Appendix E

SAMA ANALYSIS

Three Mile Island Nuclear Station Unit 1 Environmental Report

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Acronyms Used in Attachment E

AC	alternating current
ADV	atmospheric dump valve
AFW	auxiliary feedwater
ATWS	anticipated transient without scram
BWR	boiling water reactor
BWST	borated water storage tank
CCF	common cause failure
CDF	core damage frequency
CET	containment event tree
CFS	cavity flooding system
CR	control room
CRD	control rod drive
CS	containment spray
CST	condensate storage tank
DA	data analysis
DC	direct current
DCH	direct containment heating
DG	diesel generator
DHCCW	decay heat closed cooling water
DPD	dollar per dollar
ECCS	emergency core cooling system
EDG	emergency diesel generator
EFW	emergency feedwater
EOP	emergency operating procedures
EPRI	electric power research institute
EPZ	emergency planning zone
FIVE	fire induced vulnerability evaluation
FP	fire protection
FPS	fire protection system
F-V	Fussell-Vesely
GIS	geographic information system
gpm	gallons per minute
HEP	human error probability
HPCI	high pressure coolant injection
HPI	high pressure injection
HPME	high pressure melt ejection
HPSI	high pressure safety injection
HRA	human reliability analysis
HVAC	heating ventilation and air-conditioning system
IA	Instrument air
ICS	instrumentation and control system
IE	initiating event
IPE	individual plant examination
IPEEE	individual plant examination – external events
ISLOCA	interfacing system LOCA
JHEP	joint human error probability
LERF	large early release frequency
LLNL	Lawrence Livermore National Labs
LOCA	loss-of-coolant accident

Acronyms Used in Attachment E

LOOP	loss of off-site power
LPR	low pressure recirc
LPSI	low pressure safety injection
MAAP	modular accident analysis program
MACCS2	melcor accident consequences code system, version 2
MACR	maximum averted cost-risk
MCC	motor control center
MCR	main control room
MET	meteorological
MSIV	main steam isolation valve
msl	mean sea level
MTC	moderator-temperature co-efficient
NPSH	net positive suction head
NRC	U.S. nuclear regulatory commission
NSCCW	Nuclear Services Closed Cooling Water
NSRW	Nuclear Service River Water
OECR	off-site economic cost risk
OSP	off-site power
OTSG	once through steam generator
PDS	plant damage state
PORV	pressure operated relief valve
PRA	probabilistic risk analysis
PSA	probabilistic safety assessment
PTS	pressurized thermal shock
PWR	pressurized water reactor
RBNC	reactor building normal cooling
RCIC	reactor core isolation cooling
RCP	reactor coolant pump
RCS	reactor coolant system
RDR	real discount rate
RHR	residual heat removal
RHRSW	residual heat removal service water
RPV	reactor pressure vessel
RRW	risk reduction worth
RSP	remote shutdown panel
SAMA	severe accident mitigation alternative
SBO	station blackout
SDP	significance determination process
SGTR	steam generator tube rupture
SPRA	seismic PRA
SRV	safety relief valve
SSC	systems structures & components
SSES	Susquehanna Steam Electric Station
SSHR	secondary side heat removal
SSRW	secondary service river water
ST	structural response
SW	service water
TD EFW	turbine driven EFW
TMI	Three Mile Island

Appendix E
Severe Accident Mitigation Alternatives

The severe accident mitigation alternatives (SAMA) analysis discussed in Section 4.20 of the Environmental Report is presented below.

E.1 METHODOLOGY

The methodology selected for this analysis involves identifying SAMA candidates that have the highest potential for reducing plant risk below the currently acceptably-low levels and determining whether or not the implementation of those candidates is beneficial on a cost-risk reduction basis. The metrics chosen to represent plant risk include the core damage frequency (CDF), the dose-risk, and the off-site economic cost-risk. These values provide a measure of both the likelihood and consequences of a core damage event. The SAMA process consists of the following steps:

- TMI-1 Probabilistic Risk Assessment (PRA) Model – Use the TMI-1 Internal Events PRA model as the basis for the analysis (Section E.2). Incorporate external events contributions as described in Sections E.4.6 and E.6.

- Level 3 PRA Analysis – Use TMI-1 Level 1 (CDF) and Level 2 (Containment Response) Internal Events PRA output and site-specific meteorology, demographic, land use, and emergency response data as input in performing a Level 3 (offsite consequences) PRA using the MELCOR Accident Consequences Code System Version 2 (MACCS2) (Section E.3).

- Baseline Risk Monetization – Use U.S. Nuclear Regulatory Commission (NRC) regulatory analysis techniques to calculate the monetary value of taking no further action to reduce the consequences of potential severe accidents for TMI-1. This becomes the maximum averted cost-risk (MACR) that is possible (Section E.4).

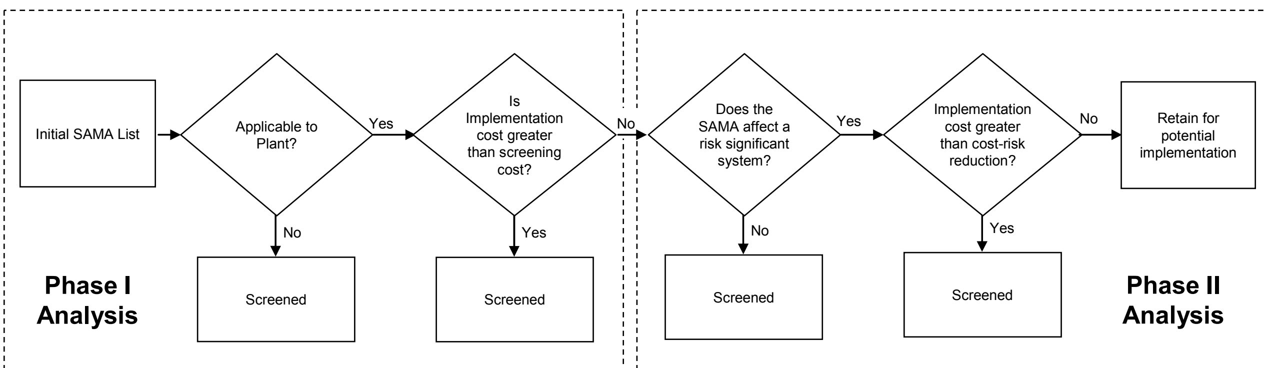
- Phase I SAMA Analysis – Identify potential SAMA candidates based on the TMI-1 PRA, Individual Plant Examination – External Events (IPEEE), and documentation from the industry and NRC. Screen out Phase I SAMA candidates that are not applicable to the TMI-1 design or are of low benefit in pressurized water reactors (PWRs) such as TMI-1, candidates that have already been implemented at TMI-1 or whose benefits have been achieved at TMI-1 using other means, and candidates whose estimated cost exceeds the possible MACR (Section E.5).

- Phase II SAMA Analysis – Calculate the risk reduction attributable to each remaining SAMA candidate and compare to a more detailed cost analysis to identify the net cost-benefit. PRA insights are also used to screen SAMA candidates in this phase (Section E.6).

- Uncertainty Analysis – Evaluate how changes in the SAMA analysis assumptions might affect the cost-benefit evaluation (Section E.7).

- Conclusions – Summarize results and identify conclusions (Section E.8).

The steps outlined above are described in more detail in the subsections of this appendix. The graphic below summarizes the high-level steps of the SAMA process.



E.2 THREE MILE ISLAND PRA MODEL

This section provides a summary of the Three Mile Island (TMI) PRA model used to support the SAMA analysis and the changes that have been made to the model since the individual plant examination (IPE). The external events models are not specifically discussed in this section.

E.2.1 LEVEL 1 TMI PRA MODELS

The TMI 2004 Revision 2 Level 1 PRA model (Exelon 2007a), the most recent model, calculated a Core Damage Frequency (CDF) of 2.37E-5/yr and a value for Large Early Release Frequency (LERF) of 3.02E-06/yr. Table E.2-1 summarizes the historical values for previous TMI models and their calculated values for CDF and LERF.

E.2.2 HISTORY OF THE TMI PRA MODELS

E.2.2.1 RISKMAN PRA MODELS

The TMI-1 Level I PRA was updated in late 1989 and 1990 to revise the internal events portion of the Level I PRA that was initially completed in 1987. The updates were undertaken to reflect changes in plant design and procedures made since 1987 and to fulfill the requirements of NRC Generic Letter 88-20, "Individual Plant Examinations". In conformance with those requirements the major objectives of the PRA update were to:

1. Further develop an appreciation of severe accident behavior.
2. Build on the understanding of the most likely severe accident sequences that could occur at TMI-1.
3. Improve the quantitative understanding of the overall probabilities of core damage.

The updates were conducted in a manner that maximized the use of in-house personnel. Plant and Support PRA analysts and engineers and operators who were familiar with the details of the design, controls, procedures, and system configurations were directly involved in the analysis as well as the technical review.

Various consultants have assisted the TMI-1 PRA staff in the update by providing expertise in the plant model revisions and in various special analyses. An additional objective of the study was to build on existing in-house PRA expertise and to develop tools for ongoing risk management activities after the completion of the PRA update.

The IPE submittal (December 1992 model) was based on the plant as it was configured in 1991. The RISKMAN models of 2000, 2001, and 2003 were based on the plant as it was configured in 1998. The 2001 model, which was known as L2RV2, was the one primarily used for configuration risk management purposes. Although the 2003 RISKMAN model (ABSA) (ABS 2003) was not officially used for configuration risk management purposes, it provided the basis for later PRA models that were converted to CAFTA. The list below shows the major plant and procedure changes made since 1987 that were significant to these RISKMAN PRA models. Most of these changes were made as a result of insights gained from the original 1987 PRA model.

1. Addition of an alternate AC source (TMI Unit 2 diesel generator) with the ability to tie into either division of 1E power.
2. Installation of improved reactor coolant pump seals that reduce the likelihood of seal failure under loss of injection and cooling conditions.
3. Modification of the power supplies to the ICS that eliminates loss of 120V AC bus ATA power as an initiating event.
4. Addition of an air compressor, air dryer and filters that improves the reliability of the instrument air system.
5. Change to procedure for loss of air that directs the operator to manually open RCP seal return valve (MU-V-20). This assures continuation of RCP seal injection during loss of air scenarios.
6. Modification of the power supplies to the "B" HPI pump and its associated lube oil pumps that assures they both are supplied from the same source of power. This reduces the chances of pump failure if power is lost.
7. Relocation of the control switches for HPI pump min-recirc valves (MU-V-36 and 37) from the back panels to the control room console. This reduces the likelihood of operator failure to re-establish min-recirc after throttling HPI and thus reduces the likelihood of pump damage and consequent loss of RCP seal injection.
8. Changes to procedures for loss of river water events that direct the operator to alternate make-up pumps to utilize the heat capacity of the DHCC system as a heat sink for pump cooling, and if necessary to cross-connect firewater to the DHCC heat exchangers. This reduces the likelihood that a loss of river water intake event would lead to loss of RCP seal injection.
9. A change to torque switch settings for DHR isolation valves (DH-V-4A & B) that improves the ability of the valves to be closed against a high differential pressure. This reduces the likelihood of an interfacing system LOCA (ISLOCA) through these valves.
10. Addition of a diverse scram system to reduce the likelihood of an ATWS.

11. Modification of the balance of plant power supply distribution to minimize the chances of trip due to loss of DC train A.

12. Replacement of the analog turbine control system with a digital control system.

For a closeout summary of the recommendations of the 1987 PRA, which includes most of these changes, see GPUN letter to NRC of February 22, 1990 (H.D. Hukill to NRC, #C311-90-2012).

Two independent reviews of the December 1992 update were conducted: one by an independent in-house group consisting of managers of key organizations, and one by an external consultant. The purpose of the independent in-house review was to ensure the accuracy of the documentation and to validate the PRA process and its results. The external consultant review was conducted to ensure that proper PRA techniques were employed and that key issues were addressed. The results of these reviews were provided in Appendix D of Reference (GPU 1992).

E.2.2.2 CAFTA PRA MODELS

As mentioned above, the ABSA 2003 RISKMAN model provided the basis for a conversion to a Level 1 CAFTA software model in 2004. The ABSA model addressed significant findings from the TMI PRA Peer Certification ("A" and "B" F&Os). The CAFTA conversion improved the details in several system models, accident sequence event trees, and updated the initiating event and component failure/unavailability rates. Changes made to the PRA were done to support procedural requirements for a periodic update to support risk informed applications and configuration risk management. The 2004 Revision 0 model was never officially implemented, with the 2004 Revision 1 model being the official model of record since June 2005 (Exelon 2005b). The 2004 Revision 1 upgrade was performed to correct errors discovered subsequent to the conversion to CAFTA (the 2004 Rev. 0 model) and enhance the model for use in configuration risk management.

Key changes made to the TMI PRA since the RISKMAN TMIL2RV2 model of 2001 are listed below. Changes made to the model for the interim 2003 update (TMIABSA) are so designated:

1. [TMIABSA] Incorporated updated values for initiating event frequencies, component failure rates, unavailability, and common cause factors.

2. [TMIABSA] Updated the Level 2 model assumptions to reflect progress in industry research and understanding from the last several years.

3. [TMIABSA] Updated entire HRA using EPRI HRA Calculator.

4. [TMIABSA] Re-evaluated success criteria and operator action timing using results from updated thermal-hydraulic (MAAP) analyses.

5. [TMIABSA] Refined the screening analysis previously used for internal flooding

6. Converted the Model from a RISKMAN linked event tree model to a CAFTA single top event fault tree model. During this conversion each event tree was modified.

7. Enhanced the following system models:

    Main Feedwater and Main Steam as they relate to OTSG isolation for SGTR and secondary line breaks.

    4KV/480V AC power was updated to include individual fault trees for 480V buses and MCCs.

    Updated common cause data to NUREG/CR-5497.

    Added logic to evaluate system availability following offsite power recovery.

8. Performed a detailed operator action dependency analysis. Developed Joint Human Error Probability (JHEP) basic events and added them to the PRA model as appropriate.

9. Performed numerous minor updates and enhancements to the model, which included changes to basic event names and probabilities, nodal logic for most event trees, and the logic for several top events and systems. These changes are all described in Attachment C of Reference (Exelon 2005b).

The 2004 Revision 2 model, upon which this SAMA analysis is based, superseded the Revision 1 model in 2007. Key changes and modifications included revision of common cause failure events and their probabilities using the data provided in (NRC 1998b). A summary listing of the changes and improvements made since the 2004 Revision 1 model is listed below:

1. New basic events were added to the PRA model for common cause failures of the batteries, inverters, battery chargers, pressurizer safety valves, and steam generator atmospheric dump valves.

2. New maintenance unavailability events were added to include maintenance on various components not previously modeled. Various old maintenance unavailability basic event names were replaced with new names to adopt a more consistent naming scheme. The time period for the maintenance unavailability data was the same as that used for the Revision 1 model (1998 to 2001).

3. Revision of fault tree logic for the makeup pumps in support of the high pressure injection and reactor coolant pump (RCP) seal injection functions.

4. Uncertainty data was added to the TMI database files, which identified error factors and the distribution type (lognormal) for type code assignments and unique basic events, such as maintenance unavailabilities, common cause events, and human event probability (HEP) actions.

5. Addition of new HEPs for controlling emergency feedwater, cooldown of the reactor coolant system (RCS), and steam generator isolation.

6. New HEP dependencies were identified and JHEP events created to account for the addition of new HEPs within the PRA model for the electrical DC and Nuclear Service River Water (NSRW) systems.

7. The loss of offsite power (LOOP) initiating event frequency was revised to be 4.48E-2 per year based on a generic prior distribution with a Bayesian update using data from 1997 to 2003.

8. Since low pressure recirculation (LPR) was considered a viable option given the success of cooling down the RCS, the event tree for Very Small LOCAs was modified to include a low pressure recirculation node.

9. New logic was added to account for makeup pump lube oil pump run failures and power supply dependencies, since failure of both lube oil pumps will fail their respective makeup pump.

10. New logic was added to the Decay Heat River Water system fault trees to account for the fact that the decay heat river pumps are running about 50% of the time (25% for each train), and thus would not need to start.

11. Improvements were made to the logic for the NSRW system that credits use of the Secondary Service River Water (SSRW) system to recover failures of NSRW, e.g., failure of the NSRW pumps. Also, adjustments were made to take credit for recovery of certain loss of NSRW initiators (%LNR); since it was found that a 73% contribution toward initiating event %LNR was recoverable by use of the NSRW-SSRW cross-tie.

12. Inverters 1E and 1F in the 120V AC vital electrical system were credited with the ability to provide a backup power supply for the normally in-service inverters.

Section E.2.4 summarizes the peer reviews performed on the TMI-1 PRA models.

E.2.2.3 TMI LEVEL 2 MODEL

The Level 2 model used for the SAMA analysis is linked to the core damage sequences from the CAFTA 2004 Revision 2 Level 1 model described above. The methodology for the Containment Event Tree (CET) solution, the CET quantification, and source term development were based on the TMI IPE Level 2 analysis of 1993, which was originally based on the Oconee PRA Level 2 analysis. Oconee and TMI-1 designs were compared to identify any significant differences in plant characteristics. Then, the Oconee CET model and its quantification were modified to reflect these differences, as well as develop a plant specific model for TMI-1. TMI-1 specific analyses using the MAAP code were performed to further enhance the Oconee model and verify its applicability to TMI-1. The TMI CAFTA Level 2 model of 2007 and CET used for this SAMA analysis are fully described in the TMI-PRA-001 (Exelon 2007b).

E.2.2.3.1 Level 1 to Level 2 Interface

In order to determine the consequences of a reactor accident, the sequences identified as leading to core damage must be analyzed in terms of various phenomena that can occur in-plant (i.e., inside the reactor vessel and containment). This involves carrying the sequences through the Containment Event Tree (CET) and determining the radionuclide releases for the various pathways through the CETs. To make this process more manageable, core damage sequences with similar characteristics are grouped into Plant Damage States (PDSs). This grouping procedure was developed through an iterative process resulting in a method that allowed core damage sequences to be grouped according to the status of plant systems at the onset of core damage (Duke 1990).

PDSs are a combination of three separate binning characteristics:

1. Core melt bin - describes the status of the primary (reactor coolant) system and related systems during core damage.
2. Containment safeguards state - describes the status of containment related systems.
3. Containment isolation state - determines whether or not containment is isolated.

