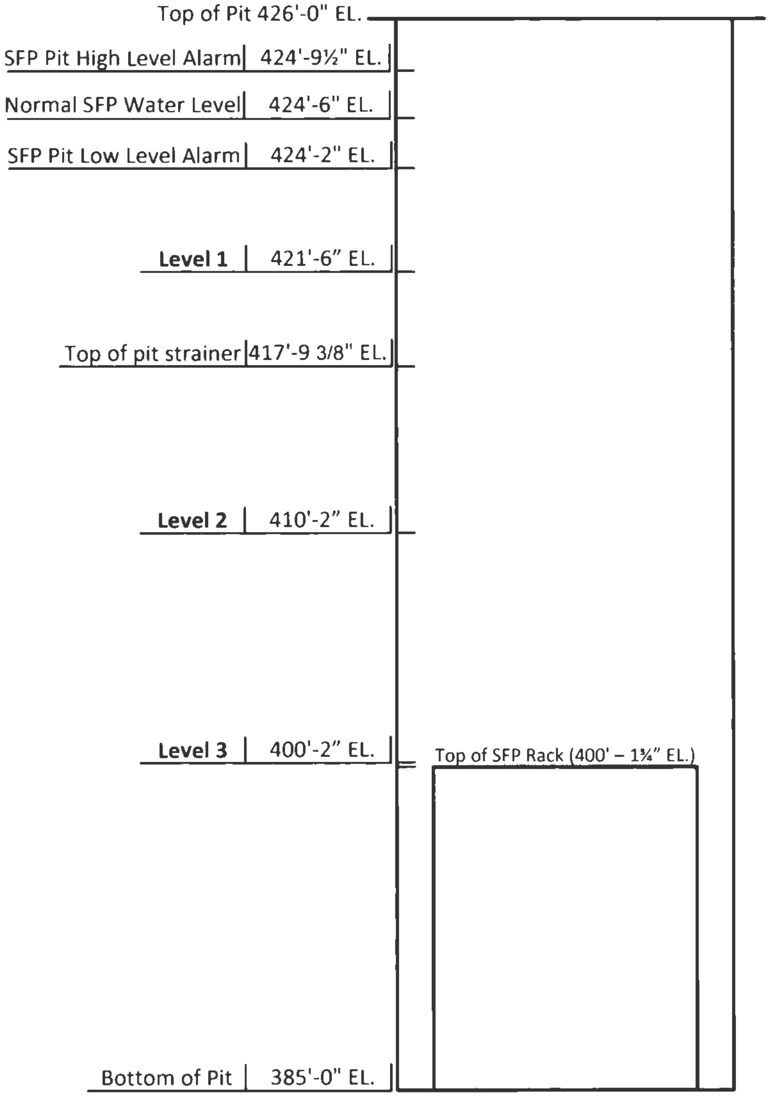

Figure 1 – Braidwood SFP Levels of Monitoring

order in regards to the design features. Below is the staff's assessment of the design features of Braidwood SFPLI.

4.2.1 Design Features: Instruments

Regarding the SFP level instrument design, in its OIP, the licensee stated that the primary and backup instrument will consist of fixed components and that both channels will utilize guided wave radar system. Related to the SFP level instrument's measuring range, in its OIP, the licensee stated that both instrument channels will provide continuous level indication over a minimum range of approximately 24' - 8" from the high level alarm at 424' - 9½" plant elevation to the top of the spent fuel racks at 400' - 1¾" plant elevation. The NRC staff noted that the instrument's measuring range will cover Levels 1, 2, and 3, as described in Section 4.1 above.

The NRC staff also noted that, beside the Westinghouse equipment, the licensee installed Weschler analog indicators in the MCR. These indicators are credited as the displays for the SFPLI. Further evaluation of the qualification for these indicators is discussed in Subsection 4.2.4, "Design Features: Qualification".

The NRC staff finds that the licensee's design, with respect to the number of SFP instrument channels and measuring range, 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

Regarding the SFP level instrument arrangement, in its letter dated August 28, 2014 [Reference 32], the licensee stated that two independent primary and backup instrument channels will be installed with indication for both channels at an operator accessible location. The location of the level sensors on the top of the west wall of the SFP, separated by a distance greater than the span of the shortest wall, provides adequate separation between the two channels. The level transmitter and level indication display for the primary and backup channels will be installed in the Auxiliary Building in Unit 1 Penetration Area 5 and Unit 2 Penetration Area 7, respectively. The 120 Vac power to the primary and backup level indication display will be provided from Unit 1 and Unit 2 engineered safety feature (ESF) MCCs, respectively. An additional analog level indicator for each channel will also be provided in the MCR at panels 1PM06J and 2PM06J, which will be credited as the level indication used to satisfy NRC Order EA-12-051. The power and instrument cables will be routed on the Unit 1 side for primary channel and on the Unit 2 side for the backup channel.

The NRC staff noted, with verification by walkdown during the onsite audit, that there is sufficient channel separation the primary and backup level instrument channels, sensor electronics, and routing cables to provide reasonable protection against loss of SFP level indication due to missiles that may result from damage to the structure over the SFP.

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

4.2.3 Design Features: Mounting

With regard to the mounting design of the sensor probe mounting bracket, in its letter dated August 28, 2014 [Reference 32], the licensee stated, in parts, that the Westinghouse has evaluated the structural integrity of the mounting brackets in Calculation CN-PEUS-13-24. The GTSTRUDL [structure design and analysis software] model, used by Westinghouse to calculate the stresses in the bracket assembly, considers load combinations for the dead load, live load and seismic load on the bracket. The reactionary forces calculated from these loads become the design inputs to design the mounting bracket anchorage to the refuel floor to withstand a SSE. The qualification of the anchorage to the floor is provided in Calculation BRW-14-0009-S, "SFPLI Sensor Mounting Detail Anchorage".

