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10 CFR 50
10 CFR 51
10 CFR 54

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U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

Braidwood Station, Units 1 and 2
Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Byron Station, Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: Response to NRC Requests for Additional Information for the Severe Accident Mitigation Alternatives Review, dated January 6, 2014, related to the Braidwood Station, Units 1 and 2 and Byron Station, Units 1 and 2 License Renewal Application

References:

1. Letter from Michael P. Gallagher, Exelon Generation Company LLC (Exelon) to NRC Document Control Desk, dated May 29, 2013, "Application for Renewed Operating Licenses."

2. Letter from Lois James, US NRC to Michael P. Gallagher, Exelon, dated January 6, 2014, "Requests for Additional Information for the Review of the Byron and Braidwood Nuclear Stations License Renewal Application - Severe Accident Mitigation Alternatives Review (TAC Nos. MF1790, MF1791, MF1792, and MF1793)

In the Reference 1 letter, Exelon Generation Company, LLC (Exelon) submitted the License Renewal Application (LRA) for the Braidwood Station, Units 1 and 2, and Byron Station, Units 1 and 2 (BBS). In the Reference 2 letter, the NRC requested additional information to support the staffs' review of the LRA.

The Enclosure contains the responses to this request for additional information.

There are no new or revised regulatory commitments contained in this letter.

If you have any questions, please contact Mr. Al Fulvio, Manager, Exelon License Renewal, at 610-765-5936.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 02-04-2014

Respectfully,

Michael P. Gallagher
Vice President - License Renewal Projects
Exelon Generation Company, LLC

Enclosure: Responses to Requests for Additional Information

cc: Regional Administrator – NRC Region III
NRC Project Manager (Safety Review), NRR-DLR
NRC Project Manager (Environmental Review), NRR-DLR
NRC Senior Resident Inspector, Braidwood Station
NRC Senior Resident Inspector, Byron Station
NRC Project Manager, NRR-DORL-Braidwood and Byron Stations
Illinois Emergency Management Agency - Division of Nuclear Safety

QUESTION 1:

Provide the following information regarding the probabilistic risk assessment (PRA) used for the severe accidents mitigation alternatives (SAMA) analysis. The basis for this request is as follows: Applicants for license renewal are required by Title 10 of the *Code of Federal Regulations* (1 0 CFR) 51.53(c)(3)(ii)(L) to consider SAMAs, if not previously considered, in an environmental impact assessment, related supplement, or environmental assessment for the plant. As part of its review of the Byron/Braidwood SAMA analyses, NRC staff evaluates the applicant's treatment of internal events and calculation of core damage frequency (CDF) in the Level 1 PRA model. The requested information is needed in order for the NRC staff to reach a conclusion on the sufficiency of the applicant's Level 1 PRA model for supporting the SAMA evaluations.

Question 1.a

In Table F.2-1, the comment for PRA Revision 5A states "Revised the model and data to address the PRA quality issues raised by CR#00142080 (1/30/03) against Rev. 5 model." Describe these quality and related process issues and associated corrective actions.

Exelon Response

Revision 5a was performed in 2003 to replace Revision 5 (approved in 2002), to address the technical issues identified in the CR142080 as well as satisfy the requirements of the three-year periodic update.

The technical issues from the CR and their resolution:

1. Inadequate use of plant specific failure probabilities for key equipment (CV Pumps, RH Pumps, SX Pumps, CC Pumps, 120VAC Inverters)
   a. Model Rev 5A includes updated probabilities.
2. Inadequate dependency analysis of modeled operator actions
   a. Model Rev 5A incorporates recovery logic to account for human action dependencies, specifically those related to closing/blocking the PORVs and recovery from loss of SX.
3. Complex recovery analysis that provides inconsistent results (risk decreases with additional equipment out of service) for use in the On-Line Maintenance Program.
   a. Component-specific recoveries causing problems were removed from the base model for Rev 5A.
4. Inadequate tests for convergence of the model results
   a. Full convergence test performed for Rev 5A.

The underlying process issue that allowed these technical quality issues to occur was a premature approval of the model prior to full review as required by the work process procedure. Exelon T&RM ER-AA-600-1015, “FPIE PRA Model Update,” provides specific process and review criteria for a new model to be officially approved. The items that must be performed prior to model approval include:

- Creation of a summary of model logic changes
- Intermediate gate quantification for systems/trains
- Cutset reviews (dominant and non-dominant)
- Review of importance measures
- Verify convergence at truncation limits
- Cutset checks against previous model
- Initiator contribution comparisons against previous model
- Accident class comparisons against previous model
- Accident sequence comparisons against previous model
- Comparison of dominant sequences & cutsets within multi-unit sites
- Review significant operator actions
- Verification that data values in model match values in the documentation

This process was not followed adequately for Revision 5, resulting in the CR. To help ensure that the review items are performed prior to model approval, the Quantification Notebook for each official model of record (including the current model of record) now includes confirmation that the reviews required by ER-AA-600-1015 were performed to check for these and other quality issues.

The Quantification Notebook documenting the listed reviews is internally independently reviewed. Signatures of the author, reviewers, and approver confirm this review has been performed, and approval of the Quantification Notebook signifies official approval of the updated model.

Question 1.b

As indicated in Table F.2-1, the core damage frequency (CDF) goes from 2.2E-5 ***{2.3E-05}*** to 1.7E-5 ***{1.6E-5}*** in going from Revision 6D to Revision 6E. The associated model changes are the inclusion of credit for the auxiliary feedwater (AFW) unit crosstie and the implementation of human error probability (HEP) changes. This corresponds to a 23 to 30 percent reduction in CDF due to the two changes in the model. The AFW unit crosstie is SAMA 15, which is indicated in Section F.6.12 to only reduce CDF by 2 to 2.5%. Discuss the relative impact of the two model changes made in Revision 6D and, unless the HEP changes are the significantly larger contributor, why the apparent benefit of the AFW unit crosstie is greater than that shown by the evaluation of SAMA 15. ***{BW values}***

Exelon Response

The documentation from Revision 6E does not specifically identify the individual contributions from the AFW crosstie and HEP changes and it is not possible to recalculate the exact contributions. However, to approximate the effect of the AFW crosstie, the crosstie operator action can be set to a failure probability of 1.0 in the Revision 6E cutsets as is done in the current model of record. This results in a CDF of 1.9E-5 **{1.8E-5}**, a reduction of approximately 2E-6. Therefore, the approximate value of the AFW crosstie in Revision 6E is 0.2/1.9~10%. The remaining decrease of ~13-20% is due to the HEP changes and other minor model changes. These results are not exact as some AFW crosstie cutsets below truncation and not captured, but it does provide a good estimate of the relative effects of the AFW crosstie versus other model changes.

The model changes from Rev 6E to the current model of record include the changes in Rev 6F and a full periodic model update in addition to removal of the AFW crosstie. Rev 6F changes, including changes to model splitting of the CC trains and the new internal flooding analysis, increased CDF to 2.5E-5 **{4.0E-5}**, accounting for some of the increase from Rev 6E for Byron and most for Braidwood.

Revision BB011a was a full periodic update incorporating many additional plant and model changes that affected the results. CDF for Byron Units 1/2 was 4.1/4.0E-5 and for Braidwood was 4.3E-5 (both units). In addition to loss of the AFW crosstie, the primary drivers for the CDF increase from Rev 6F to BB011a include a newly identified dependence of the diesel-driven AFW pump on service water and a new dependent human action analysis that identified several new key action combinations that increased CDF, particularly at Byron. These changes in Rev 6F and BB011a created newly dominant risk contributors that are not affected by the AFW crosstie, thereby reducing its importance in the PRA.

Revision BB011b improved modeling of CC and SX to support improved MSPI calculations. Related modeling changes decreased CDF to 4.0/3.8E-5 for Byron Units 1/2 and 3.6/3.5E-5 for Braidwood Units 1/2.

In summary, because the changes in CDF from model Revision 6D to the current model of record were not solely driven by the addition and removal of the AFW crosstie, it is not appropriate to expect the re-addition of the crosstie to reproduce the CDF changes associated with previous model revisions. Changes to the plant and the PRA model have shifted some of the risk away from the AFW crosstie such that its effect is expected to be less than when it was originally incorporated.

Question 1.c

Section F.2.4 states that the 27 Level A and B facts and observations (F&Os) identified during the 1999 Westinghouse Owner's Group (WOG) peer review have been "closed out". Describe what is meant by "closed out", how this was verified, and if these F&Os were considered in the 2012 self-assessment and the corrections incorporated in the PRA that was used for the SAMA analysis.

Exelon Response

The 1999 WOG review was performed against Rev 0 of the model. Peer review items were tracked in the URE (Updating Requirements Evaluation) database along with other potential model changes since that time (URE-130-155 for BW and 302-310 for BY F&Os). These UREs include F&Os identified as contingent and the six contingent F&Os from Braidwood that were identified in the Byron peer review were captured as BW UREs, but were addressed for both units. UREs are addressed during the ongoing model update process, and the associated model and documentation changes (or decision to not change the model/documentation) are reviewed and approved with each official model approval according to Exelon T&RM ER-AA-600-1015. Review of the closure of each URE is also tracked in the URE database. All of the UREs associated with the 1999 peer review were completed prior to the model used for the SAMA.

Specifically, ER-AA-600-1015 directs, "For model logic changes, summarize the basis for the change (e.g., reference to URE), the change(s) made (e.g., markup of picture of the affected logic, or reference to a URE or PRA notebook containing such information), expected impact on PRA results, and observed impact on PRA results."

The 2012 self-assessment used the 2009 version of the PRA Standard, which differs somewhat from the 1999 peer review reference. Changes due to the 1999 F&Os were fully considered as part of the 2012 self-assessment, though specific supporting requirements may have changed.

Question 1.d

Section F.2.4 identifies a 2012 self-assessment. Clarify if this self-assessment was performed following the self-assessment process guidance in RG 1.200, Rev. 2, and NEI 00-02, Rev. 1. If not, discuss the purpose, objectives, and procedures of the 2012 self-assessment.

Exelon Response

The self-assessment was performed against the high-level and supporting requirements of the ASME PRA Standard ASME RA-Sa-2009 and the corresponding guidance in Regulatory Guide 1.200, Rev. 2, and was performed consistent with the NEI 00-02 self-assessment process.

Question 1.e

Describe any actual or planned potentially significant changes to hardware or operation (including changes in fuel cycle or fuel management), that have not been incorporated in the SAMA PRA.

Exelon Response

Potential plant modifications include reactivation of the AFW crosstie, installation of new RCP Seals, SX ductwork changes to address internal flooding, and FLEX, which are already considered in the SAMA analysis either explicitly or in combination with other changes. In the case of FLEX, a SAMA is assessed that includes what are considered to be most significant capabilities associated with FLEX. These changes have been, or are being, considered for implementation by the sites for reasons unrelated to the SAMA analysis.

One additional item under consideration is a modification to the SX007 valves at Braidwood to allow them to be in accident position and remove the need for manipulation during an event.

No potential changes in fuel cycle or fuel management are known that would affect the SAMA analysis.

Question 1.f

Identify the systems that are shared or that can be cross-tied between units and describe the modeling, including the treatment of unavailability, during outages of the other unit.

Exelon Response

The systems that are shared or crosstied include service water (SX), component cooling water (CC), auxiliary feedwater (AF), auxiliary electric power (AP), and DC power (DC), and instrument air/service air (IA/SA).

The Byron/Braidwood PRA is a fully integrated two-unit model, so all components from each unit and those shared between units are explicitly modeled. Unit-specific components which can be used by the opposite unit are linked into the opposite unit's fault tree logic structure. Unavailability is modeled directly with both normal maintenance unavailabilities and outage maintenance terms for the AF pumps, AP buses (141 & 142), DC Battery Chargers, Diesel Generators and the SX012A/B & SX013A/B valves. Separate outage maintenance terms are not currently included for the SX pumps, CC pumps, or SA compressors since they are needed during both full power and outage operations.

For example, a Unit 2 component that can be used by Unit 1 is modeled in the integrated fault tree with a normal maintenance unavailability basic event based on unavailable hours during Unit 2 normal operations. It also includes another basic event to capture the likelihood that the component is unavailable to Unit 1 because Unit 2 is in an outage. For the baseline model, the probability of this basic event would be based on the amount of unavailability during outage divided by the total time. The outage term is essentially an addition to the normal unavailability since the normal value does not consider outage time for the unit the component belongs to.

Question 1.g

The anticipated transient without scram (ATWS) CDF is given in Figures F.2-1 and F.2-2 as less than a value that is equal to 1% of the unit total CDF. Confirm that the Byron/Braidwood PRAs model ATWS, that actual values are available and that the identification of SAMA includes consideration of the ATWS. If not, please justify the approach taken. Provide the actual ATWS CDF.

Exelon Response

The Byron/Braidwood PRA does model ATWS as a transfer from any other IE (except LLOCA).

Actual ATWS CDF from Rev BB011b:

BY1: 1.39E-7

BY2: 1.39E-7

BW1: 1.60E-7

BW2: 1.60E-7

ATWS sequences feed into the SAMA along with all other sequences, so are considered in SAMA appropriately.

Question 1.h

From the description of important initiators on page F-5, it is apparent that loss of essential service water (SX) can be mitigated by recovery of main feedwater. Discuss these scenarios.

Exelon Response

Recovery of main feedwater does not, by itself, mitigate the loss of SX, but it can contribute to the mitigation. Loss of SX can lead to loss of RCP seal cooling and injection due to loss of cooling to the injection pumps and the thermal barrier heat exchangers. Loss of SX also contributes to loss of AFW to the steam generators. One approach to mitigate this event is to provide seal injection by providing an alternate cooling source to the seal injection (CV) pumps and restore main feedwater as a source of secondary side cooling.

Question 1.i

Describe the Loss of Auxiliary Electric Power initiating event, how it is modeled, and how it is related to a Loss of Offsite Power (LOOP). Please provide the CDF contribution due to a LOOP as well as the LOOP initiating event frequencies.

Exelon Response

A Loss of Auxiliary Electric Power event leads to loss of an internal AP bus, which then fails running equipment (e.g., CC or SX) that triggers an initiating event. It is not a LOOP, but is more similar in effect to loss of other support systems. Loss of AP is modeled as an initiating event fault tree that is integrated into the overall model.

Actual LOOP CDF contributions from model BB011b:

BY1: 1.3%

BY2: 0.9%

BW1: 0.9%

BW2: 1.0%

Note that these LOOP contributions are from LOOP initiating events only. Other events may cause consequential LOOPs which can also contribute to CDF via SBO or other means.

Single-unit LOOP and Dual-unit DLOOP initiating event frequencies:

Single-Unit LOOPs	Braidwood	Byron	Dual-Unit LOOPs	Braidwood	Byron
Sustained LOOP			**Sustained DLOOP**		
Plant-Centered LOOP	1.71E-03	1.72E-03	Plant-Centered DLOOP	1.09E-04	1.10E-04
Switchyard-Centered LOOP	1.81E-02	6.05E-03	Switchyard-Centered DLOOP	4.83E-03	1.62E-03
Grid-Related LOOP	6.16E-04	6.19E-04	Grid-Related DLOOP	2.77E-03	2.78E-03
Weather-Related LOOP	1.27E-03	1.28E-03	Weather-Related DLOOP	2.86E-03	2.87E-03
Total Sustained LOOP	2.17E-02	9.67E-03	Total Sustained DLOOP	1.06E-02	7.38E-03
Momentary LOOP			**Momentary DLOOP**		
Plant-Centered LOOP	5.20E-05	5.21E-05	Plant-Centered DLOOP	3.32E-06	3.33E-06
Switchyard-Centered LOOP	7.42E-04	2.49E-04	Switchyard-Centered DLOOP	1.99E-04	6.65E-05
Grid-Related LOOP	0.00E+00	0.00E+00	Grid-Related DLOOP	0.00E+00	0.00E+00
Weather-Related LOOP	0.00E+00	0.00E+00	Weather-Related DLOOP	0.00E+00	0.00E+00
Total Momentary LOOP	7.95E-04	3.01E-04	Total Momentary DLOOP	2.02E-04	6.98E-05

Braidwood has a greater switchyard-centered frequency due to an actual event during the data update period. This difference is less than a factor of two in initiating event frequency and does not significantly affect the LOOP CDF contributions because these events are not significant contributors at either site. Though switchyard-centered events have a higher overall initiating event frequency, weather-related LOOPs are actually the greatest LOOP contributors due to a greater likelihood of affecting both units and lower likelihood of power recovery. At the low level of contribution of switchyard-centered LOOPs, other site and unit differences can have a similar level of effect on CDF, masking the effect of the IE frequency difference.

<u>Question 1.j</u>

The Unit 2 CDF and percent contribution values given in Byron Figure F.2-2 are internally inconsistent. Provide a correct Figure F.2-2. ***(BY only)***

<u>Exelon Response</u>

The figure is correct. The associated table should be:

Initiating event	CDF Contribution (based on percent contribution)
Loss of SX	1.72E-05
Loss of CCW	8.12E-06
Internal flooding	5.78E-06
Loss of AP	1.82E-06
Small LOCA	1.52E-06
Other	1.55E-06
SGTR	1.52E-06
Gen transient & LMFW	6.78E-07
Total	3.82E-05

Question 1.k

There is a significant difference between some of the PRA results between the Byron and Braidwood sites. See for example the contributions to total due to Loss of SX, Loss of CCW and Small LOCA as provided in Figures F.2-1 and F.2-2 of the respective ERs. See also the differences in accident sequence frequencies SLOC-02 (Braidwood higher than Byron) and SLOC-06 (Byron higher than Braidwood) as shown in Table F.2-2 of the respective ERs. Explain and provide more information on the reasons for these differences. In addition, assess if the reasons for these differences suggest design or operating changes that might be cost beneficial SAMAs for one site or the other.

Exelon Response

SLOC-06 Review: The Byron SLOC-06 sequence frequency is larger for Byron than for Braidwood primarily because the Byron results include the joint human error probability (JHEP) for 1RX-JHEP44-HOADA, which is a dependent operator action pair for the failure to establish a cool suction source for the charging pumps and the failure to align essential service water to the Unit 0 CC heat exchanger. The reason 1RX-JHEP44-HOADA is included for Byron, but not for Braidwood is because Byron operates with both SX crosstie valves (1SX005 and 2SX005) closed such that Byron would have to open an SX005 valve to establish essential service water flow to the Unit 0 CC heat exchanger on loss of an operating unit specific heat exchanger while Braidwood operates with one of the SX005 valves open.

Potential for Cost Beneficial SAMAs: The dominant contributors for the Byron SLOC-06 sequence are RCP seal LOCAs (100%). Based on the planned installation of the Flowserve RCP seals at both Byron and Braidwood (SAMA 4), seal LOCA events will become non-contributors and no additional SAMAs developed to address the risk associated with SX005 operation would be cost beneficial.

Without installation of the Flowserve RCP seals, it would potentially be cost beneficial to change the nominal plant configuration such that the Unit 0 CC heat exchanger is normally aligned to one of the two units. This assessment is based on an assumed implementation cost of about $100,000 for procedure changes, training, and engineering analyses versus an estimated averted cost-risk of $1.2 million resulting from the deletion of JHEP 1RX-JHEP44-HOADA from the Byron cutsets (using the 95th percentile PRA results multiplier from the response to RAI 6.f and the updated External Events multiplier documented in the response to RAI 3.d). However, Byron has previously considered changing the normal position of 1(2) SX005 (prior to the planned installation of the Flowserve RCP seal), but no changes were made due to considerations unrelated to PRA insights. No additional SAMAs are suggested to address the risk associated with manually operating the SX005 valves.

SLOC-02 Review: The SLOC-02 frequency is larger for Braidwood than for Byron primarily because the Braidwood 0(1, 2) SX007 valves must be throttled open to establish an appropriate flow rate through the CC heat exchangers. At Braidwood, the lake temperature can vary throughout the year, necessitating throttling of the SX007 service water valves to the CC heat exchangers. During an accident that requires cold leg recirculation cooling, such as a LOCA, these valves must be manipulated into their proper position at Braidwood in order to assure success. Therefore, LOCA-type events, including seal LOCAs, have a higher contribution at Braidwood. At Byron, the SX007 valves do not need manipulation during an accident.

Potential for Cost Beneficial SAMAs: The dominant contributor for the Braidwood SLOC-02 sequence is a small pipe break LOCA combined with the failure to properly throttle 0SX007 valve. As documented in the ER, a low cost, potentially cost beneficial SAMA was developed to address the 0SX007 valve throttling issue (SAMA 6). If SAMA 6 is implemented, most of the risk associated with the action to throttle the SX007 valves would be eliminated and the potential for additional cost beneficial enhancements would be small.

In addition to SAMA 6, Braidwood is considering the potential to install a bypass line around the CC heat exchanger that would allow the SX007 valves to remain “full open”; however, this is an expensive enhancement relative to SAMA 6. Furthermore, the “bypass” enhancement would not necessarily eliminate the need for operator intervention because the cooling rate would still have to be managed, albeit, from the control room using the CC system controls. No additional SAMAs are suggested to address the risk associated with SX007 valve throttling.