The description of the binning process is discussed in terms of assigning sequences to core melt bins and use of a “bridge” tree to categorize containment safeguards/isolation states; however, these are concepts that are applied in the nodal logic of the CET rather than complete, stand alone event trees or decision trees. For example, each CET sequence includes all core damage cutsets in the “initiating event” of the sequence, but for each node, specific core melt binning logic is used to quantify the node. For the “BYPASS” CET node, one of the inputs is a gate containing Core Melt Bin 19 events (CM-019), which are ISLOCA events. Gate CM-019 was manually created based on the Plant Damage State rules and used for the “BYPASS” evaluation because it satisfied the requirements for “containment bypass” cases.

Similarly, the containment safeguards/isolation state bridge tree was used to manually develop logic gates for use in the CET nodes. An example of how the bridge tree logic is used is the evaluation of the “Fission Product Scrubbing is Effective” node. One potential means of scrubbing is the “plateout” mechanism, which is possible for releases that occur in the lower section of the auxiliary building. These include safeguard/isolation states G through R of the bridge tree. Logic representing these safeguard/isolation states was developed and included in the CET logic to allow only those sequence including isolation failures to pass through "plateout" logic for the "Fission Product Scrubbing is Effective" node.

Section E.2.2.3.1.1 provides further details related to the development of the PDS definitions for TMI-1.

E.2.2.3.1.1 DEVELOPMENT OF PLANT DAMAGE STATES

The plant damage states consider both the characteristics of the core material released to the environment and the mechanism by which the release is made from the containment. The content of the release is determined by the multiple factors, including the way in which core debris interacts with the containment and on the operation of mitigating systems, such as containment spray. The containment failure mode determines other factors such as the size and timing of the release. These issues are described in more detail in the following subsections.

E.2.2.3.1.1.1 SEQUENCE CHARACTERISTICS THAT AFFECT CONSEQUENCE ANALYSIS

Source Term Magnitude and Isotopic Content

The magnitude and isotopic content of the source term are affected by:

- The mechanisms by which radionuclides are released from the fuel,
- Retention of radionuclides in the primary system,
- The performance of active radionuclide removal systems such as the containment sprays,
- The mechanisms by which radionuclides are naturally removed from the containment atmosphere, and
- The mode of containment failure.

The mechanisms by which radionuclides are released from the fuel depend on the progression of the accident. For example, if energetic attack of the concrete basemat by the core debris occurs, this can release large amounts of tellurium, a significant contributor to early fatalities. If a continuous supply of water contacts the core debris, a coolable debris bed can be formed and the tellurium release can be prevented or terminated (FAI 1987). Thus, it is necessary to know what plant conditions cause water to be present in the reactor cavity and at what times.

Retention of fission products in the primary system can also be affected by system response. For example, core melt sequences following a large LOCA would result in significantly less primary inventory retention than would station blackout core melt sequences. Additionally, such factors as secondary side heat removal (SSHR) also affect the likelihood of revaporization of deposited radionuclides later in an accident. Revaporization of deposited radionuclides near the time of containment failure can significantly increase the release to the environment from a late containment overpressurization.

Active radionuclide removal is accomplished by the containment sprays (NRC 1982). Containment sprays affect the magnitude of the source term by removing radionuclides from the atmosphere. Sprays affect the isotopic content of the source term because they are much more efficient in removing particulates than other forms of radionuclides. Therefore, it is necessary to know if and when containment sprays are operating.

Natural removal processes also affect the magnitude of the source term. The effectiveness of gravitational settling and plateout on walls is dependent to a certain extent on the thermal-hydraulic conditions of the containment atmosphere. More importantly, it depends on the residence time of radionuclides in a given volume and thus on the type and time of containment failure.

Containment Failure

The energy and duration of the radionuclide release and the warning time for evacuation are influenced by the type and time of containment failure. A structural (large breach) failure due to overpressurization will have a high energy of release as the containment rapidly depressurizes to atmospheric pressure from its failure pressure. The duration of release will be short due to the rapidity of the depressurization. Containment leakage due to an isolation failure would be more gradual. The duration of the release would be longer, and the energy associated with that release would be lower than for the puff release from overpressurization-induced failure. If containment integrity is maintained and the only releases are associated with design leakage, the energy of release is negligible and its duration is very long. Thus, the energy and duration of release depends on the type, or mode, of containment failure.

Warning time for evacuation is the time between the loss of long-term cooling capability and the release of radioactivity to the environment. An early core melt followed by an early containment failure (prior to 5 hours) does not allow much warning time (approximately 0-2 hours), whereas a late overpressurization may be gradual and predictable, allowing a significant amount of time for evacuation. The timing of containment failure can thus have an effect on warning time.

Containment overpressurization can result from large combustible gas burns, steam spikes, direct containment heating (DCH), and a gradual buildup of steam and/or non-condensables. Since TMI-1's containment is constructed on limestone concrete, core-concrete interaction results in significant non-condensable gas (e.g., CO and CO2) production. Carbon monoxide is a combustible gas. The computer code MAAP, which was used to model containment behavior following postulated core melt events, allows for carbon monoxide to burn in the same fashion as hydrogen for combustible gas burns in containment.

Combustible gas burns are influenced by the concentrations of oxygen and steam within the containment. The timing and severity of a combustible gas burn can also depend on the rate at which hydrogen is released to the containment from the Reactor Coolant System (RCS). In general, the larger the leak path (break size), the faster the hydrogen is released and the smaller the amount that is retained in the RCS until reactor vessel failure. The leakage path also affects the rate of hydrogen production in the core by controlling the release rate of steam. The amount of steam available for the oxidation reaction affects the rate at which hydrogen is formed. The Containment Air Cooling Units (CACUs) also affect the combustible gas phenomenon within the containment. The CACUs are responsible for removing heat from the containment atmosphere and they also circulate the air within the containment, thus developing uniform concentrations of atmospheric constituents. The CACUs reduce the steam concentration, thus providing more suitable conditions for combustible gases to burn. However, the operation of the CACUs will also lower the containment base pressure and help to mitigate the effects of a combustible gas burn.

DCH is another phenomenon that can lead to containment overpressurization. This phenomenon is important for sequences in which a core melt is initiated while the RCS is at a high pressure. It has been hypothesized that the corium (molten core material) can be ejected, under high pressure, from the reactor vessel and be dispersed into the containment atmosphere as finely fragmented particles. Airborne particulate debris could then rapidly release chemical (oxidation of metallic constituents) and thermal energy directly to the containment atmosphere.

Although the CACUs are not sufficient to stop DCH from occurring, their operation would be expected to lower the containment base pressure and thus help to mitigate the effects of DCH.

The containment sprays can also help mitigate the effect of combustible gas burns and DCH by reducing the static containment pressure.

It has been stated that the warning time for evacuation is defined as the time between loss of long-term cooling capability and the release of radionuclides to the environment. The time from shutdown to the loss of long-term cooling capability impacts the warning time given that the core decay heat load, and therefore the time to core melt, is a function of time. Even though recommended evacuation times are much longer than two hours, studies of past evacuations have shown that two hours is more than sufficient time to evacuate the majority of the population participating in the evacuation plan (PRC 1981). The SAMA evaluation uses site specific analysis to evaluate the impact of evacuation of offsite consequence, as described in Section E.3.6.

E.2.2.3.1.1.2 CORE MELT BINS

The core melt bin is the first of three characteristics that define the PDS. The core melt bin definition describes the status of the RCS and associated systems at the onset of core damage. Table E.2-2 lists the 19 core melt bins used in the TMI-1 PRA and provides a brief definition of each. This section describes the derivation of the core melt bin definitions, in terms of the RCS leakage rate, loss of primary system makeup capability, and the condition of SSHR. Tables E.2.3 through E.2.13 document how each of the core damage sequences are assigned to the core melt bins.

E.2.2.3.1.1.2.1 Reactor Coolant System Leakage Rate

The RCS leakage rate is important in binning core damage sequences because it affects primary system pressure, timing of core damage, fission product retention in the primary system, and hydrogen release rate. There are four distinct leakage rate categories:

- Small LOCA,
- Medium LOCA,
- Large LOCA, and

- Cycling relief valve.

Also, there are two special leakage categories:

- Steam generator tube rupture (SGTR),
- Interfacing systems LOCA.

The small LOCA leakage rate is small enough that SSHR is effective in delaying core damage. Also, for small LOCAs, the primary system pressure will remain high during core damage (expected pressures are in the 1000 psia range) and may lead to a high-pressure melt ejection (HPME) when the reactor vessel fails. For TMI-1, a core melt sequence can be grouped as a small LOCA if it has one of the following break size characteristics:

- 0.007 ft2 to 0.1 ft2 breaks (DE&S 1992)
- Stuck open pressurizer PORV
- Stuck open SRV
- Reactor coolant pump (RCP) seal LOCA
- Steam generator tube ruptures that have an intact secondary system

The medium LOCA leakage rate is a primary system failure that is small enough that the primary pressure will be relatively low (expected pressures are in the 300 to 400 psia range) so that the risk of a HPME accident is significantly reduced. For TMI-1, the medium LOCA size is from 0.1 ft2 to 0.5 ft2 breaks (DE&S 1992).

The large LOCA leakage rate is large enough that the primary system pressure will be very low (expected pressure is less than 200 psia) so that there is little risk of a HPME. For TMI-1, breaks of this size are equal to or larger than 0.5 ft2.

For those primary system ruptures involving pressurized thermal shock (PTS), a rapid cooling transient stress on the reactor vessel while at relatively high pressure, it was assumed that for this condition to occur, some type of primary injection must have been successful in order to achieve the requisite low temperatures at pressure. It was further assumed that the PTS condition would lead to a rupture of a size equivalent to a large LOCA. Therefore, those core damage sequences identified by PTS were categorized as large LOCA with successful injection but failure of early recirculation, i.e., core melt bin 2.

A stuck open or cycling pressurizer relief or safety valve sequence would result in the primary system pressure remaining high (around the PORV set point) such that, if core melt occurred, the risk of a HPME would be high. In general, non-LOCA core melt sequences, such as transient and loss of offsite power (LOOP) sequences, were grouped with the cycling relief valve core melt category.

The leakage category SGTR represents those steam generator tube rupture sequences where there is also a failure of the secondary system. This would result in a direct path for fission product release to the environment with little or no possibility of retention. The scrubbing and retention that is provided by SGTRs with intact steam generators are sufficient to group these with the intact containment plant damage states. For event sequences involving an intact primary system, i.e., no LOCA, and only a tube rupture within a single generator (with failure of the secondary system), core melt bin 16 (Table E.2-2) was chosen to represent this particular scenario.

The interfacing systems LOCA leakage category contains core melt sequences resulting from a rupture in a low-pressure system connected to the primary system. These sequences result in fission product releases that bypass the Reactor Building, but there is still the possibility of some retention in the buildings outside containment.

E.2.2.3.1.1.2.2 Loss of Primary System Makeup Capability

For core damage to occur, multiple failure of mitigation systems must occur. The timing and mode of failure of the primary system makeup capability can affect the characteristics of the PDS. For example, for sequences involving a loss of primary coolant, the timing of core damage is significantly affected by the time at which the safety injection systems fail. Also, the status of safety systems helps to determine whether or not the reactor cavity can be flooded, which impacts the post-core damage analysis. Core damage sequences are grouped into one of the following groups:

- Injection failure – sequences in which injection systems fail initially and do not inject the Borated Waste Storage Tank (BWST) contents into containment.
- Recirculation switchover failure – sequences in which injection systems fail when the BWST

contents have been injected into containment and switchover to sump recirculation is attempted.

- Recirculation run failure - sequences in which injection systems switchover to sump recirculation following successful injection, but then fail later due to a run failure of the injection or support systems.

A simplification was made with regard to start and run failures associated with recirculation of water from the containment sump. The dominant early recirculation failures (start failures) were associated with either failure of human actions (including dependent actions) involving operator switchover to sump recirculation prior to emptying the BWST or common cause failure mechanisms, such as valves DH-V-6A, and -6B, or DH-7A, and -7B failing to open, or the DHR pumps both failing to start. All other failures were assumed to be non-dominant start failures or are those that are truly designated as run failures, e.g., heat exchangers plugging, valves failing to remain open, etc.

E.2.2.3.1.1.2.3 Condition of Secondary Side Heat Removal

The status of the SSHR System at the onset of core damage is also an important characteristic of the core damage sequence. SSHR can affect the time of core damage, the primary system pressure, the fission product retention in the primary, and operator actions that might affect core damage progression. There are two categories for the SSHR status:

- SSHR is available.
- SSHR is unavailable.

E.2.2.3.1.1.2.4 Anticipated Transients Without SCRAM

1. For Anticipated Transients without Scram (ATWS) scenarios, the reactor fails to trip in conjunction with another initiating event that prompted the trip signal. Failure to trip the reactor when a valid trip signal occurs results in excessive thermal energy increasing reactor coolant system (RCS) pressure and temperature. The assumptions given below were imposed in order to associate the various ATWS scenarios with the appropriate, or at least conservative, core melt definition from Table E.2-2. Also, since the ATWS event tree (Exelon 2005a) did not address availability of high-pressure injection for certain sequences that lead directly to core damage, failure of early injection was assumed.
2. Core moderator temperature coefficient (MTC) provides a natural feedback control mechanism in which core power is reduced as the moderator (reactor coolant) temperature increases. It is a function of the time in cycle for a given core. For

conditions where there is an unsatisfactory moderator temperature coefficient (e.g., early in a cycle), excessively high RCS pressures may result due to insufficient negative feedback. Although the precise impact on the RCS in such a scenario depends on many other factors and could be benign, this scenario was assumed to result in a large LOCA without the ability to use high-pressure injection (core melt bin 1).

3. For both pressurizer safety valves and PORV unavailability, a large LOCA scenario without high-pressure injection (core melt bin 1) was assumed.

4. For loss of feedwater and inadequate secondary side pressure relief, the core melt bin with cycling primary relief valve without injection (core melt bin 12) was assumed.

5. For those scenarios with explicit failure of high-pressure injection, core melt bin 12 was assumed. SSHR, even if successful, was assumed inadequate for RCS heat removal.

6. For those scenarios involving failure of high-pressure recirculation, core melt bin 14 was assumed (late recirculation failure) instead of bin 13, since it is not clear that this sequence would actually lead to core damage.

E.2.2.3.1.1.3 CONTAINMENT SAFEGUARDS STATES

The containment safeguards state is the second of three characteristics that define the PDS. The containment safeguards state describes the status at the onset of core damage for systems that provide a containment protective function. These systems include the reactor building spray system, and the containment air cooling units (CACUs), which are part of the reactor building emergency cooling system. These systems affect many decisions in the CET and, as a result, they affect accident progression. For example, the containment sprays affect fission product scrubbing, the flooding of the reactor cavity, and the time to reach core damage.

E.2.2.3.1.1.4 CONTAINMENT ISOLATION STATES

The third and final PDS characteristic is the status of containment isolation. Containment isolation is critical to preventing fission product release to the environment. Scoping studies with the MAAP computer code have indicated that there are two categories of containment isolation failure. Small isolation failures allow fission product releases much greater than those for an isolated containment with design leakage. However, the small isolation failures are less severe than early containment failures because they significantly reduce the release rate of fission products. Large isolation failures provide little or no delay in the fission product releases and are essentially the same as early containment failures. For TMI-1, the three containment isolation states are:

1. Isolated - containment is properly isolated.

2. Small isolation failure - containment failure prior to core damage with hole size less than or equal to six inches. A small isolation failure precludes late overpressurization of containment, but does not preclude early overpressurization of containment.

3. Large isolation failure - containment failure prior to core damage with hole sizes larger than six inches. Large isolation failures preclude both early and late overpressurization of containment.

E.2.2.3.1.1.5 PLANT DAMAGE STATE DEFINITION

The PDSs are developed by combining the core melt bins, the containment safeguards states, and the containment isolation states. The PDS definition contains sufficient information about the sequences grouped into it that they may be treated as one. This information is critical input information for solving the CET. The PDS, rather than the individual sequences, determine the branch point frequencies in the CET.

Table E.2-2 lists and describes the 19 core melt bins and Table E.2-14 lists and describes the 18 combinations of containment safeguards states and containment isolation states. PDSs are described by a two-designator variable as follows:

XY

Where: X = core melt bin

Y = containment safeguards and isolation states

The containment safeguards and isolation states were determined by the use of an event tree termed the “bridge” tree, since it bridges the gap between core melt scenarios, plant damage states, and the containment event tree for quantification of release categories. As discussed in Section 2.2.3.1, these PDSs manifest themselves in the model as local portions of CET nodal logic representing the applications of the binning concepts described above. There are no PDS flags associated with the cutsets as is common in other Level 2 model applications.

E.2.2.3.2 Containment Event Tree Purpose

The purpose of the Containment Event Tree (CET) is to quantify containment failure modes and radionuclide releases. Any phenomena that have a significant effect on the radionuclide release fractions or the timing, energy, and duration of the release are included in the tree as a top (header) event. The core damage sequences were categorized into Plant Damage States (PDSs), as determined in Section 2.2.3.1. These core damage sequences are treated as initiating events for the CET. The paths that the PDSs can take through the event tree depend on how they affect the various events modeled. Because the path taken at each top event is based on probabilities and system fault tree evaluations, each PDS will appear at more than one CET end point with varying frequency. Thus, each end point can have more than one PDS state contributing to its total frequency.

E.2.2.3.2.1 CONTAINMENT EVENT TREE DESCRIPTION

Containment event trees, in some cases, have become so complex that the CETs can not be easily represented and are difficult to understand by anyone other than a consequence analyst. The approach used for the TMI-1 analysis relies on converting the large and complex CET into a combination of a small event tree and large decision trees.

In developing the TMI-1 small CET, the only questions included are those that have an effect on the release timing, energy, location, or fission product fractions. When completed, each CET end state represented a separate release category. The CET release category results are presented in Section 2.2.3.3.

After the containment event tree was developed, decision trees using both success and failure logic were developed to determine the probability of the appropriate top event (node) in the CET. This approach was used to avoid the use of NOT gates for sequence success logic, which tended to make the model more complicated and difficult to quantify.