As for potential hydrodynamic effects on the SFPLI probes, in its letter dated August 28, 2014 [Reference 32], the licensee stated that sloshing forces were obtained by analysis. The TID-7024, "Nuclear Reactors and Earthquakes," 1963, by the US Atomic Energy Commission, approach has been used to estimate the wave height and natural frequency. Horizontal and vertical impact force on the bracket components was calculated using the wave height and natural frequency. Methodology, sloshing forces have been calculated and added to the total reactionary forces that would be applicable for bracket anchorage design. The analysis also determined that the level probe can withstand a credible design-basis seismic event. During the design-basis event, the SFP water level is expected to rise and parts of the level sensor probe are assumed to become submerged in borated water. The load impact due to the rising water and submergence of the bracket components has also been considered for the overall sloshing impact.

For the mounting design of the SFPLI displays, in its letter dated August 28, 2014 [Reference 32], the licensee stated that Braidwood Station specific Calculations 12.3.4-BRW-10-0021-S, "Seismic Qualification of Instrument Mounting Details Associated with Plant Process Computer Replacement," and BRW-14-0109-M, "Seismic Qualification of Weschler Indicator VX-252," are being developed to address the seismic qualification of the readout display (Weschler Instruments) in the MCR. The design criteria used in this calculation meets the requirements to withstand a SSE and will meet the Braidwood Station safety-related installation requirements. The methods used in the calculation follow Institute of Electrical and Electronics Engineers (IEEE) Standard 344-2004 and IEEE Standard 323-2003 for seismic qualification of the instrument.

Related to the methodology used to design the SFP level instrument conduits and conduit supports, in its letter dated August 28, 2014 [Reference 32], the licensee stated that structural adequacy of rigid conduit is evaluated by determining the critical span condition, loads, checking conduit stresses and verifying structural adequacy of conduit clamps. Structural adequacy of conduit, junction boxes and junction box supports is evaluated by determining loads, calculating member forces and joint reactions, checking member stresses, checking connections, checking expansion anchor assemblies, checking attachments to structure and resolving overstresses.

During the onsite audit, the NRC staff reviewed Calculation BRW-14-0010-S, "Seismic Qualification of the Spent Fuel Pool Instrument System Equipment," Revision 1, which analyzes the seismic mounting of the enclosures for the SFP level instrument electronics, transmitters, and excess cable. This calculation analyzed the structural integrity of the electronics enclosure's face plates, mounting tabs, mounting fasteners, and spring-nuts at the local frequencies. The staff found the design inputs and methodologies used in the calculation to be adequate.

The NRC staff found that the licensee adequately addressed the design criteria and methodology used to estimate and test the total loading on the mounting devices, including the design-basis maximum seismic loads and the hydrodynamic loads that could result from pool sloshing. The site-specific seismic analyses demonstrated that the SFP level instrumentation's mounting design is satisfactory to allow the instrument to function per design following the maximum seismic ground motion. The assumptions, analytical, and model used in the sloshing analysis for the sensor mounting bracket are adequate. The staff also noted that the licensee adequately addressed the design inputs and methodology used to qualify the structural integrity of the affected plant structures.

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

4.2.4 Design Features: Qualification

4.2.4.1 Augmented Quality Process

Appendix A-1 of the guidance in NEI 12-02 describes a quality assurance process for non-safety systems and equipment that 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, the licensee stated that the reliability of the instrumentation will be established through the use of an augmented quality assurance process (e.g., a process similar to that applied to the site fire protection program).

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 Equipment Reliability

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

> The instrument channel reliability shall be demonstrated via an appropriate combination of design, analyses, operating experience, and/or testing of channel components for the following sets of parameters, as described in the paragraphs below:

- conditions in the area of instrument channel component use for all instrument components,
- effects of shock and vibration on instrument channel components used during any applicable event for only installed components, and
- seismic effects on instrument channel components used during and following a potential seismic event for only installed components.

Equipment reliability performance testing was performed by the vendor to (1) demonstrate that the SFP instrumentation will not experience failures during BDB conditions of temperature, humidity, emissions, surge, and radiation, and (2) to verify those tests envelop the plant-specific requirements.

During the vendor audit [Reference 44], the NRC staff reviewed the Westinghouse SFP level instrumentation's qualifications and testing for temperature, humidity, radiation, shock and vibration, seismic, and electromagnetic compatibility (EMC). The staff further reviewed Braidwood's seismic, radiological, and environmental anticipated conditions during the onsite audit [Reference 17] to verify Braidwood bounding conditions. Below is the staff's assessment of the equipment reliability of Braidwood SFPLI.

4.2.4.2.1 Temperature, Humidity, and Radiation

Spent Fuel Pool Area:

Regarding the BDB environmental and radiological conditions of the Braidwood SFP area related to the SFPLI qualifications, in its letter dated August 28, 2014 [Reference 32], the licensee stated that Westinghouse qualified the probe, connector, and cable located in the SFP area to the BDB environment. These components were subjected to BDB conditions of heat and humidity, thermal and radiation aging mechanisms. The testing confirmed functionality of these system components under these BDB environmental conditions. In addition, the licensee stated that the level sensor probe, coax coupler and connector assembly, launch plate and pool side bracket assembly, and coax cable are designed and qualified to operate reliably in the below specified environmental conditions (Table 1 – Environmental and Radiological Limits for Equipment in SFP Area).