QUESTION 2

Provide the following information regarding the Level 2 analysis used for the SAMA analysis. The basis for this request is as follows: Applicants for license renewal are required by 10 CFR 51.53(c)(3)(ii)(L) to consider SAMAs, if not previously considered, in an environmental impact assessment, related supplement, or environmental assessment for the plant. As part of its review of the Byron/Braidwood SAMA analyses, NRC staff evaluates the applicant's treatment of accident progression and radionuclide release analysis in the Level 2 PRA model. The requested information is needed in order for the NRC staff to reach a conclusion on the sufficiency of the applicant's Level 2 PRA model for supporting the SAMA evaluations.

Question 2.a

Provide a brief description of any reviews (e.g., in-house review, self-assessments, peer review, etc.) of the updated Level 2 model included in Rev. BB011b1 of the PRA model and/or any reviews of WCAP-16341-P, "Simplified Level 2 Modeling Guidelines." Discuss the major reasons for the factor of 2-3 decrease in large early release frequency (LERF) shown in Table F.2-1 from implementing this updated methodology.

Exelon Response

For the initial completion of the updated Level 2 model included in Rev BB011b1 of the PRA, an internal review was conducted examining accident sequence modeling, fault tree modeling, and cutset reviews. The documentation of the BB011b1 model also included a self-assessment / roadmap against Capability Category II of the ANS PRA Standard. This self-assessment / roadmap concluded that all applicable LE (LERF) supporting requirements were met at Capability Category II. The signature of the preparer and the reviewer confirm the internal review and agreement with the conclusion of the self-assessment / roadmap.
The new Level 2 model replaced the simplified, and generally conservative, previous LERF model. Reductions in LERF come from several improvements, including credit for operator action to keep a steam generator full to scrub a release from a SGTR and reduced early containment failure probabilities.

Question 2.b

It is stated that, "The Level 2 model is generally consistent with the “Simplified Level 2 Modeling Guidelines,” WCAP-16341-P." Describe any major areas where it is not consistent with these guidelines and the rational and/or basis for these deviations.

Exelon Response

Differences between the Level 2 model and the WCAP include:

1. No credit for recovery of AC power after core damage. The ability for offsite power recovery prior to core damage is addressed by the Level 1 PRA. Given that power recovery has not occurred prior to core damage, there is a small, but non-zero chance of power recovery in the period between core damage and radioactive release. This time window will vary for different scenarios, and therefore the slightly conservative

assumption of no power recovery during this window is taken. No credit is taken for diesel generator repair.

2. Modeling of potential hot leg rupture following an induced tube rupture, such that the release to the environment is substantially reduced, based on recent research results from the State-of-the-Art Reactor Consequence Analysis (SOARCA) project. The SOARCA project was not complete at the time WCAP-16341-P was written.
3. Use of a combined containment event tree rather than separate SBO and non-SBO CETs. This is a modeling choice and has no effect on the overall model since recovery of offsite power is not credited.
4. The Byron and Braidwood Level 2 analysis developed an HRA for modeling the action to maintain a sufficient water pool over the SG tubes to scrub releases in SGTR events. The WCAP guidance identifies that this type of scrubbing is possible, but that the recovery action is not currently included in the WCAP model.

Question 2.c

From the containment event tree (CET) in Figure F.2-4, the containment isolation failures lead to Sequence LERF09 which is release category LERF-CI. Table F.3-8 indicates that this has a cesium iodide (CsI) release fraction of 0.0142. This analysis must assume that isolation failure is large enough so that early containment failures due to such things as hydrogen explosion and direct containment heating are prevented. If not, it would appear that the CsI release fraction for release category LERF-CFE of 0.3 is more appropriate for the fraction of isolation failures that might have an early containment failure. Discuss the impact of this on the SAMA analysis.

Exelon Response

Hydrogen explosion and direct containment heating are potential failure modes for the containment isolation failure sequence; however, as documented in the “Containment Failure at Vessel Breach” node of Section F.2.3.2 of the ER, the probability of early containment failure due to the hydrogen explosion and direct containment heating is 1E-3. While the LERF-CFE CsI release fraction may be about 20 times larger than the CsI release fraction for LERF-CI, the frequency is 1000 times less. The characterization of LERF-CI with the LERF-CFE source term would be inappropriate.

Further, the LERF-CI contributions that result in early containment failure represent only about 1 percent of the LERF-CFE frequency for both Byron and Braidwood. Re-binning the early containment failure contributions from the LERF-CI release category into the LERF-CFE release category results in no measurable change to the reported dose-risk and offsite economic cost risk values and, therefore, would have no impact on the SAMA analysis.

Question 2.d

Table F.2-8 indicates about a 20% difference between Units 1 and 2 for Release Category LATE-CHR-NOAFW frequency. Describe the reason for this difference. **{BY only}**

Exelon Response

The difference in Unit 1 and Unit 2 results for LATE-CHR-NOAFW is related to the assumed default configurations for the two units. Investigation of the cutsets for Unit 1 shows a susceptibility to AP bus 142 failure that does not appear for Unit 2 (which would be AP bus 242). This difference in unit-to-unit results is seen in other applications of the model and is tied back to the assumed pump configurations of the two units. For Unit 1, the assumed SX pump configuration models pump 1A in standby and pump 1B running. For Unit 2, the opposite configuration is modeled, with pump 2A running and pump 2B in standby. Because other pumps (such as CV) have the same default configurations in both units, unique train-based power failures can occur at Unit 1 that do not occur at Unit 2. This can result in slightly different sequences due to power dependency failures such as seen here. Unit 1 has the higher frequency and was used for the purposes of the SAMA analysis.

Question 2.e

Section F.2.3.2 indicates that containment failure due to direct containment heating is “0.000”. Clarify if this is a zero failure probability, and how this and other early containment failure probabilities are included in the Level 2 models.

Exelon Response

The 0.000 containment failure probability is not a typo. That is the value reported from WCAP-16341-P, which in turn quotes the value from NUREG/CR-6338, “Resolution of Direct Containment Heating Issue for all Westinghouse Plants with Large Dry Containments or Subatmospheric Containments”. The WCAP notes that the NUREG only provides 3 significant digits. The 0.000 value applies to all sequences and all combinations of hydrogen burns, steam explosion, and/or direct containment heating. Therefore, the probability of early containment failure at Byron or Braidwood is negligible for any sequence. However, in order to maintain flexibility in the model for sensitivity analyses, the early containment failure (CFE) probability is maintained in the model and assigned a probability of 0.001 for all combinations (CFE1 is the combination of steam explosion and hydrogen burn, CFE2 is hydrogen burn by itself, CFE3 is direct containment heating, and CFE4 is the combination of all three effects).

Question 2.f

Table F.2-7provides the modular accident analysis program (MAAP) results for several cases for 200, 800 and 1600 hour runs. Section F.3.5 and Table F.3-8 identify that the "MAAP cases were run to achieve a plateau of the release fractions, with primary attention paid to CsI and [cesium hydroxide] CsOH release fractions." Provide additional discussions concerning the CsI and CsOH release fraction contribution occurring for Cases 4a, Sa, 6a, 9a, 1 Oa and 12b (e.g. what were the relative increase in fractions for extending the MAAP cases to such long time frames; what was the fundamental cause of the continuing release, etc.)

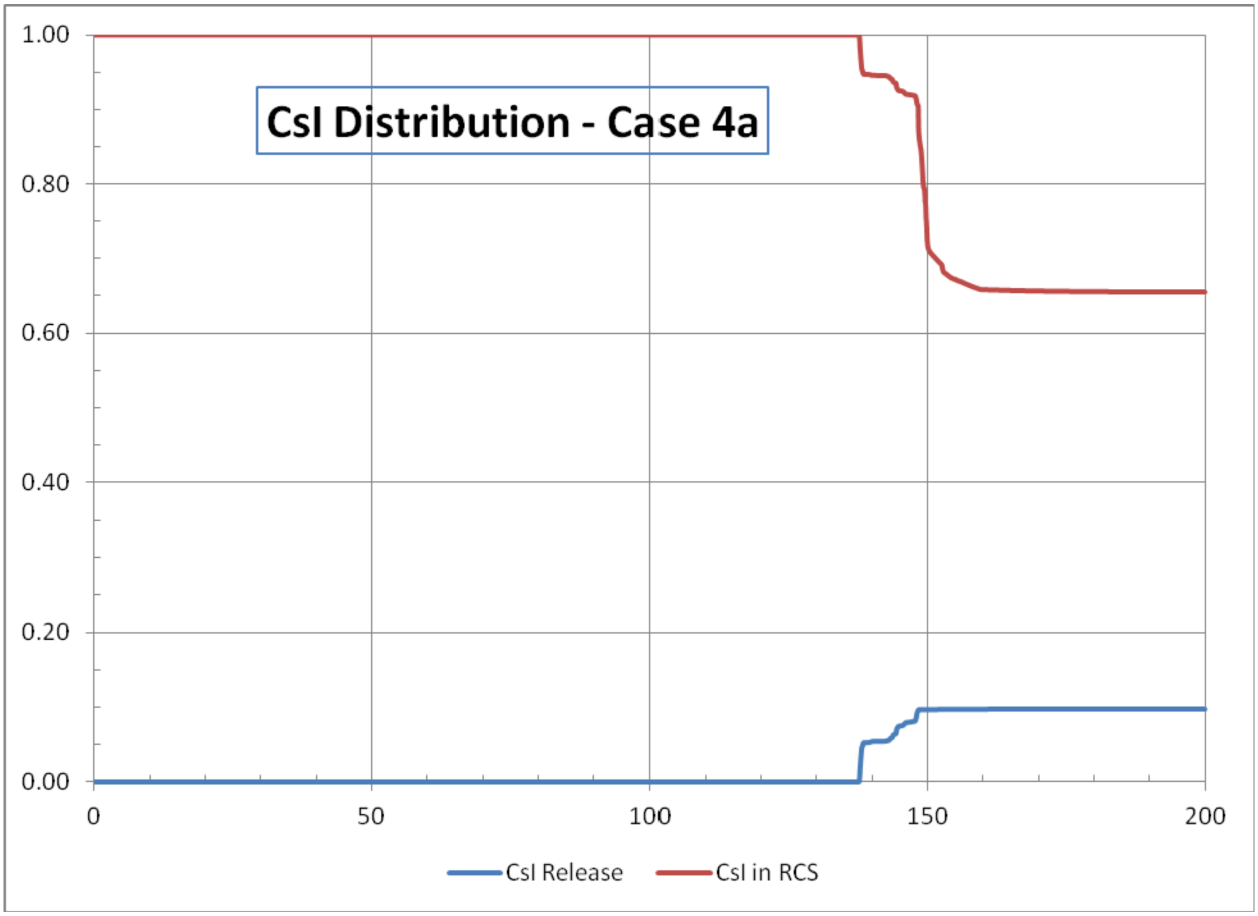
Exelon Response

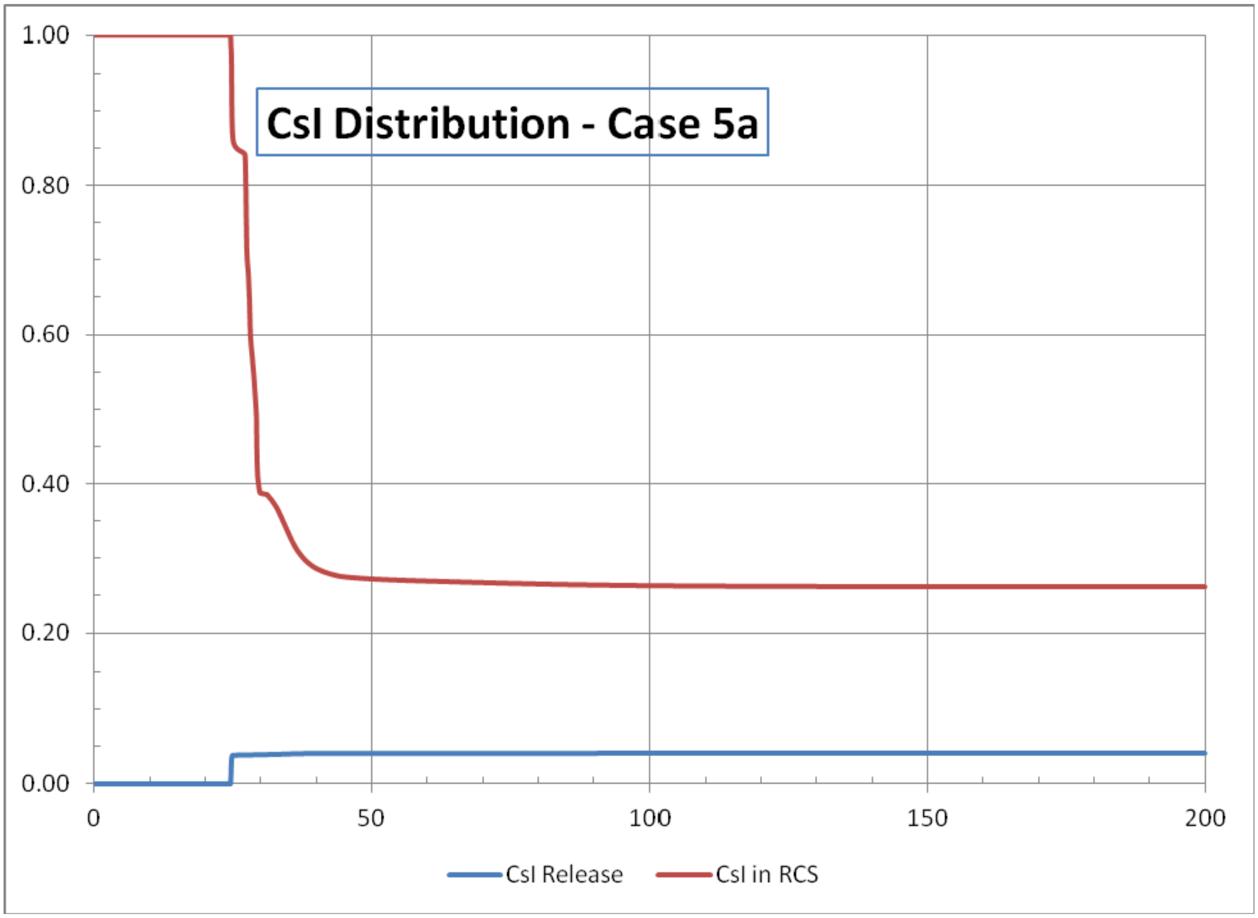
Additional information is provided in the attached figures showing the CsI release fraction along with the fraction of CsI contained within the RCS boundary. The run time for various MAAP calculations is established based on:

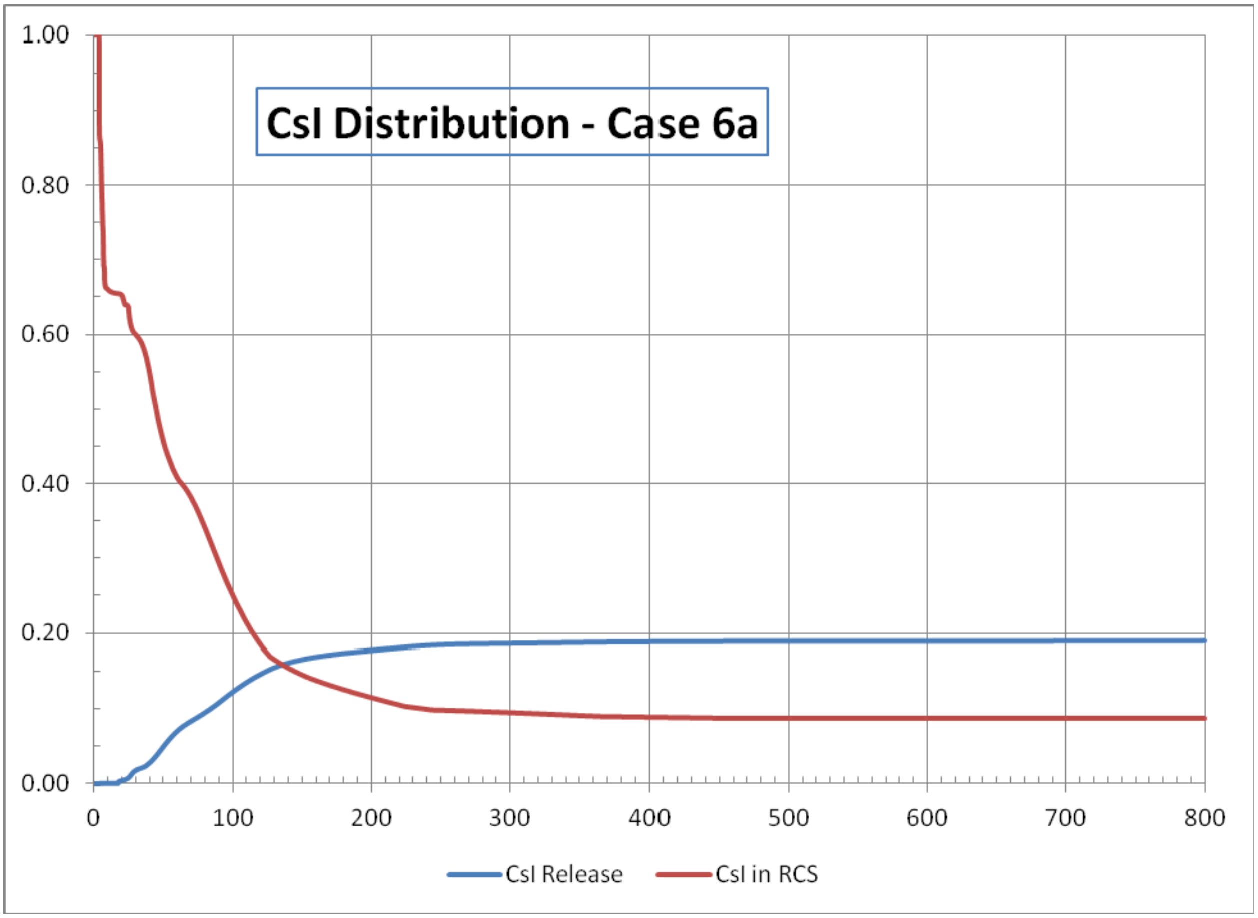
1. The timing for the onset of core damage. Sufficient time after core damage is selected to represent the initial release from the core and subsequent release from the containment.
2. The timing for either containment failure or containment bypass. The run time is established based on the initial release from the containment with sufficient time to obtain a stable release.
3. Fission products can be initially deposited within the RCS, particularly on the steam generator tubes. After the steam generator dries out and the tube temperature increases, the deposited fission products can revaporize and become available for release late in the event.

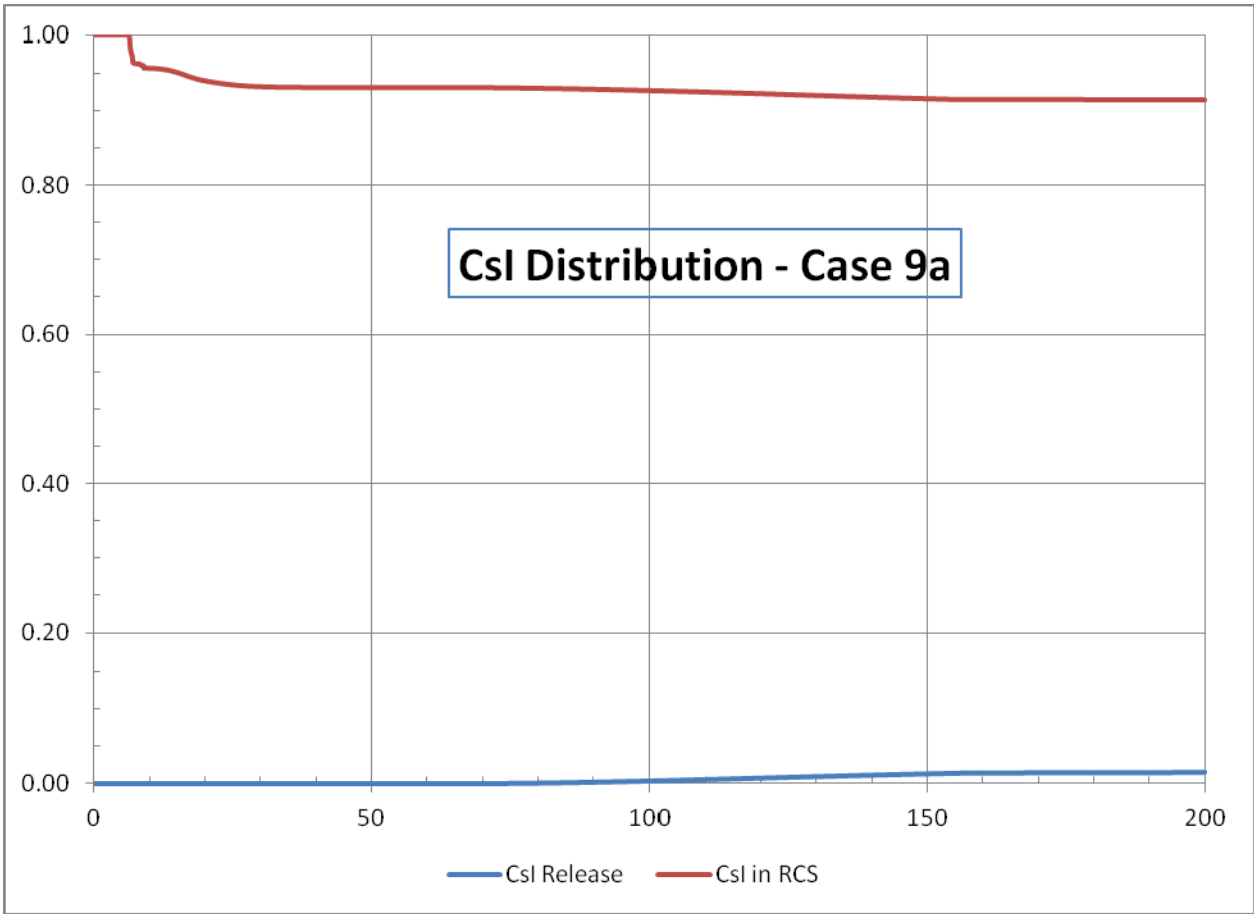
The attached plots show the release from the containment along with the amount of CsI within the RCS. As a result of core heatup, the amount of CsI in the RCS can be seen to decrease. Even though the majority of the CsI is released from the core, it may remain within the RCS as deposited mass on the steam generator tubes. Later in the scenario, the CsI fraction within the RCS may be seen to continue to decrease as a result of heatup and revaporization.