The CET developed for TMI-1 consists of 11 nodal top events that were modeled via the use of Boolean logic, for both success and failure of each branch. The following section defines and describes the CET top events and their associated decision trees. The top events are summarized in Table E.2-15. The logic for each of the CET nodes is cumbersome and complex, so it is not included in this discussion.

To make use of the CET, the important characteristics of the plant's containment must be identified. Three of the more important features that must be considered are the containment ultimate strength capacity, the concrete type, and the reactor cavity arrangement.

The ultimate capacity of containment provides the basis for establishing containment failure probability and failure modes given various accident progression scenarios. TMI-1, is a Babcock & Wilcox PWR with vertical straight-tube (once-through) steam generators that produce superheated steam at constant pressure. The reactor and the nuclear steam supply system are contained within a Reactor Building that is a post-tensioned reinforced-concrete cylinder and dome. The interior of the surface of the building is lined with a one-quarter inch thick welded steel plate to ensure a high degree of leak tightness.

Generally, TMI-1 can be placed into the category of PWR large dry containments, because of their high mean failure pressure, overall containment volume, and open lower containment configuration.

The type of concrete affects the type and properties of gases released during concrete attack. TMI-1's concrete contains a limestone aggregate, which can result in significant non-condensable gas production during concrete ablation.

The reactor cavity geometry affects how (or if) water can reach the cavity during a core damage sequence. The cavity arrangement is important when considering the following phenomena:

- Ex-vessel debris bed coolability
- Potential for direct containment heating
- Ex-vessel steam generation
- Ex-vessel hydrogen or combustible gas production
- Ex-vessel fission product release
- Hydrogen or combustible gas recombination
- Long-term containment overpressurization
- Basemat melt-through
- Potential for debris-liner contact
- Sources of water and pathways to the lower reactor cavity

E.2.2.3.2.2 CONTAINMENT EVENT TREE TOP EVENTS

In this section, the CET top events are defined and described. The CET top events are summarized in Table E.2-15.

CET Top Events	Description
A: Containment Bypass	**Does the release of radionuclides take place within the containment?** Success for this event means that containment is available as a barrier to fission product release. Failure means containment is not available as a barrier to fission product release. The types of accidents that bypass the containment are steam generator tube ruptures (as an initiating event or an induced event) and interfacing-systems LOCA. This top event is further developed using a decision tree model.
B: Containment Isolation	**Does the containment isolate such that: 1) a leakage rate sufficient to cause a substantial increase in radionuclide release to the environment does not occur, and 2) containment pressure response is not significantly affected?** Success for this event means that containment isolation performs its function so that containment becomes a barrier against flow of radionuclides to the environment. Failure means containment integrity is lost and a path is available for radionuclides to reach the environment. This event is concerned with the time at the beginning of the accident sequence (i.e., when isolation occurs) before radionuclides are released to the containment atmosphere.
C: Isolation Failure Size	**Is the isolation failure equivalent to a small hole size in containment?** Success for this event means that the isolation failure is small, i.e., system top event SMALL-ISO. For the TMI-1 analysis, a small isolation failure is defined as a six-inch equivalent diameter hole. Isolation failures of this type allow some time for holdup inside containment where natural removal mechanisms (e.g., plateout) will reduce radionuclide concentrations. Failure of this event implies that the isolation failure is not small, i.e., system top event LARGE-ISO, and allows little or no holdup in containment. Both small and large isolation failures preclude late overpressurization. All other containment overpressure sequences (hydrogen burns, direct containment heating, etc.) are prevented only by large isolation failures.
D: Auxiliary Building Release	**Does the fission product release pass through the Auxiliary Building?** Success for this event means that the fission product release will pass through the Auxiliary Building. This release path is the result of an interfacing-system LOCA or an isolation failure to the Auxiliary Building. Failure for this event means that the fission product release does not pass through the Auxiliary Building. A release path that bypasses the Auxiliary Building is a pathway directly to the environment. This top event is applicable only if containment is not isolated or is bypassed. Determination of success or failure depends on the type of isolation failure, where the fission products are released, and the PDS. For example, a SGTR would be a failure, while most interfacing systems LOCAs would be a success.
E: Early Containment Failure	**Does the containment remain intact until long after reactor vessel failure (i.e., a time period which allow sufficient time for fission product settling)?** Success for this event means that containment remains intact long after reactor vessel failure. Failure for this event means that containment has failed prior to or within the time required for fission product settling and decay of short-lived isotopes. This time period is typically defined as five hours after reactor vessel failure.
F: Late Containment Failure	**Does the containment remain intact throughout the entire core melt sequence?** Event success means that the containment remains intact throughout the entire core melt sequence. Releases to the environment after this point, if any, are due to normal containment leakage or basemat melt-through. Failure of this event means that containment fails late in the core melt sequence due to an overpressurization event.

CET Top Events	Description
G: Benign Containment Failure	**Is late containment failure benign?** Success for this event means that a late overpressurization results in a benign containment failure, i.e., leak-before-break. This failure mode is described as a series of small cracks that develop in the containment structure such that further pressurization does not occur. Failure of this event means that a late overpressurization results in a catastrophic containment failure, which would cause containment to depressurize rapidly. This is strictly a function of the containment type, and is quantified identically for all PDSs.
H: Ex-Vessel Release Of Fission Products	**Is a coolable debris bed established outside the reactor vessel so that significant ex-vessel fission product releases do not occur?** Success for this event means that a coolable debris bed is established in the reactor cavity or the containment, preventing an ex-vessel release. Failure means that a coolable debris bed is not established, allowing the corium to attack the concrete (producing non-condensable gases) and resulting in an ex-vessel release. The ex-vessel release involves a significant amount of tellurium and other fission products.
I: Containment Basemat Failure	**Is a coolable debris bed established in the reactor cavity to prevent containment failure from basemat melt-through?** Success for this event means that the debris bed in the cavity is cooled, and concrete ablation is stopped. Failure means that the debris bed is not cooled and ablates concrete until the basemat is failed.
J: Revaporization Release	**Is a revaporization release of volatile fission products at or near the time of containment failure prevented?** Success for this event means that large amounts of volatile fission products have not revaporized and are not available for release when containment overpressurizes. Failure means that volatile fission products that were deposited in the RCS have revaporized and are available to be released in large amounts when containment fails. Revaporization is only considered for late catastrophic containment failures. Early containment failures release fission products at or shortly after reactor vessel failure resulting in high release fractions. The effects of revaporization, if any, would not be seen for this failure mode. Late containment failures, however, provide time for radionuclide removal from the atmosphere by various methods. As a result, release fractions at containment failure are lower so that revaporization of fission products will have a larger impact. Revaporization is not considered for benign failures of containment since the pressure remains high due to the slow depressurization of containment. Since the pressure remains high in containment, revaporization is unlikely to occur.
K: Fission Product Scrubbing	**Are fission product removal mechanisms available to reduce the amount of radionuclides released to the environment?** Success for this event means that the fission products are scrubbed by some method prior to release to the environment. These mechanisms include: - Containment scrubbing (e.g., sprays) - Auxiliary Building scrubbing (e.g., plateout) - Steam Generator scrubbing (e.g., water pool release) Failure for this event means the fission products are not scrubbed prior to release to the environment by any method.

E.2.2.3.3 Release Categories and Source Terms

The endpoint of the CET contains two major pieces of information, which are the release frequency and the release category designation. The parameters that define a release category and are important in the analysis of offsite consequences are:

1. Time of release
2. Duration of release
3. Energy of release
4. Warning time for evacuation
5. Isotopic fractions released to the environment

Each CET end point is capable of describing a unique sequence with potentially unique release characteristics. For TMI-1, 39 release categories were identified in the CET with most endpoints having a unique release category designation. A numbering scheme is used to separate major categories:

- 1 = Containment Bypass with Auxiliary Building Bypass
- 2 = Interfacing-Systems LOCA
- 3 = Large Isolation Failures
- 4 = Small Isolation Failures
- 5 = Early Containment Failure
- 6 = Late Containment Failure (Catastrophic)
- 7 = Late Containment Failure (Benign)
- 8 = Basemat Melt-Through
- 9 = No Containment Failure

Different sequences within these major categories were given a designation such as 1.01, 1.02, 2.01, etc. in order to distinguish between specific details of the containment response. The 39 TMI-1 release categories are summarized in Table E.2-16.

The MAAP thermal hydraulics code was used to analyze the plant specific containment responses for each of the CET sequences. The 39 TMI-1 release categories were then reviewed in order to determine how they could be grouped for the assignment of source terms. It is possible to develop source terms for every release category in the CET, but in many cases, the results are so similar that maintaining unique source terms for every release category does not provide any measurable benefit. As a result, release categories with similar traits were grouped together and a single source term was used to represent the entire group to streamline the Level 3 analysis. For TMI-1, nine major source term groups identified above were found to be an adequate structure for segregating the source terms. The table below correlates the major source term groups to the source term designators and provides basic descriptions of the representative sequence established for each source term group:

Representative Sequence Descriptions for Source Term Groups

Release Category Group	Source Term Designator	General Description of Contributing Sequences
1: Containment Bypass w/ Aux Bldg Bypass	SGTR	This event is initiated with a double ended failure of a steam generator tube with the SG safety valve failed open. All injection is assumed unavailable. Emergency feedwater is available.
2: ISLOCA	ISLOCA	This event is initiated with a small break outside of containment followed by failure of injection. Emergency feedwater is available.
3: Large Isolation Failure	ISO-LG	This scenario is represented by a loss of main feedwater followed by a failure of all injection. A large containment isolation failure is assumed to occur at time zero. Emergency feedwater operates successfully for a period of 6 hours. At 15 minutes into the event, 42 gpm seal leakage is assumed per loop. Core damage occurs at 9.4 hours into the event followed by failure of the hot leg due to creep rupture 36 minutes later. Vessel breach occurs at 16 hrs.
4: Small Isolation Failure	ISO-SM	This scenario is represented by a loss of main feedwater followed by a failure of all injection. A small containment isolation failure is assumed to occur at time zero. Emergency feedwater is assumed unavailable. At 15 minutes into the event, 42 gpm seal leakage is assumed per loop. Core damage occurs at 50 minutes into the event followed by failure of the hot leg due to creep rupture 36 minutes later. Vessel breach occurs at 6 hrs.
5: Early Containment Failure	EARLY	This scenario is represented by a Station Blackout. Emergency feedwater operates successfully for a period of 6 hours. At 15 minutes into the event, 42 gpm seal leakage is assumed per loop. Core damage occurs at 9 hours into the event. Vessel breach occurs at 11.7 hrs. It is assumed that containment failure occurs at the time of vessel breach.

Representative Sequence Descriptions for Source Term Groups

Release Category Group	Source Term Designator	General Description of Contributing Sequences
6: Late Containment Failure (catastrophic)	LATE-LG	This scenario is represented by a loss of main feedwater followed by a failure of all injection. Emergency feedwater operates successfully. At 15 minutes into the event, 42 gpm seal leakage is assumed per loop. Core damage occurs at 26 hours into the event followed by failure of the hot leg due to creep rupture 40 minutes later. Vessel breach occurs at 34.8 hrs. The containment fails due to overpressure at 70 hours into the event with an assumed large failure area, resulting a rapid depressurization of containment.
7: Late Containment Failure (benign)	LATE-SM	This scenario is represented by a Station Blackout. Emergency feedwater operates successfully for a period of 6 hours. At 15 minutes into the event, 42 gpm seal leakage is assumed per loop. Core damage occurs at 9 hours into the event followed by failure of the hot leg due to creep rupture 50 minutes later. Vessel breach occurs at 16.5 hrs. Containment sprays are assumed to be recovered at 24 hours into the event. The core debris remains covered with water, however, without heat removal, the containment fails due to overpressure at 52 hours into the event. The breach area is assumed to be represented by a leak-before-break and results in a very slow containment depressurization.
8: Basemat Melt-Through	BMMT	This scenario is represented by a loss of main feedwater followed by a failure of all injection. Emergency feedwater operates successfully. At 15 minutes into the event, 42 gpm seal leakage is assumed per loop. Core damage occurs at 26 hours into the event followed by failure of the hot leg due to creep rupture 40 minutes later. Vessel breach occurs at 34.7 hrs. All of the core debris is forced to remain in the reactor cavity in order to accelerate the amount of core concrete attack. When concrete erosion has exceeded 6 feet, containment failure is assumed to occur with a representative failure area equal to 1 ft2.
9: No Containment Failure	INTACT	This scenario is represented by a loss of main feedwater followed by a failure of all injection. Emergency feedwater operates successfully. At 15 minutes into the event, 42 gpm seal leakage is assumed per loop. Core damage occurs at 26 hours into the event followed by failure of the hot leg due to creep rupture 40 minutes later. Vessel breach occurs at 34.6 hrs. Successful operation of containment sprays and fan coolers prevents containment overpressure failure long term.

Table E.2-17 provides additional accident progression information for the representative sequences described above, including the time to core damage, time to containment failure, and notable release fractions.

In some cases, there were competing contributors to a release category group with measurable differences in some of the release fractions (e.g., scrubbed vs. unscrubbed releases). The representative source term for the release category is typically chosen based on the largest frequency, but when the consequences of a source term with a smaller frequency are more severe, the more severe source term is used if it is believed that the group would otherwise be underrepresented.

The source terms that are used as input to the TMI-1 Level 3 model are a combination of radionuclide release fractions, the timing of the radionuclide release relative to the declaration of a general emergency, and the frequencies at which the releases occur. This combination of information is used in conjunction with other TMI-1 site characteristics in the Level 3 model to evaluate the consequences of a core damage event. Table E.2-18 provides a summary of the TMI-1 source term information, which includes the following:

- MAAP case identifier (for reference),
- Airborne release for each of the fission product groups provided my MAAP,
- Start time of the airborne release (measured from the time of accident initiation),
- End time of the airborne release (measured from the time of accident initiation).

Note that the individual release category frequencies are provided in Table E.2-16.

E.2.2.4 TMI MODEL RESULTS

Figure E.2-1 is a pie-chart showing the initiating event contribution to internal events CDF from the quantification of the TMI PRA 2004 Revision 2 model at a truncation limit of 1E-11. Table E.2-19 presents the ranked list of initiating events by their contribution to CDF. As can be seen in the table, about a third of the total CDF comes from loss of offsite power events. About one-half of CDF is due to a combination of transients and very small break (<1.0" diameter) and small break LOCAs (1"-4.3" in diameter). The next largest single contributor is loss of nuclear services river water, which accounts for about 16% of CDF. It is interesting to note that the large LOCA initiator, which represents the design basis accident for TMI-1, accounts for less than 1% of the total CDF. Figure E.2-2 is a bar chart displaying the system importance rankings (basically by Fussell-Vesely). Onsite emergency electrical power and offsite power sources dominate the contributions to CDF.

The TMI PRA includes a Level 2 model from which each of the release category frequencies can be calculated. The Release Category results are based on the TMI 2004 Revision 2 model, which was completed in 2007. Table E.2-20 presents the top initiating events for each of the release categories.

With regard to Large Early Release frequencies (LERF), the TMI LERF is estimated at 3.0E-6/year (12.7% of CDF). These results are slightly higher when compared to other PWRs with large dry containments that generally fall in the range from 3% to 10% of CDF. The contributions to LERF consist of the following release categories:

RC1-02	RC3-03	RC4-04
RC2-01	RC3-04	RC4-05
RC2-02	RC3-05	RC4-06
RC2-03	RC3-06	RC4-07
RC2-04	RC4-01	RC4-08
RC3-01	RC4-02	RC5-01
RC3-02	RC4-03	RC5-02

E.2.3 EXTERNAL FLOODING MODEL

The External Flooding model developed for the IPEEE was a simplified, Level 1 PRA evaluation. While there are words in the IPEEE that indicate it is a Level 2 analysis, the depth of any containment performance analysis that was carried out was not robust enough to support the SAMA analysis. In order to provide a means of evaluating the external flooding based SAMAs, it was necessary to develop representative source terms and release frequencies for the most important flooding contributors. This process is described in Sections E.2.3.1 and E.2.3.2.

E.2.3.1 CORE DAMAGE SEQUENCE IDENTIFICATION

The core damage sequences developed for the external flooding model include three major groups:

- Floods with elevations greater than 310 feet mean sea level (msl)
- Floods with elevations between 305 and 310 feet msl,
- Floods with elevations less than 305 feet msl.

Of these groups, the floods above 310 feet and those below 305 feet are each represented by a single core damage sequence. The floods between 305 and 310 feet are represented by six sequences that were quantified using an event tree developed specifically for the IPEEE external flooding evaluation. The descriptions and frequencies of these sequences are summarized in Table E.2-21.

E.2.3.2 LEVEL 2 BINNING OF EXTERNAL FLOODING SCENARIOS

In order to provide the input required for the Level 3 analysis of the external flooding scenarios, it was necessary to use the information in the IPEEE to estimate the plant response after core damage. Two separate processes were required to address the different flood scenarios. For the 305’ to 310’ msl floods and the floods greater than 310’ msl, the flooding sequences were analyzed and direct correlations between the core damage sequences and the source terms were developed. For floods below 305’ msl, the containment performance characteristics for LOOP events were used to determine the releases given the similarity in the events.

E.2.3.2.1 Source Term Correlation for External Flood Sequences Over 305’ msl

In order to determine the quantitative distribution of the flooding sequences among the TMI-1 source terms, it was necessary to make assumptions about the reactor status based on the information available in the IPEEE, determine which sequences should be binned to specific source terms, and then calculate the conditional probabilities of the relevant CET sequences.

For cases where the transition to cold shutdown was not completed before accident initiation, a specific set of valves corresponding to a small pathway would be left open and a conditional probability of 1.0 was assigned to the “Iso Sm” source term (small isolation failure). These sequences are all from the IPEEE 305’ to 310’ msl flood cases and include:

- Sequence “B”
- Sequence “D”
- Sequence “E”
- Sequence “F”

The remaining sequences are evolutions in which the plant is successfully transitioned to cold shutdown before the onset of accident conditions. These sequences include:

- Floods >310’ msl
- 305’ to 310’ msl flood sequences “A”
- 305’ to 310’ msl flood sequences “C”

In these cases, there are a number of ways in which the containment could fail and the Level 2 CET was used to estimate the conditional failure probabilities assuming that containment isolation was initially successful. The conditional probabilities for theses sequences were calculated by quantifying specific nodal events in the CET that were chosen because they helped establish source term bins. Table E.2-22 summarizes the binning characteristics of each of these nodes:

A simplified version of the TMI-1 CET (see Figure E.2-3) has been developed using only these nodes to graphically depict the binning process and to document the fractional division of the relevant external flooding sequences among the source terms. Additional details related to the CET development and uses are provided in the TMI-1 Containment Event Tree Analysis Notebook (Exelon 2007b).