Table 1 – Environmental and Radiological Limits for Equipment in SFP Area

Parameter	Normal	BDB
Temperature	50-140 °F	212 °F
Humidity	0-95% Relative Humidity (RH)	100% RH (saturated steam)
Radiation Total Integrated Dose (TID) γ (above pool)	1E03 Rads	1E07 Rads
Radiation TID γ (12" above top of fuel rack)	1E09 Rads (probe and weight only)	1E07 Rads

The licensee further stated that the environmental conditions for Spent Fuel Pool Instrumentation System (SFPIS) components installed in the SFP area at Braidwood Station are bounded by test conditions, except for radiation TID 12" above top of fuel rack for BDB conditions. The BDB radiation TID, 12" above top of fuel rack for Braidwood is 4.E07 R γ, per calculation BYR13-051, "NEI 12-02 Spent Fuel Pool Doses." The BDB radiation value to which the Westinghouse equipment is qualified to is 1.E07 R γ, per Section 5.1.1 of WNA-TR-03149-GEN. The radiation value of 4.E07 R γ is higher than 1.E07 R γ to which Westinghouse qualified the instrument to. However, this value of 4.E07 R γ is applicable only when the water is at Level 3. At Level 2 the TID reduces to 2.E07 R γ and it further reduces to 8.E06 at Level 1 and above. With SFP water level at Level 3 the only components of SFPI that are exposed to high radiation are the stainless steel probe and the stainless steel anchor. The materials with which the probe and the anchor are manufactured are resistant to radiation effects. The stainless steel anchor and stainless steel probe can withstand 40 year dose. Westinghouse updated the design specification (WNA-DS-02957-GEN) and LTR-SFPIS-13-35, Revision 1, documentation to include the above technical justification.

The NRC staff noted that the licensee used Byron Design Analysis BYR13-051, "NEI 12-02 Spent Fuel Pool Doses" to analyze the expected radiological condition for Braidwood SFP area. However, Braidwood was listed as an applicable station under the scope of BYR13-051, Revision 1, dated November 21, 2014, and therefore this is acceptable to the staff.

Based on the information in the letter dated August 28, 2014 [Reference 32], the Westinghouse document, and the NEI 12-02 guidance regarding expected environmental and radiological conditions in the SFP area during a BDB event, the NRC staff finds that the equipment qualifications envelop the expected environmental and radiological conditions of the Braidwood SFP area.

Outside SFP Area:

The primary instrument channel's electronics equipment is located at Unit 1 Auxiliary Building 426' Electrical Penetration Area, and the backup (secondary) instrument channel's electronics equipment is located at Unit 2 Auxiliary Building 426' Electrical Penetration Area. The credited displays for both instrument channels are located in the MCR.

As for the environmental and radiological conditions outside of the SFP area related to the SFP level instrument qualifications, in its letter dated August 28, 2014 [Reference 32], the licensee stated that the level sensor transmitter and electronics display enclosure are designed and qualified to operate reliably in the below specified environmental conditions (Table 2, "Environmental and Radiological Limits for Equipment Outside of SFP Area").

Table 2 –Environmental and Radiological Limits for Equipment Outside of SFP Area

Parameter	Normal	BDB	BDB (Level Sensor Electronics Only)
Temperature	50-120 °F	140 °F	140 °F
Humidity	0-95% RH	0-95% (non-condensing)	0-95% (non-condensing)
Radiation TID γ	≤ 1E03 R	≤ 1E03 R	≤ 1E03 R

In its email dated February 15, 2017 [Reference 35], the licensee further described the temperature conditions of the Electrical Penetration Areas, Elevation 426', as follows. The SFP level instrument components are located in EQ [Environmental Qualification] Zone A11. Per calculation BRW-01-0153-E, "Environmental Parameters of EQ Zones," Revision 2, EQ Zone A11 is a Mild Zone with maximum normal temperature of 133°F. EQ Zone A11 does not have a temperature for accident conditions, however, Note 14 of the calculation addresses conditions of LOCA [loss of coolant accident] and LOOP [loss of off-site power] as follows: "Under conditions of LOCA and LOOP, maximum temperature will increase during 2-hour period due to HVAC systems operation using available electrical power sources and with consideration of equipment heat loads for event mitigation. Maximum temperatures during this condition are: 140° F for Zone A11." The bounding value of 140°F is determined in calculation VA-102, "Aux Bldg. Energy Load Calcs. for El. 330', 346', 364', 383', 401' & 426' in Abnormal Condition," Revision 4, which determines temperatures for multiple locations within EQ Zone A11. With the Primary and Secondary SFP Level electronics located in Unit 1 and Unit 2 Electrical Penetration Areas, Elevation 426', per VA-102, the calculated temperature of this location is 127.1°F during conditions of LOCA and LOOP for a 2-hour period, which is below the stated 140°F maximum temperature for Zone A11 (140°F bounds all locations above in EQ Zone A11).

According to the licensee, the LOCA and LOOP conditions described above include heat loads from electrical equipment and liquid systems that will not exist during an ELAP. During an ELAP event, there will be no heat loads from electrical equipment or liquid systems in the area. The heat generated from the SFP has to be transmitted to 426' Electrical Penetration Areas, which includes a 3' concrete wall. There is a significant heat sink in the 426' Electrical Penetration areas from the containment wall and surrounding Auxiliary Building walls. There is also a significant heat sink from the FHB walls and ceiling. Due to the lack of heat sources in the area of the instruments, barriers between the FHB and instrument areas, and the large heat sink that will dissipate heat, the licensee determined that the 140 °F rating of the SFP Level instrumentation is adequate.

Regarding the radiological conditions of the Electrical Penetration Areas, Elevation 426', in its email dated February 15, 2017 [Reference 35], the licensee stated that for the primary channel electronics enclosure and transmitter enclosure on the Unit 1 side of the plant, the straight line distance from the pool to the panels is 63' and the enclosures are directly adjacent to a 3' thick concrete wall. For conservatism, using a distance of 60', neglecting other walls or materials along the path, and using the straight thickness of the wall instead of the slant thickness, an overall dose rate for the area can be obtained. Based on BYR13-187 Table 7.4-1 (which lists calculated dose rates as a function of distance) and Table 7.3-4 (which lists wall thickness scaling factors), the dose rate is 9.92E+01 rem/hr (function of distance from spent multiplier) x 2.151E-10 (wall thickness scaling multiplier) = 2.1E-08 rem/hr at the primary channel enclosures during a BDBEE when the water in the SFP is at the top of the fuel assemblies.