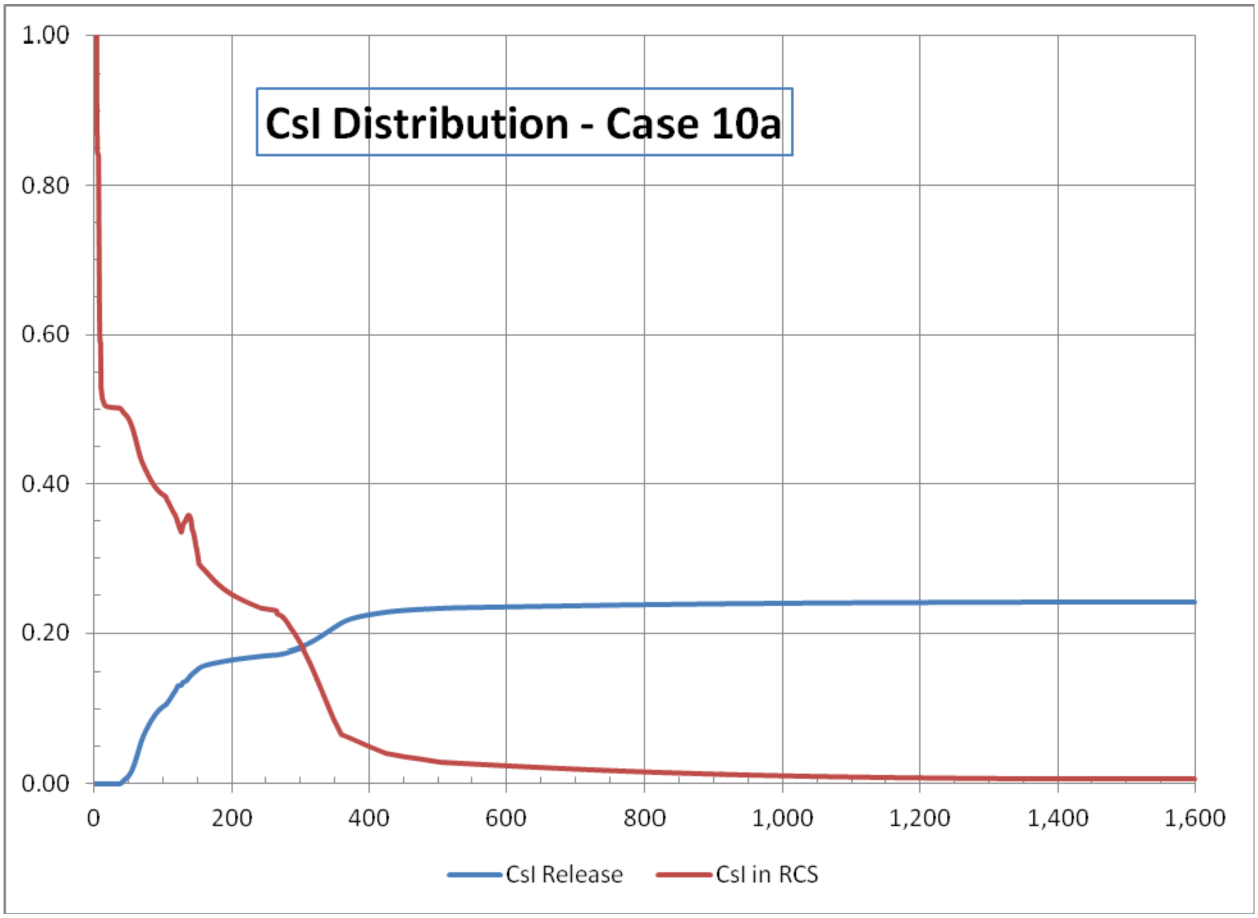
The run times were selected to make sure to capture this phenomenon and in many cases a stable total release from the containment is achieved well before the end of the run. As an example, the figure for Case 5a would indicate that a run time of about 50 hours would have been sufficient. On the other hand, Case 10a shows that the release does not reach a stable value until about 600 hours. Where CsI is used here to demonstrate the method for establishing the run time, CsOH releases would yield a similar conclusion.

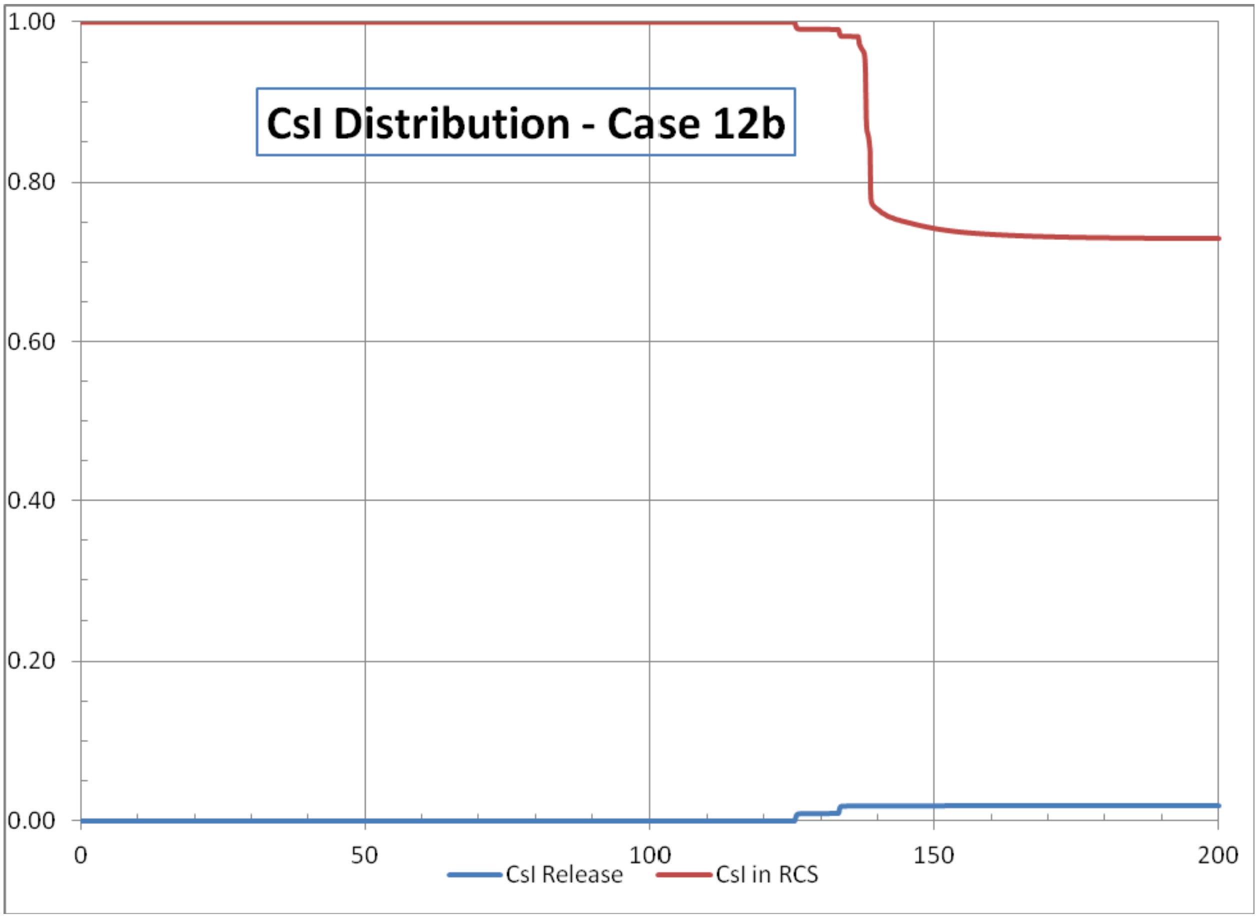

CsI Distribution - Case 4a
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
CsI Release
CsI in RCS


CsI Distribution - Case 5a
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
CsI Release
CsI in RCS


CsI Distribution - Case 6a
1.00
0.80
0.60
0.40
0.20
0.00
0
100
200
300
400
500
600
700
800
CsI Release
CsI in RCS


CsI Distribution - Case 9a
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
CsI Release
CsI in RCS


CsI Distribution - Case 10a
1.00
0.80
0.60
0.40
0.20
0.00
0
200
400
600
800
1,000
1,200
1,400
1,600
CsI Release
CsI in RCS


CsI Distribution - Case 12b
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
CsI Release
CsI in RCS

QUESTION 3

Provide the following information regarding the treatment and inclusion of external events in the SAMA analysis. The basis for this request is as follows: Applicants for license renewal are required by 10 CFR 51.53(c)(3)(ii)(L) to consider SAMAs, if not previously considered, in an environmental impact assessment, related supplement, or environmental assessment for the plant. As part of its review of the Byron/Braidwood SAMA analyses, NRC staff evaluates the applicant's treatment of external events in the PRA model and the SAMA analysis. The requested information is needed in order for the NRC staff to reach a conclusion on the sufficiency of the applicant's PRA model for supporting the SAMA evaluations.

Question 3.a

Provide more information on the 2009 Byron ***{2008 Braidwood}*** Fire PRA including: scope, status of development, major conservatisms and non-conservatisms, QA activities, and reviews. Discuss qualitatively the impact on the SAMA results of the conservatisms and non-conservatisms.

Exelon Response

The FPRA scope and development status is described through the FPRA documents associated with the development of the FPRA.

The FPRA development tasks are not part of an Appendix B type program and therefore do not have any specific QA activities. However, there are internal processes that are used to ensure that the tasks are being performed and reviewed by knowledgeable personnel. This is accomplished by the use of Certification guides in addition to each document having 3 levels of signatures; preparer, reviewer and approver.

Some of the major conservatisms in the analysis may be found in the following tasks: Fire Modeling, Human Reliability Analysis. The non-conservatisms may be found in the development of the following tasks: Human Reliability Analysis, Hot Gas Layer (HGL) analysis, modeling of all MSOs. These are described in more detail below.

Conservatisms:

Fire Modeling – The Zone of Influences that are used are based on generic treatments, there may be some cases where these generic treatments provide an over estimation of the targets being damaged. There is no credit for the severity of the fire for the given scenarios. The current fire scenarios represent a fire that has reached its full intensity with the max Heat Release Rate.

HRA – The current HRA uses a flow chart method to determine the HEP for a fire event. These HEPs are generic failure probabilities modified based on certain parameters that may not be accurate given the actual fire. If a detailed calculation were to be performed for the given action it is possible that the final HEP may be lower than that determined by the flow chart method.

Non-Conservatisms:

HRA – The current HRA uses a flow chart method to determine the HEP for a fire event. These HEPs are generic failure probabilities modified based on certain parameters that may not be accurate given the actual fire. If a detailed calculation were to be performed for the given action it is possible that the final HEP may be higher than that determined by the flow chart method. The reason for this could be the availability of the cues to give the operators a chance to respond the event or in some cases, timing constraints.

Hot Gas Layer – The current revision of the FPRA does not account for the effects of HGL. This can lead to an increase in total plant CDF/LERF if added to the analysis. This type of scenario represents the case in which a fire is not suppressed before the temperature within the room reaches a point at which the other cables and/or equipment reach their failure temperature.

Modeling of Multiple Spurious Operations – In the current revision of the model there were only a few of the MSOs that were modeled. There are other MSOs that should be added to the model and these could lead to additional cutsets that result in core damage.

Because of the multitude of the changes and the potential for interaction among the changes, it is not possible to provide an assessment of the impacts of these issues on the model or on the SAMA analysis.

Question 3.b

It is noted that the sum of the fire zone CDFs given in Section F.5.1.6.1 for Unit 2 is considerably higher than that for Unit 1 (7.03E-05 versus 4.38E-05). Provide justification to support the use of the Unit 1 fire CDF value in the external event multiplier. **{BY only}**

Exelon Response

At the time the SAMA analysis was performed, the Byron fire model was in the process of being refined to remove model conservatisms. These types of changes include:

- Taking credit for hot short probabilities to more accurately represent the potential for spurious operation, and
- Refining the cable impacts based on additional circuit analysis.

As with Braidwood Units 1 and 2, Byron Unit 1 had completed this process, but Byron Unit 2 had not. Because the units are similar and because the reduction resulting from the modeling refinements is large, it is logical that a representative CDF for Byron would be much closer to the Unit 1 CDF than the Unit 2 CDF.

Question 3.c

The results from the 2008 Braidwood fire PRA were reduced by a factor of 1.262 to account for using the lower ignition frequencies from EPRI 1016735. A comparison of the important fire zones between Braidwood and Byron indicates that there are considerable differences between the results for the two sites and the validity of using the Byron reduction factor for Braidwood. Provide further justification for the use of the Byron factor or assess the impact on the SAMA results if this factor is not used ***{BW only}***.

Exelon Response

In order to simplify the analysis, a decision was made to eliminate the use of the fire reduction factor of 1.262 from the reporting and cost benefit calculations for the individual fire zones. The text in Section F.5.1.6.1 was not updated to reflect this decision. The CDF results reported in Section F.5.1.6.1 are taken directly from the Braidwood Fire PRA (Braidwood reference Exelon 2008a) and the cost benefit calculations use ratios of those CDF values to the internal events CDF to derive averted cost-risk estimates. The CDF reduction factor of 1.262 was used, however, to establish the Braidwood MACR.

The Byron Fire PRA (Byron reference Exelon 2009) does contain a comparison of the NUREG/CR-6850 ignition frequencies to the EPRI 1016735 frequencies and these can be used to show that it would be reasonable to reduce the contributions for almost every fire zone. This is demonstrated in Tables 3.c-1 and 3.c-2 below. In addition, the reduction factor for the major fire zones for both Braidwood units would be larger than the factor of 1.262 that was used in the MACR calculation (1.37 for Unit 1 and 1.38 for Unit 2). Based on this comparison, the use of the factor of 1.262 to reduce the Braidwood fire CDF from 7.50E-05 to 5.94E-05 is considered to be reasonable.

Table 3.c-1: Potential Impact of Using EPRI Ignition Frequencies For Braidwood Unit 1 Major Fire Zones

Fire Zone	Zone Desc	Base CDF	6850 IGF	EPRI 1016735 IGF	Reduction Factor	EPRI 1016735 CDF
1-1	UNIT 1 CONTAINMENT	7.02E-06	9.08E-03	6.21E-03	1.46	4.80E-06
11.3-1	Unit 1 containment pipe penetration area	5.74E-06	1.16E-03	8.70E-04	1.33	4.31E-06
11.3-0	Auxiliary building general area, elv. 364	5.66E-06	4.00E-03	3.04E-03	1.32	4.30E-06
11.4c-0	Radwaste and remote shutdown panel control room	5.25E-06	1.43E-03	1.07E-03	1.34	3.93E-06
11.6-1	Division 12 containment electrical penetrations area	3.68E-06	3.17E-03	2.40E-03	1.32	2.79E-06
5.2-1	Division 11 ESF switchgear room	3.21E-06	2.98E-03	2.10E-03	1.42	2.26E-06
5.6-1	Division 11 Miscellaneous electric equipment room and battery room	3.18E-06	1.01E-03	6.62E-04	1.53	2.09E-06
5.5-1	Unit 1 auxiliary electric equipment room	2.50E-06	4.99E-03	3.61E-03	1.38	1.81E-06
5.6-2	Division 21 Miscellaneous electric equipment room and battery room	2.06E-06	1.16E-03	7.79E-04	1.49	1.39E-06
5.1-1	Division 12 ESF switchgear room	1.53E-06	2.86E-03	2.02E-03	1.42	1.08E-06
11.6c-0	Auxiliary building laundry room	1.49E-06	6.97E-04	5.37E-04	1.30	1.15E-06
18.12-0	Circ water pump house (Byr)/Lake screen house (Bdw)	1.26E-06	6.79E-03	5.77E-03	1.18	1.07E-06
11.6-0	Auxiliary building general area, elv. 426	1.20E-06	4.84E-03	3.86E-03	1.25	9.61E-07
11.5a-1	Division 11 containment electrical penetrations area	1.05E-06	2.71E-03	2.10E-03	1.29	8.11E-07
	Total CDF for Major Zones =	4.48E-05			EPRI 1016735 Total CDF=	3.27E-05
		Reduction Factor for Major Zones		1.37		

Table 3.c-2: Potential Impact of Using EPRI Ignition Frequencies For Braidwood Unit 2 Major Fire Zones

Fire Zone	Zone Desc	Base CDF	6850 IGF	EPRI 1016735 IGF	Reduction Factor	EPRI 1016735 CDF
5.2-2	Division 21 ESF switchgear room	7.84E-06	2.91E-03	2.05E-03	1.42	5.52E-06
11.4C-0	Radwaste and remote shutdown panel control room	6.05E-06	1.43E-03	1.07E-03	1.34	4.53E-06
1-2	UNIT 2 CONTAINMENT	4.88E-06	9.06E-03	6.22E-03	1.46	3.35E-06
5.6-1	Division 11 Miscellaneous electric equipment room and battery room	4.61E-06	1.01E-03	6.62E-04	1.53	3.02E-06
5.6-2	Division 21 Miscellaneous electric equipment room and battery room	3.73E-06	1.16E-03	7.79E-04	1.49	2.51E-06
11.6-2	Division 22 containment electrical penetrations area	3.44E-06	3.43E-03	2.60E-03	1.32	2.60E-06
5.5-2	Unit 2 auxiliary electric equipment room	3.13E-06	5.04E-03	3.64E-03	1.38	2.26E-06
5.2-1	Division 11 ESF switchgear room	2.22E-06	4.99E-03	3.61E-03	1.38	1.61E-06
11.6-0	Auxiliary building general area, elv. 426	1.75E-06	4.84E-03	3.86E-03	1.25	1.39E-06
11.5A-2	Division 21 containment electrical penetrations area	1.64E-06	3.00E-03	2.33E-03	1.29	1.28E-06
11.4-0	Auxiliary building general area, elv. 383	1.45E-06	2.77E-04	2.52E-04	1.10	1.32E-06
18.12-0	Circ water pump house (Byr)/Lake screen house (Bdw)	1.32E-06	6.79E-03	5.77E-03	1.18	1.12E-06
11.5-0	Auxiliary building general area, elv. 401	1.24E-06	6.09E-03	4.68E-03	1.30	9.55E-07
1-1	UNIT 1 CONTAINMENT	1.21E-06	9.08E-03	6.21E-03	1.46	8.28E-07
11.6C-0	Auxiliary building laundry room	1.20E-06	6.97E-04	5.37E-04	1.30	9.25E-07
18.10E-2	System auxiliary transformers 242-1 and 242-2	1.08E-06	5.75E-03	3.93E-03	1.46	7.38E-07
18.10E-1	System auxiliary transformers 142-1 and 142-2	1.08E-06	5.75E-03	3.93E-03	1.46	7.38E-07
8.6-0	Turbine building operating floor	1.02E-06	9.76E-03	6.38E-03	1.53	6.67E-07
	Total CDF for Major Zones =	4.89E-05			EPRI 1016735 Total CDF=	3.54E-05
		Reduction Factor for Major Zones		1.38		

Question 3.d

A seismic CDF (SCDF) of 1E-06 per year was used for determining the external events multiplier. Assess the impact on the SAMA analysis if the Generic Issue 199 weakest link SCDF values based on the 2008 United States Geology Survey (USGS) seismic hazard curves of 5.8E-06 per year for Byron and 7.3E-06 for Braidwood are used or provide technical support for use of other assessments of the Byron/Braidwood SCDFs.