E.2.3.2.2 Source Term Correlation for External Flood Sequences Below 305’ msl

External floods below 305’ msl do not have an impact on TMI-1 other than any LOOP event that may accompany the flood conditions, which is an insight that was used to estimate the containment performance and release characteristics for these events. The PRA model was quantified with all initiating events other than LOOP set to zero in order to simulate the conditions expected to exist for external floods below 305’ msl. The resulting release category frequencies were used to define the generic fractional distribution of these flood events among the 39 release categories.

Review of the release category frequencies demonstrated that 95% of the risk is associated with only 8 of the release categories. In order to simplify external flooding calculations, only these 8 release categories are used in the external flooding quantifications. The 5.3 percent contribution from the non-used release categories has been accounted for by adding 5.31E-02 to the total for RC5-01, the “Early” release bin, which is conservative for the purposes of the SAMA analysis. The following table summarizes the RC fractions used in the quantifications:

RC name	Probability	Fraction of total	Correction to account for non-used RCs	Revised RC fractions
1-02	1.59E-06	6.71E-02	0	6.71E-02
4-04	3.16E-07	1.33E-02	0	1.33E-02
5-01	7.39E-07	3.12E-02	5.31E-02	8.43E-02
7-03	7.45E-07	3.15E-02	0	3.15E-02
7-04	2.89E-07	1.22E-02	0	1.22E-02
8-01	3.19E-06	1.35E-01	0	1.35E-01
9-01	1.32E-05	5.57E-01	0	5.57E-01
9-03	2.36E-06	9.96E-02	0	9.96E-02
Totals		9.47E-01	5.31E-02	1.00E+00

The source terms for these release categories are provided in Section E.2.2.3.3.

E.2.3.2.3 External Flooding Binning Summary

The desired product of the External Flooding binning process is a set of frequencies that are correlated to the TMI-1 source terms so that they can be used with the Level 3 model results to quantify the consequences of External Flooding accidents. The consequence results are then used in the cost benefit analysis, as described in Section E.4. Table E.2-23 summarizes the source term specific frequencies for each of the TMI-1 External Flooding sequences.

E.2.4 TMI-1 PEER REVIEW SUMMARY

The TMI-1 internal events PRA received a formal industry PRA Peer Review in August 2000. The final report was issued in March, 2001. “It was the general assessment of the peer review team that the Three Mile Island PRA can be effectively used to support applications involving risk significant determinations supported by deterministic analysis, once the technical issues and recommendations for enhancements that are noted in the element summaries and Fact and Observation Sheets are addressed to an appropriate level of quality.”

Table E.2-24 contains the grades of the individual PRA Elements recorded by the Peer Review Team.

All ‘A’ and ‘B’ F&Os are closed with exception of one ‘B’ level observation. F&O SY-21 relates to the need for independent technical and system engineer reviews of system notebooks. Most of the system notebooks have not been systematically reviewed by the system engineers.

The Peer Review Report also credits items of strength in the TMI PRA. Some of the strengths were:

- Treatment of dependencies in sequence and system models. There was excellent treatment and documentation of system functional dependencies and physical dependencies evidenced by system dependency matrices.

- Room heatup tests to support model. To resolve some earlier uncertainties regarding the impact of loss of room cooling to the electrical switchgear rooms and other areas, TMI conducted test to verify the success criteria for associated HVAC systems.

- Excellent ISLOCA treatment. The treatment of interfacing system LOCA sequences, including the systematic review of candidate pathways, quantification of initiating event frequencies, evaluation of response of low pressure systems to overpressure, and treatment of containment isolation interfaces, was state of the art and well conducted.

E.3 LEVEL 3 PRA ANALYSIS

This section addresses the critical input parameters and analysis of the Level 3 portion of the probabilistic risk assessment. In addition, Section E.7.3 summarizes a series of sensitivity evaluations to potentially critical parameters.

E.3.1 ANALYSIS

The MACCS2 code (NRC 1998a) is used to perform the Level 3 probabilistic risk assessment (PRA) for the Three Mile Island Nuclear Generating Plant. Three Mile Island site specific parameters are used for population distribution and economic parameters. Plant-specific release data included the time-dependent nuclide distribution of releases and release frequencies. The behavior of the population during a release (evacuation parameters) is based on plant and site-specific set points. Other input parameters given with the MACCS2 “Sample Problem A”, formed the basis for the present analysis. These data are used in combination with site-specific meteorology to simulate the probability distribution of impact risks (both exposures and economic effects) to the surrounding 50-mile radius population as a result of the release accident sequences at Three Mile Island.

E.3.2 POPULATION

The population surrounding the Three Mile Island site is estimated for the year 2034.

Population projections within 50 miles of Three Mile Island are determined using SECPOP2000, (NRC 2003) utilizing a geographic information system (GIS). U.S Census block-group level population data is allocated to each sector based on the area fraction of the census block-groups in that sector. U.S. Census data from 1990 and 2000 are used to determine a ten year population growth factor for each of the 50-mile radius rings. The population growth factor for each ring is applied uniformly to all sectors in the ring to calculate the year 2034 population distribution.

The distribution is given in terms of population at distances to 1, 2, 3, 4, 5, 10, 20, 30, 40 and 50 miles from the plant and in the direction of each of the 16 compass points (i.e., N, NNE, NE……NNW).

The total year 2034 population for the 160 sectors (10 distances × 16 directions) in the region is estimated as 3,609,252. The ten year population growth factor (in parenthesis) and distribution of the population is given for the 10-mile radius from Three Mile Island and for the 50-mile radius from Three Mile Island in Tables E.3-1 and E.3-2, respectively.

E.3.3 ECONOMY

MACCS2 requires certain economic data (fraction of land devoted to farming, annual farm sales, fraction of farm sales resulting from dairy production, and property value of farm and non-farm land) for each of the 160 sectors. These values are calculated using the SECPOP2000 code (NRC 2003). SECPOP2000 utilizes economic data from the U.S. Department of Agriculture, "1997 Census of Agriculture" (USDA 1998) and from other 1998 and 1999 data sources. Economic values for up to 97 economic zones are calculated and allocated to each of the 160 sectors.

In addition, generic economic data that are applied to the region as a whole are revised from the MACCS2 sample problem input when better information is available. These revised parameters include per diem living expenses (applied to owners of interdicted properties and relocated populations), relocation costs (for owners of interdicted properties), and value of farm and non-farm wealth. These values are updated to the year 2006 value using the Consumer Price Index ratio.

Three Mile Island MACCS2 economic parameters include the following:

Three Mile Island MACCS2 Economic Parameters

Variable	Description	Three Mile Island Value
DPRATE(1)	Property depreciation rate (per yr)	0.2
DSRATE(1)	Investment rate of return (per yr)	0.12
EVACST(2)	Daily cost for a person who has been evacuated ($/person-day)	48.72
POPCST(2)	Population relocation cost ($/person)	9022.00
RELCST(2)	Daily cost for a person who is relocated ($/person-day)	48.72
CDFRM0(2)	Cost of farm decontamination for various levels of decontamination ($/hectare)	1015.00 2256.00
CDNFRM(2)	Cost of non-farm decontamination per resident person for various levels of decontamination ($/person)	5413.00 14435.00
DLBCST(2)	Average cost of decontamination labor ($/man-year)	63155.00

Three Mile Island MACCS2 Economic Parameters

Variable	Description	Three Mile Island Value
VALWF0[(3)]	Value of farm wealth ($/hectare)	3311.00
VALWNF[(3)]	Value of non-farm wealth ($/person)	110473.00

(1) DPRATE and DSRATE are based on NUREG/CR-4551 value (NRC 1990).
(2) These parameters for Three Mile Island use the NUREG/CR-4551 value (NRC 1990), updated top the 2006 CPI value.
(3) VALWF0 and VALWNF are based on SECPOP2000 values for Three Mile Island, updated to the 2006 CPI value.

E.3.4 FOOD AND AGRICULTURE

Food ingestion is modeled using the COMIDA2 methodology consistent with Sample Problem A. The COMIDA2 model 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. The fraction of population dose due to food ingestion is typically small compared to other population dose sources. For Three Mile Island, approximately five percent of the total population dose is due to food ingestion.

E.3.5 NUCLIDE RELEASE

MACCS2 requires input for 60 radionuclides. The core inventory at the time of the accident is based on a plant specific ORIGEN2.1 calculation for a 24 month refueling cycle (obtained from C-1101-900-E-220-178, Rev. 0, 2002). Table E.3-3 provides the MACCS2 Three Mile Island core inventory.

Three Mile Island nuclide release categories are related to the MACCS categories as shown in Table E.3-4. All releases are modeled as occurring at 51.6 meters (top of the Reactor Building). The thermal content of each of the releases are assumed to be 1.0E+07 watts based on values provided in Sample Problem A and NUREG/CR-4551 (NRC 1990). The release associated with each source term is modeled as two or three individual plume segments to capture nuclide release changes as a function of time.

Two nuclide release sensitivity cases were performed to determine the effect of release height and thermal content assumptions. One sensitivity case modeled the releases occurring at ground level (0.0 meters). The second sensitivity case modeled the thermal content of each release to be the same as ambient (i.e., buoyant plume rise is not modeled). The results are discussed in Section E.7.3.

E.3.6 EVACUATION

Reactor scram signal begins each evaluated accident sequence. A General Emergency is declared when plant conditions degrade to the point where it is judged that there is a credible risk to the public. Therefore, the timing of the General Emergency declaration is sequence specific and ranges from 48 minutes to 26 hours for the release sequences evaluated.

The MACCS2 User's Guide input parameters of 95 percent of the population within 10 miles of the plant [Emergency Planning Zone (EPZ)] evacuating and 5 percent not evacuating are employed. These values have been used in similar studies (e.g., Hatch, Calvert Cliffs, (SNOC 2000) and (BGE 1998)) and are conservative relative to the NUREG-1150 study, which assumed evacuation of 99.5 percent of the population within the EPZ. The evacuees are assumed to begin evacuating 90 minutes after a General Emergency has been declared and are evacuated at an average radial speed of 1.18 miles per hour (0.53 m/sec). This speed is the time weighted value accounting for season, day of the week, time of day, weather conditions, and special events. The evacuation time weighted average of 600 minutes is for the full 0-10 mile EPZ, an assumed 15 minute notification time, 15 minutes for evacuation preparation, and 60 minutes average departure time. (ETI 2003)

One evacuation sensitivity case is performed to determine the impact of evacuation assumptions. The sensitivity case reduced the evacuation speed by a factor of two (0.26 m/sec). The results are discussed in Section E.7.3.

E.3.7 METEOROLOGY

Annual Three Mile Island meteorology data from year 1998 is used in MACCS2 for the base case results. The year 1998 meteorological data set is utilized for the Three Mile Island base case MACCS2 analysis based on the fact that the year 1998 provided the most complete data set, the highest population dose risk and offsite economic cost risk, and is judged to be the most conservative.

Year 1998, 1999, and 2000 meteorology data for the Three Mile Island site contains wind speed, wind direction, and stability data. Site specific precipitation data was not included. The 1998 Three Mile Island meteorological data set contained 39 total hours of missing data, representing 0.45% of the hourly readings. The 1999 and 2000 Three Mile Island meteorological data sets contained 54 and 23 total hours of missing data, respectively, representing 0.62% and 0.26% of the hourly readings. Of the three data sets used the 1998 data set is the only data set that did not include any gaps of missing data of more than two hours. Therefore, it is judged the year 1998 provided the most complete data set.

The year 1998 meteorological data set contained several one or two hour gaps of missing data (39 hours, 0.45%). Traditionally, up to 10% of missing data is considered acceptable. All of the missing gaps consisted of two hours or less and interpolation was used to fill in the missing meteorological data. It is noted that MACCS2 results used in the SAMA analysis are the statistical mean of 384 weather sequences (each sequence contains 120 hours of data) chosen at random from pre-sorted weather bins. Due to the large number of samples analyzed, the adjustment of any particular weather sequence has negligible impact on the mean results.

Three Mile Island MACCS2 analysis evaluated three meteorological data sets (Calendar years 1998, 1999, and 2000) to ensure that the meteorological data set used in the analysis is adequate. The use of the most conservative data set (year 1998) accounts for any weather sequences that may have been misrepresented by substitute data. Based on the multiple years analyzed, minimum data gaps in the year 1998 meteorological data, and the sampling methodology used, the reported mean results are judged acceptable and appropriate for use in averted cost risk calculations.

Meteorological data is prepared for MACCS2 input as follows:

1. Wind speed, wind direction, and atmospheric stability data is provided from the site. Precipitation data from the Middletown/Harrisburg Airport is utilized.

2. If a brief period (i.e., < 6 hr.) of missing data exists, interpolation is used between hours.

3. For larger data voids (i.e., > 6 hr.), data from the previous or following day is utilized to fill data gaps (for the same time of day).

4. Atmospheric mixing heights are specified for morning and afternoon. These values were taken from the document *Mixing Heights, Windspeeds, and Potential for Urban Air Pollution throughout the Contiguous United States* (EPA 1972).

   This source defined morning as being the four-hour period from 0200 to 0600 Local Standard Time and afternoon as being the four-hour period from 1200 to 1600 Local Standard Time.

   The Code Manual for MACCS2: Volume 1 (from Appendix A, pages A-1 and A-2) states the following:

"The first of these two values corresponds to the morning mixing height and the second to the afternoon height. In the current implementation, the larger of these two values and the value of the boundary weather mixing height is used by the code."
"In its present form, that atmospheric model implemented in MACCS2 does not allow a change in the mixing layer to occur during transport of the plume. Mixing layer height is assumed to be constant and therefore only a single value is used by the code."

For the Three Mile Island MACCS2 analyses, these conditions mean that, only the afternoon mixing height is used since it is larger than the morning mixing height. Note that the boundary weather mixing height, wind speed and stability category are only used when there is no meteorological data. These fixed boundary weather values are ignored by the code when an hourly meteorological data file is supplied by the user, as was the case in the MACCS2 runs for Three Mile Island.

As noted above, site meteorological data for years 1999 and 2000 are also evaluated as sensitivity cases to ensure year 1998 data is an appropriate data set. The results are discussed in Section E.7.3.

E.3.8 MACCS2 RESULTS

Tables E.3-5 shows the mean off-site doses and economic impacts to the region within 50 miles of Three Mile Island for each of nine source term groups evaluated using MACCS2. These impacts are multiplied by the annual frequency for each release category and then summed to obtain the dose-risk and offsite economic cost-risk (OECR) for the TMI-1 internal events initiators. Table E.3-6 provides the results for the non-zero release categories.

Table E.3-7 summarizes the base case results for the sequence specific external flooding contributions based on the source term frequencies identified in Section E.2.3.2.3 and the source term specific dose and cost results identified in Table E.3-5.

E.4 BASELINE RISK MONETIZATION

This section explains how Exelon calculated the monetized value of the status quo (i.e., accident consequences without SAMA implementation). Exelon also used this analysis to establish the maximum benefit that could be achieved if all on-line risk were eliminated.

E.4.1 OFF-SITE EXPOSURE COST-RISK

The baseline annual off-site exposure risk was converted to dollars using NRC's conversion factor of $2,000 per person-rem, and discounted to present value using NRC standard formula (NRC 1997a):

$W_{pha} = C \times Z_{pha}$

Where:

W_{pha} = monetary value of public health risk after discounting

C = $[1-\exp(-rt_f)]/r$

t_f = years remaining until end of facility life = 20 years

r = real discount rate (RDR) (as fraction) = 0.03 per year

Z_{pha} = monetary value of public health (accident) risk per year before discounting ($ per year)

The Level 3 analysis showed an annual off-site population dose risk of 32.61 person-rem. The calculated value for C using 20 years and a 3 percent discount rate is approximately 15.04. Therefore, calculating the discounted monetary equivalent of accident dose-risk involves multiplying the dose (person-rem per year) by $2,000 and by the C value (15.04). The calculated off-site exposure cost-risk is estimated to be $980,884.

E.4.2 OFF-SITE ECONOMIC COST-RISK

The Level 3 analysis showed an annual off-site economic cost-risk of $112,259. Calculated values for off-site economic cost-risks caused by severe accidents over the license renewal period must be discounted to present value as well. This is performed in the same manner as for public health risks and uses the same C value. The resulting value is $1,688,328.

E.4.3 ON-SITE EXPOSURE COST-RISK

Occupational health was evaluated using NRC methodology that involves separately evaluating immediate and long-term doses (NRC 1997a).

For immediate dose, NRC recommends using the following equation:

Equation 1:

$$W_{IO} = R\{(FD_{IO})_S - (FD_{IO})_A\}\{[1 - \exp(-rt_f)]/r\}$$

Where:

W_{IO} = monetary value of accident risk avoided due to immediate doses, after discounting

R = monetary equivalent of unit dose ($2,000 per person-rem)

F = accident frequency (2.37E-05 events per year)

D_{IO} = immediate occupational dose [3,300 person-rem per accident (NRC estimate)]

$_S$ = subscript denoting status quo (current conditions)

$_A$ = subscript denoting after implementation of proposed action

r = RDR (0.03 per year)

t_f = years remaining until end of facility life (20 years).