For the backup channel electronics enclosure and transmitter enclosure on the Unit 2 side of the plant, the straight line distance from the pool to the panels is 59' and directly adjacent to a 3' thick concrete wall but is near the 1'-6" section. For conservatism, using a distance of 55' and a 1' wall for these values, an overall dose rate for the area can be obtained. Based on BYR13-187 Table 7.4-1 and Table 7.3-4, the dose rate is 1.10E+02 rem/hr (function of distance from spent multiplier) x 7.505E-05 (wall thickness scaling multiplier) = 8.3E-03 rem/hr at the primary channel enclosures during a BDBEE when the water in the SFP is at the top of the fuel assemblies.

The licensee further stated that NRC Order EA-12-051 requires that 7 days (168 hours) with the water level at the top of the fuel rack in the SFP be considered to establish a TID. Using the dose rate of primary channel 2.1E-08 Roentgen equivalent man (Rem)/hr and backup channel 8.3E-03 Rem/hr, and duration of 168 hours, the 7 day TID can be calculated as 3.5E-06 Rem for the primary channel and 1.4 Rem for the backup channel. The dose these instruments will be subject to is within the qualified radiation level for the instrument, 1E03R, and will not impact the operation of the SFP equipment, located outside the SFP area.

The NRC staff noted that the Westinghouse equipment's design limits envelop the expected radiological and environmental conditions of Braidwood Auxiliary Building 426' Electrical Penetration Areas.

Related to qualification of the analog indicators in the MCR credited for the SFP level display, in its letter dated August 28, 2014 [Reference 32], the licensee stated that Braidwood Station specific Calculation, "BRW-14-0109-M-Seismic Qualification of Weschler Indicator VX-252," describes the results of the qualification testing of the MCR readout display to the design-basis temperature, humidity, and vibration to demonstrate its reliability. The display was also tested to demonstrate that it performed accurately under extreme heat and humidity conditions.

The staff finds that the licensee adequately addressed the equipment qualification of SFPLI with respect to temperature, humidity and radiation. The equipment's design limits envelop Braidwood's anticipated conditions of radiation, temperature, and humidity during a postulated BDBEE and post event. The equipment environmental testing demonstrated that the SFP instrumentation should maintain its functionality under expected BDB conditions.

4.2.4.2.2 Shock and Vibration

Regarding the SFPLI's shock and vibration qualification, in its letter dated August 28, 2014 [Reference 32], the licensee stated that the SFPIS pool side brackets were analyzed for SSE design requirements per NRC order EA-12-051 and NEI 12-02 guidance. The SFPIS pool side brackets for both the primary and backup channels will be permanently installed and fixed to rigid refuel floors, which are Seismic Category 1 structures. The SFPIS components, such as level sensor and its bracket, display enclosure and its bracket, were subjected to seismic testing, including shock and vibration test requirements. The results for shock and vibration tests were consistent with the anticipated shock and vibration expected to be seen by mounted equipment. The level sensor electronics are enclosed in a NEMA-4X housing. The display electronics panel utilizes a NEMA-4X rated stainless steel housing as well. These housings are mounted to a seismically qualified wall and contain the active electronics. The housings aid in protecting the internal components from vibration induced damage.

The NRC staff noted that the licensee adequately addressed the equipment reliability of SFP level instrumentation with respect to shock and vibration.

4.2.4.2.3 Seismic

Related to the SFPLI design with respect to seismic qualification, in its letter dated August 28, 2014 [Reference 32], the licensee stated, in parts, that all SFPIS equipment will be designed in accordance with the Braidwood Station SSE design requirements. Westinghouse has seismically qualified the SFPI instrument and its components. With the instrument being seismically qualified and installed, including the displays in the MCR, the instrument is assured to maintain reliable and accurate indication when required. The seismic adequacy of the SFPIS (all components) is demonstrated by vendor testing and analysis in accordance with the standards and calculations listed below:

- IEEE 344-2004, "IEEE Recommended Practice for Seismic Qualification of Class IE Electrical Equipment for Nuclear Power Generating Stations"
- IEEE-323-2003, "Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations"
- USNRC Regulatory Guide 1.100, Revision 2
- USNRC Regulatory Guide 1.92, Revision 1
- Calculation 12.3.4-BRW-10-0021-S, "Seismic Qualification of Instrument Mounting Details Associated with Plant Process Computer Replacement"
- BWR-14-0109-M, "Seismic Qualification of Weschler Indicator VX-252"

In addition, in describing the design criteria and methodology used to design the SFP level instrument, the licensee stated that the following Westinghouse documents provide the analyses used to verify the design criteria and describe the methodology for seismic testing of the SFP instrumentation and electronics units, inclusive of design-basis maximum seismic loads and hydrodynamic loads that could result from pool sloshing and other effects that could accompany such seismic forces:

- CN-PEUS-13-24 – Pool-side Bracket Seismic Analysis
- LTR-SEE-II-13-47, WNA-TR-03149-GEN – Sloshing Analysis
- EQ-QR-269, WNA-TR-03149-GEN, EQ-TP-353 – Seismic Qualification of other components of SFPI

With regard to the analog indicator installed in the MCR seismic design, in its letter dated August 28, 2014 [Reference 32], the licensee stated that Braidwood Station specific calculations 12.3.4-BRW-10-0021-S, "Seismic Qualification of Instrument Mounting Details Associated with Plant Process Computer Replacement," BRW-14-00009-S, "SFPI Sensor Mounting Detail Anchorage," and BRW-14-0109-M, "Seismic Qualification of Weschler Indicator VX-252," address the seismic qualification of the MCR indicators. The design criteria used in these calculations satisfy the requirements to withstand a SSE and will meet the Braidwood Station safety-related installation requirements for mounting the readout displays in the MCR.

The NRC staff noted that the licensee adequately addressed the design inputs and methodology used to design the SFP level instrument with respect to seismic qualification. The SFP level instrument was tested to the seismic conditions that envelop Braidwood's expected SSE. Further seismic qualifications of the SFP level instrumentation mounting are addressed in Subsection 4.2.3, "Design Features: Mounting," of this SE.