Exelon Response

If the weakest link SCDF values from Generic Issue (GI) 199 were used in the SAMA analysis, the external events (EE) multipliers for both sites would have been larger, as documented below:

- The Byron EE multiplier would have been 2.6 instead of 2.5.
- The Braidwood EE multiplier would have been 3.0 instead of 2.8.

Table's 3.d-1 and 3.d-2 provide the cost benefit results with these EE multipliers applied for Byron and Braidwood, respectively.

In addition to the updated EE multipliers, the results in Tables 3.d-1 and 3.d-2 also account for:

- The corrected site specific SAMA implementation cost estimates documented in the response to RAI 6.a,
- The updated 95th percentile PRA multipliers documented in the response to RAI 6.f.

The cumulative impact of these changes on the cost benefit analysis can be determined based on a comparison of the updated 95th percentile net values to the 95th percentile net values from the Environmental Report (ER), which are also included in Tables 3.d-1 and 3.d-2.

For Braidwood, one SAMA that was determined to be potentially cost beneficial in the ER would no longer be classified as cost beneficial when the changes described above are accounted for:

- SAMA 32: Install Fire Barriers Around MCC 131X2

For Byron, the impact is that the 95th percentile net values become positive for SAMAs 1 and 4 and they are considered to be potentially cost beneficial:

- SAMA 1: Diesel Driven SX Pump
- SAMA 4: Install “No Leak” RCP Seals

However, as described in Section F.8.1 of the Byron ER, implementation of the Diverse Mitigation System and the AFW Cross-tie would reduce the Byron MACR to about $5 million when the 95th percentile PRA results are used. This indicates that SAMA 1 would not be cost effective after implementation of those SAMAs.

Because Byron SAMA 1 was screened in the ER, the results of the quantification were not documented as part of the SAMA analysis. The modeling changes and assumptions used to quantify Byron SAMA 1 are the same as those documented in Section F.6.1 of the Braidwood ER. Table's 3.d-3 and 3.d-4 provide the results of the Byron quantification. The SAMA 1 cost benefit analysis was performed in a manner consistent with the Byron ER, the results of which are reflected in Table 3.d-1.

Table 3.d-1
Summary of the Updated Byron Cost Benefit Analysis

SAMA ID	Updated Implementation Cost (per unit)	Averted Cost Risk (Updated Results)	Net Value (Updated Results)	95th Percentile Averted Cost Risk (Updated Results)	95th Percentile Net Value (Updated Results)	95th Percentile Net Value (ER Results)
SAMA 1	$15,200,000	$12,784,639	-$2,415,361	$32,345,137	$17,145,137	-$15,821,592
SAMA 2	$2,875,555	$4,097,883	$1,222,328	$10,367,644	$7,492,089	$4,060,167
SAMA 3	$565,150	$1,809,532	$1,244,382	$4,578,116	$4,012,966	$3,202,138
SAMA 4	$6,547,600	$4,250,347	-$2,297,253	$10,753,378	$4,205,778	-$2,053,689
SAMA 5	$328,600	$3,914,487	$3,585,887	$9,903,652	$9,575,052	$8,714,986
SAMA 7	$100,000	$76,391	-$23,609	$193,269	$93,269	$82,895
SAMA 8	$217,415	$332,163	$114,748	$840,372	$622,957	$456,444
SAMA 9	$174,650	$710,837	$536,187	$1,798,418	$1,623,768	$1,352,608
SAMA 10	$660,150	$1,735,851	$1,075,701	$4,391,703	$3,731,553	$2,835,727
SAMA 11	$7,347,600	$13,391,646	$6,044,046	$33,880,864	$26,533,264	$19,032,689
SAMA 13	$3,075,555	$13,370,284	$10,294,729	$33,826,819	$30,751,264	$26,060,435
SAMA 14	$3,800,000	$71,315	-$3,728,685	$180,427	-$3,619,573	-$3,629,256
SAMA 15	$0	$417,118	$417,118	$1,055,309	$1,055,309	$998,677
SAMA 16	$496,900	$822,619	$325,719	$2,081,226	$1,584,326	$975,740
SAMA 17	$490,865	$25,147	-$465,718	$63,622	-$427,243	-$921,522
SAMA 18	$804,340	$77,412	-$726,928	$195,852	-$608,488	-$1,423,337
SAMA 19	$900,000	$637,770	-$262,230	$1,613,558	$713,558	$626,968
SAMA 20	$20,000,000	$30,124	-$19,969,876	$76,214	-$19,923,786	-$19,927,877
SAMA 21	$1,600,000	$164,960	-$1,435,040	$417,349	-$1,182,651	-$1,205,049
SAMA 22	$250,000	$46,085	-$203,915	$116,595	-$133,405	-$139,663
SAMA 23	$760,000	$40,131	-$719,869	$101,531	-$658,469	-$663,918
SAMA 24	$1,250,000	$32,916	-$1,217,084	$83,277	-$1,166,723	-$1,171,192
SAMA 25	$5,700,000	$9,831,037	$4,131,037	$24,872,524	$19,172,524	$17,837,771
SAMA 26	$2,400,000	$13,353,337	$10,953,337	$33,783,943	$31,383,943	$29,570,970
SAMA 27	$975,000	$2,078,479	$1,103,479	$5,258,552	$4,283,552	$4,200,413
SAMA 28	$975,000	$903,687	-$71,313	$2,286,328	$1,311,328	$1,275,181
SAMA 29	$1,225,000	$44,390	-$1,180,610	$112,307	-$1,112,693	-$1,118,722
SAMA 30	$975,000	$570,829	-$404,171	$1,444,197	$469,197	$446,364
SAMA 31	$975,000	$1,596,513	$621,513	$4,039,178	$3,064,178	$3,000,317

Table 3.d-2
Summary of the Updated Braidwood Cost Benefit Analysis

SAMA ID	Updated Implementation Cost (per unit)	Averted Cost Risk (Updated Results)	Net Value (Updated Results)	95th Percentile Averted Cost Risk (Updated Results)	95th Percentile Net Value (Updated Results)	95th Percentile Net Value (ER Results)
SAMA 1	$15,200,000	$41,374,440	$26,174,440	$81,507,647	$66,307,647	$41,999,970
SAMA 2	$2,875,555	$5,409,684	$2,534,129	$10,657,077	$7,781,522	$5,811,187
SAMA 3	$565,150	$4,183,446	$3,618,296	$8,241,389	$7,676,239	$7,811,120
SAMA 4	$6,547,600	$6,058,137	-$489,463	$11,934,530	$5,386,930	$718,258
SAMA 5	$328,600	$17,687,799	$17,359,199	$34,844,964	$34,516,364	$37,147,521
SAMA 6	$100,000	$673,152	$573,152	$1,326,109	$1,226,109	$1,338,750
SAMA 7	$100,000	$118,380	$18,380	$233,209	$133,209	$153,018
SAMA 8	$217,415	$784,143	$566,728	$1,544,762	$1,327,347	$1,337,145
SAMA 9	$174,650	$1,671,966	$1,497,316	$3,293,773	$3,119,123	$3,224,250
SAMA 10	$660,150	$5,511,990	$4,851,840	$10,858,620	$10,198,470	$10,460,660
SAMA 11	$7,347,600	$40,727,673	$33,380,073	$80,233,516	$72,885,916	$74,018,614
SAMA 12	$70,000,000	$7,137,810	-$62,862,190	$14,061,486	-$55,938,514	-$54,744,121
SAMA 13	$3,075,555	$40,899,339	$37,823,784	$80,571,698	$77,496,143	$81,464,410
SAMA 14	$3,800,000	$161,475	-$3,638,525	$318,106	-$3,481,894	-$3,454,874
SAMA 15	$0	$1,307,877	$1,307,877	$2,576,518	$2,576,518	$2,795,369
SAMA 16	$496,900	$3,506,766	$3,009,866	$6,908,329	$6,411,429	$6,501,329
SAMA 17	$490,865	$56,835	-$434,030	$111,965	-$378,900	-$860,255
SAMA 18	$804,340	$330,855	-$473,485	$651,784	-$152,556	-$901,533
SAMA 19	$900,000	$2,947,698	$2,047,698	$5,806,965	$4,906,965	$5,400,214
SAMA 20	$20,000,000	$48,915	-$19,951,085	$96,363	-$19,903,637	-$19,895,452
SAMA 21	$1,600,000	$745,497	-$854,503	$1,468,629	-$131,371	-$6,625
SAMA 22	$250,000	$170,142	-$79,858	$335,180	$85,180	$113,650
SAMA 23	$760,000	$116,766	-$643,234	$230,029	-$529,971	-$510,431
SAMA 24	$1,250,000	$124,902	-$1,125,098	$246,057	-$1,003,943	-$983,043
SAMA 25	$5,700,000	$35,000,538	$29,300,538	$68,951,060	$63,251,060	$69,107,817
SAMA 26	$2,400,000	$40,669,452	$38,269,452	$80,118,820	$77,718,820	$84,524,175
SAMA27	$975,000	$2,627,975	$1,652,975	$5,177,111	$4,202,111	$5,043,063
SAMA28	$975,000	$1,708,648	$733,648	$3,366,037	$2,391,037	$2,937,804
SAMA29	$554,500	$1,476,495	$921,995	$2,908,695	$2,354,195	$2,826,674
SAMA30	$1,225,000	$90,474	-$1,134,526	$178,234	-$1,046,766	-$1,031,628
SAMA31	$975,000	$557,168	-$417,832	$1,097,621	$122,621	$300,915
SAMA32	$975,000	$487,522	-$487,478	$960,418	-$14,582	$141,425
SAMA33	$975,000	$1,030,760	$55,760	$2,030,597	$1,055,597	$1,385,440
SAMA34	$975,000	$812,536	-$162,464	$1,600,696	$625,696	$885,707
SAMA35	$975,000	$761,463	-$213,537	$1,500,082	$525,082	$768,750

Table 3.d-3: Byron SAMA 1 Results Summary

	CDF	Dose-Risk	OECR
Base Value	3.97E-05	35.45	$254,593
SAMA Value	1.48E-05	7.25	$29,251
Percent Change	62.7%	79.5%	88.5%

Table 3.d-4: Byron SAMA 1 Release Category Specific Results

Release Category	$Freq._{BASE}$	$Freq._{SAMA}$	Dose-$Risk_{BASE}$	Dose-$Risk_{SAMA}$	$OECR_{BASE}$	$OECR_{SAMA}$
INTACT	1.16E-05	1.17E-05	1.25E-01	1.26E-01	$118	$119
SERF-TISGTR-HLF	6.49E-09	6.56E-09	6.17E-03	6.23E-03	$44	$44
SERF-SGTR-AFW-SC	1.38E-06	1.38E-06	1.33E+00	1.33E+00	$8,349	$8,349
LATE-BMMT-AFW	5.30E-07	1.15E-06	1.63E-02	3.54E-02	$22	$48
LATE-BMMT-NOAFW	7.95E-08	1.19E-07	6.36E-03	9.52E-03	$14	$22
LATE-CHR-AFW	1.89E-05	1.07E-06	1.05E+01	5.95E-01	$35,721	$2,022
LATE-CHR-NOAFW	8.35E-06	1.68E-07	1.78E+01	3.58E-01	$187,040	$3,763
LERF-ISLOCA	3.40E-07	3.40E-07	4.42E+00	4.42E+00	$11,832	$11,832
LERF-CI	3.67E-07	1.06E-07	3.41E-01	9.86E-02	$1,655	$478
LERF-CFE	3.55E-08	1.18E-08	8.88E-02	2.95E-02	$582	$194
LERF-SGTR-AFW	5.49E-08	5.49E-08	1.31E-01	1.31E-01	$1,005	$1,005
LERF-SGTR-NOAFW	8.57E-10	8.15E-10	6.68E-04	6.35E-04	$6	$5
LERF-ISGTR	2.69E-07	4.49E-08	6.97E-01	1.16E-01	$8,205	$1,369
Total	4.19E-05	1.62E-05	3.55E+01	7.25E+00	$254,593	$29,251

QUESTION 4.0

Please provide the following information regarding the Level 3 PRA used in the SAMA analysis. The basis for this request is as follows: Applicants for license renewal are required by 10 CFR 51.53(c)(3)(ii)(L) to consider SAMAs, if not previously considered, in an environmental impact assessment, related supplement, or environmental assessment for the plant. As part of its review of the Byron/Braidwood SAMA analyses, NRC staff evaluates the applicant's analysis of accident consequences in the Level 3 PRA. The requested information is needed in order for the NRC staff to reach a conclusion on the sufficiency of the applicant's Level 3 PRA model for supporting the SAMA evaluations.

Question 4.a

Section F.3.7 discusses the meteorological data used in the SAMA analysis. Clarify whether all of the data is from onsite meteorological stations, or whether a local weather station was also used. If data from a local weather station was used, identify the local station and its location.

Exelon Response

The meteorological data used for the Level 3 analyses of the Byron and Braidwood Stations were obtained from onsite meteorological stations. No additional offsite meteorological data were used with the exception of mixing layer height which is noted in the ER Section F.3.7.

Question 4.b

Section F.3.2 identifies that transient and special facility population data were included within the 10 mile radius. Provide the year 2000 transient and special facility population used in the SAMA analysis.

Exelon Response

Table 4b-1 displays the transient and special facility population distribution data included for the Braidwood Station. Table 4b-2 displays the transient and special facility population distribution data included for the Byron Station. No seasonal resident data was identified for the Byron Station in the Byron Evacuation Time Estimate study.

TABLE 4b-1
INCLUDED TRANSIENT AND SPECIAL FACILITY POPULATION WITHIN A 10-MILE RADIUS OF BRAIDWOOD, YEAR 2000

Sector	0-1 mile	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-mile Total(1)
N	0	0	0	0	212	1564	1776
NNE	0	695	0	0	3440	310	4445
NE	0	1061	1535	300	0	3098	5994
ENE	0	0	5	0	0	82	87
E	0	0	60	0	0	11368	11428
ESE	0	0	175	0	0	275	450
SE	0	0	0	1220	0	0	1220
SSE	0	0	0	3170	0	595	3765
S	0	0	0	0	2500	220	2720
SSW	0	0	0	0	0	839	839
SW	0	283	0	2500	0	539	3322
WSW	0	0	212	0	0	379	591
W	0	0	0	0	0	0	0
WNW	0	0	0	0	0	0	0
NW	0	0	0	0	378	3268	3646
NNW	0	0	0	132	60	2302	2494
Total	0	2039	1987	7322	6590	24839	42777

TABLE 4b-2
INCLUDED TRANSIENT AND SPECIAL FACILITY POPULATION WITHIN A 10-MILE RADIUS OF BYRON, YEAR 2000

Sector	0-1 mile	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-mile Total(1)
N	0	1835	520	0	0	0	2355
NNE	0	0	0	2546	1471	1095	5112
NE	0	0	0	0	0	0	0
ENE	0	0	270	0	0	1517	1787
E	0	0	0	0	0	0	0
ESE	0	0	0	0	0	559	559
SE	0	0	0	0	0	0	0
SSE	0	0	0	0	0	200	200
S	0	0	0	0	0	0	0
SSW	0	0	0	0	103	981	1084
SW	0	0	0	595	146	4489	5230
WSW	0	0	350	751	0	3415	4516
W	0	0	0	0	0	0	0
WNW	0	0	0	0	0	193	193
NW	0	0	3	0	0	0	3
NNW	0	0	80	0	0	0	80
Total	0	1835	1223	3892	1720	12449	21119

Question 4.c

Tables F.3 2 and 3 3 provide the year 2046 population distribution used in the MELCOR Accident Consequence Code System, Version 2 (MACCS2) analysis. Since the SECPOP2000 code was utilized to develop initial residential population estimates for each spatial element within the 50 mile region based on year 2000 census data, provide the SECPOP year 2000 population distribution.

Exelon Response

Table 4c-1 displays year 2000 residential population distribution data developed from SECPOP used for the Braidwood Station. Table 4c-2 displays year 2000 residential population distribution data developed from SECPOP used for the Byron Station. This data does not include transient and special facility population.

TABLE 4c-1
SECPOP2000 BASED RESIDENTIAL POPULATION DISTRIBUTION WITHIN A 50-MILE RADIUS OF BRAIDWOOD, YEAR 2000

Sector	0-1 miles	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-20 miles	20-30 miles	30-40 miles	40-50 miles	50-mile Total
N	72	895	636	7	0	843	26040	67443	347901	342554	786391
NNE	197	950	919	368	32	527	20273	145328	281213	905106	1354913
NE	0	560	0	71	57	5451	5688	82779	371680	1266314	1732600
ENE	12	71	0	147	141	1424	1457	10869	138167	308640	460928
E	6	15	9	47	250	1474	4014	9336	8834	23448	47433
ESE	0	0	0	19	17	413	28447	43295	5947	3030	81168
SE	0	0	11	0	82	342	1625	4961	2553	9825	19399
SSE	0	0	0	26	415	349	2308	1396	5528	2888	12910
S	0	0	0	3	0	471	785	1352	3022	2555	8188
SSW	0	0	15	7	45	875	621	1053	6681	1510	10807
SW	368	79	210	32	36	1505	5830	1636	14723	6246	30665
WSW	168	114	473	26	339	194	519	1349	20796	5689	29667
W	9	12	66	13	32	358	2007	1399	9795	29587	43278
WNW	0	9	20	69	184	293	2038	9575	17491	4780	34459
NW	61	3	82	1413	2960	1309	14791	4121	20092	5197	50029
NNW	0	726	202	1340	178	1308	2420	10013	36562	17876	70625
Total	893	3434	2643	3588	4768	17136	118863	395905	1290985	2935245	4773460

TABLE 4c-2
SECPOP2000 BASED RESIDENTIAL POPULATION DISTRIBUTION WITHIN A 50-MILE RADIUS OF BYRON, YEAR 2000

Sector	0-1 miles	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-20 miles	20-30 miles	30-40 miles	40-50 miles	50-mile Total
N	0	42	3	716	1098	865	4237	3825	9085	12160	32031
NNE	2	41	19	1376	1130	547	43437	38399	59701	67805	212457
NE	0	6	26	771	168	1424	118568	62731	6267	25936	215897
ENE	8	45	0	46	110	1509	5920	25242	12526	48736	94142
E	0	0	0	69	38	757	2574	6249	17592	102270	129549
ESE	0	10	4	0	24	249	1345	43389	15686	30086	90793
SE	18	0	9	26	19	291	13316	2453	2895	28086	47113
SSE	0	17	13	15	100	476	1697	1462	11848	3500	19128
S	0	51	8	11	142	244	2001	4610	2279	9274	18620
SSW	11	5	41	60	862	2356	9336	1457	3069	5858	23055
SW	0	31	59	43	1325	776	10789	30631	9997	5615	59266
WSW	0	6	27	97	61	3524	3293	2884	5672	22813	38377
W	0	5	23	48	218	429	798	2739	4134	7737	16131
WNW	0	289	9	5	0	772	2617	3193	2935	3921	13741
NW	0	0	167	26	44	391	1361	31605	6900	4869	45363
NNW	0	0	4	220	19	373	3610	5604	5561	13516	28907
Total	39	548	412	3529	5358	14983	224899	266473	176147	392182	1084570

Question 4.d

For Byron, Section F.3.2 identifies the year 2046 population as 1,734,765, and Section 2.6.1 identifies a population base of 1,247,087. For Braidwood, Section F.3.2 identifies the year 2047 population as 7,554,998, and Section 2.6.1 identifies a population base of 4,968,734. Clarify if Section 2.6.1 is the year 2010 or 2000 population base.

Exelon Response

The population values displayed in Section 2.6.1 are based on census information from the year 2010.

The year 2010 census data for the population surrounding the Byron and Braidwood Stations were not directly incorporated into the SAMA analysis. As noted in Section F.3.2, year 2010 census data had not yet been incorporated into the SECPOP code or into the state population projection data used to estimate county growth rates at the time of the Level 3 analysis. The SAMA population is based on the projection of the year 2000 population data (including transient and special facility population) to the year 2030 and then to the year 2046 for Byron and 2047 for Braidwood.

Question 4.e

Section F.3.2 identifies that the year 2010 population data were not incorporated. Briefly address how the 2010 population (from Section 2.6.1) compares to an estimated year 2010 population assuming the growth rates from Table F.3-1 for both Byron and Braidwood.

Exelon Response

The projected year 2010 population distribution (including transient, special facility, and seasonal resident populations) based on growth projections from the year 2000 to 2030 (i.e., SAMA 30 year county growth rate, divided by 3.0 to estimate the 10 year growth rate) for the area surrounding the Braidwood site is displayed in Table 4e-1. Similarly, the projected year 2010 population distribution (including transient and special facility populations) based on growth projections from the year 2000 to 2030 for the area surrounding the Byron site is displayed in Table 4e-2.