Assuming F_A is zero, the best estimate of the immediate dose cost is:

$$W_{IO} = R\,(FD_{IO})_S\{[1 - \exp(-rt_f)]/r\}$$

$$= 2{,}000 * 2.37\text{E-}05 * 3{,}300 * \{[1 - \exp(-0.03 * 20)]/0.03\}$$

$$= \$2{,}352$$

For long-term dose, NRC recommends using the following equation:

Equation 2:

W_{LTO} = $R\{(FD_{LTO})_S - (FD_{LTO})_A\} \{[1 - exp(-rt_f)]/r\}\{[1 - exp(-rm)]/(rm)\}$

Where:

W_{LTO} = monetary value of accident risk avoided long-term doses, after discounting, $

D_{LTO} = long-term dose [20,000 person-rem per accident (NRC estimate)]

m = years over which long-term doses accrue (as long as 10 years)

Using values defined for immediate dose and assuming F_A is zero, the best estimate of the cost associated with long-term dose is:

W_{LTO} = $R (FD_{LTO})_S \{[1 - exp(-rt_f)]/r\} \{[1 - exp(-rm)]/(rm)\}$

= $2{,}000*2.37E\text{-}05 *20{,}000*\{ [1 - exp(-0.03*20)]/0.03\} \{[1 -exp(-0.03*10)]/(0.03*10)\}$

= $12,318

The total occupational exposure is then calculated by combining Equations 1 and 2 above. The total accident related on-site (occupational) exposure cost-risk (W_O) is:

W_O = $W_{IO} + W_{LTO}$ = ($2,352 + $12,318) = $14,670

E.4.4 ON-SITE CLEANUP AND DECONTAMINATION COST-RISK

The total undiscounted cost of a single event in constant year dollars (C_{CD}) that NRC provides for cleanup and decontamination is $1.5 billion (NRC 1997). The net present value of a single event is calculated as follows. NRC uses the following equation to integrate the net present value over the average number of remaining service years:

PV_{CD} = $[C_{CD}/rm][1-exp(-rm)]$

Where:

PV_{CD} = net present value of a single event

C_{CD} = total undiscounted cost for a single accident in constant year dollars

r = RDR (0.03)

m = years required to return site to a pre-accident state

The resulting net present value of a single event is $1.3E+09. The NRC uses the following equation to integrate the net present value over the average number of remaining service years:

U_{CD} = $[PV_{CD}/r][1-\exp(-rt_f)]$

Where:

PV_{CD} = net present value of a single event ($1.3E+09)

r = RDR (0.03)

t_f = 20 years (license renewal period)

The resulting net present value of cleanup integrated over the license renewal term, $1.95E+10, must be multiplied by the total CDF (2.37E-05) to determine the expected value of cleanup and decontamination costs. The resulting monetary equivalent is $461,912.

E.4.5 REPLACEMENT POWER COST-RISK

The long-term replacement power cost-risk was determined following NRC methodology in NUREG/BR-0184 (NRC 1997a). The net present value of replacement power for a single event, PV_{RP}, was determined using the following equation:

PV_{RP} = $[1.2\times10^8(\$\text{-yr})/r] * [1 - \exp(-rt_f)]^2$

Where:

PV_{RP} = net present value of replacement power for a single event, ($)

r = RDR (0.03)

t_f = 20 years (license renewal period)

To attain a summation of the single-event costs over the entire license renewal period, the following equation is used:

$U_{RP} = [PV_{RP} / r] * [1 - \exp(-rt_f)]^2$

Where:

U_{RP} = net present value of replacement power over life of facility ($-year)

After applying a correction factor to account for TMI-1 size relative to the generic reactor described in NUREG/BR-0184 (i.e., 875 megawatt electric/910 megawatt electric) the replacement power costs are determined to be 5.31E+09 ($-year). Multiplying this value by the CDF (2.37E-05) results in a replacement power cost-risk of $125,917.

E.4.6 MAXIMUM AVERTED COST-RISK

The TMI-1 Maximum Averted Cost-Risk (MACR) is the total averted cost-risk if all internal and external events risk associated with on-line operation were eliminated. This is calculated by summing the following components:

Maximum Internal Events Averted Cost-Risk

Maximum External Flooding Averted Cost-Risk

Maximum External Events Averted Cost-Risk (excluding external flooding)

As described in Section E.5.1, the MACR is used in the SAMA identification process to determine the depth of the importance list review. In addition, the MACR is used in the Phase I analysis as a means of screening SAMAs.

The following subsections provide a description of how each of these components are calculated and used together to obtain the TMI-1 MACR.

E.4.6.1 INTERNAL EVENTS MAXIMUM AVERTED COST-RISK

The maximum internal events averted cost-risk is the sum of the contributors calculated in Sections E.4.1 through E.4.5:

Maximum Averted Internal Events Cost-Risk

Off-site exposure cost-risk	=	$980,884
Off-site economic cost-risk	=	$1,688,328
On-site exposure cost-risk	=	$14,670
On-site cleanup cost-risk	=	$461,912
Replacement Power cost-risk	=	$125,917
Internal Events Maximum Averted Cost-Risk	=	$3,271,711

This total represents the monetary equivalent of the risk that could be eliminated if all on-line internal events based events could be eliminated for TMI-1.

E.4.6.2 EXTERNAL FLOODING EVENTS MAXIMUM AVERTED COST-RISK

The same process used to calculate the maximum averted cost-risk for the internal events contributors is used to calculate the maximum averted cost-risk for the external flooding contributors. The external flooding CDF, dose-risk, and economic cost risk estimates are used as input to the equations presented in Sections E.4.1 through E.4.5. As documented in Section E.2.3.1, the total external flooding CDF is 8.11E-05 when the contributions from all of the flood regimes are summed:

- External floods over 310’ msl,
- External floods between 305’ msl and 310’ msl, and
- External floods below 305’ msl

The total dose-risk and economic cost-risk for these flood regimes are 177.16 person-rem and $542,159, respectively, as documented in Section E.3.8.

The results of the external flood MACR calculations are provided below:

Maximum External Flooding Cost-Risk

Off-site exposure cost-risk	=	$5,328,835
Off-site economic cost-risk	=	$8,153,861
On-site exposure cost-risk	=	$50,177
On-site cleanup cost-risk	=	$1,579,915
Replacement Power cost-risk	=	$430,685
External Flooding Maximum Averted Cost-Risk	=	$15,543,473

E.4.6.3 NON-FLOODING EXTERNAL EVENTS MAXIMUM AVERTED COST-RISK

Finally, the maximum averted cost-risk for external events (excluding external flooding) must be estimated; however, this cost-risk must be estimated based on information in the IPEEE given that current, quantifiable external events models are not available. As described in Sections E.5.1.5 and E.5.1.6, these models have not been updated to reflect recent plant changes or current PRA techniques. Therefore, the absolute CDF values included in the IPEEE are generally not considered to be directly comparable to the results of the internal events PRA model.

The method chosen to account for non-flooding external events in the SAMA analysis is to use a multiplier on the internal events results. In previous SAMA analyses, it has been assumed that the risk posed by external events and internal events is approximately equal. This assumption is not unreasonable unless available analyses indicate that there are external events contributors that present an exceptionally high risk to the site. For TMI-1, external flooding scenarios are considered to present such a risk and are treated separately due to the potentially high frequency of severe flooding events.

The relative contributions of the remaining initiators are summarized in the following table:

IPEEE Contributor Summary (No External Flooding)

External Event	CDF
Seismic (LLNL seismic hazard curves)	8.43E-05
Fire	2.16E-05
High Winds	7.77E-07
Aircraft Impact	3.95E-07
Hazardous Chemicals	1.60E-07
Total	1.07E-04

While the CDF total of 1.07E-04 is about a factor of 3 greater than the internal events contribution, a large portion of the CDF is related to seismic risk. The large seismic CDF could be viewed as an indicator that earthquakes, like external floods, may represent an exceptionally high risk to TMI-1. However, as described in Section E.5.1.6.2.1, there are several specific issues related to the conservative nature of the seismic analysis that suggest seismic events are not a dominant contributor to the TMI-1 risk profile. As a result, seismic events are grouped with the remaining initiator types.

Similarly, the large external events CDF is not considered to be a basis for using a multiplier greater than 2 to account for external events risk due to the high seismic contribution. In fact, the use of unsupported, large multipliers for external events can be detrimental to the SAMA process:

- Over predicting the averted cost-risk of internal events based SAMAs through the use of an inflated multiplier could divert site resources to issues that are not important to the plant,
- Over predicting the averted cost-risk of an external events based SAMA could change the prioritization of addressing cost effective SAMAs away from important issues identified by the internal events model to highly uncertain issues identified by the external events analyses,
- Use of a larger multiplier impacts the MACR, which forces the identification of internal events based SAMAs that are not important to plant risk (refer to Sections E.5.1.1 and E.5.1.2) and consequentially reduces the credibility of the analysis.

For these reasons, a multiplier of 2 has been chosen to account for the TMI-1 external events contributions. This implies that the contribution to the MACR from the non-flooding external events is the same as the contribution from the internal events model ($3,271,711).

E.4.6.4 TMI-1 MAXIMUM AVERTED COST-RISK

As stated in Section E.4.6, the MACR is the total of these three components:

Internal Events	=	$3,271,711
External Events (excluding External Flooding)	=	$3,271,711
External Flooding	=	$15,543,473
Maximum Averted Cost-Risk	=	$22,086,895

The MACR is rounded to next highest thousand ($22,087,000) for SAMA calculations. It should be noted that the Phase II cost benefit calculations account for the difference between the rounded MACR and the actual MACR by adding the difference to the averted cost-risk calculated for each SAMA.

E.5 PHASE I SAMA ANALYSIS

The Phase I SAMA analysis, as discussed in Section E.1, includes the development of the initial SAMA list and a coarse screening process. This screening process eliminated those candidates that are not applicable to the plant's design or are too expensive to be cost beneficial even if the risk of on-line operations were completely eliminated. The following subsections provide additional details of the Phase I process.

E.5.1 SAMA IDENTIFICATION

The initial list of SAMA candidates for TMI-1 was developed from a combination of resources including:

- TMI-1 PRA results
- Industry Phase II SAMAs
- TMI-1 IPE (GPU 1993a)
- TMI-1 IPEEE (GPU 1994)

These resources are judged to provide a list of potential plant changes that are most likely to reduce risk in a cost-effective manner for TMI-1.

In addition to the "Industry Phase II SAMA" review identified above, an industry based SAMA list was used in a different way to aid in the development of the TMI-1 plant specific SAMA list. While the industry SAMA review cited above was used to identify SAMAs that might have been overlooked in the development of the TMI-1 SAMA list due to PRA modeling issues, a generic SAMA list was used as an idea source to identify the types of changes that could be used to address the areas of concern identified through the TMI-1 importance list review. For example, if long term DC power availability was determined to be an important issue for TMI-1, the industry list would be reviewed to determine if a plant enhancement had already been conceived that would address TMI-1's needs. If an appropriate SAMA was found to exist, it would be used in the TMI-1 list to address the DC power issue; otherwise, a new SAMA would be developed that would meet the site's needs. This generic list was compiled as part of the development of several industry SAMA analyses and has been provided in Addendum 1 for reference purposes.

E.5.1.1 LEVEL 1 TMI-1 IMPORTANCE LIST REVIEW

The TMI-1 PRA was used to generate a list of events sorted according to their risk reduction worth (RRW) values. The top events in this list are those events that would provide the greatest reduction in the TMI-1 CDF if the failure probability were set to zero. The events were reviewed down to the 1.010 level, which was chosen because it corresponds to the definition of a risk significant event, as defined in the PSA Applications Guide. [EPRI 1995]

An alternate method of establishing the lower review threshold would be to correlate the minimum expected SAMA implementation cost to an RRW value. For TMI-1, the minimum expected cost of implementation is believed to be a procedure change. The cost of procedure changes can vary depending on the type of procedure being modified and the scope of the changes, but a representative value is considered to be about $50,000, which is supported by previous industry cost estimates for procedure modifications [CPL 2004].

For TMI-1, the RRW value corresponding to $50,000 is about 1.008 (excluding External Flooding contributions). This can be demonstrated by reducing the CDF, dose-risk and off-site economic cost-risk by a factor of 1.008, which corresponds to an event with Level 1 and Level 2 based RRW values of just under 1.008. The corresponding internal events based averted cost-risk would be $25,966. Applying a factor of 2 to estimate the potential impact of external events (refer to Section E.4.6) results in a cost-risk of $51,932. This is approximately equal to the assumed minimum expected cost of implementation. While the RRW value of 1.008 is not exactly equal to the 1.010 established by the PSA Applications Guide definition of risk significance, the RRW threshold values are consistent and the use of 1.010 is considered to be adequate for this analysis.

The External Flooding contributions are excluded from the calculations establishing the RRW review threshold because the identification and quantification processes for External Flooding SAMAs are performed separate from the internal events model.

Table E.5-1 documents the disposition of each event in the Level 1 TMI-1 RRW list with RRW values of 1.010 or greater. Note that the review of each event involves a detailed evaluation of the cutsets including the event to identify the factors that make the event important.

E.5.1.2 LEVEL 2 TMI-1 IMPORTANCE LIST REVIEW

A similar review was performed on the importance listings from the Level 2 results. In this case, a composite importance file based on all release categories except RC9 was used to identify potential SAMAs. This method was chosen to prevent high frequency-low consequence events from dominating the importance listing. While RC9 contributes about 13 percent of the dose-risk, that small contribution depends on over 66 percent of the Level 2 frequency, which would heavily bias the importance list toward RC9 contributors.

The Level 2 RRW values were also reviewed down to the 1.010 level. As described for the Level 1 RRW list, events below the 1.010 threshold value are not "risk significant" and are not expected to yield cost beneficial SAMAs.

Table E.5-2 documents the disposition of each event in the Level 2 TMI-1 RRW list with RRW values greater than 1.010.

E.5.1.3 INDUSTRY SAMA ANALYSIS REVIEW

The SAMA identification process for TMI-1 is primarily based on the PRA importance listings, the IPE, and the IPEEE. In addition to these plant-specific sources, selected industry SAMA submittals were reviewed to identify any Phase II SAMAs that were determined to be potentially cost beneficial at other plants. These SAMAs were further analyzed and included in the TMI-1 SAMA list if they were considered to address potential risks not identified by the TMI-1 importance list review.

While many of the industry SAMAs reviewed are ultimately shown not to be cost beneficial, some are close contenders and a small number have been estimated to be cost beneficial at other plants. Use of the TMI-1 importance ranking should identify the types of changes that would most likely be cost beneficial for TMI-1, but review of selected industry Phase II SAMAs may capture potentially important changes not identified for TMI-1 due to PRA modeling differences or SAMAs that represent alternate methods of addressing risk. Given this potential, it was considered prudent to include a review of selected industry Phase II SAMAs in the TMI-1 SAMA identification process.

Phase II SAMAs from the following U.S. nuclear power sites have been reviewed:

- Turkey Point

- Arkansas Nuclear One, Unit 1
- Palisades
- D.C. Cook, Units 1 and 2
- Susquehanna Units 1 and 2
- Fitzpatrick

Four PWR and two boiling water reactor (BWR) sites were chosen from available documentation to serve as the Phase II SAMA sources. Few of the Phase II SAMAs from these sources were included in the initial TMI-1 SAMA list. Many of the industry Phase II SAMAs were already represented by other SAMAs in the TMI-1 list, were known not to impact important plant systems, or were judged not to have the potential to be close contenders for TMI-1. These SAMAs were not considered further. The following provides a summary of some of the issues considered during the review of the industry SAMAs.

E.5.1.3.1 Turkey Point

Turkey Point used a generic SAMA list as its starting point and few plant specific insights were available that might pertain specifically to B&W PWRs. In addition, only limited averted cost information was provided for the SAMAs and no changes were identified as cost beneficial, which made review of the list difficult. One SAMA had the potential to address a portion of TMI-1 risk in an inexpensive manner, but equipment limitations precluded its direct application to TMI-1:

- Turkey Point SAMA 111 – This SAMA suggests using Firewater as an alternate means of providing makeup to the steam generators. The prominent Level 1 cases involving loss of SG makeup flow at TMI-1 are SBO cases where the seals are in jeopardy. Providing alternate secondary side makeup without addressing the seal LOCA would not have a large impact on risk for TMI-1. In order for the use of Firewater to address important TMI-1 sequences, it would have to be capable of providing SG makeup early in the accident sequence and be combined with the installation of high temperature, damage resistant seals so that primary side inventory is not lost. Given that early SG makeup would require a pressure greater than the 130 psig available from the Fire Service Water system, this SAMA is not considered to be practical for TMI-1 and it is not included on the SAMA list. For Level

2, a large contributor to dose-risk is the failure to maintain water in the SGs to provide fission product scrubbing and for preventing induced tube rupture events. These events are considered to be best addressed by the addition of an independent auxiliary feedwater system, which is included as SAMA 22 based on the TMI-1 Level 2 importance list review.

E.5.1.3.2 ANO-1

While a generic SAMA list similar to the one used for Turkey Point was used in the ANO-1 SAMA submittal, one SAMA was found to be cost beneficial for ANO-1. This SAMA addresses the operator action to swap to recirculation mode, which was identified as an important contributor to TMI-1 risk:

- ANO-1 SAMA 129 suggests emphasizing a timely swap to recirculation mode in operator training and procedures. Theoretically, more emphasis could be placed on this well recognized issue for TMI-1, but in order to achieve a meaningful risk reduction based on training improvements, a specific deficiency would have to be identified in the TMI-1 training materials or procedures that could be rectified. No such deficiency has been identified based on the information available in the HRA. A SAMA has been proposed for TMI-1 to automate the swap to recirculation (SAMA 15), which would remove the operator from the primary role in the action. This is considered to be a more effective means of reducing the risk related to recirculation initiation failures for TMI-1. No additional SAMA related to improved training for swap to recirculation mode has been added to the TMI-1 SAMA list.

E.5.1.3.3 Palisades

Palisades identified several cost beneficial SAMAs; however, most of the changes were related to plant specific issues that are not applicable to TMI-1. Potential exceptions include adding the capability to operate EFW without power support and installation of a diesel motor to drive an EFW pump. These types of changes were shown to have a large impact on risk for Palisades and subsequent review of the plant design yielded the conclusion that the most effective means of addressing LOOP/SBO risk for the site was the installation of an additional EDG. For TMI-1 these three issues are dispositioned as follows:

- SAMA 2 addresses the use of a portable generator to allow extended EFW operation. It is combined with RCP seal upgrades as the important contributors including prolonged EFW operation are those in which seal integrity is challenged. This is considered to be the most appropriate means of addressing prolonged EFW operation for TMI-1 and no additional

SAMAs are suggested.