4.2.4.2.4 Aging

Depending on the installation configurations, Westinghouse provided two types of SFP cable connectors, a straight connector or a 90-degree connector. Both of them originally were qualified for a 15-month life. Westinghouse performed the life-upgrade tests for both straight and 90-degree cable connectors. The tests included radiation aging, thermal aging and steam tests. While the 90-degree connector passed the initial tests, the straight connector failed the steam test due to leakage caused by the sealant around the connector. Westinghouse solution was to encapsulate the exposed epoxy of the connector with Raychem boots. The straight connector modification eventually passed the aging tests.

During the onsite audit, the NRC staff learned that Braidwood utilizes the 90-degree connectors at the SFP level probes (pool side). Since modification is required only for pool-side straight connectors, which is not applicable to Braidwood, the NRC staff found the design of cable connector at Braidwood to be adequate.

4.2.4.2.5 Electromagnetic Compatibility

As a result of the NRC staff's evaluation of the EMC testing results during the vendor audit, the staff identified a generic open item applicable to all licensees using the Westinghouse SFP level instrument to identify any additional measures, site-specific installation instructions or position taken to address the potential effect of an EMC event on the SFPI equipment. During the onsite audit, the NRC staff enquired as to an assessment of potential susceptibilities of Electromagnetic Interference/Radio Frequency Interference (EMI/RFI) in the areas where the SFP instrument located and how to mitigate those susceptibilities.

The licensee provided a response in the email dated February 15, 2017 [Reference 35], in which it stated that Braidwood has painted "No-radio" zones around the electronics boxes and transmitters to mitigate any potential EMC susceptibilities. Instructions provided in the EC package CC-AA-107 for testing susceptibilities in the SFP instrument areas have been completed. These tests include operating a radio near the perimeter of no-radio zones around electronics boxes and transmitters and verifying that no noticeable interference is introduced (i.e. verify that no sporadic behavior of the level signal is present at the level displays). The testing instructions directed that if interference is detected, the no-radio zone needs to be expanded to the perimeter where there is no interference detected.

The NRC staff finds that the licensee adequately addressed the potential for susceptibilities of EMI/RFI. The radio exclusion zones established based on the radio-emitting test should provide preventive measures for EMI/RFI susceptibilities.

In conclusion, the NRC staff finds the licensee's SFP level 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

In its letter dated August 28, 2014 [Reference 32], the licensee described the SFP level instrument channel's physical independence. The two instrument channels of the level measurement system are installed such that a) the level probes are not mounted on the west wall of the SFP and are separated by a distance greater than the span of the shortest side of the pool, and that b) the level sensor enclosure and the electronics/Uninterruptible Power Supply (UPS) enclosure for the primary instrument channel are installed in the Auxiliary Building in the Unit 1 Electrical Penetration Area. The level sensor enclosure and the electronics/ UPS enclosure for the backup instrument channel are installed in the Unit 2 Electrical Penetration Area. Independence, physical and spatial separation of the level sensors and electronics/UPS enclosures for primary and backup instrument channels is maintained by routing the associated instrument channel cables through Unit 1 and Unit 2, respectively. The primary channel indicator is located on the Unit 1 side of the MCR at panel 1PM06J. The backup channel indicator is located on the Unit 2 side of the MCR at panel 2PM06J. All power and instrument cables associated with the primary channel are routed on the Unit 1 side of Auxiliary Building and Fuel Handling Building. All power and instrument cables associated with the backup channel are routed on the Unit 2 side of the Auxiliary Building and Fuel Handling Building to meet the physical and spatial separation requirements.

Related to the SFPLI power source independence, in its letter dated August 28, 2014 [Reference 32], the licensee stated, in parts, that the 120 Vac power to the primary instrument will be provided from a Unit 1 ESF-Division 2 MCC, and 120 Vac power to the backup level instrument will be provided from a Unit 2 ESF-Division 2 MCC. The 120Vac distribution panels for the primary and backup instruments are powered by different 480V safety buses. Therefore, the loss of any one bus will not result in the loss of ac power to both instrument channels. Providing the 120Vac power to primary and backup instrument channels from separate MCCs will address the concerns regarding power supply independence.

The NRC staff noted, and verified during the walkdown, that the licensee adequately addressed the SFP level instrument channel independence. The instrument channels' physical separation is further discussed in Subsection 4.2.2, "Design Features: Arrangement". With the licensee's SFP level instrument design, the loss of one level instrument channel would not affect the operation of other channel under BDBEE conditions. The staff finds the licensee's proposed design, with respect to instrument channel independence, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.6 Design Features: Power Supplies

Regarding the SFPLI power supplies, in its letter dated August 28, 2014 [Reference 32], the licensee stated that the primary and backup SFPLI instrument channels will be normally powered from 120 Vac Unit 1 and Unit 2 ESF Division 2 MCCs respectively. These are on different safety buses, which maintains power source independence. Upon loss of normal ac power, individual batteries installed in each channel's electronics/UPS enclosure will automatically maintain continuous channel operation for at least 3 days. These ESF MCCs have also been identified as part of the FLEX strategy to ensure that the SFPLI will have ac power restored if a BDBEE would occur. Additionally, a receptacle and a selector switch are installed in each channel electronics/UPS enclosure to directly connect emergency power to the SFPLI.

As for the instrument battery's duty cycle, in its letter dated August 28, 2014 [Reference 32], the licensee stated that Westinghouse Report, WNA-CN-00300-GEN, provides the results of the calculation depicting the battery backup duty cycle. This calculation demonstrates that battery capacity is 4.22 days to maintain the level indicating function to the display. The calculation also determines that the battery will last for 72 hours assuming the remote display in the MCR consumes a maximum of 0.064 Amps. Braidwood Station is crediting the MCR display as the primary display. The remote display vendor (Weschler's) data sheet indicates the readout display is self-contained. It will be calibrated to consume no more than 0.022 Amps, which is bounded by the 0.064 Amps assumed in the Westinghouse calculation above. Therefore, the Braidwood Station readout display of level indication in the MCR will be available for greater than 72 hours of operation.