Based on this projection, the projected year 2010 populations for the area surrounding the Byron and Braidwood sites are reasonably close to the calculated total populations displayed in Section 2.6.1. The population for the 50 mile radius surrounding Braidwood, reported as 4,968,734 in Section 2.6.1 of the Braidwood submittal, is smaller than the projected population value of 5,296,523 as shown in Table 4e-1. The population for the 50 mile radius surrounding Byron, reported as 1,247,087 in Section 2.6.1 of the Byron submittal, is slightly larger than the projected population value of 1,224,858 as shown in Table 4e-2.

Table 4e-1
Estimated Population Distribution within a 50-Mile Radius of BRAIDWOOD, Year 2010

Sector	0-1 miles	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-20 miles	20-30 miles	30-40 miles	40-50 miles	50-mile Total(1)
N	100	1245	885	10	295	3214	34011	88961	414308	380170	923199
NNE	274	2288	1278	512	4829	1164	28198	202135	312432	942034	1495144
NE	0	2255	2135	516	79	11891	7911	112210	392132	1309663	1838792
ENE	17	99	7	204	196	2095	1957	15014	174756	326750	521095
E	8	21	96	65	348	17862	4431	10158	9732	23873	66594
ESE	0	0	243	26	24	792	30498	46391	6282	3054	87310
SE	0	0	15	1677	98	367	1742	5253	2686	10236	22074
SSE	0	0	0	3783	445	1012	2466	1468	5817	3039	18030
S	0	0	0	3	2680	746	831	1410	3154	2665	11489
SSW	0	0	19	8	50	1897	649	1101	7005	1634	12363
SW	512	453	234	2820	40	2276	6194	1710	15392	6721	36352
WSW	234	130	763	29	378	638	576	1437	22015	6100	32300
W	13	14	73	14	36	399	2230	1524	10669	32014	46986
WNW	0	10	22	77	205	326	2267	10453	19052	5193	37605
NW	85	4	91	1574	3717	5097	16525	4703	22332	5792	59920
NNW	0	1010	261	1782	275	4020	2756	11872	43841	21493	87310
Total(1)	1243	7529	6122	13100	13695	53796	143242	515800	1461605	3080431	5296563

Table 4e-2
Estimated Population Distribution within a 50-Mile Radius of BYRON, Year 2010

Sector	0-1 miles	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-20 miles	20-30 miles	30-40 miles	40-50 miles	50-mile Total(1)
N	0	2032	566	775	1189	938	4647	4195	9734	13058	37134
NNE	2	44	21	4245	2815	1779	47642	42116	63958	72213	234835
NE	0	6	28	835	182	1548	130046	68343	6905	29693	237586
ENE	9	49	292	50	119	3276	6461	27430	15076	60139	112901
E	0	0	0	75	41	819	2811	7069	20744	125512	157071
ESE	0	11	4	0	26	875	1461	49040	18116	36563	106096
SE	19	0	10	28	21	315	14263	2643	3254	31475	52028
SSE	0	18	14	16	108	732	1779	1500	12705	3812	20684
S	0	55	9	12	154	264	2081	4729	2377	9787	19468
SSW	12	5	44	65	1045	3612	9763	1495	3180	6147	25368
SW	0	34	64	691	1592	5699	11435	31625	10399	5833	67372
WSW	0	6	408	918	66	7511	3565	2990	5879	23621	44964
W	0	5	25	52	236	464	864	2803	4218	7849	16516
WNW	0	313	10	5	0	1045	2816	3274	3082	4335	14880
NW	0	0	184	28	48	423	1408	32180	7121	5146	46538
NNW	0	0	91	238	21	404	3822	5772	6050	15019	31417
Total(1)	42	2578	1770	8033	7663	29704	244864	287204	192798	450202	1224858

(1) Population projections developed in electronic spreadsheet calculation and totals may differ slightly due to rounding of individual values.

Question 4.f

Section F.3.3 identifies that SECPOP economic data was not utilized due to known errors. Clarify if this included the formatting error associated with population data. If not, provide an assessment of the impact on the SAMA analysis of using corrected population data.

Exelon Response

The SECPOP 2000 error identified in Section F.3.3 does not impact population distribution inputs into the MACCS2 code. The error in question only impacts economic inputs. This has been confirmed with the MACCS2 code developer at Sandia National Laboratories (Dr. N. Bixler). Additionally, the Byron and Braidwood population data contained in the SAMA basecase MACCS2 Site Input Files have been checked and they conform to the formatting requirements specified in NUREG/CR-6613, Vol. 1 (Code Manual for MACCS2: Users Guide).

Question 4.g

Section F.3.6 of the ERs note the longest evacuation times presented in the study. Clarify if these were for a specific event evacuation or used for all event evacuations.

Exelon Response

The Level 3 evacuation modeling is based on data contained in the Evacuation Time Estimate (ETE) studies for the Byron and Braidwood Stations. The ETE studies present different evacuation time estimates based on season (summer vs. winter), time of day (daytime vs. nighttime), and weather conditions (fair vs. adverse). The ETE studies do not present any specific event (e.g., festival) evacuation time estimates. As discussed in Section F.3.6, the Level 3 model evacuation speed is developed as a time-weighted average value accounting for season, time of day, and weather conditions.

For the Byron Station the estimated evacuation times in the ETE ranged from 2 hours and 15 minutes (for either Summer, Nighttime, Fair Weather, or Winter, Nighttime, Fair Weather) to 3 hours and 50 minutes (for Winter, Daytime, Adverse Weather).

For the Braidwood Station the estimated evacuation times in the ETE ranged from 2 hours and 10 minutes (for either Summer, Nighttime, Fair Weather or Winter, Nighttime, Fair Weather) to 4 hours and 45 minutes (for Summer, Daytime, Adverse Weather).

Question 4.h

Provide the values and associated assumptions made regarding the following MACCS2 input parameters: rainfall, mixing heights, building wake effects, plume release energy, land fraction, region index, watershed index, growing season, fraction of farmland, and shielding and protection factors.

Exelon Response

Rainfall

The meteorological file used as input into the MACCS2 code consists of one (1) year of hourly recordings (8760) of accumulated precipitation. When precipitation occurs during a release, the depletion of the plume develops more rapidly due to plume washout. The amount of plume washout is proportional to the intensity and duration of precipitation. The MACCS2 code does not differentiate between rain and snow precipitation.

For the Byron Station base case year (2008), the annual meteorological file has approximately 39 inches of precipitation. For the Braidwood Station base case year (2010), the annual meteorological file has approximately 35 inches of precipitation.

Mixing Heights

The MACCS2 code requires morning and afternoon mixing layer heights to be defined in the meteorological file for the four (4) seasons of the year. For a given season, MACCS2 uses the larger of the two values. The start day of each weather sequence determines the season in which that sequence lies.

Table 4h-1 displays the mixing layer heights specified for the Braidwood Station. Table 4h-2 displays the mixing layer heights specified for the Byron Station.

TABLE 4h-1
BRAIDWOOD SEASONAL MIXING LAYER HEIGHTS

Season	Time of Day	Mixing Height (m)
Winter	Morning	470
	Afternoon	610
Spring	Morning	480
	Afternoon	1500
Summer	Morning	320
	Afternoon	1600
Autumn	Morning	400
	Afternoon	1200

TABLE 4h-2
BYRON SEASONAL MIXING LAYER HEIGHTS

Season	Time of Day	Mixing Height (m)
Winter	Morning	470
	Afternoon	580
Spring	Morning	480
	Afternoon	1400
Summer	Morning	300
	Afternoon	1600
Autumn	Morning	390
	Afternoon	1200

Building Wake Effects

Building wake effect data are based on Byron and Braidwood Containment Building dimensions. The top of each containment is approximately 199.0 ft (60.7m) above grade. The outer diameter of each containment is approximately 147 ft (44.8 m). Plume standard deviations sigma-y (10.4m) and sigma-z (28.2m) are based on MACCS2 User's Guide formulas.

Plume Energy Release

As discussed in Section F.3.5, buoyant plume rise is modeled assuming a thermal plume heat content of 1.0E+7 watts for all releases except for the intact containment release where zero heat content is assumed. A value of 1.0E+7 bounds typical values of NUREG-4551. Sensitivity cases examine different plume energy releases.

Land Fraction

The fraction of each spatial element that is land (as opposed to water) was visually estimated using maps and images of the regions surrounding the Byron and Braidwood Stations. Table 4h-3 displays the estimated land fraction of the area surrounding the Braidwood Station. Table 4h-4 displays the estimated land fraction of the area surrounding the Byron Station.

TABLE 4h-3
ESTIMATED LAND FRACTIONS WITHIN A 50-MILE RADIUS OF BRAIDWOOD

Sector	0-1 miles	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-20 miles	20-30 miles	30-40 miles	40-50 miles
N	0.50	1.00	1.00	0.85	0.85	0.80	0.95	0.99	1.00	1.00
NNE	1.00	1.00	0.95	0.90	0.92	0.95	0.98	0.99	0.99	1.00
NE	0.70	0.98	0.90	0.90	0.98	0.95	1.00	1.00	1.00	0.96
ENE	0.99	1.00	0.98	0.99	0.80	0.98	1.00	1.00	1.00	0.98
E	0.98	0.98	1.00	1.00	0.97	0.95	1.00	0.99	0.99	0.98
ESE	0.90	0.98	0.99	1.00	0.99	0.99	0.99	0.99	1.00	0.98
SE	0.85	0.98	0.90	0.99	1.00	0.99	1.00	0.99	0.99	0.99
SSE	0.90	0.95	0.90	0.90	0.95	1.00	1.00	1.00	1.00	0.99
S	1.00	0.87	0.75	0.95	0.80	0.92	1.00	1.00	1.00	1.00
SSW	1.00	1.00	0.99	0.95	0.75	0.95	1.00	1.00	1.00	1.00
SW	1.00	1.00	0.99	0.95	0.98	0.99	1.00	0.99	0.99	1.00
WSW	1.00	1.00	0.99	0.99	0.98	0.98	1.00	1.00	0.99	1.00
W	1.00	1.00	0.98	1.00	1.00	0.98	1.00	0.92	0.98	0.98
WNW	1.00	1.00	1.00	1.00	1.00	0.99	0.95	1.00	0.99	1.00
NW	1.00	0.99	1.00	1.00	0.95	0.95	0.90	1.00	0.98	1.00
NNW	0.95	1.00	1.00	0.97	0.90	0.90	0.92	1.00	0.99	1.00

TABLE 4h-4
ESTIMATED LAND FRACTIONS WITHIN A 50-MILE RADIUS OF BYRON

Sector	0-1 miles	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-20 miles	20-30 miles	30-40 miles	40-50 miles
N	1.00	1.00	0.96	0.90	0.99	1.00	0.99	0.99	0.99	0.99
NNE	1.00	1.00	1.00	0.90	0.92	0.98	0.99	0.99	0.99	0.99
NE	1.00	1.00	1.00	1.00	0.97	0.98	0.99	0.99	0.99	0.99
ENE	1.00	1.00	1.00	1.00	0.99	1.00	0.99	0.99	0.99	1.00
E	1.00	1.00	0.98	1.00	1.00	1.00	0.99	0.99	1.00	1.00
ESE	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00
SE	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	0.99
SSE	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.99	0.99
S	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00
SSW	1.00	1.00	1.00	1.00	0.92	0.97	0.98	0.99	0.99	0.99
SW	1.00	1.00	1.00	0.90	0.93	0.99	0.98	0.95	0.99	0.99
WSW	1.00	0.99	0.92	0.88	1.00	0.99	1.00	0.99	1.00	0.92
W	1.00	1.00	0.90	1.00	1.00	0.99	1.00	1.00	1.00	0.70
WNW	1.00	1.00	0.90	1.00	1.00	1.00	1.00	0.99	0.98	1.00
NW	1.00	0.99	0.88	1.00	1.00	1.00	1.00	0.99	0.99	0.99
NNW	1.00	1.00	0.85	1.00	1.00	1.00	0.99	0.99	1.00	0.99

Region Index

Index values were assigned based on application of the county level data to a 50-mile radius grid surrounding each site. Spatial elements within the same county have the same index value. Spatial elements involving multiple counties have unique index values.

Watershed Index

All spatial elements are designated as river systems. Per NUREG/CR-4551 the designation of lake is only used for very large bodies of water, such as Lake Michigan, which may serve as drinking water sources. The 50 mile region surrounding Braidwood Station encompasses a negligible portion of Lake Michigan. Lake Michigan is beyond the 50 mile SAMA analysis region for Byron Station. The other lakes around the Byron and Braidwood Stations are smaller and are expected to behave like river systems.

Growing Season

The growing season values included in the Byron and Braidwood Station MACCS2 Site files are presented in Table 4h-5. It is noted, however, that the COMIDA2 based food ingestion model is utilized for the Byron and Braidwood analyses, consistent with the MACCS2 User's Guide. The COMIDA2 module utilizes national based food production parameters derived from the annual food consumption of an average individual such that site specific food production values, including those listed in Table 4h-5, are not utilized.

TABLE 4h-5
BYRON AND BRAIDWOOD GROWING SEASONS

Crop	Growing Season Start Day	Growing Season End Day
Pasture	90	270
Stored Forage	150	240
Grains	150	240
Green Leafy Vegetables	150	240
Other Food Crops	150	240
Legumes and Seeds	150	240
Roots and Tubers	150	240

Fraction of Farmland

Data from the 2007 Census of Agriculture was used to determine the farmland fraction for each of the counties surrounding the Byron and Braidwood Stations. The fractional area of farmland for each county within 50 miles of Braidwood Station is provided in Table 4h-6. The fractional area of farmland for each county within 50 miles of Byron Station is provided in Table 4h-7. The fractional area of farmland in each spatial element surrounding the Byron and Braidwood Stations was developed accounting for the percentage of county in each spatial element.

TABLE 4h-6
FARMLAND FRACTION OF COUNTIES WITHIN 50 MILES OF BRAIDWOOD

County	Fraction of Farmland
Bureau,IL	0.860
Cook,IL	0.014
DeKalb,IL	0.918
DuPage,IL	0.038
Ford,IL	0.871
Grundy,IL	0.805
Iroquois,IL	0.948
Kane,IL	0.578
Kankakee,IL	0.891
Kendall,IL	0.814
LaSalle,IL	0.886
Lee,IL	0.852
Livingston,IL	0.941
McLean,IL	0.893
Marshall,IL	0.828
Putnam,IL	0.613
Will,IL	0.412
Woodford,IL	0.854
Jasper,IN	0.950
Lake,IN	0.404
Newton,IN	0.741

**TABLE 4h-7
FARMLAND FRACTION OF COUNTIES WITHIN 50 MILES OF BYRON**

County	Fraction of Farmland
Boone,IL	0.764
Bureau,IL	0.860
Carroll,IL	0.933
DeKalb,IL	0.918
Henry,IL	0.930
Jo Daviess,IL	0.732
Kane,IL	0.578
Kendall,IL	0.814
LaSalle,IL	0.886
Lee,IL	0.852
McHenry,IL	0.558
Ogle,IL	0.755
Stephenson,IL	0.936
Whiteside,IL	0.925
Winnebago,IL	0.558
Clinton,IA	0.889
Jackson,IA	0.728
Green,WI	0.821
Lafayette,WI	0.845
Rock,WI	0.749
Walworth,WI	0.612

Shielding and Protection Factors

Shielding and exposure factors are chosen consistent with those developed and used in the NUREG-1150 (NUREG/CR-4551) study. Of the sites evaluated in NUREG-1150, Zion was located in Illinois and therefore judged to appropriately represent the conditions (e.g., housing types) surrounding the Byron and Braidwood Stations (also in Illinois). Therefore, values from Zion are used. The shielding and protection factors used for the Byron and Braidwood Stations are displayed in Table 4h-8.

TABLE 4h-8
SHIELDING AND PROTECTION FACTORS USED FOR THE BYRON AND BRAIDWOOD SAMA ANALYSES

Shielding and Protection Factors	Evacuees	Normal Activity in Shelter and Evacuation Zone	Sheltered Activity
Cloud Shielding Factor	1.00	0.75	0.50
Protection Factor for Inhalation	1.00	0.41	0.33
Breathing Rate	2.66E-04	2.66E-04	2.66E-04
Skin Protection Factor	1.00	0.41	0.33
Ground Shielding Factor	0.50	0.33	0.10

Question 4.i

Section F.3.4 discusses ingestion dose. Identify the critical input parameters used to produce these results.

Exelon Response

The COMIDA2 based food ingestion model is utilized for the Byron and Braidwood Stations MACCS2 analyses, consistent with the MACCS2 User's Guide. The COMIDA2 module utilizes national based food production parameters derived from the annual food consumption of an average individual such that site specific food production values are not utilized. Annual dose limits trigger crop or milk disposal, as appropriate. Values are chosen consistent with the most recent guidance of FDA 63 FR-43402 (1998).

Other than the COMIDA2 binary input file used by MACCS2, there are three user specified input variables used in the COMIDA2 food chain model. These parameters and their values used in the Byron and Braidwood analyses are presented in Table 4i-1.

TABLE 4i-1
COMIDA2 RELATED INPUT PARAMETER VALUES USED FOR THE BYRON AND BRAIDWOOD SAMA ANALYSES

PARAMETER	PARAMETER DESCRIPTION	VALUE EFFECTIVE (Rem)	VALUE THRYOID (Rem)
DOSEMILK	Maximum allowable food ingestion dose from milk crops during the year of the accident	0.25	2.5
DOSEOTHER	Maximum allowable food ingestion dose from non-milk crops during the year of the accident	0.25	2.5
DOSELONG	Maximum allowable long term annual dose to an individual from ingestion of the combination of milk and non-milk crops.	0.50	5.0

Question 4.j

MAAP Users Group News Bulletin, “MAAP-FLASH #68” (August 5, 2008), recommended that users of MAAP versions 4.0.5 through 4.0.7 (MAAP software version 4.0.6 was used in the SAMA analysis) include plant-specific values for the mass of the relevant fission product elements instead of the isotopic activity of those elements. Clarify whether plant specific fission product mass or isotopic activity were used in the MAAP 4.0.6 analyses. If the isotopic inventory was used, assess the impact on the SAMA analysis if the mass inventory is used.

Exelon Response

The Byron and Braidwood MAAP parameter file uses the fission product mass input method as recommend by the news bulletin.

Question 4.k

For Braidwood Section F.7.4, the base maximum averted cost-risk (MACR) and decrease in MACR for including SAMA 15 in the base case do not match Section F.6.14 ($64.7M and $63.0M versus $46.4M and $45.2M). Please clarify. **{BW only]**.

Exelon Response

The values in the phrase “resulted in a decrease in the MACR from $64,713,600 to $63,028,969” from section F.7.4 are from an interim revision of the analysis. The correct values are those from Section F.6.14 and the corrected phase would read “resulted in a decrease in the MACR from $46,412,800 to $45,192,115”.

Question 4.l

For both Byron and Braidwood, provide a discussion of the major contributors/factors that contribute to the magnitude of the Byron and Braidwood MACR and provide a qualitative assessment of the relative effect and the realism or conservatism of these factors.

Exelon Response

For Braidwood, which has the larger MACR of the two sites, the largest contributors to the $16,576,000 internal events MACR are the offsite economic cost-risk (≈73%) and the offsite exposure cost (≈21%). In turn, these costs are driven by the contribution from the “LATE-CHR-NOAFW” release category. About 58% of the dose-risk and 79% of the offsite economic cost-risk are attributable to the LATE-CHR-NOAFW category. The characteristics of the Byron dose and cost risks are similarly influenced by the LATE-CHR-NOAFW category.

There are several issues that contribute to the relatively high risk values of the LATE-CHR-NOAFW category, which are summarized below:

- The LATE-CHR-NOAFW source term release fraction was developed as part of the Level 2 model update to support the SAMA analysis. One of the goals of the source term analysis was to ensure the run times for the scenarios were long enough to adequately characterize the radionuclide release fractions. The MAAP case for this release was run out to an extraordinarily long time of 1600 hours (i.e., more than 60 days following core damage) in order to capture the CsI and CsOH release that continued to trend upward with time (see Figure 4.l-1). The CsOH release magnitude is a primary driver for long term dose and costs. Modeling the release over this long time period is considered conservative since off-site resources are expected to be available in this timeframe to mitigate the continued significant releases of CsOH. In addition, NUREG/CR-7110 indicates that only a small fraction of the Cs is in the form of CsI and that the dominant chemical form will be cesium molybdate with the remaining Cs in the form of CsOH. The Byron & Braidwood SAMA analyses assume that the dominant Cs chemical form is CsOH. Cesium molybdate has a very low vapor pressure and would therefore be expected to remain deposited on structures (e.g., the tubes in a steam generator) for a longer time relative to CsOH. Had the LATE-CHR-NOAFW MAAP run been terminated at an earlier time, such as 200 hours (similar to most of the other releases), the CsOH release would have been significantly lower. Thus, the long release time of 1600 hours and assumption of the Cs release taking a chemical form that is predominantly CsOH is judged to make the SAMA results conservative.