- Installation of a diesel engine to drive an EFW pump would improve the capability of TMI-1 to address SBO cases in which EFW has failed. Other industry investigations of this SAMA have concluded that connecting a diesel motor to an EFW pump would be easier/cheaper for a turbine driven pump than for a motor driven pump; however, for TMI-1, the initial TD EFW failure may preclude the use of the pump even with the diesel engine. For improved effectiveness in the important TMI-1 scenarios, the diesel engine should be connected to a motor driven EFW pump or a unique diesel driven pump should be used. In addition, this type of change needs to be accompanied by the installation of the high temperature, damage resistant seals to preclude the seal LOCA that will result from an SBO. Without securing primary side integrity, extended secondary side cooling would provide limited benefit. Finally, a portable generator would be required to power SG level instrumentation for effective level control. While TMI-1 SAMA 10 already addresses SBO cases with EFW failures, this diesel driven pump option provides an alternate approach to the issue and it has been included on the SAMA list for evaluation (SAMA 24).

- The addition of an EDG at Palisades as a result of the SAMA analysis would bring the total number of EDGs at the plant to three, which is equivalent to the current TMI-1 configuration. Some benefit could be gained through the installation of a fourth EDG for TMI-1, but common cause failures would limit the benefit and there are more cost effective changes that could be made to the existing EDG configuration that would greatly reduce risk (i.e., SAMA 1). Even with the inclusion of SAMAs 11 and 24 already on the SAMA list, a SAMA suggesting the addition of another EDG has been added to the TMI-1 SAMA list as an alternate means of reducing SBO risk (SAMA 25).

E.5.1.3.4 D.C. Cook

The D.C. Cook SAMA analysis showed that 5 different types of changes were determined to be cost beneficial. In three of the five areas, multiple SAMAs are identified as potentially cost beneficial and no single approach is identified as the most appropriate for D.C Cook. These risk areas were reviewed for TMI-1 and it was determined that the issues are already adequately addressed by the TMI-1 SAMA list or that the risk areas were not important contributors for the site:

- Minimize Consequences of RCP seal LOCAs: The TMI-1 SAMA list includes multiple

SAMAs addressing seal LOCA prevention, including the use of new seals (SAMA 2) and a means of providing an alternate heat sink for the thermal barrier cooling system (SAMA 7).

- Minimize Consequences of Loss of HVAC: TMI-1 does not require HVAC for successful operation of the plant during the 24 hour mission time considered in the PRA.

- Remove Dependence of Distributed Ignition System on AC Power: TMI-1 does not have igniters in the containment. A battery backed hydrogen ignition system could be added, which is included as SAMA 19 based on the TMI-1 Level 2 importance list review.

- Minimize Consequences of AC Bus Failures: AC cross-ties are proposed in the D.C. Cook SAMA analysis as a means of reducing the contribution of bus failures. It is not clear how a cross-tie would mitigate the bus failure cited in the analysis, but for TMI-1 bus failures are not large contributors to risk. The availability of the SBO EDG and its capability to be aligned to either division reduces the risk of these events.

- Improve Recovery from ISLOCA: For TMI-1, ISLOCA is dominated by DHR suction path failures after leak or rupture of valves DH-V-1 and DH-V-2. While the TMI-1 ISLOCA analysis does not take credit for any potentially mitigating actions, no actions that could reliably terminate the event are believed to be available. For example, 1) the isolation of DH-V-3 may not isolate the break or additional breaks may occur after isolation, 2) reduction of primary system pressure may reduce the flow out of the break, but it would not stop it, and 3) refill of the BWST does not place the plant in a stable state and the impacts of aux building flooding would have to be addressed. A SAMA was added to the TMI-1 list to extend the high pressure boundary in the DHR suction lines to include an additional isolation valve based on the TMI-1 Level 2 importance list review (SAMA 20).

E.5.1.3.5 Susquehanna

The Susquehanna SAMA analysis showed that five SAMAs were potentially cost beneficial when considered independently. When consideration was given to the overlapping benefits of the SAMAs and limits of the assessment process, only two were considered to be likely candidates for implementation. For TMI-1, it was determined that the issues are already adequately addressed by the TMI-1 SAMA list or that the risk areas were not important contributors for the site:

- SSES SAMAs 2a and 2b (4kV AC Cross-ties): The availability of the SBO EDG, which can be aligned to either division, serves a purpose similar to that of an AC cross-tie and minimizes the benefit of any cross-tie SAMAs. The existing cross-tie capability is not credited in the model.

- SSES SAMAs 5 and 6 (Additional/Auto Aligning Portable 480V AC Generators): The use of a portable 480V generator is suggested in TMI-1 SAMA 2 in combination with the installation of improved RCP seals. This change is considered to be the most appropriate for the TMI-1 design.
- SSES SAMA 3 (Staggered Depressurization): This is a 2 unit BWR issue that is not applicable to TMI-1.

No additional SAMAs have been added to the TMI-1 SAMA list based on a review of these SAMAs.

E.5.1.3.6 Fitzpatrick

The Fitzpatrick SAMA analysis identified two types of SAMAs as potentially cost beneficial. The SAMAs related to extending DC power availability are addressed by TMI-1 SAMA 2 and the SAMA related to providing alternate EDG HVAC is not applicable to TMI-1 as HVAC is not required for the 24 hour PRA mission time. No additional SAMAs have been added to the TMI-1 SAMA list based on a review of these SAMAs.

E.5.1.3.7 Industry SAMA identification Summary

The important issues for TMI-1 are considered to be addressed by the SAMAs developed through the PRA importance list review. Further, the plant changes suggested as part of that review were developed to meet the specific needs of the plant such that those SAMAs are more likely to provide effective means of risk reduction than SAMAs taken from other sites. However, effort was made to review other industry SAMA analyses to determine if other sites identified plant changes that could be cost beneficial for TMI-1. While it was found that other plants had developed SAMAs that addressed areas of concern for TMI-1, only two have been identified that could be adapted for inclusion in the TMI-1 SAMA list. While these SAMAs can be considered unique, the SAMAs only propose alternate means of addressing issues already targeted by other TMI-1 SAMAs:

- Install Damage Resistant, High Temperature RCP Seals with a Diesel Engine as an

Alternate Drive for an EFW Pump and Portable Generator for Level Control Instrumentation (SAMA 24).

- Install an Additional EDG (SAMA 25).

E.5.1.4 TMI-1 IPE

The TMI-1 IPE generated a list of risk-based insights and potential plant improvements. Typically, changes identified in the IPE process are implemented and closed out; however, there are some items that are not completed within the industry due to high projected costs or other criteria. Because the criteria for implementation of a SAMA may be different than what was used in the post-IPE decision-making process, these recommended improvements are re-examined in this analysis.

As a result of the IPE, five potential plant improvements were identified and considered for implementation at the plant. The following table summarizes the status of these plant improvements.

Description of Potential Enhancement	Status of Implementation	Disposition
Provide additional procedural guidance to direct operators to throttle low pressure injection prior to swapping the pump suction source from the BWST to the containment sump. Ensuring this step is taken will reduce the likelihood of incurring pump damage during the transition.	Implemented. Current procedures direct throttling of LPI flow after injection initiation as well as actions to mitigate pump cavitation in the event that the initial throttling steps do not preclude cavitation.	No further review required.
Enhance accident management guidelines for SGTR events to direct isolation of the failed OTSG and cooldown of the primary system using the intact OTSG. This is considered an effective means of mitigating SGTR scenarios.	Implemented. B&W Generic Emergency Operating Guidelines direct OTSG isolation on a number of signals, including high radiation and SG level, which are indicators of SGTR events. Cooldown of the reactor is also part of the generic guidance; therefore, the intent of this SAMA is met by the existing procedures.	No further review required.
For those SGTR cases in which isolation of the ruptured SG is not possible, inventory loss may continue through the ruptured OTSG. Updating the accident management guidelines to direct refill of the BWST to keep pace with the RCS inventory loss would help mitigate the evolution until other steps to stabilize the plant could be taken.	Implemented	No further review required.
Update the accident management guidelines to direct the operators to verify closure of the MU-14 valves after the transition to “piggyback recirculation mode” from high pressure injection mode. This would provide additional assurance that pathways to the BWST and the environment are isolated when this mode of recirculation is used.	Implemented	No further review required.

Description of Potential Enhancement	Status of Implementation	Disposition
Consider including the following operator actions in the Licensed Operator Requalification training Program: 1. Switchover to reactor sump recirculation following a LOCA 2. Refilling the BWST given SGTR 3. Properly throttling HPI flow after ES actuation 4. Holding open or reopening RCP seal injection valve MU-V-20 on loss of instrument air 5. Tripping RCPs before seal damage after loss of NSCCW 6. Taking actions to prevent boron concentration when in recirculation following a LOCA	Partial implementation: 1. The action to swap to recirculation following a LOCA is included in requalification training, most recently in year 2005. 2. No specific training has been identified for BWST refill in an SGTR. 3. The action to throttle HPI flow to prevent overcooling/overpressurization is included in requalification training, most recently in year 2006. 4. No specific training has been identified related to re-opening MU-V-20 on loss of IA. 5. The action to trip RCPs before seal damage on loss of NSCCW is included in requalification training, most recently in years 2005 and 2006. 6. The action to prevent boron concentration effects while in recirc mode after a LOCA is included in requalification training, most recently in year 2005.	The actions suggested for inclusion in the TMI-1 training program were based on the importance of the actions as evaluated in the IPE model. As the PRA is a living analysis, there is a potential for the importance of the operator actions to change based on the use of new failure data, inclusion of logic to reflect plant changes, application of improved modeling practices that remove conservatism, or elimination of errors. The importance list review performed for the SAMA analysis will identify the most important actions modeled in the current TMI-1 PRA. While no requalification training appears to be performed for items 2 or 4 from the list of actions suggested for inclusion in the requalification training by the IPE, the current PRA model does include these events: • BWST-HRE27-HTKOA: FAILURE TO REFILL BWST (SPLIT FRAC REV) (HRE27 in the IPE) • INHINJ4_MUHHVCOA: OPERATOR REOPENS MU-V20 (HINJ4 in the IPE) As a result, the SAMA process will address these actions, if necessary, and inclusion of a SAMA to add these actions to the requalification program independently from the importance list review is not required.

All of the plant changes proposed by the IPE have either been implemented or are addressed by the SAMA process. No SAMAs are included on the TMI-1 SAMA list to address IPE insights.

E.5.1.5 TMI-1 IPEEE

Similar to the IPE, any insights that were previously dispositioned based on non-SAMA criteria are re-examined as part of this analysis. In addition, any insights that are in the process of being addressed are examined as their resolutions could be important to the disposition of some SAMAs. The IPEEE was used to identify these items.

The following table summarizes the status of the potential plant enhancements resulting from the IPEEE processes and their treatment in the SAMA analysis. As can be seen, several unimplemented insights have been identified and included on the SAMA list:

Description of Potential Enhancement	Status of Implementation	Disposition
Install a flood safe means of providing 480V AC power and pumps to provide RCP seal cooling and makeup to the steam generators.	Implemented	While implemented, the design has been reviewed to determine if additional changes could be made to improve reliability. See Section E.5.1.6.4.
Load centers 1P, 1R, 1S, and 1T: add gusset weld reinforcements to improve seismic ruggedness.	Not implemented	Included as SAMA 27. See section E.5.1.6.2.2.
Install additional supports for the main control room ceiling to prevent failure in seismic events.	Implemented	No further review required.
Install a restraint on penetration pressurization tank PP-T-1A to prevent seismic interaction with reactor building purge inlet isolation valve AH-V-1D.	Implemented	No further review required.
Modify the diesel fire pump battery and fuel oil tank supports to increase their seismic ruggedness.	Not implemented	Included as SAMA 30. See section E.5.1.6.2.2.
Modify the anchorage for the decay heat service heat exchangers (DC-C-2A(B)) to improve their seismic ruggedness.	Not implemented	Included as SAMA 28. See section E.5.1.6.2.2.
Modify the anchorage for the EDG air receivers to improve their seismic ruggedness.	Implemented	No further review required.

An effort was also made to use the IPEEE to develop new SAMAs based on a review of the original results. However, the TMI-1 IPEEE was not maintained as a “living” analysis. This limits the capability of the models that make up the IPEEE as they do not include the latest PRA practices nor do they necessarily represent the current plant configuration or operating characteristics. The fact that the models are not currently in a quantifiable state presents further difficulty because the results are limited to what has been retained from the original analysis. These factors limit the qualitative insights and quantitative estimates that can be made with regard to external events contributors. On a larger scale, given that the industry has generally not pursued external events modeling at a level consistent with internal events models, the technology for external events analysis is not as robust or refined. The result is that the CDF values yielded by the internal and external events models are not necessarily comparable. External events models are considered to be useful tools for identifying important accident sequences and mitigating equipment, but the quantitative results should not be directly combined with those from the internal events models. In this analysis, external events contributions are estimated using a multiplier on the internal events results for the reasons described above. The exception is the treatment of external flooding.

Finally, it was necessary to review the changes to the site and surrounding area that were implemented after the completion of the IPEEE to determine if the changes could impact the conclusions of those analyses. The only changes identified with the potential to impact the conclusions of the IPEEE are the installation of the security towers and security fencing on the site grounds. In high wind events,

- Security towers may be sources for wind generated missiles, and
- Security fencing could blow into areas where they may prevent access to equipment required for mitigating actions.

The security towers are considered to be unlikely sources for wind generated missiles due to the fact that their design requires them to be able to withstand vehicle impact. With respect to the security fence issue, the only potentially important action identified that normally requires travel in areas where the fences could be an issue is the start of the SBO EDG. However, there is an access door to the SBO EDG building in the Unit 2 structure that could be used, if required. Finally, as described in Section E.5.1.6.3, the maximum averted cost risk for high wind related scenarios is well under the minimum expected cost of implementation of $50,000. This indicates that SAMAs that only impact high wind risk can not be cost beneficial. As a result, it has been concluded that plant changes subsequent to the completion of the IPEEE do not invalidate the docketed results.

E.5.1.6 USE OF EXTERNAL EVENTS IN THE TMI-1 SAMA IDENTIFICATION PROCESS

The IPEEE was used in the TMI-1 SAMA analysis primarily to identify the highest risk accident sequences and the potential means of reducing the risk posed by those sequences. The types of events considered in the TMI-1 external events analysis were identified by Supplement 4 of Generic Letter 88-20 (NRC 1991) and included:

- Internal Fires (Section E.5.1.6.1)
- Seismic Events (Section E.5.1.6.2)
- High Wind Events (Section E.5.1.6.3)
- External Flooding (Section E.5.1.6.4)
- Transportation and Nearby Facility Accidents (Section E.5.1.6.5)

Based on the TMI-1 review, no additional hazards were identified for analysis in the IPEEE.

The type of information available for the initiators that were evaluated by TMI-1 varied due to the manner in which they were addressed in the IPEEE. For instance, the fire analysis used an approach that combined the deterministic evaluation techniques from the EPRI Fire Induced Vulnerability Evaluation (FIVE) methodology with classical PRA techniques. The TMI-1 seismic analysis was performed using modified versions of the TMI IPE model to address seismic impacts on the plant's accident response capabilities. Core damage frequencies were also estimated for external flooding, high wind events, and transportation and nearby facility accidents. Due to limitations of the modeling processes, however, the results of these kinds of analyses are not necessarily compatible with those of the internal events analysis. As a result, each of the external event contributors must be considered in a manner suiting the type of analysis performed. A summary of the review process used to identify SAMAs is provided for each of the external event types listed above.

E.5.1.6.1 Internal Fires

As discussed above, the techniques used to model external events vary according to the type of initiator being analyzed. The TMI-1 Fire Model shares many of the same characteristics as the internal events model, but limitations on the state of technology produce results that are typically more conservative than the internal events model. The following summarizes the fire PRA topics where quantification of the CDF may introduce different levels of modeling uncertainty than the internal events PRA.

In general, fire PRAs are useful tools to identify design or procedural items that could be clear areas of focus for improving the safety of the plant. Fire PRAs use a structure and quantification technique similar to that used in the internal events PRA. Since less attention historically has been paid to fire PRAs, conservative modeling is common in a number of areas of the fire analysis to provide a "bounding" methodology for fires. This concept is contrary to the base internal events PRA, which has had more analytical development and is judged to be closer to a realistic assessment (i.e., best estimate) of the plant. There are a number of fire PRA topics involving technical inputs, data, and modeling that prevent the effective comparison of the CDF between the internal events PRA and the fire PRA. These areas are identified as follows:

PRA Topic	Comment
Initiating Events:	The frequency of fires and their severity are generally conservatively overestimated. A revised NRC fire events database indicates the trend toward lower frequency and less severe fires. This trend reflects the improved housekeeping, reduction in transient fire hazards, and other improved fire protection (FP) steps at plants.
System Response:	FP measures such as sprinklers, CO_2, and fire brigades may be given minimal (conservative) credit in their ability to limit the spread of a fire.
Sequences:	Sequences may subsume a number of fire scenarios to reduce the analytic burden. The subsuming of initiators and sequences is done to envelope those sequences included. This results in additional conservatism.
Fire Modeling:	Fire damage and fire spread are conservatively characterized. Fire modeling presents bounding approaches regarding the immediate effects of a fire (e.g., all cables in a tray are always failed for a cable tray fire) and fire propagation.
HRA:	There is little industry experience with crew actions under conditions of the types of fires modeled in fire PRAs. This has led to conservative characterization of crew actions in fire PRAs. Because the CDF is strongly correlated with crew actions, this conservatism has a profound effect on the calculated fire PRA results.
Level of Detail:	The fire PRAs may have reduced level of detail in the mitigation of the initiating event and consequential system damage.
Quality of Model:	The peer review process for fire PRAs is not as developed as internal events PRAs. For example, no industry standard, such as NEI 00-02, existed for the structured peer review of a fire PRA. This may result in less assurance of the realism of the model.

In addition to modeling limitations, the fire PRA may be subject to more modeling uncertainty than the internal events PRA evaluations. While the fire PRA is generally self-consistent within its calculational framework, the fire PRA does not compare well with internal events PRAs because of the number of conservative assumptions that have been included in the fire PRA process. Therefore, the use of the fire PRA results as a reflection of CDF may be inappropriate. Any use of fire PRA results and insights should consider areas where the "state of the art" in fire PRAs is less evolved than other PRA topics.