The NRC staff finds the licensee's 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

Regarding the SFPLI accuracy, in its letter dated August 28, 2014 [Reference 32], the licensee stated that Westinghouse documents WNA-CN-00301 and WNA-DS-02957-GEN describe the channel accuracy under both (a) normal SFP level conditions and (b) at the BDB conditions that would be present if SFP level were at Level 2 and Level 3 datum points. Each instrument channel will be accurate to within ±3" during normal SFP level conditions. The instrument channels will retain this accuracy after BDB conditions in accordance with the above Westinghouse documents. Related to the channel accuracy of the MCR display, in its email dated February 27, 2015 [Reference 35], the licensee stated that Braidwood Station has analyzed the channel accuracy to the MCR indicators in the calculation BRW-14-0220-I for the normal and BDB operating conditions and determined the displayed level is accurate to within ±5". The accuracy is within the channel accuracy requirements of the order (±1 foot) for BDB conditions and meets the NEI 12-02 requirements.

Related to the methodology the licensee used to determine the total instrument loop uncertainties for a combined Westinghouse and Weschler instrument loop, in its letter dated August 28, 2014 [Reference 32], the licensee stated that instrument channel loop accuracy and set point deviation/error are determined using the Braidwood Station Engineering Standard NES-EIC-20.04 for safety-related instruments. The methodology used to determine the set point deviation in this standard is consistent with ANSI/ISA-67.04.01-2000. Per this methodology, since drift value was not specified by the vendor, a default random drift value of ±1% of span (or ±1% of full scale, for conservatism) for mechanical components were assigned. A setting tolerance of twice the reference accuracy, which is a typical value, was applied to the indicator to yield an overall setting tolerance of ± 2 percent of full scale. This value will be used for the calibration procedure being developed for this instrument loop. The resultant non-negligible terms (Reference Accuracy, Drift, Readability, Measurement and Test Equipment Effect, and Setting Tolerance) are all random terms, and will be combined using the Square Root Sum of Squares (SRSS) methodology given in Engineering Standard NES-EIC-20.04. Thus, the maximum deviation introduced by the indicator, in percent of full span, is computed. Calibration will be performed once per refueling cycle for Braidwood Station.

The NRC staff noted that the licensee adequately addressed the SFPLI accuracy design including the expected instrument channel accuracy performance under both normal and BDB conditions. The methodology used to determine the total instrument loop uncertainties for a combined Westinghouse and Weschler instrument loop is adequate. If implemented properly, the instrument channels should maintain the designed accuracy following a change or interruption of power source without the need for recalibration.

Based on the evaluation above, the NRC staff finds the licensee's SFP level 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

In its letter dated August 28, 2014 [Reference 32], the licensee described the SFPLI capability of periodic testing and calibration. In this letter, the licensee stated that Westinghouse calibration procedure WNA-TP-04709-GEN and functional test procedure WNA-TP-04613-GEN describe the capabilities and provisions of SFPI periodic testing and calibration, including in-situ testing. Westinghouse calibration and functional test procedures are acceptable for Braidwood. However, Braidwood must use a different in-situ test methodology to accommodate Braidwood's low profile bracket installation. Westinghouse provided letter LTR-SFPIS-14-55, "SFPIS 2 Point Verification Methodology," Revision 0, describing the new in-situ test methodology to accommodate low profile bracket.

Related to the instrument non-Tech Spec channel check, in its letter dated August 28, 2014 [Reference 32], the licensee stated that the level displayed by the channels will be verified per the Braidwood Station administrative and operating procedures, as recommended by Westinghouse vendor technical manual WNA-G0-00127-GEN. If the level is not within the required accuracy per Westinghouse recommended tolerance in WNA-TP-04709-GEN, channel calibration will be performed. For the instrument functional checks testing feature, in the same letter above, the licensee stated that functional checks will be performed per Westinghouse functionality test procedure WNA-TP-04613-GEN at the Westinghouse recommended frequency. Calibration tests will be performed per Westinghouse calibration procedure WNA-TP-04709-GEN at the Westinghouse recommended frequency. In its letter dated June 9, 2015 [Reference 34], the licensee further stated that Braidwood Station has developed calibration, functional test, and channel verification procedures for the SFPI per Westinghouse recommendations to ensure reliable, accurate, and continuous SFPI functionality.

The NRC staff finds the licensee's proposed SFPLI design that allows for testing and calibration, including functional test and channel check, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.9 Design Features: Display

Regarding the SFPLI display location, in its letter dated August 28, 2013 [Reference 32], the licensee stated that the [local] level indication display for the primary and backup channels will be installed in the Auxiliary Building in Unit 1 Penetration Area 5 and Unit 2 Penetration Area 7, respectively. An additional analog indicator for each channel will also be provided in the MCR at panels 1PM06J and 2PM06J, which will be credited as the level indication used to satisfy NRC Order EA-12-051.

The NRC staff noted that the NEI 12-02 guidance for "Display" specifically mentions the MCR as an acceptable location for SFP level instrumentation displays as it is occupied by trained personnel and promptly accessible, outside the area surrounding the SFP, inside a structure providing protection against adverse weather, and outside of any very high radiation areas or locked high radiation areas during normal operation. Further evaluation of the display qualification is discussed in Subsection 4.2.4, "Design Features: Qualification".

The NRC staff finds that the licensee's location and design of the SFP level 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

4.3.1 Programmatic Controls: Training

In its OIP, the licensee stated that personnel performing functions associated with the SFP level instrumentation channels will be trained to perform the job specific functions necessary for their assigned tasks (maintenance, calibration, surveillance, etc.). This training will be consistent with equipment vendor guidelines, instructions and recommendations. The SAT will be used to identify the population to be trained and to determine the initial and continuing elements of the required training. Training will be completed prior to placing the instrumentation in service.