- The frequency associated with the LATE-CHR-NOAFW release category is 7.51E-6/yr for Braidwood, which accounts for about 20% of the total release frequency (including the "Intact" release category). The frequencies of other release categories with large consequences, such as LERF-ISLOCA, are relatively small, contributing less than 1% of the total release frequency each. The internal events PRA model was developed to provide a best estimate result and the LATE-CHR-NOAFW frequency is considered to be realistic.

In addition, a number of modeling attributes impact all of the release categories in ways that lead to the relatively high Byron & Braidwood MACR values. These include the following:

- The Byron & Braidwood modeled core power level of 3645 MWt is relatively large compared to many other plants, which have smaller cores. A larger core power level contributes to a larger source term release for all release categories. The core power level value used is judged realistic.
- The Level 3 analysis generally modeled three plumes for each source term release. These plumes are often separated by a significant period of time for longer releases. This modeling approach provides for wind shifts to occur as a function of time and distribute the radioactive material over larger geographic areas. This larger spread of radioactive material generally increases the dose-risk and cost-risk, dependent upon threshold effects. Other SAMA Level 3 models have sometimes limited release modeling to one plume. The Byron & Braidwood multi-plume modeling may yield results that are high relative to those models. The multi-plume modeling is judged more realistic than single plume modeling.
- The Level 3 base case model assumed a 6 month "intermediate phase" in the MACCS2 model, which effectively delays decontamination efforts for 6 months. As evaluated in the SAMA sensitivity analysis (Environmental Report Appendix F.7.3), eliminating this 6 month delay assumption results in a 40% decrease in the cost-risk (but also a 17% increase in the dose-risk). Eliminating this assumption would be expected to decrease the MACR. The length of delay prior to large scale decontamination efforts is uncertain, and this 6 month delay assumption may be conservative for many releases, particularly smaller releases or releases that impact a smaller geographic area.
- The 50 mile regional population, especially for the Braidwood site which is projected to be approximately 7.5 million people by 2047, is significant as compared to most nuclear plant sites and directly impacts the dose-risk and cost-risk which are highly correlated to the impacted population. The location of Braidwood outside the Chicago area is one contributor to the high population projection. Another contributor is that the population is projected out to a further time period (i.e., to 2047 for Braidwood) than some other SAMA evaluations based on the end date of the original 40 year license for Byron and Braidwood. The projected populations used for the Byron and Braidwood sites are judged realistic for those sites and license time periods.
- The external events multipliers are 2.5 for Byron and 2.8 for Braidwood. For both Byron and Braidwood, internal fire events dominate the external events CDF values. The fire results are based on the sites' NUREG/CR-6850 fire models, which are not yet considered to be finalized and are over a factor of 17 greater than the IPEEE fire results. As documented in the response to RAI 3.a, these models include both conservative and non-conservative elements that will be addressed as the model is refined. At this time,

the relative impact of the conservatisms and non-conservatisms is not clear, but the general trend is for estimated risk to go down as more detailed analyses are incorporated into PRA models.

In conclusion, the cumulative effects and interactions of the attributes listed above are judged to contribute to the relatively large MACR values developed in the SAMA analyses for Byron and Braidwood.

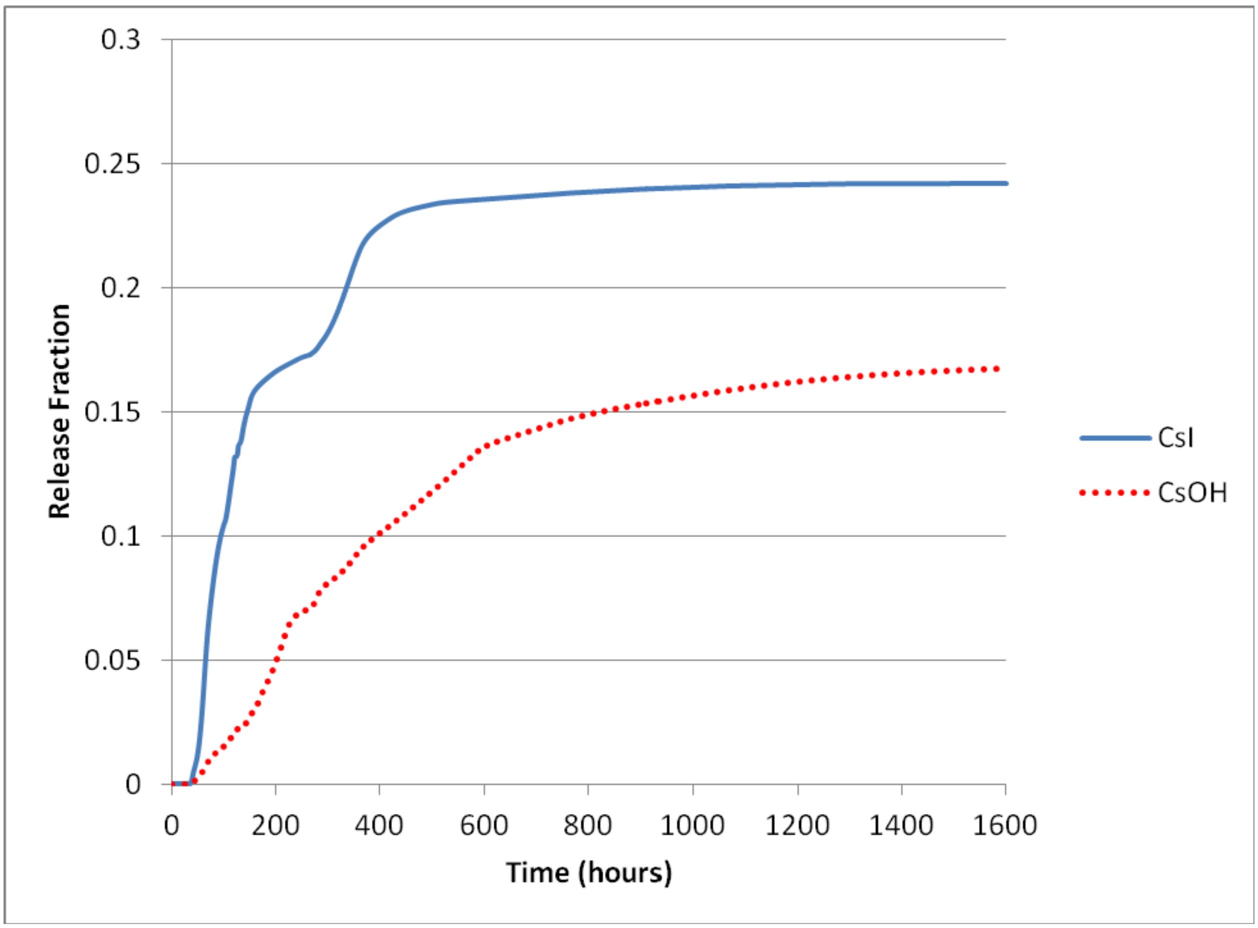


Figure 4.I-1

LATE-CHR-NOAFW Scenario CsI and CsOH Release Fractions

QUESTION 5.0

Provide the following information regarding the identification and screening of Phase I SAMA candidates. The basis for this request is as follows: Applicants for license renewal are required by 10 CFR 51.53(c)(3)(ii)(L) to consider SAMAs, if not previously considered, in an environmental impact assessment, related supplement, or environmental assessment for the plant. As part of its review of the Byron/Braidwood SAMA analyses, NRC staff evaluates the applicant's identification and screening of Phase I candidate SAMAs. The requested information is needed in order for the NRC staff to reach a conclusion on the sufficiency of the applicant's identification and screening of Phase I SAMAs in the overall SAMA evaluations.

Question 5.a

Section F.5.1.1 indicates that the external events multiplier was not used in determining the risk reduction worth (RRW) corresponding to the least cost SAMAs used in identifying potential SAMAs from the Units PRA importance. The reasons given are that 1) the fire results were reviewed separately for the purposes of SAMA identification, and 2) the fire model is in an interim state. Provide further justification for not extending the review down to a RRW value which would encompass failures whose mitigation would have a benefit of $100,000 as determined in the Braidwood Phase II cost-benefit analysis. **{BW only}**

Exelon Response

The NEI 05-01 guidance describes the SAMA identification process in Section 5.1 as a process to “identify plant-specific SAMA candidates by reviewing dominant risk contributors (to both CDF and population dose) in the Level 1 and Level 2 PSA models.” Section 5.1 indicates that the definition of the dominant contributors is open to interpretation, but the guidance does not imply that the identification process should represent an exhaustive search for all plant enhancements that could be cost beneficial. For example, some minor plant procedure changes could be very inexpensive, but the SAMA identification process should not be defined as one that requires a review all events that would correlate to the cost associated with such a change.

The PRA Applications Guide (EPRI 1995) defines risk significant events to be those events with risk reduction worth values of 1.010 and greater. A review of all risk significant events is considered to be adequate to meet the intent of the NEI 05-01 guidance to review all “dominant risk contributors”. The Braidwood SAMA identification process, however, exceeded this threshold and extended the review threshold down to a risk reduction worth value of 1.005. No additional review of the Braidwood PRA results is considered to be required.

Question 5.b

Section F.5.1 indicates that Phase I SAMAs were based on Byron/Braidwood PRA results and PRA Group Insights. Explain what is meant by PRA group insights. Discuss if this was a separate task or if PRA group insights were used to develop SAMAs for the importance of other reviews?

Exelon Response

As part of routine work, PRA groups identify major contributors to plant risk and in some cases, the groups have identified specific changes that could reduce risk. As part of the SAMA identification process, the site PRA group is questioned to determine if they have identified any such changes. If the PRA group does have plant enhancements that are not already represented on the SAMA list, they are included on the list.

For Byron and Braidwood, the PRA group did not identify any plant enhancements that were not already identified by the SAMA identification process.

Question 5.c

Describe the steps taken to identify SAMAs involving improvements in procedures, training or available cues for the important human errors.

Exelon Response

The HRA quantifications are reviewed to identify the major contributors to the HEP and to determine if there are any practical means of reducing those contributors. This would include reviewing consideration of adding steps to procedures as cues or recovery steps, simplifying the language of the procedures, re-ordering steps, or including additional information to aid the operator in the performance of the actions. This is driven by issues considered by the HRA methodology used to assess the action and the key issues are action dependent. Changes to the procedure must be specific to be useful; SAMAs directing the general improvement of procedures are not valid. Byron SAMAs 7 and 8 are examples of the results of this process.

Question 5.d

In Table F.S-1 (p. F-208) for basic event OVA1SUPP----PNMM "UNIT 1 VA SUPPLY PLENUM MAINTENANCE," the only SAMA identified is SAMA 4, Installation of the "no-leak" [reactor coolant pump] RCP seals. Consider other potentially lower cost alternatives such as providing portable ventilation during maintenance activities. ***{BY only}***

Exelon Response

Adequate CV pump room cooling requires operation of either the cubicle coolers, which are supported by the essential service water system (SX), or by at least one train of the Auxiliary Building HVAC system. The CV pumps themselves also require the SX system for lube oil cooling. If both Auxiliary Building HVAC and the CV pump cubicle coolers fail, the CV pumps are assumed to fail even if alternate lube oil cooling is established.

The event 0VA1SUPP----PNMM "UNIT 1 VA SUPPLY PLENUM MAINTENANCE" represents the condition in which the Unit 1 Auxiliary Building HVAC intake paths are out of service for maintenance. When this condition exists, the Unit 2 cross connect path could be opened, but the fans are not capable of supplying both units with the air flow required for CV pump room cooling in loss of SX scenarios (dominant cases for 0VA1SUPP----PNMM are loss of SX to both units). There are no other existing systems or alignments that can be used to provide the required air flow for CV pump room cooling.

Current plant procedures already direct the alignment of portable fans for CV pump room cooling in loss of essential service water scenarios, which represent 96% of the contributors including the 0VA1SUPP----PNMM event. The step to align the portable fans is included in the human failure event for establishing alternate lube oil cooling to the CV pumps, which is successful in these scenarios. While potentially conservative, the portable fans are not credited in the PRA model because there is no basis for assuming they would provide adequate CV pump room cooling.

This question suggests that portable ventilation be provided as a contingency during periods when one train of Auxiliary Building HVAC is in maintenance; however, the function of the portable fans would be the same whether they are aligned before the event or during the event and such a change would not provide a success path.

Question 5.e

In Table F.5-1 (p. F-222) basic events 1AP-142-1---TRMM and 1AP-142-2---TRMM appear to result in the unavailability of the same equipment, the startup feedwater pump and the same 2 of 4 condensate pumps. This implies that both system auxiliary transformers (SATs) are needed. Provide additional information to explain this situation. In addition, since these are maintenance unavailabilities, explain if it is possible to use a temporary alignment while this maintenance is underway. ***{BY only}***

Exelon Response

Normally, the non-Class 1E 4KV buses (143 and 144) are aligned to the Unit Auxiliary Transformers (UATs), which are powered from the main generator. These buses supply balance of plant systems, including the lube oil pumps for the feedwater, condensate, and condensate booster pumps. On a plant trip, a fast bus transfer would normally align buses 143 and 144 to the associated System Auxiliary Transformer (SAT), which is energized by the offsite power source. When either SAT 142-1 or 142-2 is in maintenance, the fast bus transfer function that would align non-Class 1E 4KV bus 143 from the UAT to the SAT is disabled (by procedure) due to the potential to overload the lone available SAT. This results in the loss of power to bus 143 whenever there is a plant trip with one of the SATs in maintenance. For example, if SAT 142-1 is in maintenance when a trip occurs, bus 144 would auto transfer to SAT 142-2, but bus 143 would be de-energized. A plant trip when either SAT is out of service will result in the unavailability of the startup feedwater pump and the "A" and "C" condensate pumps and condensate booster pumps.

Because of the load limitations on a single SAT, there are no viable temporary power alignments that could be implemented during SAT maintenance using existing hardware. Bus 143 could not be pre-aligned to the available SAT (load limit issue) and the UATs would be de-energized after a plant trip. The opposite unit's SAT can be tied to the non-Class 1E bus through the Class 1E busses, but non-accident operation in this configuration is not desirable due to the potential for a single fault to fail a division of power on both units.

Plant procedures could be enhanced to direct the alignment of bus 143 to the opposite unit's SAT via bus 141 in accident conditions; however, the PRA model conservatively does not credit existing plant procedures that would mitigate the risk associated with the SAT maintenance events (1AP-142-1---TRMM and 1AP-142-2---TRMM). The "Loss of Secondary Heat Sink" procedure provides guidance for making up to the steam generators using:

- Single condensate pump/condensate booster pump pair in conjunction with either the startup FW pump or the motor driven FW pump, or
- Single condensate pump/condensate booster pump pair in conjunction with depressurization.

The contributions associated with the 1AP-142-1---TRMM and 1AP-142-2---TRMM events have at least one condensate/condensate booster pump pair available and in some cases a feedwater pump is also available. If the guidance in the existing procedures to use a single condensate/condensate booster pump pair were credited, maintenance events 1AP-142-1---RMM and 1AP-142-2---TRMM would no longer be risk-significant contributors and no SAMAs would be required to address them.

The SAMA proposed in the ER for these events, SAMA 13: "Alternate AFW Cooling with Seal Protection", is valid means of addressing the scenarios in which the 1AP-142-1---TRMM and 1AP-142-2---TRMM events occur, however, the benefit estimated for SAMA 13 in the ER is conservatively overstated (i.e., crediting the existing guidance to use the condensate/condensate booster pumps would reduce the benefit of SAMA 13).

Question 5.f

Discuss the effectiveness of SAMA 15 (inter unit AFW cross-tie) if both units are tripped.

Exelon Response

The PRA does not credit the AFW cross-tie during dual-unit events (both units are tripped) since the donating unit may require use of its own AFW pump.

Question 5.g

Seven potentially cost-beneficial SAMAs in the Indian Point Generating Station (Indian Point) Unit 2 SAMA analysis were discussed in ER Section F.5.1.3.6. The NUREG-1437, Supplement 38, identifies a total of 13 potentially cost- beneficial SAMAs. Address the applicability of these additional SAMAs to Byron/Braidwood.

Exelon Response

The dispositions of the 6 SAMAs identified in NUREG-1437 Supplement that were not addressed in Section F.5.1.3.6 of the ER are discussed below:

- SAMA 9 - Create a reactor Cavity Flooding System: Cavity flooding systems may help prevent vessel melt-through and/or reduce the likelihood of basemat failure after vessel failure by ensuring there is water on the containment floor. For Byron and Braidwood, the Level 2 model accounts for transfer of the refueling water storage tank to the cavity via the Containment Spray system, but it does not credit the presence of the water as a means of preventing vessel failure. Crediting additional means of transferring water to the cavity would, therefore, result in no measurable change in the vessel failure probability. A cavity flooding system would provide a diverse means of transferring water to the cavity, but dry basemat failures (represented by event 1L2-CNT-VF-BMMTD) are not risk significant contributors for Byron and Braidwood. No SAMAs are required.
- SAMA 21 - Install additional pressure leak monitoring instrumentation to reduce the frequency of ISLOCAs: The ISLOCA initiating event frequency calculations for Byron and Braidwood do not provide any insights related to the mode of failure of the dominant paths or any means of estimating how the installation of pressure monitoring instruments would impact the initiating event frequencies. Rather than attempt to address failure modes that are not defined for the ISLOCA events with an enhancement that may or may not provide a means to prevent the event, the Byron and Braidwood SAMA analyses considered a type of change that would mitigate an ISLOCA in the event that it did occur (SAMA 19: Replace MOVs in the RHR Discharge Line with Valves that Can Isolate an ISLOCA Event). SAMA 19 was determined to be potentially cost beneficial for both Byron and Braidwood.
- SAMA 22 - Add redundant and diverse limit switches to each containment isolation valve: The dominant contributors to the ISLOCA frequency are valve failures in the RHR suction and discharge piping and a failure of the RCP thermal barrier heat exchanger. None of these frequencies would appear to be impacted by diverse limit switches.
- SAMA 53 - Keep both pressurizer PORV block valves open: Already implemented.
- SAMA 62: Provide a hard-wired connection to an SI pump. This modification would reduce the CDF from events that involve loss of power from the 480V vital bus: The SI pumps are 4kV pumps for BBW and this change is not applicable.
- Unnumbered SAMA – Main Steam Safety Valve Gagging Device: The details of this SAMA are not provided in NUREG-1437, Supplement 38 and it is not clear if the device described for Indian Point Unit 2 is intended to address the main steam safety valves, as implied by the description in that document, or if it is intended to address the steam generator PORVs, which is the intent of the gagging device described in RAI question 7.b. If the intent is to gag the steam generator PORVs, Byron and Braidwood have

isolation valves that can be used to isolate the steam generator PORVs, as described in the response to RAI 7.b, and the function of the gagging device is met by existing equipment. However, whether the gagging device is intended to be used on the main steam safety valves or on the steam generator PORVs, the benefit of the SAMA is not clear. For the Byron and Braidwood main steam relief valves and steam generator PORVs, no analysis has been performed to show that a valve that is stuck open could be closed by a gagging device. In addition, for steam generator tube rupture events that lead to core damage, steam and hydrogen will pass from the primary side to the secondary side of the ruptured steam generator and force open the main steam safety valves or PORVs that are not gagged closed, which still leads to a release of radionuclides to the environment. Gagging all of the main steam safety valves is not recommended because it can lead to rupture of the steam generator.

Question 5.h

According to the NRC safety evaluation report (SER) on the Byron and Braidwood individual plant examination (IPE) reports, the transmittal of the modified IPE reports indicated that a potential vulnerability involving a dual loss of SX due to internal flooding had been identified and that a modification was being considered. Confirm the implementation of this modification.

Exelon Response

The modification was not implemented, but is addressed as SAMA 10 in the Byron and Braidwood SAMA analyses.

Question 5.i

From the discussion in Braidwood Section F.5.1.6.1, it is not clear how the fire zone CDF results from the 2008 Braidwood fire PRA were modified to account for using the lower ignition frequencies from EPRI 1016735. Discuss how this was done. Provide further justification for this use of the Byron results or assess the impact on the identification and evaluation of fire specific SAMAs if the 2008 Braidwood fire PRA results are not modified or if a different approach to the modification is taken ***{BW only}***.

Exelon Response

As documented in the response to RAI question 3.c, the Braidwood fire zone CDF results were not reduced for the SAMA identification task or for the cost benefit calculations.