While the ability to directly compare the results of the internal events and fire models is limited, information is available that may be used to identify the most important contributors for TMI-1. The IPEEE provides some information related to equipment failures by fire scenario. This information has been summarized in the table below for the five fire scenarios that were not screened on low CDF.

Fire Area/ Scenario	Description	CDF	Major Equipment Failed
CB-FA-2d	East Inverter Room	4.94E-06/yr	Vital instrument bus ATA, battery chargers 1A and 1C, inverters 1A, 1C, and 1E, and control cables for 4.16kV AC emergency bus 1D.
CB-FA-2e	West Inverter Room	5.81E-06/yr	Battery chargers 1B and 1D, inverters 1B and 1D, and control cables for 4.16kV AC emergency bus 1E.
CB-FA-3a	1D Switchgear Room	3.94E-06/yr	4.16kV AC emergency bus 1D.
CB-FA-3b	1E Switchgear Room	4.96E-06/yr	4.16kV AC emergency bus 1E.
CB-FA-4b	Control Room – Console CR	1.96E-06/yr	• RCS inventory control and injection: makeup pumps MU-P-1B, MU-P-1C, and injection valves MU-V-16C, D • Nuclear Service River Water Pumps NR-P-1B, C • Nuclear Services Closed Cycle Cooling Water Pumps NS-P-1B, C • RCP seal injection and cooling: ICCW pumps, NR-V-10A, and B, NR-V-15A and B • Train B of DHR, DR, and DCCW, including DH-V-4B, 5B, 6B, and 7B. • ESAS manual actuation for train B • Operation of Containment spray and fans • Essential AC power: EDG 1A controls, EDG 1B controls, SBO DG controls, 1D 4.16kV AC bus controls, 1E 4.16kV AC bus controls.

Since the fire IPEEE is based on a progressive screening methodology, the CDF values for the fire areas presented above should not be arbitrarily added. Due to the differing levels of detail required to screen the various areas from further consideration, there can be significant conservative assumptions implicit in some of the final values, whereas some of these conservative assumptions may have been relaxed for more detailed analysis. Given this perspective, the CDF for these fire areas could be estimated as 2.16E-05/yr. The table above demonstrates that the CDF is distributed more or less evenly among the non-screened fire scenarios and that there are no dominant scenarios that contribute nearly all of the fire risk. In addition, while fires in each of these areas may impact a wide range of equipment, damage is typically limited to a single division. As a result, redundant equipment is often available to mitigate the fire events. Further discussion is provided for each of the fire area/scenarios below.

E.5.1.6.1.1 CB-FA-2d: East Inverter Room

Fires in the East Inverter room essentially fail the "A" division of AC and DC power. Random failures of specific "B" train equipment in conjunction with the fire event result core damage. Providing a means of maintaining primary side integrity and secondary side cooling without electric support is a potential means of reducing the risk of these fire scenarios.

Given that two portable 480V AC generators are already available at TMI-1, one to support the severe flooding guidelines and one for general plant use, the TMI-1 turbine driven EFW pump would be capable of providing secondary side cooling for extended periods without 4.16kV AC power if one of the 480V AC generators was used to power one of the 125V DC battery chargers (for level instrumentation/valve and pump control). Installation of the forthcoming Westinghouse type high temperature, damage resistant seals would virtually prevent seal LOCAs and maintain primary side inventory for extended periods (SAMA 2). Providing power to a 125V DC battery charger is considered to be required because the 125V DC system supports the vital 120V AC power supply for the OTSG level indicators. No credit is taken for operation of the TD EFW pump without level indication.

Some of the risk from fires in this room was identified in the IPEEE as resulting from damage to cables that run over ignition sources. Early insights from the work being performed for the TMI-1 fire model update indicate that there are no cables over ignition sources in this area that would be problematic. As a result, no SAMA is suggested to re-route or wrap the cables in this area; however, the core damage frequency for this room is conservatively not reduced to reflect this insight.

E.5.1.6.1.2 CB-FA-2e: West Inverter Room

Fires in CB-FA-2e are similar to fires in CB-FA-2d. A fire in the West Inverter room essentially fails the "B" division of AC and DC power. Random failures of the "A" train equipment typically result in loss of the corresponding systems and core damage will ensue. Providing a means of maintaining primary side integrity and secondary side cooling without electric support is a potential means of reducing the risk of these fire scenarios.

Given that two portable 480V AC generators are already available at TMI-1, one to support the severe flooding guidelines and one for general plant use, the TMI-1 turbine driven EFW pump would be capable of providing secondary side cooling for extended periods without 4.16kV AC power if one of the 480V AC generators was used to power one of the 125V DC battery chargers (for level instrumentation/valve and pump control). Installation of the forthcoming Westinghouse type high temperature, damage resistant seals would virtually prevent seal LOCAs and maintain primary side inventory for extended periods (SAMA 2). Providing power to a 125V DC battery charger is considered to be required because the 125V DC system supports the vital 120V AC power supply for the OTSG level indicators. No credit is taken for operation of the TD EFW pump without level indication.

Some of the risk from fires in this room is from damage to cables that run over ignition sources. If the cable trays were re-routed away from the electrical equipment that they currently overpass or if the cables were wrapped with fireproof material, the consequences of fires in the inverter room equipment could be reduced (SAMA 26).

E.5.1.6.1.3 CB-FA-3a and CB-FA-3b: 1D and 1E Switchgear Rooms

The only critical equipment located in these areas is the switchgear itself. Due to the layout of the switchgear, with main distribution buswork running through each major cubicle, a fire in virtually any cubicle could short the main buses to ground, disabling the entire train of switchgear. Even if the main buses are not failed, the fire brigade may require the bus to be de-energized to allow fire suppression.

It may theoretically be possible to improve the response of the fire brigade or provide some automated fire mitigation system to prevent the spread of the initiating fire; however, the fire would cause some damage to the switchgear before the mitigating actions could be initiated and the extinguishing method itself could cause additional damage to the switchgear. Due to the uncertainty related to potential switchgear damage, mitigating the effects of a fire in this area is considered to be a more appropriate means of addressing the fire risk than attempting to mitigate the fire itself. Given that two portable 480V AC generators are already available at TMI-1, one to support the severe flooding guidelines and one for general plant use, the TMI-1 turbine driven EFW pump would be capable of providing secondary side cooling for extended periods without 4.16kV AC power if one of the 480V AC generators was used to power one of the 125V DC battery chargers (for level instrumentation/valve and pump control). Installation of the forthcoming Westinghouse type high temperature, damage resistant seals would virtually prevent seal LOCAs and maintain primary side inventory for extended periods (SAMA 2). Providing power to a 125V DC battery charger is considered to be required because the 125V DC system supports the vital 120V AC power supply for the OTSG level indicators. No credit is taken for operation of the TD EFW pump without level indication.

E.5.1.6.1.4 CB-FA-4b: Control Room, Console CR

A main control room fire in console CR results in the loss of a variety of equipment and will likely force evacuation of the area to the remote shutdown panel (RSP). The RSP contains only a subset of the controls found in the main control room that were determined to be required to control the plant assuming that all of the equipment on the panel is available. In the case of a Console CR fire, some of this critical equipment is considered to be failed as a result of the fire, including NSRW pump NR-P-1C, NSCCW pump NS-P-1C, and train “B” of DHR/DR. Consequently, the RSP does not provide an adequate means of controlling the reactor in these scenarios.

A potential means of addressing this issue would be to expand the RSP to include both trains of the safe shutdown equipment. However, this option creates an area where a single fire could disable both trains of safety equipment. For this reason, enhancing the RSP in this way is not suggested.

Other SAMAs could be developed to address risk in this area, but given that the main control room is always manned and that no credit was taken for manual detection of a fire, the contribution from this fire area is considered to be overestimated and no SAMAs are believed to be required for main control room fires. Even if main control room fires could only be detected and extinguished 90 percent of the time, taking this credit in the IPEEE would have reduced the contribution of main control room fires to 1.96E-7, which would have been below the screening criteria for retention.

E.5.1.6.1.5 Fire SAMA Identification Summary

Based on the review of the TMI-1 fire area results, two SAMAs have been identified as potentially cost beneficial methods of reducing fire risk:

- Install Damage Resistant, High Temperature RCP Seals with a Portable 480V Generator for Extended EFW Operation (SAMA 2),
- Re-route Cables in Inverter Rooms (SAMA 26),

Any SAMAs that improve the plant response to an accident have the potential for reducing fire risk through the same mechanisms; however, these SAMAs are also considered to explicitly address the fire scenarios identified above. While SAMA 2 has been identified as potential means of reducing fire risk, it was also identified based on the internal events importance list and is not unique to the fire review.

E.5.1.6.2 Seismic Events

In response to Generic Letter 88-20, Supplement 4 (NRC 1991), TMI-1 prepared a seismic PRA (SPRA) to asses seismic risk at the site. The SPRA considered site specific seismic event frequencies in conjunction with the plant specific response to quantify a CDF using a modified version of the IPE risk model. The baseline case was developed using seismic event frequencies developed by EPRI (EPRI 1989), but also quantified risk based on the frequencies estimated by Lawrence Livermore National Labs (NRC 1994). The results from the Lawrence Livermore National Lab (LLNL) sensitivity are assumed to be the baseline results for the purposes of the SAMA analysis.

E.5.1.6.2.1 Seismic Modeling Overview

As with the Fire model, the TMI-1 seismic model was not maintained as a living model. As a result, the state of knowledge, use of current PRA techniques, and subsequent plant changes are not reflected in the SPRA results. However, the development of a full SPRA likely provided a more thorough evaluation of seismic risk than a seismic margins analysis, which many plants in the industry used for the IPEEE. The following steps summarize the seismic modeling process used for TMI-1:

1. **Determination of site specific seismicity characteristic**. This step involves the development of the frequencies of occurrence and magnitude of seismic events for the TMI site. Site structure analysis is also performed. The resulting frequencies and magnitudes of seismic events are the initiating events for the SPRA. Site structure responses are input into Step 5 where the capacities of the components which impact risk are calculated.

5. **Identification of those components important to plant safety**, including equipment, structures and procedures. The Level 1 PRA developed for TMI-1 is utilized to

determine those components which impact risk. Other studies such as the TMI Environmental and External Hazards Report and the USI A-46 Safe Shutdown Equipment List are used to ensure that the list of components which impact risk is comprehensive.

6. **An initial plant walkdown** of the identified systems and components is performed. Any plant seismic system interactions and unique plant features which may impact risk are identified.
7. **Develop plant logic models.** The plant logic models are developed using the Level 1 TMI-1 PRA with the addition of the failure rates (fragilities) of components due to seismically initiated events. A “pre-tree” approach is utilized to ensure that independent as well as seismic failures are accounted for in the logic model.
8. **A second plant walkdown** is performed to verify plant seismic response models and to collect data to determine component capacities.
9. **Analyze the plant seismic response models** to determine seismic initiated accident sequences and their frequency. This step involves the assembly and quantification of the plant logic models as well as the reporting and analyzing of the results.
10. **Identify plant seismic vulnerabilities**. This step defines any site specific vulnerabilities which are discovered as a result of the performance of the study.

While the systematic process described above was used to identify and quantify seismic risk, SPRAs include major sources of uncertainty, as described in Aggregation of Quantitative Risk Assessment Results (EPRI 2005). The areas of uncertainty were summarized in that document as follows:

- Hazard Curve: The seismic hazard curve is developed using a combination of actual data and expert judgment. The actual data used to develop the seismic hazard curve is generally very sparse. The expert judgment is generated using expert elicitation process and includes technical experts in their subject matter fields. However, technical experts tend to be conservatively biased as a result of a desire to be conservative knowing the implications of the development of the seismic hazard curves is the design specifications for important safety systems. This conservatism is evidenced in the development of the distribution assigned to the hazard curve. With a larger distribution, the mean values of the frequency of occurrence increase.

- Fragility Curves: Fragility analysis performed in a typical seismic PRA is based on the “weak link” method. In this method, a seismic capacity engineer determines the weak link associated with a system or a particular function of a system, structure or component and develops a fragility of the component based on seismic acceleration. Similar to the development of a hazard curve, a combination of actual experience, testing, analysis, and expert judgment (to a lesser degree) is used to develop the fragility. The determination of the weak link is based on the subjective judgment of the seismic capacity engineer as is the final fragility albeit to a lesser degree.

- Correlation of seismic failures: Typical seismic PRA assume that systems, structures and components (SSC) that are similar are assigned a 100 percent failure correlation in the model. That is, one fragility applies to the failure of all similar components. For example, if a high pressure ECCS pump fails during a given seismic acceleration, then all similar ECCS pumps also fail. However, it is more likely that these components are not 100 percent correlated and that subtle, and sometimes not so subtle, differences between the components and their respective anchorages provide significant margins between the failure accelerations.

- Treatment of offsite power: In a typical seismic PRA a loss of offsite power is assumed for seismic events of any significant magnitude. The probability of a seismically induced loss of offsite power event can vary significantly and considerable judgment is usually used in the development of the fragility of the offsite power grid. In addition, the loss of offsite power is typically a significant contributor to the results of the seismic PRA.

- Treatment of balance of plant equipment: In a typical seismic PRA, the balance of plant equipment is omitted from the analysis as an analysis simplification. The reduction in the scope of the seismic PRA by the elimination of balance of plant equipment is performed to reduce the resources required to develop the seismic PRA. Generally, the balance of plant equipment is not seismically designed and details of the design and anchorage of the equipment is difficult to obtain, which further complicates the development of fragilities. However, for some plant designs, specifically Boiling Water Reactors (BWRs), the balance of the plant systems provide significant mitigative potential. This is particularly true for the lower seismic accelerations where continued equipment operability is reasonably likely.

- Modeling simplifications: Other modeling simplifications are also employed to reduce the scope of the seismic analysis. These analysis simplifications are generally performed to reduce the scope of the fragility analysis which is resource intensive. These analysis simplifications include the treatment of human reliability analysis, support system operability/availability following a seismic event and others.

These characteristics of the SPRA limit the use of the absolute risk metrics that are a result of the analysis, but the relative rankings of the seismic contributors and the insights from the model are considered to be useful for identifying potential areas for plant improvements.

E.5.1.6.2.2 Seismic Contributor Review

For both the EPRI NP-6395-D and the NUREG-1488 seismic hazard curves, the largest CDF contributions came from the seismic events between 0.2g and 0.5g. The lower magnitude events (0.052g to 0.2g) had higher frequencies of occurrence, but the consequential damage to the plant systems was not severe and the conditional core damage probability was relatively low. The higher magnitude events (0.5g to 1.01g) caused heavy damage and resulted in high conditional core damage probabilities, but the frequencies of occurrence for seismic events of this magnitude were estimated to be low. The table below summarizes the Seismic CDF by initiating event category for both the EPRI and LLNL seismic hazard curves:

TMI-1 Seismic Results Summary

Initiating Event	Earthquake Range	Based on EPRI NP-6395-D		Based on NUREG-1488	
		CDF	Percent of Total CDF	CDF	Percent of Total CDF
SEIS1	0.052g to 0.2g	5.78E-06	18.0%	1.26E-05	14.9%
SEIS2	0.2g to 0.3g	1.04E-05	32.4%	2.61E-05	31.0%
SEIS3	0.3g to 0.5g	1.22E-05	38.0%	3.25E-05	38.6%
SEIS4	0.5g to 1.01g	3.71E-06	11.6%	1.31E-05	15.5%

As shown in the table above, the distribution of CDF among the initiating event categories remains consistent whether the EPRI or LLNL seismic hazard curves are used. The use of the LLNL seismic hazard curves amounts to a fairly linear increase in the CDF for each of the seismic initiating event categories without significantly changing the types of challenges that have the highest frequencies of occurrence. Because the absolute seismic CDF estimates are not directly used in the SAMA analysis, the choice of which seismic hazard curve is used to extract risk insights does not impact the SAMA analysis. Examination of the seismic component Fussell-Vesely values for the top contributors confirms this assertion:

Top Seismic Component Fussell-Vesely Contribution Summary

Component ID	Top Event	Fussell-Vesely Contribution (EPRI)	Fussell-Vesely Contribution (LLNL)	Description
FRAG15	GW	4.42E-01	4.00E-01	1P, 1S, 1R, 1T 480V Class 1E load centers seismic failure with offsite power available.
FRAG15	GY	1.57E-01	1.50E-01	1P, 1S, 1R, 1T 480V Class 1E load centers seismic failure with offsite power failure.
FRAG01	OX	1.21E-01	1.10E-01	Seismic offsite power insulator failure.
FRAG20	CX	7.34E-02	7.00E-02	Seismic control room ceiling failure.
FRAG09	GY	5.90E-02	6.00E-02	Seismic failure of EDG air start receivers.
FRAG11	RX	2.05E-02	2.00E-02	Seismic failure of DHCCW heat exchangers.
FRAG17	GY	1.07E-02	1.00E-02	Seismic failure of EDG ground resistors.

A review of the LLNL based results shows that the largest Fussell-Vesely value for a non-seismic failure is Riskman top event “GA” (Class 1E AC power train “A”) at 7.33 E-03, which implies that seismically induced failures are the main contributors to the seismic risk profile. As a result, the focus of the seismic review is based on the seismically induced failures rather than the independent failures. A review of each of the top seismic contributors is provided below.

FRAG15

This seismic component group includes 480V AC Class 1E load centers 1P, 1S, 1R, and 1T, which have been identified as components with low seismic ruggedness. As these load centers provide power to critical equipment and have HCLPF capacities slightly greater than the weaker off-site power related components, the availability of the load centers is important in both cases when off-site power is available and when it has failed. This is significant as seismic events that do not fail off-site power would not present a large threat to the site if the 480V AC load centers remained available. The low HCLPF values associated with these load centers demonstrate that the probability of a seismically induced failure of the equipment is not unlikely in earthquakes where off-site power remains available, which is problematic.

The IPEEE indicates that plant specific HCLPF values were estimated for these components types and were determined to be 0.12g. This implies that damage to these load centers may occur for even the SEIS1 initiating event group. One of the recommendations resulting from the IPEEE analysis was to reinforce the load center framework to prevent failure in seismic events; however, no work was done to strengthen the load center supports because the reduction in risk was considered to be low compared with the total CDF. Because these load centers are large contributors to the seismic risk profile and have not been strengthened since the IPEEE, reinforcing these 480V load centers has been added to the TMI-1 SAMA list (SAMA 27).