Guidance document NEI 12-02 specifies that the SAT process can be used to identify the population to be trained, and also to determine both the initial and continuing elements of the required training. The NRC staff finds that the licensee's plan to train personnel in the operation, maintenance, calibration, and surveillance of the SFP level instrumentation, including the approach to identify the population to be trained, 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

Regarding Braidwood procedures related to the SFPLI, in its letter dated August 28, 2014 [Reference 32], the licensee stated that site procedures will be developed for system inspection, calibration and test, maintenance, repair, operation and normal and abnormal responses, in accordance with Exelon's procedure control process. Technical objectives to be achieved in each of the respective procedures are described below:

System Inspection: To verify that system components are in place, complete, and in the correct configuration, and that the sensor probe is free of significant deposits of crystallized boric acid.

Calibration and Test: To verify that the system is within the specified accuracy, is functioning as designed, and is appropriately indicating SFP water level.

Maintenance: To establish and define scheduled and preventive maintenance requirements and activities necessary to minimize the possibility of system interruption.
Repair: To specify troubleshooting steps and component repair and replacement activities in the event of system malfunction.

Operation: To provide sufficient instructions for operation and use of the system by plant operation staff.

Responses: To define the actions to be taken upon observation of system level indications, including actions to be taken at the levels defined in NEI 12-02.

In the email dated February 15, 2017 [Reference 35], the licensee noted that the following SFPLI-related procedures have been developed:

Calibration and Test Procedures:

- BwIP 2500-181, “Calibration of Guided Wave Radar Spent Fuel Level Instruments,” provides instructions to calibrate the SFP level instrumentation system (SFPLIS), loops 0L-FC001 and 0L-FC002.

- TRP 0FC-001, “Calibration Test Report” – primary channel, provides local indicator calibration check and calibration of main control board indicator.

- TRP 0FC-002, “Calibration test report” – backup channel, provides local indicator calibration check and calibration of main control board indicator.

- 0BwOS FX-2A, “AAR spent fuel pool (SFP) level instrumentation,” provides a tracking mechanism for unavailability of the SFP level instrumentation.

- 0BwOS FX-3, “Spent Fuel Pool Level Instrumentation Channel Checks,” outlines the steps necessary to verify the availability of the SFPLI by performing a Channel Check of the required instruments and indications and verifying the required number of channels are available. This procedure shall be performed once per 31 days and is applicable in all modes.

System Inspection Procedures:

- BwOP FX-E3, “Electrical Lineup - Unit 0 Operating,” provides normal operating positions for SFPI power supply breakers.

- 1BwOS XCB-R1, "U0 and U1 MCR and RSDP Meter Color Banding," outlines the steps necessary to perform a check for proper MCR and Remote Shutdown Panel meter color banding after each refueling cycle.
- 2BwOS XCB-R1, "U2 MCR and RSDP Meter Color Banding," outlines the steps necessary to perform a check for proper MCR and Remote Shutdown Panel meter color banding after each refueling cycle.
- 0BwOSR 0.1-0, "Unit Common All Modes/At All Times Shiftly and Daily Operating Surveillance," outlines the steps necessary to perform the required Tech Spec and Administrative verifications of shiftly and daily parameters and is applicable in all MODES/at all times (providing a method for recording SFP level as information only).

Operation/Response Procedures:

- 1BwFSG-5, "Initial Assessment and FLEX Equipment Staging," provides actions for the initial assessment of plant equipment and system status, and for staging FLEX equipment in preparation for use in plant recovery.
- BwOP AP-60, "Bus 142 Outage While in Mode 6 or Defueled," outlines the steps necessary to de-energize and restore Bus 142 while Unit 1 is in Mode 6 or Defueled (entering AAR or providing an alternate power source to the electronics cabinet for SFPLI).
- BwOP AP-60T1, "Bus 142 Outage Checklist," provides checklist for actions to be completed during Bus 142 bus outage (entering AAR or providing an alternate power source to the electronics cabinet for SFPLI).
- BwOP AP-64, "Bus 242 Outage While in Mode 6 or Defueled," outlines the steps necessary to de-energize and restore Bus 242 while Unit 2 is in Mode 6 or Defueled.
- BwOP AP-64T1, "Bus 242 Outage Checklist," provides checklist for actions to be completed during Bus 242 bus outage.

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

4.3.3 Programmatic Controls: Testing and Calibration

Regarding Braidwood testing and calibration program related to the SFPLI, in its letter dated August 28, 2014 [Reference 32], the licensee stated that the level displayed by the channels will be verified per the Braidwood Station administrative and operating procedures, as recommended by Westinghouse vendor technical manual WNA-G0-00127-GEN. If the level is not within the required accuracy per Westinghouse recommended tolerance in WNA-TP-04709-

GEN, channel calibration will be performed. Functional checks will be performed per Westinghouse functionality test procedure WNA-TP-04613-GEN at the Westinghouse recommended frequency. Calibration tests will be performed per Westinghouse calibration procedure WNA-TP-04709-GEN at the Westinghouse recommended frequency.

For the Braidwood PM program related to the SFPLI, in its letter dated June 9, 2015 [Reference 34], the licensee stated that Braidwood Station has developed PM tasks for the SFPI per Westinghouse recommendation identified in the technical manual WNA-G0-00127-GEN to assure that the channels are fully conditioned to accurately and reliably perform their functions when needed.
In its email dated February 15, 2017 [Reference 35], the licensee listed Braidwood PM tasks related to the SFPLI as shown below in Table 3, " Braidwood SFPLI Preventive Maintenances".

Table 3 – Braidwood SFPLI Preventive Maintenances

PM	Description	Frequency
00193396-01, 00193397-01	SFPI Battery Replacement	3 years
00193901-01	Channel Check – SFP Level Indication	1 month
00193877-01, 00193878-01	Electronic Component replacement	28 years
00193882-01, 00193883-01	SFP Level Indication Calibration	18 months
Operator Rounds Point number 863 and 842	Verify Power Source Walkdown	4 days
00193882-02, 00193883-02	Probe Replacement	40 years
	Transmitter Replacement	7 years

Related to the compensatory measures for the SFP level instrument channel(s) out-of-service, during the onsite audit, the licensee stated that Braidwood Procedure 0BwOS FX-2a, "AAR Spent Fuel Pool Level Instrumentation," provides compensatory actions for out-of-service events as summarized below in Table 4, "Compensatory Measures for SFP Level Instrument Channel(s) Out-of-Service".