Question 5.j

Important fire zones at Braidwood were reviewed for potential SAMAs down to a zone CDF of 1 E-06 per year. This corresponds to a benefit of $474K. Provide assurance that use of this lower end cutoff does not result in missing some potentially cost effective SAMAs. **{BW only}**

Exelon Response

As described in the response to RAI 5.a, the NEI 05-01 guidance indicates that the SAMA identification process should address the dominant contributors to plant risk, which is considered to be met by a review of risk significant contributors. For Braidwood, the fire cost benefit calculations are based on the unmodified fire CDFs, which would correspond to a total fire CDF of 6.20E-05/yr for Unit 1 and 7.50E-05/yr for Unit 2. A risk reduction worth of 1.01 corresponds to a CDF of 6.14E-07 for Unit 1 and 7.42E-7 for Unit 2. Use of these frequencies to establish the lower CDF threshold for fire zone review would result in the identification of one fire zone that was not reviewed in the ER. A more conservative approach to the identification process would be to use the CDF that was used to establish the MACR for the ER, which corresponds to a review threshold of 5.9E-07 (5.94E-05 – 5.94E-05/1.01 = 5.88E-07). The previously un-reviewed Braidwood fire zones with CDFs greater than 5.9E-07 are all from the Unit 2 results (the largest un-reviewed Unit 1 result is 5.57E-07). Table 5.j-1 lists these fire zones in conjunction with the associated CDF, the cost-risk based on the point estimate PRA results, and the cost-risk based on the 95th percentile PRA results (using the multiplier of 1.97 from the response to RAI 6.f).

Table 5.j-1
Summary of Previously Un-Reviewed Fire Zones

Fire Zone	Description	CDF	Fire Zone Cost-Risk (point estimate case)	Fire Zone Cost-Risk (95th percentile PRA results case)
5.1-2	Division 22 ESF Switchgear Room	9.03E-07	$419,269	$825,960
18.17-0	Hydrogen/Nitrogen Storage Area	7.41E-07	$344,051	$677,780
3.4A-2	Unit 2 Cable Riser Area, elevation 451	6.51E-07	$302,264	$595,460

The results for each of these fire zones have been reviewed to determine if any previously unidentified potentially cost beneficial SAMA exist. These reviews are documented below:

U2: 5.1-2 (Scenarios E, F, and G), (Division 22 ESF Switchgear Room)

The ignition sources for these fire scenarios are 480V switchgear 232X/transformer for switchgear 232X (scenario E), 4160V switchgear 242 (scenario F), and 4160V switchgear 244 (scenario G).

For scenario E (57% of zone 5.1-2 CDF), the initiating fire results in the loss of the division 2 480V ESF bus, which fails a large portion of the division 2 safety related equipment. Scenario F (18.5% of the zone 5.1-2 CDF) results in the failure of a similar set of division 2 equipment.

For these scenarios, random failure combinations of division 1 AFW and RHR lead to core damage. For scenario G, the impact of the fire is not as extensive and random failures that impact both divisions of RHR are required to fail recirculation mode.

The largest contributor to all three fire scenarios is the failure to manually start AFW after a fire related failure of the existing initiation logic. This operator action failure could be mitigated by providing a diverse initiation signal for AFW via SAMA 17 (Use AMSAC for Alternate LOW SG Level AFW Initiation).

AFW hardware failures are also large contributors for these scenarios. About 40% of each scenario is related to the unavailability of the division 1 AFW pump due to start, run, and maintenance failures. The Diverse Makeup System (either SAMA 11 or 26) could be used to provide an alternate means of SG makeup in these scenarios, which were both determined to be potentially cost beneficial in the ER.

No new, potentially cost-beneficial SAMAs have been identified to mitigate the risk associated with fire zone 5.1-2.

U2: 18.17-0 (Scenario A), (Hydrogen/Nitrogen Storage Area)

This is a bounding fire scenario representing the impact of failing all equipment in the fire zone based on the total ignition frequency for the fire zone. The ignition frequency is dominated (82%) by the contribution from the hydrogen tanks themselves. No other equipment targets are listed in the ignition frequency report for that zone.

The top contributors for this zone are operator action failures for manual AFW start, transition to high pressure recirculation mode, and failure to stop the RH pumps. These contributors are all addressed by existing SAMAs:

- SAMA 17 addresses failure to manually start AFW by providing a diverse, alternate AFW initiation signal using the AMSAC logic.
- SAMA 30 addresses the failure to establish high pressure recirculation mode by automating the transition to recirculation mode.
- SAMA 7 changes the location of the step to establish CC flow to the RH heat exchangers so that the operators do not have to stop the RH pumps.

AFW pump unavailability is another top contributor to this scenario, which is addressed by the portable SG makeup capability that is included in SAMAs 11 and 26.

No new potentially cost-beneficial SAMAs have been identified to mitigate the risk associated with fire zone 18.17-0.

U2: 3.4A-2 (Scenario T1), (Unit 2 Cable Riser Area, elevation 451)

The ignition source for this fire is a transient source. The scenario fails the AFW, RHR, CCW, SI, and CVCS of division 1 and seal LOCAs are top contributors. The seal LOCAs are the result of the failure of a valve in the CCW thermal barrier cooling water return path in conjunction with valves in the “B” and “D” RCP seal injection lines. Spurious valve operation results in both a head vent LOCA and a draindown of the RWST to the sump.

The ignition source for this scenario is a transient, the largest contributor being related to welding and cutting events. The fire ignition frequency analysis categorizes the frequency of these events as “low” (rarely performed), which is the lowest frequency category apart from the category for areas that are not accessible during power operations. No changes have been identified that would result in a quantifiable reduction in the estimated fire ignition frequency for this fire zone.

In these scenarios, the RCP seal LOCA and head vent LOCA require reactor coolant system makeup and recirculation for long term success, which is possible, but there a number of single failures that eliminate the injection/recirculation capabilities of the equipment that is not failed by the fire. For example, failure of the “B” division RHR pump, RHR sump suction valve, or charging pump leads to core damage for fires in zone 3.4A-2. None of the random failures, however, contribute more than 10% of the conditional core damage probability for this fire scenario. Because of the diversity of contributors, an effective mitigation strategy would be required to provide diverse makeup and heat removal capabilities.

As shown in Table 5.j-1, eliminating all risk associated with fire zone 3.4A-2 would result in an averted cost-risk of $302,264 when the base PRA results are used. If the 95th percentile results are considered, the averted cost-risk would be $595,460 (1.97 * $302,264 = $595,460) using the 95th percentile PRA results multiplier from the response to RAI 6.f. The cost of installing a low flow seal injection pump alone, which may not even be capable of providing the makeup flow required to mitigate the head vent LOCA, is $2.9 million per unit (refer to the updated implementation costs in the response to RAI 6.a). These types of changes would not be cost beneficial. The costs of installing cable wrap or fire barriers were estimated to be about $1 million (refer to SAMA 35, for example) and are also greater than the 95th percentile averted cost-risk associated with this zone. No new potentially cost-beneficial SAMAs have been identified to mitigate the risk associated with fire zone 3.4A-2.

Question: 5.k

In section F.5.1.6.1 the "major" scenarios contributing to the fire zone risk are identified. What is meant by major?

Exelon Response

A major contributor in this review was a fire scenario with a frequency of at least 10% of the fire zone frequency.

Question: 5.l

The Unit 2 fire zone results given in Section F.5.1.6.1 include a fire in Unit 1 Containment. It is stated that the fire induced failures are Unit 1 equipment and the fire is modeled as requiring a Unit 2 shutdown without the availability of untraced equipment, such as the main feedwater system. Discuss whether or not the same modeling logic is applicable to Unit 1 for a fire in Unit 2 containment. In addition, please discuss if this modeling logic is applicable to fires in other areas. **{BW only}**

Exelon Response

The fire model considers the impact of a fire in each of the site's fire zones for each unit, even if the fire zone is in the opposite unit. The Unit 1 results also include Unit 2 containment fires as contributors, but these fires were below the review threshold used in the ER and were, therefore, not reported in Section F.5.1.6.1.

The Braidwood fire PRA, which is an interim model, conservatively assumes failure of the equipment for which the cable routing is not known, which includes the main feedwater system.

Question 5.m

Fire zone U2: 11.6-2 is the largest contributor to Unit 2 fire CDF and is analyzed using a bounding scenario. Discuss whether or not insights from the analysis of the same or similar fire zone in Unit 1 can be used to identify potential fire specific SAMAs. **{BY only}**

Exelon Response

The Unit 1 counterpart of Fire Zone 11.6-2 (Division 22 containment electrical penetrations area) is Fire Zone 11.6-1 (Division 12 containment electrical penetrations area), which was also analyzed as a bounding fire and does not provide any additional insights related to fire sources or propagation.

Question 5.n

The discussions of fire zones U2: 5.2-2 and U2: 5.1-2 (and others) in Section F.5.1.6.1 state:

"One of the larger contributors to the conditional core damage probability for the scenario is the operator failure to refill the DG B fuel oil tank. Automating the refill capability would help reduce the risk from these fires (SAMA 18)."

SAMA 18 is described as automating the refill of the diesel driven AFW pump fuel oil day tank, not DG B fuel oil tank. Clarify.

Exelon Response

References to failures to "refill the DG B fuel oil tank" in the fire zone discussions are erroneous. The correct contributor is the failure of the operator to refill the diesel driven AFW pump fuel oil day tank, for which the appropriate mitigating SAMA is SAMA 18.

Question 5.o

Describe the extent to which new or improvements in Byron/Braidwood fire procedures to mitigate the important Byron/Braidwood fires have been considered in the SAMA analysis.

Exelon Response

Review of the fire procedures to identify improvements in the fire response is an iterative task that is performed as part of the fire PRA development process and is not within the scope of the SAMA analysis. Unlike SAMAs to modify AOPs and EOPs, the identification of fire response enhancement requires coordination with the fire modeling team and procedure writers to ensure the actions are consistent with existing procedures and that the proposed changes are appropriate for the failure modes caused by the fire events.

Question 5.p

Fire zone U1: 11.6c-O is the auxiliary building laundry room with the fire source described as totally being composed of transient initiators. If these are due to the laundry room operation, consider a SAMA involving moving the laundry to another facility.

Exelon Response

The ignition sources for fire zone 11.6c-0 were confirmed to be transient sources. The Byron Fire PRA documentation lists two electric motors in that fire zone as ignition sources, but as part of the ongoing update work, those motors have been verified to no longer be located in that room. While the room description is the "auxiliary building laundry room", the laundry equipment has been removed from that room and it no longer serves that function.

Question 5.q

For the discussion of seismic outliers in Section F.5.1.6.2, provide further information on the disposition of the following: ***{BY only}***

i. For the Equipment Identification (ID) group 1AP10E, 2AP06E, etc., discuss how the seismic interaction issues were addressed
ii. For the Equipment ID group 1(2) DC03E, 1(2) DC05E, etc., discuss whether or not the proceduralized operator actions were implemented. Also, for these and for Equipment ID 1 RD05E and 2RD05E, please discuss if relay chatter is the only adverse consequence of cabinet interactions.
iii. Equipment ID 1 DC04E and 1 DC06E of IPEEE Table 3.3 do not appear to be thoroughly addressed in Section F.5.1.6.2. Unit 2 items are addressed, however Unit 1 items are not. Please include a similar discussion for Unit 1 items.

Exelon Response

i. ER References Exelon 2012a and Exelon 2012b include information on the "proposed resolution" and the "actual resolution of condition". The "proposed resolution" is that the breakers would be located in a designated area where no interaction hazard exists and the "actual resolution of condition" indicates that the issues were addressed, suggesting that the proposed resolution was carried out. The date of completion was 10/15/1997 for both units.

ii. The actions to address the chatter issues are currently proceduralized for Byron and Braidwood. Based on a review of the evaluations in the tracking system related to resolution of the seismic interactions for 1(2) DC03E, 1(2) DC05E, and 1(2) RD05E, relay chatter was the only interaction issue identified. These components are associated with the reactor trip switchgear and the rod control MG set switchgear and are in adjacent cabinets subject to seismic interaction. The relays associated with the rod control switchgear 1(2) DC03E were not included in the success path equipment list and therefore not evaluated further for impact. Relays 1(2) DC05E, and 1(2) RD05E were evaluated for a change of state and result in either driving an annunciator in the main control room or generating a trip signal that results in a loss of power to the MG sets and subsequent insertion of the control rods resulting in a reactor trip. As a result, no modification was required to alleviate the potential relay chatter. A control room alarm response card requires response to the rod drive MG sets to investigate.

iii. Table G-1 "IPEEE Vulnerability Status" developed in response to the 50.54(f) information request regarding Fukushima NTTF Recommendation 2.3 indicates that the resolution of seismic concern involving adjacent cabinets not bolted together was resolved for the similar Unit 1 cabinets.

Question 5.r

Section F.5.1.3.1 identifies two additional Vogtle Electric Generating Plant (Vogtle) SAMAs (6, 16) that were found not cost beneficial (to Vogtle). However, the costs of implementation were moderate to low (816K and 25K, respectively), as documented in the Vogtle ER, 2007 and RAI responses dated December 20, 2007, Agencywide Documents Access and Management System (ADAMS) Accession No. ML073580627. The base case cost-risk for Byron is approximately five times greater than Vogtle, and the dose risk more than ten times greater. Clarify whether these SAMAs would be applicable or potentially cost beneficial to Byron or Braidwood.

Exelon Response

SAMA 6 - Add bypass line around CT return valves: This SAMA mitigates loss of EDG cooling due to the failure of a specific valve. For BBW, this type of failure is not a significant contributor to risk and the SAMA would not be cost beneficial.

SAMA 16 – Enhance procedures for ISLOCA response: This SAMA proposes an improvement to procedures without providing any explicit changes to achieve such an improvement. Byron and Braidwood have procedures that are constantly trained on and improved by the plant staff and the intent of this SAMA is considered to be met by these activities.

Question 5.s

SAMA 24 provides a reactor vessel cooling system to prevent vessel melt through. Based on the Byron IPE (ComEd 1994), plant procedures were implemented to direct reactor cavity flooding in core damage scenarios to provide a means of exterior vessel cooling (Section F.5.1.4). Clarify why vessel cooling requires an additional cooling system to perform this function.

Exelon Response

The IPE enhancement was implemented at Byron and Braidwood. The existing Severe Accident Control Room Guidelines direct the operators to ensure that at least 18 inches of water are on the containment floor and multiple methods of satisfying this requirement are provided. The systems identified include Containment Spray, Residual Heat Removal, RWST gravity drain, and the use of Residual Heat Removal to transfer water from other tanks to containment.

For cases where the core damage occurred, the concern was that it might not be possible to perform the cavity flooding action in the time available; therefore, a high volume system that could be rapidly aligned was suggested (SAMA 24).

Further review, however, identified that SAMA 24 is suggested to mitigate conditions in which basemat melt through occurs when water has already been transferred to the containment floor. These cases occur when Containment Spray was successful, which implies that if Containment Spray was directed to be used for this task prior to when it might otherwise be required in the scenario, it would be available for cavity flooding. The Containment Spray system can provide high flow to containment and the RWST volume is adequate to provide the 18 inches of water required by the procedure. For Byron and Braidwood, an additional cavity flooding system is not required.

To prevent basemat melt through when water is already on the containment floor, a core catcher would be required. These types of changes are extremely costly to install in existing plants and have been determined to not be cost beneficial in previous analyses. No alternate SAMA suggested.

Question 6.0

Provide the following information regarding the Phase II cost-benefit evaluations. The basis for this request is as follows: Applicants for license renewal are required by 10 CFR 51.53(c)(3)(ii)(L) to consider SAMAs, if not previously considered, in an environmental impact assessment, related supplement, or environmental assessment for the plant. As part of its review of the Byron/Braidwood SAMA analyses, NRC staff evaluates the applicant's cost-benefit analysis of the Phase II SAMAs. The requested information is needed in order for the NRC staff to reach a conclusion on the sufficiency of the applicant's cost estimates for individual SAMAs and the cost-benefit evaluations.

Question 6.a

Section F.6 provides only a brief description of the cost estimating process for determining the implementation cost for the various SAMAs. Provide a more detailed description of the cost estimating process including: whom or what organization performed the estimate, what is included or not included in the costs (for example: lifetime training and/or maintenance costs, inflation) and the treatment of cost savings due to the sharing of certain costs between units at the same site (or potentially between sites). If such cost sharing is not considered provide justification for this or describe the impact such cost sharing would have on the results of the SAMA analysis.

Exelon Response

Sargent and Lundy was used to develop “order of magnitude” cost estimates based on present day information (i.e., does not account for inflation) and estimating methods. Sargent and Lundy served as the consulting engineering firm during the construction of the Byron and Braidwood sites and has over 100 years of experience with clients in both public and private sectors worldwide. Details such as cost of equipment, demolition, scaffolding, overtime, consumables, freight, engineering, etc. were used to develop the costs. Exelon provided the components of the cost estimates associated with developing supporting procedures, providing lifelong training, and updating the simulator for those SAMAs requiring these types of elements. The estimates do not address any replacement power costs that would be associated with the implementation of SAMAs that would require an extension of outage times.

The implementation costs were developed on a “per site” basis and cost sharing between units was accounted for in the estimation process by dividing the “per-site” costs in half to obtain the “per-unit” costs. If a SAMA were only to be implemented at a single unit, most of the costs for items such as engineering and procedure changes would be incurred by the single unit implementing the SAMA.

Cost sharing was not, however, considered between sites. Based on input from the engineering firm that developed the cost estimates, engineering costs at the first sister plant are generally 75% to 80% of the original costs if the modifications are identical. For the Byron and Braidwood SAMA analyses, attempting to modify the cost estimates at this level of detail is not considered to be required:

- It is not necessarily true that a SAMA implemented at one site will be implemented at the other site,

- Accounting for cost sharing between sites could reduce some implementation costs. However, these reductions in cost would be offset (reduced or eliminated) if other costs were also accounted for such as inflation and replacement power costs.
- The SAMA designs are conceptual and the cost estimates provided are "order of magnitude" estimates. Changes in the per-site engineering costs of 12% to 13% are expected to be within the margin of error.
- Actual installation costs are generally larger than estimated installation costs.
- The impact of accounting for inter-site cost-sharing is bounded by the 95th percentile PRA results sensitivity analysis.

When the cost estimates from the engineering consulting firm were reviewed to respond to this RAI, it was determined that the SAMA analyst misinterpreted the definition of the cost estimates that were provided. The cost estimates reflect the cost of implementing a SAMA for both units at a given site, but when the estimates were applied in the SAMA analysis, they were used as "per unit" costs. The implication is that the implementation costs for the following SAMAs were overestimated. Table 6.a-1 identifies the impacted SAMA, the original cost, and the corrected cost:

Table 6.a-1: Corrected Implementation Costs

SAMA ID	SAMA Description	ER Implementation Cost (per unit)	Corrected Implementation Cost (per unit)
2	Replace the Positive Displacement Pump with a Self-Cooled, Auto Start Pump	$5,751,110	$2,875,555
3	Auto Start of Standby SW Pump	$1,130,300	$565,150
4	Install "No-Leak" RCP Seals	$12,230,000	$6,547,600
5	Modify the Startup Feedwater Pump to Start Using the AMSAC SG Low-Low-Low Level signal to Mitigate AFW Failure	$657,200	$328,600
8	Install Kill Switches for the Fire Protection Pumps in the MCR	$338,830	$217,415
9	Install Flow Restrictors in Fire Protection Pipes	$349,300	$174,650
10	Alter Ductwork Between the Aux Bldg Sump Drain Room and the SX Pump Room	$1,320,300	$660,150
11	Implement DMS	$13,030,000	$7,347,600
13	Alternate AFW Cooling with Seal Protection	$5,951,110	$3,075,555
16	Install High Flow Sensors On the Non-Essential Service Water System	$993,800	$496,900
17	Use AMASC for Alternate LOW SG Level AFW Initiation	$981,730	$490,865
18	Automate Refill of the Diesel Driven AFW Pump Fuel Oil Day Tank	$1,608,680	$804,340

The response to RAI 3.d provides an updated cost benefit analysis that includes the corrected cost estimates documented in Table 6.a-1. Based on the correction of these implementation costs and the other factors described in RAI 3.d pertaining to these SAMAs, only one SAMA was determined to be potentially cost beneficial that was not identified in the ER:

- Byron SAMA 4: Install "No-Leak" RCP Seals

Question 6.b

Provide further support for the $100,000 per unit value used for the cost of a procedure change and its applicability to Byron/Braidwood.

Exelon Response

Depending on the procedure change a spectrum of cost can be incurred. Typically, procedure changes for beyond design basis conditions involve changing procedures that involve the alternate use of systems or lineups that are not consistent with normal operation. Changing a procedure using the Exelon process (including validation) and then developing/communicating the basis and the inclusion of training to Operations and station personnel, including periodic training can accrue significant cost.

The cost of a procedure change has been used in other SAMA analyses to establish the review threshold for the plant specific PRA results. The intent of this approach was to show that the scope of the review would be robust enough to identify even low cost SAMAs that could potentially be cost beneficial, which was predicated on the assumption that procedure changes are among the lowest cost plant enhancements. However, because the cost of procedures can vary significantly, this is an inexact means of establishing a PRA results review threshold. As documented in the response to question 5.a, a more appropriate approach to demonstrating that the NEI 05-1 requirement to review the dominant risk contributors has been met is to use the definition of "risk significant" to establish the review threshold. When this approach is taken, the cost of a procedure change for Byron and Braidwood is no longer required to support the review threshold definition.