Table 4 – Compensatory Measures for SFP Level Instrument Channel(s) Out-of-Service

CONDITION	REQUIRED ACTION	COMPLETION TIME
A.1 One FLEX SFP level channel unavailable	A.1.1 VERIFY alternate FLEX SFP level channel AVAILABLE	IMMEDIATELY
	AND	
	A.1.2 RESTORE FLEX SFP level channel	90 days
	OR	
	A.1.3 PROVIDE alternate equipment with equal capability	90 days
A.2 Two FLEX SFP level channels unavailable	A.2.1 INITIATE actions to establish ONE FLEX SFP level channel AVAILABLE	24 hours
	AND	
	A.2.2 PROVIDE alternate equipment of equal capability	72 hours

Note: If it is expected that FLEX SFP level channel restoration will exceed 90 days, then initiate an Incident Report to document the condition, develop and implement an alternate method of monitoring, determine the cause of the unavailability, and the plans and schedule for restoration of the channel(s) to available status.

The NRC staff noted that the licensee adequately addressed testing and calibration programs to maintain the SFP level instrument channels at the design accuracy. The licensee testing and calibration plan appears to be consistent with the vendor recommendations. Additionally, compensatory actions for instrument channel(s) out-of-service appear to be consistent with guidance in NEI 12-02. The staff finds that the licensee's proposed testing and calibration program appears to be consistent with NEI 12-02, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.4 Conclusions for Order EA-12-051

In its letter dated June 9, 2015 [Reference 34], the licensee stated that they would meet the requirements of Order EA-12-051 by following the guidelines of NEI 12-02, as endorsed by JLD-ISG-2012-03. In the evaluation above, the NRC staff finds that, if implemented appropriately, the licensee 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 SFP level instrumentation is installed at Braidwood Station according to the licensee's proposed design, it should adequately address the requirements of Order EA-12-051.

5.0 CONCLUSION

In August 2013 the NRC staff started audits of the licensee's progress on Orders EA-12-049 and EA-12-051. The staff conducted an onsite audit in May 2015 [Reference 17]. The licensee reached its final compliance date on October 25, 2016, and has declared that both of the reactors are in compliance with the orders. The purpose of this safety evaluation is to document the strategies and implementation features that the licensee has committed to. Based on the evaluations above, the NRC staff concludes that the licensee has developed guidance and proposed designs 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, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," dated March 12, 2012 (ADAMS Accession No. ML12054A736)

5. Order EA-12-051, "Order Modifying 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," Revision 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," Revision 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. Braidwood, 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. ML13060A362)

11. Braidwood, 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. ML13241A286)

12. Braidwood 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. ML14059A353)

13. Braidwood Station, 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 (ADAMSAccession No. ML14248A223)

14. Braidwood 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. ML15058A420)

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. U. S. Nuclear Regulatory Commission, Braidwood 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. ML13225A592)

17. U. S. Nuclear Regulatory Commission, Braidwood Station, Units 1 and 2, Report for the Audit Regarding Implementation of Mitigating Strategies and Reliable Spent Fuel Pool Instrumentation Related to Orders EA-12-049 and EA-12-051, dated May 27, 2015 (ADAMS Accession No. ML15134A459)

18. Braidwood Station, Unit 2 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 December 16, 2015 (ADAMS Accession No. ML15350A414)

19. U.S. Nuclear Regulatory Commission, "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. Braidwood Station, Units 1 and 2 - Fifth 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, 2015 (ADAMS Accession No. ML15246A081)

23. Braidwood Station, Unit 1 - Sixth 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 26, 2016 (ADAMS Accession No. ML16057A208)

24. Braidwood Station, Unit 1, Seventh 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 26, 2016 (ADAMS Accession No. ML16239A321)

25. Braidwood 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 December 7, 2016 (ADAMS Accession No. ML16348A053)

26. Braidwood 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. ML13059A265)

27. NRC, Braidwood Station, Units 1 and 2, Request for Additional Information Regarding Overall Integrated Plan for Reliable Spent Fuel Pool Instrumentation, dated July 11, 2013 (ADAMS Accession No. ML13191B255)

28. Braidwood 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 31, 2013 (ADAMS Accession No. ML13212A364)

29. U. S. Nuclear Regulatory Commission, Braidwood 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. ML13280A566)

30. Braidwood 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. ML13241A240)

31. Braidwood 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. ML14062A056)

32. Braidwood Station, Units 1 and 2, Third Six-Month Status Report to the March 12, 2012 Commission Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation (Order Number EA-12-051), dated August 28, 2014 (ADAMS Accession No. ML14248A208)

33. Braidwood Station, Units 1 and 2 Fourth Six-Month Status Report to the March 12, 2012 Commission Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation (Order Number EA-12-051), dated February 27, 2015 (ADAMS Accession No. ML15058A555)

34. Braidwood Station, Units 1 and 2 - Report of Full Compliance with March 12, 2012 Commission Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation (Order Number EA-12-051), dated June 9, 2015 (ADAMS Accession No. ML15160A351)

35. E-mail from David Distel (Exelon) to John Hughey (NRC), Braidwood Station Information request Related to Spent Fuel Pool Instrumentation, dated February 15, 2017 (ADAMS Accession No. ML17046A069).

36. NRC Office of Nuclear Reactor Regulation Office Instruction LIC-111, Regulatory Audits, dated December 16, 2008 (ADAMS Accession No. ML082900195).

37. 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).

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

39. 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)

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

41. 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," Revision 1, January 22, 2012 (ADAMS Accession No. ML15357A163)

42. 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)

43. 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)

44. U.S. Nuclear Regulatory Commission, "WATTS Bar Nuclear Plant, Units 1 and 2- Report for the Westinghouse Audit in Support of Reliable Spent Fuel Instrumentation Related to Order EA-12-051," August 18, 2014 (ADAMS Accession No. ML14211A346)

45. 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)

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

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BRAIDWOOD 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 DATED MAY 10, 2017

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