More detailed cost estimates of the procedure changes applicable to the Byron and Braidwood SAMAs could be developed; however, all of these SAMAs were found to be potentially cost beneficial. It is possible that the cost of the procedure changes could be determined to be less than $100,000 and that the SAMAs could be re-classified as "not cost beneficial". In that case, retaining the current cost estimates would be potentially conservative.

Question 6.c

The cost estimate of $46M for SAMA 1(to install a diesel driven SX pump in a new dedicated building) is based on the inflation adjusted cost of a new suppression pool cooling system evaluated in the Limerick Generating Station (Limerick) severe accident mitigation design alternative assessment. While the reference to Limerick's cost estimate is justified as being similar in scope, the NRC staff notes that a suppression pool cooling system will include a large heat exchanger that is expected to significantly contribute to the cost. Also, it is not clear if the Limerick addition for a dedicated suppression pool cooling system was for a safety related system. Provide further support for the SAMA cost estimate and the impact of using non-safety grade equipment.

Exelon Response

In response to this RAI, Sargent and Lundy was employed to develop an estimate of the implementation cost for Byron and Braidwood SAMA 1. The cost estimate was developed in the same manner as the other cost estimates developed by Sargent and Lundy for the Byron and Braidwood SAMA analyses. The functional requirements for this modification were based on the SAMA 1 description documented in the Environmental Reports. The exceptions are:

- The strainer design is not diverse from the existing strainers. The strainers used for the SAMA pumps are of the same design as those used in the current essential service water system; however, a strainer bypass line was included to help mitigate the conditions in which common cause strainer clogging occurs.
- The SAMA pump suction line is tied to the existing essential service water system suction line rather than the non-essential service water forebay.

In order to assess the impact of using non-safety grade equipment, the SAMA was designed as a non-safety grade enhancement (with the exception of a small portion of piping and isolation valves).

The total cost per-site was estimated to be $30,400,000, or $15,200,000 per unit. The impact of using this estimate in the SAMA analyses is that SAMA 1 would become cost beneficial for Byron when the 95th percentile PRA results are used (it was determined to be cost beneficial for Braidwood in the ER). The quantitative results are included in the response to RAI 3.d.

As described in Section F.8.1 of the Byron ER, implementation of the Diverse Mitigation System and the AFW Cross-tie would reduce the Byron MACR to about $5 million when the 95th percentile PRA results are used, which indicates that SAMA 1 would not be cost effective after implementation of those SAMAs.

Question 6.d

The SAMA 12 cost estimate is based on an estimate that moving the SAT maintenance from on-line to an outage would require an additional one week added to each outage. Provide additional details why an outage must be extended versus being able to perform the maintenance in parallel with other outage work. Provide a similar discussion for the SAMA 20 cost estimate.

Exelon Response

For SAMA 12: Each unit's SAT actually consists of two separate 100% transformers per SAT, one for each of the unit's two electrical trains (Unit 1: SAT 141-1 and 141-2, Unit 2: SAT 241-1 and 242-2). If SAT outages were performed during a refuel outage, the refuel outage duration would be extended anywhere from 7 to 14 days, depending on the scope of the SAT outage. The primary driver for the extension is the requirement that any work on the SAT be performed during the defueled window. At Byron and Braidwood, SAT work has not been performed during refueling outages; in fact, the refueling unit's SAT is protected for the entire duration of the outage. The SAT is the primary source of power to the decay heat removal systems when fuel is in the reactor vessel, and the SAT is the primary source of power to systems supporting spent fuel pool cooling when the fuel is in the spent fuel pool. Our shutdown risk procedures would not allow SAT work anytime fuel is in the reactor vessel due to the importance of providing power to the decay heat removal systems. While not desired, the SAT protection could be removed during the defueled period, when the core is in the spent fuel pool. The standard template for the defueled window at Byron and Braidwood is 32 hours. Therefore, any work scope that is greater than 32 hours would extend the outage. The Byron/Braidwood SAT outage schedule alignment is two 100% transformers per unit that are normally electrically connected via mechanical links in the electrical buses. There are two sets of links, one for the 4KV winding and one for the 6.9KV winding. Moving these links allows one of the 100% SAT transformers to power both of the unit's electrical trains. A typical SAT outage contains the following work with associated durations: 2 days to move the links to isolate one SAT transformer (e.g., 141-1) and provide power from the other SAT transformer (i.e., 141-2), 4-5 days to complete the work on the isolated SAT (141-1), 2 days to reconfigure to perform work on the other SAT (141-2), 4-5 days to complete work on the second SAT, and finally 2 days to restore. The addition of this work would result in a 14 day outage extension. Modifying the scope and working around the clock could possibly reduce the extension to 7 to 10 days.

Additional Concerns:

1. The non ESF buses (6.9 KV) are powered by the SATs during refueling outages. No other backup sources exists for the non-ESF buses, therefore during the time periods that the SATs are being reconfigured as described above there would be no power to the non-ESF buses. This condition would severely hamper the ability to perform normal outage activities as most all lighting, ventilation; weld receptacles, sump pumps, and other support equipment would be lost.

2. During outage periods many contract personnel (>1000) are onsite supporting outage activities, which increases the possibility of human performance errors that could adversely impact the remaining power sources.

3. The online unit would be in a 72 hour LCO during the periods that SAT reconfiguration is in progress.

For SAMA 20: If all Residual Heat Removal (RH) work, including heat exchanger and pump work, was performed during refuel outages, typical refuel outage duration would be extended anywhere from 3-4 days, depending on the scope of the work. The primary driver for the extension is the desire that any work on an RH train be performed during the defueled window. Byron and Braidwood have 2 decay heat removal trains. It is desired that both trains be available when fuel is in the reactor vessel, with one train in service, and one train available as back-up. With one train unavailable, defense in depth is degraded, and in the event the remaining train is lost, decay heat removal in the vessel may be unavailable, depending on the configuration. For this reason, RH work is typically done when defueled. The standard template for the defueled window at Byron and Braidwood is 32 hours. Therefore, any work scope that is greater than 32 hours would extend the outage. Currently at Byron and Braidwood, work on the pump and pump suction; and heat exchanger work on the component cooling (CC) side of the heat exchanger, is done online. Due to the inability to adequately vent the RH pump discharge line with the unit online, work on the RH side of the RH heat exchanger, and any work on the pump discharge line, is performed during refuel outages. Work on the RH side of the RH heat exchanger is very rare, and work on the RH discharge line is typically of short duration (12-24 hrs). Typical online work includes minor CC leak repairs on the heat exchanger, RH motor maintenance, mechanical seal replacement, and pump flange gasket replacement. This work typically requires 4-5 days to complete, which, if performed during an outage, would result in a 3-4 day outage extension. Performing work online results in entry into a 7 day Limiting condition for Operation (LCO). If RH work were expected to take more than 5 days, the work would be performed during a refuel outage to prevent a possible technical specification required shutdown. RH work in excess of 5 days is rare.

Additional Concern:

Dose rates are highest on RH trains during refueling outages due to the impact of forced oxidation that is performed early in the outage. Additional dose would be taken if more RH work was performed during outages. The least amount of dose is taken when RH work is performed at the end of a cycle because dose rates decrease as decay time accumulates since the previous outage.

Question 6.e

The CDF uncertainty multiplier is based on the BB011a CDF. However, the point estimate CDF and summary table CDFs in Section F.7.2 do not match the CDF in Table F.2-1. Please explain this apparent discrepancy. ***{BY only}***

Exelon Response

While the 95th percentile multiplier of 2.49 is correct, the PRA information listed is not. The correct information is provided below:

Point Est. CDF	Mean	5%	50%	95%	Factor > CDFpe
4.17E-05	3.95E-05	1.03E-05	2.78E-05	1.04E-04	2.49

QUESTION 6.f

Section F.7.2 gives for the BY BB011a model a mean CDF of 3.95E-05 and a point estimate of 4.26E-05 (which should be 4.17E-05) and for the Braidwood BB011a model a mean CDF of 4.12E-05 and a point estimate of 4.26E-05. Usually the mean is greater than the point estimate due to the correlation of uncertainties. Please explain these results and assess the impact on the SAMA analysis.

Exelon Response

Many of the largest contributors to the Byron and Braidwood Level 1 results are human error probabilities, joint human error probabilities, or flood mitigation events that include operator errors, none of which are correlated events. In addition, several contributors with larger failure probabilities were assigned lognormal distributions with relatively high error factors. These types of assignments often result in failure probabilities that are greater than 1.0 when the uncertainty analysis is performed. Both of these factors can act to reduce the mean relative to the point estimate.

In order to respond to this question, the error factors for selected events in the Byron and Braidwood BB011b models were adjusted to be consistent with those used in other Exelon uncertainty analyses. As shown in Figures 6.f-1 and 6.f-2, these changes resulted in mean CDFs (Byron: 3.99E-05, Braidwood: 3.568E-05) that are larger than the point estimate CDFs that were used in the ER (Byron: 3.97E-05, Braidwood 3.566E-05). For Byron, the ratio of the 95th percentile CDF to the point estimate CDF increased from 2.49 to 2.53, but for Braidwood, the ratio decreased from 2.29 to 1.97.

The increase in Byron's 95th percentile PRA results multiplier alone would not impact the conclusions of the SAMA analysis. The reduction in the Braidwood 95th percentile PRA results multiplier alone would result in the reclassification of SAMAs 4 and 32 as "not cost beneficial".

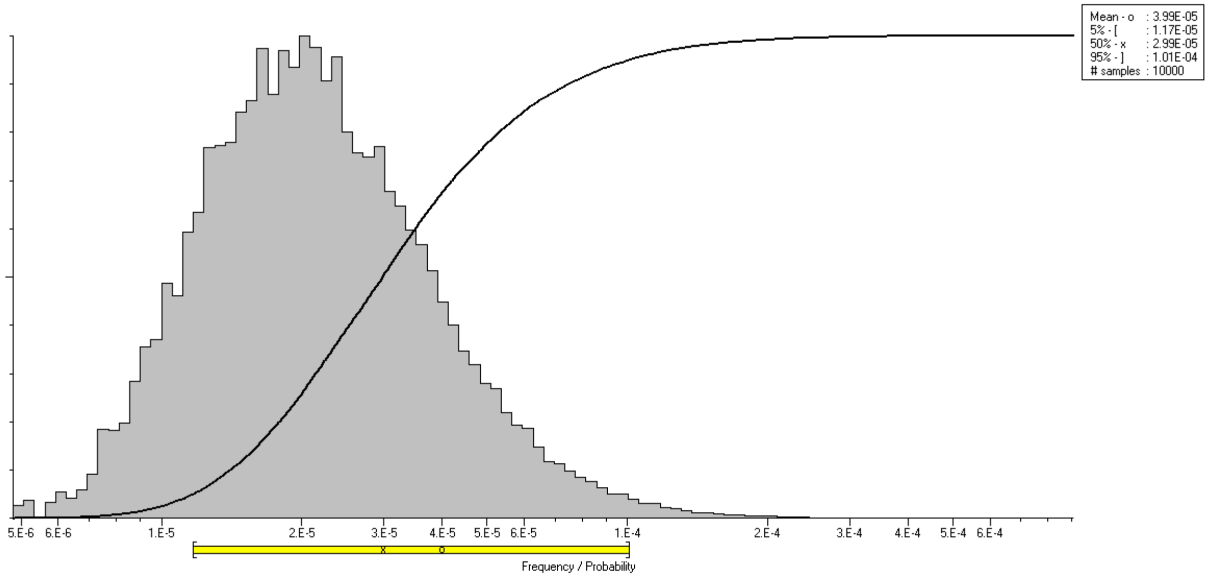


Figure 6.f-1: Byron BB011b Unit 1, Level 1 Uncertainty Analysis Results

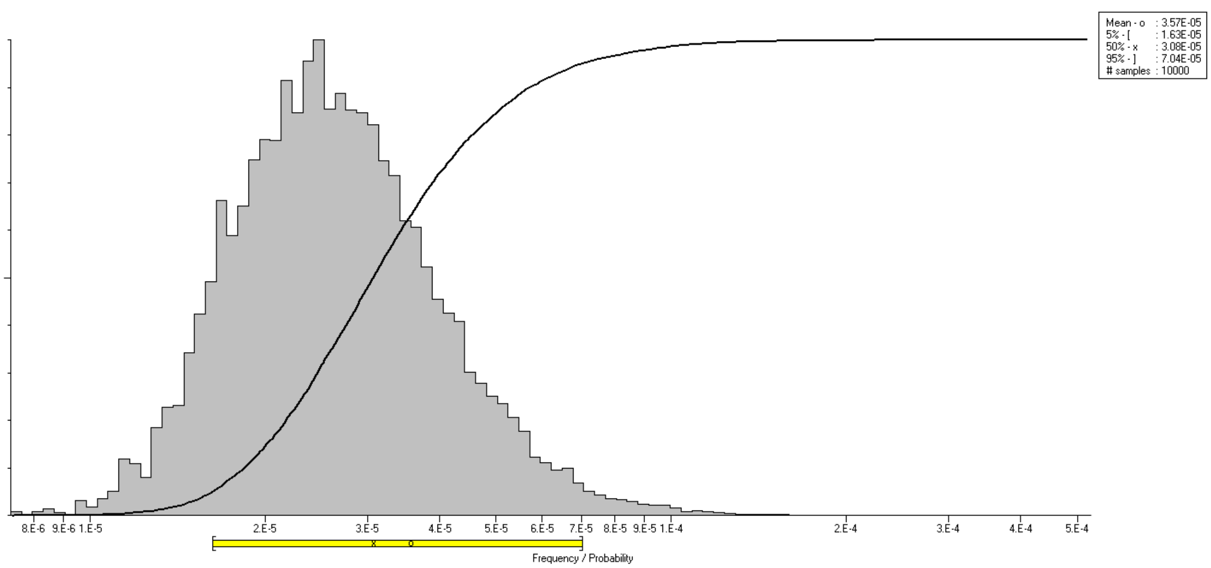


Figure 6.f-2: Braidwood BB011b Unit 1, Level 1 Uncertainty Analysis Results

Question 6.g

SAMA 14, Section F.6.11 for Byron and F.6.13 for Braidwood, identifies that for steam generator tube rupture (SGTR) scenarios, installing an automated refueling water storage tank makeup system could provide 'indefinite' cooling, but for non-SGTR scenarios this action "would extend the time available for transition to recirculation mode." However, it is also stated that "it is assumed that the actions to control injection and perform a cooldown will eventually have to be taken to reach a successful endstate." Clarify whether this applies to both SGTR and non-SGTR scenarios.

Exelon Response

For SGTR, inventory supplied to the RWST would enter the RCS, transfer to the secondary side through the ruptured SG tube, and boil off outside of containment. In these scenarios, containment overfill is not an issue and the process could be maintained “indefinitely”. For breaks inside containment, the RWST inventory will be transferred to the containment and the injection would eventually need to be terminated to prevent containment overfill.

Ultimately, it is assumed that both scenarios will require a controlled cooldown to place the plant in a safe state. This is reflected in the quantification approach.

Question 6.h

In Section F.7.3, the MACCS2 sensitivity case for economic rate of return shows a change in dose consequence. This variable is effectively an interest rate. Please clarify why there is an impact on dose consequence in the table of sensitivity results presented in Section F.7.3.

Exelon Response

MACCS2 evaluates potential mitigative actions for both farm and population in order to determine if it is possible to satisfy the applicable criteria for acceptable exposures (i.e., if land contamination is below a threshold that permits occupation). If either of these criteria, for farm or land, cannot be satisfied after the maximum-duration interdiction, then that land use is permanently interdicted, or condemned.

However, the use of land for farm or population can also be condemned if the total cost involved in restoring it to use would exceed the user-specified value of the property. If this is done, the use of land for either farm or population or both can be condemned. When a land use is condemned for either reason (i.e., the dose criteria cannot be satisfied, or the cost of reclamation exceeds the property’s value), MACCS2 calculates the corresponding long-term food and population exposures as zero, and assesses an economic cost for the condemnation of the property.

The rate of return is defined as the expected rate of return on land and improvements. When the input for rate of return on property is increased, more interdicted property will be condemned since it will not be economically feasible to reclaim a portion of the property that was recoverable relative to the base case. Consequently, no dose will be accumulated from the use of that condemned property and the total dose consequence will decrease. When the rate of return is reduced, less property will be condemned since it will be economically feasible to reclaim more of this interdicted property relative to the base case. This property reclamation will result in additional dose consequence in the form of dose to those that occupy the property after it has been reclaimed. The reclaimed property will still be marginally contaminated and results in the increase of the dose consequence.

Question 7.0

For certain SAMAs considered in the Byron/Braidwood ER, there may be lower-cost or more effective alternatives that could achieve much of the risk reduction. In this regard, provide an evaluation of the following SAMAs. The basis for this request is as follows: Applicants for license renewal are required by 10 CFR 51.53(c)(3)(ii)(L) to consider SAMAs, if not previously considered, in an environmental impact assessment, related supplement, or environmental assessment for the plant. As part of its review of the Byron/Braidwood SAMA analyses, NRC staff considers additional SAMAs that may be more effective or have lower implementation costs than the other SAMAs evaluated by the applicant. The requested information is needed in order for the NRC staff to reach a conclusion on the adequacy of the applicant's determination of cost-beneficial SAMAs.

Question 7.a

A cost beneficial SAMA identified in the Diablo Canyon submittal might represent an unevaluated SAMA candidate for Byron (i.e., Diablo Canyon Power Plant (Diablo Canyon) SAMA 24 - Prevent clearing of [reactor coolant system] RCS cold leg water seals). Please provide additional information evaluating the applicability of this SAMA to Byron/Braidwood.

Exelon Response

As part of the SAMA development process, the Byron and Braidwood procedures were reviewed to determine if they directed the action to operate the RCP pumps to inject the inventory of the recirculation lines into the RPV. It was determined that the BwFr-C.1 procedure only directs “RCP bump” if SG level is greater than 10%, which satisfies the intent of Diablo Canyon SAMA 24 (already implemented at Byron/Braidwood).

Question 7.b

Design and fabrication of a steam generator (SG) power operated relief valve (PORV) gagging device to be used following a SGTR with a stuck open SG PORV is a potential alternate SAMA to SAMA 14. Note that this is disposed of in the Byron/Braidwood SAMA assessments by citing information from a Diablo Canyon RAI response. This response was specific to the Diablo Canyon safety valve design. It is not clear if it is applicable to the Byron/Braidwood design. Please provide additional information evaluating the applicability of this SAMA to Byron/Braidwood.

Exelon Response

As identified in the importance review in the ER, the top SGTR contributors (over 70%) for Byron and Braidwood are driven by the dependent operator action combination to cooldown the RCS before overfilling the SGs and to fail to cool down the RCS to terminate flow after opening the PORVs. There is also an additional contribution from these actions by themselves (12% or more) and more still from other actions related to mitigation of the event. The availability of a gagging device, even if it worked, would not provide any meaningful risk reduction due to operator dependence issues. If they fail to take EOP based control room actions to terminate the event, it is unlikely the local actions to achieve the same type of goal would be successful.

Further, there are isolation valves with manual handwheels upstream of the SG PORVs that could be closed to isolate the open PORV. It would be easier to close the manual isolation valve than to use a gagging device and there is no apparent need for such a mechanism.

Question 7.c

SAMA 4 replaces the RCP seal with "no leak" seals at an estimated cost of $12.3M. Vogtle SAMA 7 identified the potential for installing enhanced seals that 'reduce' RCP seal leakage at a lower cost ($1.05M). Clarify whether this is a similar RCP seal modification, and, if yes, provide addition justification for the cost difference. If not, please clarify whether this RCP seal modification is applicable to Byron/Braidwood.

Exelon Response

As described on the response to RAI 6.a, the order of magnitude cost estimate developed for RCP seal replacement is about $6.5 million per unit. Awards for the replacement of the seals have been made and the cost of engineering and analysis development has already far exceeded the reference $1.05M on a per unit basis. The Vogtle reference cost seems low, but the details of that modification are not known to Exelon.

Question 7.d

In the Phase I SAMA development, the installation of a flood alarm was found not to be needed as the particular event was not applicable to Byron/Braidwood (e.g., Indian Point SAMA 054). Discuss the more generic position of whether additional flood alarms would be potentially beneficial if applied to Byron/Braidwood flooding events.

Exelon Response

For the flooding events originating in the fire protection system, the existing Auxiliary Building sump level alarms are credited in the human reliability analysis as cues for the flooding events. There is a delay for sump alarm actuation due to its location, but the fire protection flood events are not time challenged and a reduction in the delay would not have a significant impact on the operator failure rates.

For the flooding events originating in the Essential Service Water system, the situation is the same as for the fire protection flood events with the exception of the largest system break. In that scenario, the sump alarm delay does play a role; however, the largest RRW value for that flood mitigation action (set to 1.0) is 1.002 for the Braidwood Late results. Improvements to the response for that scenario would have a minimal impact on plant risk and no SAMAs are suggested.

For flooding events originating in the Non-Essential Service Water System, flood sensors are already evaluated in SAMA 16.

Floods originating in other systems are not risk significant and do not required SAMAs.