FRAG01

The ceramic insulators on the off-site power lines outside of the site and coming into the TMI-1 switchyard are susceptible to relatively low seismic shocks (HCLPF = 0.09). Other components, such as the auxiliary transformers and the 6.9kV AC distribution buses were also assessed to have the same low HCLPF capacity as the ceramic insulators. As a result, off-site power may be failed in many of the higher frequency, low magnitude earthquakes. The seismically induced LOOP requires the availability of the on-site AC systems to prevent core damage in the long term as recovery of off-site power is not credited in seismic events where widespread damage to the off-site AC distribution system could exist.

Improving the off-site AC distribution system is not considered to be feasible and it is not suggested as a SAMA. Even if a seismically rugged, dedicated line to another generating station could be established, no information is available related to how other generating stations would respond to seismic challenges and their availabilities can not be assured.

A more cost effective means of addressing the loss of off-site power cases would be to improve on-site AC power reliability. The issues related to improving the seismic capacities of plant components related to on-site AC power generation are discussed for FRAG20, FRAG09, and FRAG17 below.

Another potential means of addressing off-site AC power failures is to implement changes that would allow the plant to operate without 4.16kV AC power for extended periods of time. As described in Section E.5.1.6.1, installation of the Westinghouse type high temperature, damage resistant seals would maintain primary side integrity while providing power to a 125V DC battery charger would allow for long term operation of the TD EFW pump for secondary side heat removal (SAMA 2). Even though control of the TD EFW pump is possible, powering the batter chargers is considered to be required because the 125V DC system is supports the vital 120V AC power supply for the OTSG level indicators. No credit is taken for operation of the TD EFW pump without level indication.

FRAG20

Failure of the main control room ceiling is assumed to result in the loss of the "B" division of Class 1E AC power in the IPEEE. The consequences of the failure of the main control room ceiling are not highly predictable and may result in damage to other equipment, cause fires, injure plant operators, or on the other extreme, cause no damage at all. However, because these types of failures have the potential to impact important plant functions, supports were added to the main control room ceiling to reduce the likelihood of failure, as suggested in the IPEEE. The changes were accepted as adequate to address the identified issue and no additional changes are considered to be required to address control room ceiling failure.

FRAG09

The IPEEE identified a potential plant enhancement related to securing the EDG air start receivers to reduce the probability that they will fail after a seismic event. The changes were accepted as adequate to address the identified issue and no additional changes are considered to be required to address the EDG air start receiver anchorages.

FRAG11

The IPEEE identified a potential plant enhancement related to strengthening the anchorage used to secure the decay heat closed cooling water heat exchangers (DC-C-2A(B)) to reduce the probability that they will fail during a seismic event. This suggested change was reviewed, but not implemented as it was not considered to be a cost beneficial change.

Failure of the DHCCW heat exchangers results in the loss of the ability to remove decay heat from the RPV and would lead to core damage if the secondary side heat removal function were also disabled. Given the low HCLPF capacity estimated for these components (0.09g) and the high importance of the DHCCW system, the anchorage enhancements suggested in the IPEEE have been included on the TMI-1 SAMA list for evaluation (SAMA 28).

FRAG17

Failure of the EDG ground resistors results in failure of the EDGs, which will lead to core damage in the event that off-site power is not available. Given that the HCLPF capacity for these components was estimated at 0.25g compared with 0.09g capacities of off-site power components (such as the 1/A and 1/B distribution buses or the aux transformers), it is likely that core damage will ensue due to long term loss of power if the EDG ground resistors fail from seismic shock.

A potential means of addressing this issue would be to replace these components with a more seismically durable design (SAMA 29).

Diesel Fire Pump

The IPEEE includes a potential plant improvement that suggests enhancing the supports for the diesel driven fire pump fuel oil tanks and batteries. This insight was based on a walkdown of the fire suppression system that was performed as part of the seismic/fire interaction assessment (not for the SPRA model). No quantitative estimates of seismically induced fire risk were presented in the IPEEE, but the conclusion based on the plant review was that the risk was low. However, this modification was included in the IPEEE as a potential plant improvement given that the fuel tanks and battery racks appeared to have low seismic capacities and that the fire protection function could be degraded in a seismic event due to the weakness of the identified support structures.

The supports for fuel oil tanks and batteries could be improved, but the impact of implementing these changes would be difficult to determine given that the SPRA assumed that the fire protection system was failed. The available results do not provide any insights on how improving the fire protection system's availability could impact risk. Based on the information in the current PRA model documentation, it is known that the fire protection system supports operation of the following equipment:

- SBO EDG engine cooling
- Backup cooling for the DHCCW heat exchangers (not credited)
- Backup Instrument Air 1A and 1B compressor cooling

The SBO EDGs depend on the fire protection system as the primary engine cooling source. If the proposed fire protection system modifications were implemented, the fire protection system could be used to cool the SBO EDG in a seismic event. However, because of the similarity between the "1E" EDGs and the SBO EDG, the seismic model would assume SBO EDG failure in the same scenarios where the 1E EDGs fail. The only likely benefit would come from cases where random failures disable the other two EDGs, which are much smaller contributors than other, seismic based equipment failures.

The ability to provide backup cooling to the DHCCW system is of limited importance as the DHCCW heat exchangers, even with the improved anchorages, are the likely failure points of the system. In addition, the DHCCW system and the DHR system it supports depends on the availability of the AC distribution system, which may not be available.

The 1A and 1B Instrument Air (IA) compressors are normally cooled by SSCCW, but fire protection is available as an alternate means of cooling in the event that SSCCW is unavailable. As the SSCCW heat exchangers are identified as low capacity components, the SSCCW system would likely be unavailable in even the 0.052g to 0.2g initiating event category causing failure of the IA system. Some improvement in the Instrument Air system availability could be gained through improving the fire protection system's seismic durability.

While the Fussell-Vesely importance value for the IA system is low (0.01), improving the supports for the diesel fire pump fuel oil tank and the battery racks has been added to the SAMA list (SAMA 30) to address potential IA improvements, as identified in Section E.5.1.5.

E.5.1.6.2.3 Containment Performance Analysis

The effect of seismic events on the containment building performance was evaluated from two perspectives:

- Containment structure seismic capacity,
- Fragility of containment isolation valves and signals.

The containment structure analysis concluded that the lowest median acceleration capacity for the containment building was 11.0g and that the HCLPF was 3.5g. Based on the high seismic capacity of the containment structure, seismic failure was not considered to be a credible event and no further evaluation was performed. As a result, no SAMAs are considered to be required to address containment building failures.

The IPEEE analysis of the containment isolation function showed that most containment isolation valves would fail closed on loss of Instrument Air, which is a non-seismic designed system. As the lowest fragility of the containment isolation system was determined to be the

ESAS relays at 0.89g, Instrument Air is not expected to be available after seismic events that challenge the containment isolation system components. One issue was identified related to the potential seismic interaction between containment purge line isolation valve AH-V-1D and air supply tank PP-T-1A, which has a low seismic capacity. As a result of the IPEEE, the restraints for PP-T-1A were improved and failure of valve AH-V-1D due to contact with the tank was no longer considered to be an issue. No additional changes are suggested to address this issue.

The only other containment isolation issue of concern was for motor operated valves that would fail "as-is" on loss of the corresponding power supply. The IPEEE concluded that the recovery times for containment isolation failure allowed sufficient time for manual or automatic closure of the valves after the seismic event, prior to core damage. No changes were considered to be required to address any of these types of release pathways in the IPEEE.

While manual isolation is a proceduralized action at TMI-1 and is considered to be a credible recovery path for seismic scenarios, the containment penetration isolation valves were reviewed again for the SAMA analysis. In all cases where MOVs are used in containment isolation paths, it was determined that they are either on closed cooling system lines that would not provide a release path without additional failures, are on lines with diameters of one inch or less (not significant release paths), or are in series with AOVs and SOVs that would fail closed on loss of air/power.

The small containment penetrations (1 inch in diameter or less) do not provide a significant release pathway even if they are not isolated. These penetrations are screened from further review based on the small potential for release in conjunction with the ability to manually isolate the valves, if required.

The pathways that include MOVs in series with AOVs or SOVs that "fail closed" on loss of power/air are screened from consideration as the pathway would be isolated in loss of power cases that fail the MOVs. Manual action is also available to isolate the penetration in the event that the "in series" AOV or SOV fails to close.

Closed loop cooling systems could provide a release path through a "failed open" motor operated isolation valve; however, multiple boundary failures would be required in conjunction with core damage. For TMI-1, two closed loop cooling water system penetrations have been identified that include only MOVs as isolation valves:

- Nuclear Services Closed Cooling Water: Three MOVs, NS-V-4, NS-V-15, and NS-V-35, are used as isolation valves on an 8 inch line which penetrates the reactor building.

- Reactor Building Normal Cooling Water: Two MOVs, RB-V-2A and RB-V-7, are used as isolation valves on 8 inch cooling lines which carry water to and from the reactor building cooling units.

None of these penetrations are connected to the RCS and a release through either of these paths would require a pressurized containment atmosphere, a break in the reactor building side of the closed cooling water system boundary, and a break in the ex-reactor building side of the closed cooling water system boundary. These may be unlikely events, but no assessment of the probability of seismically induced failure of these pathways is available. The identified pathways could be isolated without operator actions if the valves were modified so that they fail in the "closed" position (SAMA 31). This SAMA is included the SAMA list, but it should be noted that changing the valves to "fail closed" introduces a failure mode for the valves that did not previously exist and may be detrimental in other accident scenarios.

E.5.1.6.2.4 Seismic SAMA Identification Summary

Based on the review of the TMI-1 seismic analysis, five Seismic related SAMAs have been identified:

- Install Damage Resistant, High Temperature RCP Seals with a Portable 480V Generator for Extended EFW Operation (SAMA 2),

- Improve the 480V AC load center welds (SAMA 27),

- Improve the DHCCW Heat Exchanger (DC-C-2A(B)) Anchorages (SAMA 28),

- Replace EDG Ground Resistors (SAMA 29).

- Improve Diesel Fire Pump Fuel Oil Tank and Battery Rack Supports (SAMA 30)

- Modify Specific Containment Penetration MOVs to "Fail Closed" (SAMA 31)

E.5.1.6.3 High Wind Events

The strategy taken to examine high wind risk in the TMI-1 IPEEE was to quantify the CDF due to high wind events and show that was below the screening frequency of 1.0E-06/yr. For the

IPEEE, initiating events with a CDF below the screening frequency were precluded from further analysis and no detailed review of the plant response for these types of events was required. For TMI-1, the high wind based CDF (sum of high wind damage and missile strikes) was estimated to be 7.77E-07/yr based on some simplifying assumptions, including:

- The exceedance frequency used for 400 mph winds was taken to be the exceedance frequency for the 318-380 windspeed range (5.0E-04). The 400 mph wind speed was used to determine the tornado strike frequency because it was assumed to be the wind speed at which damage to category 1 structures could occur. This was based on the design limit of 360 mph and consideration of material stress safety factors employed in the design process. As a result, the initiating event frequency may be overestimated,

- Any site tornado strike with wind speeds ≥ 400 mph is assumed to fail the BWST and CST and lead to core damage,

- Any tornado missile strike to outside equipment is assumed to fail the equipment.

No potential plant improvements related to high wind risk were identified in the IPEEE as the events were screened from detailed analysis based on low frequency of occurrence. For the purposes of the SAMA analysis, an estimate of the cost-risk corresponding to high winds can be used to determine if any cost beneficial changes could be identified for the site. The cost-risk corresponding to high wind events is determined using the following assumptions:

- Internal and external events risk are approximately equal (excluding external flooding),

- The external events CDFs are directly proportional to the cost-risk associated with a given external event.

For TMI-1, the internal events maximum averted cost-risk is $3,271,711, which implies that the non-external flood based external events contribution is also $3,271,711. For any given external event type, the corresponding cost-risk can then calculated by multiplying the total external event cost-risk by the ratio of the specific external event CDF to the total external events CDF (excluding external flooding). For example, for seismic events:

seismic cost-risk = total external events cost-risk * (seismic CDF / total external events CDF)

seismic cost-risk = $3,271,711 * (8.43E-05 / 1.07E-04) = $2,577,454

The following table summarizes the results for the non-flooding external events:

External Events Cost-Risk Summary

External Event	CDF	Ratio of CDF to Total External Event CDF	Corresponding Cost-Risk[3]
Seismic[1]	8.43E-05	7.88E-01	$2,577,454
Fire	2.16E-05	2.02E-01	$660,886
High Winds	7.77E-07	7.26E-03	$23,753
Aircraft Impact[2]	3.95E-07	3.69E-03	$12,073
Hazardous Chemicals	1.60E-07	1.50E-03	$4,908

1 Based on the NUREG-1488 seismic hazard curves.
2 Intentional aircraft impact is treated outside of SAMA and is not accounted for here due to the specific nature of the threat. The CDF quantified in the IPEEE is used to address the potential for accidental impact.
3 These cost-risks are calculated by multiplying the external events based cost-risk (see section E.4.6) by the percent contribution of the external event type.

The cost-risk associated with high winds is only $23,753, which is less than the minimum expected cost of implementation of $50,000 (see section E.5.1). As a result, it is unlikely that any cost-beneficial SAMAs could be found to reduce the risk of high wind events and no further review is considered to be required for the SAMA analysis.

E.5.1.6.4 External Flooding

As part of the TMI-1 IPEEE, the site was reviewed to identify the largest flooding risks. This included high river flows from dam breaks, hurricane effects, snow melt, and other non-hurricane events. The bounding risk was determined to be a flood of the Susquehanna River most likely caused by a hurricane event.

The external flooding analysis performed in the TMI-1 IPEEE divided flood risk into three categories:

- Floods with elevations greater than 310 feet mean sea level (msl)
- Floods with elevations between 305 and 310 feet msl,
- Floods with elevations less than 305 feet msl.

The main contributors to core damage for each of these flood elevation ranges are different and are examined separately for the SAMA analysis.

E.5.1.6.4.1 Floods Greater than 310 Feet msl

Given the configuration of the plant at the time of the IPEEE, floods with elevations over 310 feet msl were assumed to result in the loss of all electrical equipment due to flooding of site buildings. As the existing flood gates would not prevent flooding of these buildings for these scenarios, successful installation of the flood gates would increase the length of time available before building flooding, but not prevent core damage. Based on insights from the IPEEE and previous TMI-1 external flooding analyses, a strategy was implemented at the site to use a temporary power source and submersible pumps to maintain the reactor in a safe state during these extreme flood conditions. The CDF of 8.10E-05/yr that was reported in the IPEEE credited the use of this strategy.

As is the case with the other external events contributors, the level of development and uncertainty of the external flooding results is not comparable to the current internal events PRA. Assuming that external flooding risk dominates the risk profile for TMI-1 because the CDF is about two times greater than the internal events CDF is not necessarily correct. However, because there are no reliable means of demonstrating that floods exceeding 310 feet msl are low risk events and because the consequences of the events are severe, TMI-1 should have a reliable method in place to address these scenarios. Tangible work has already been completed at TMI-1 to satisfy this need, but the flood scenarios must be considered in the context of the SAMA analysis to determine if additional changes could be cost-beneficial.

Based on the evaluation presented in the TMI-1 IPEEE, the major contributors to the CDF for flood events over 310 feet msl include:

- Failure of secondary side cooling (7.03E-02) (represented only by operator error),
- Failure of primary side makeup and seal injection (4.22E-02) (represented only by operator error).
- Failure of the portable EDG in the 48 hour mission time (1.43E-01)

These contributors can be evaluated to identify areas of weakness and potential means of improving the associated reliabilities.

The guidance that was developed to mitigate floods greater than 310 feet msl as a result of the IPEEE is considered to provide an appropriate level of detail for the actions required in the relevant scenario. For the current configuration, no additional risk reduction is considered to be possible through procedural changes alone.

Flood risk could be reduced by improving the state of readiness of the corresponding equipment (prestaging, SAMA 32). Examples of the things that should be considered include:

- Permanently mount the power cables between the generator and pump staging areas,
- Permanently mount injection lines required for primary and secondary side makeup (may not be practical for the secondary side pump that takes suction from flood water in the turbine building),
- Consider an alternate secondary side suction source given that flood waters may recede well before an alternate secondary side makeup source will become available when AC power is re-established to the site,
- Ensure the power cables have all required connectors attached or stored in the staging areas,
- Pre-manufacture any required air supply or fuel oil connectors and store them in the staging areas,
- Stage the portable generator on the turbine deck or provide a means of hoisting the generator and fuel oil to the turbine deck when offsite power is not available,

Another area of interest is the reliability of the portable EDG. The operation of the portable diesel generator for the 48 hour mission time is a large contributor to failure that is based on data similar to what is used in the PRA. While it may be true that the failure rate for the portable generator is much less than a standard EDG, a lower failure rate cannot be justified without a verifiable data source. A potential means of improving the reliability of the temporary AC supply would be to procure a spare 480V AC generator.

An alternative to the pre-staging option would be to increase the flood height for which the unit is protected (SAMA 33). The current configuration protects to the design basis limit of 310 feet msl and levels any higher result in topping of the existing flood doors and flooding of sensitive areas. In order to decrease the flood CDF to about 1E-5/yr, the flood protection height would have to be increased to 324.5 feet msl on the following gates/structures (completely sealing doors is suggested, where possible):

EDG Building

- Gate D-1
- Gate D-3
- Gate D-4
- Air Vent Valves for the fuel oil day tanks
- Seal underground cable vaults to prevent short circuits due to water incursion

Air Intake Structure

- Access Door
- Air Intake Vents

Intermediate Building

- Gate C-1

Control Building

- Gate B-1
- Gate B-2

Intake Screen Pumphouse

- Gate E-1
- Gates E-2
- Gate E-3
- Gate E-4

By preventing the incursion of water, the existing safety equipment should be capable of maintaining safe shutdown conditions as long as fuel oil is available to the EDGs.

E.5.1.6.4.2 Floods with Elevations Between 305 and 310 Feet msl

Flood events with elevations between 305 and 310 feet msl were evaluated with an event tree in order to describe and quantify the various core damage scenarios initiated by such floods. Of the six core damage scenarios evaluated in the event tree, three scenarios contributed 94 percent of the risk:

- Sequence CD-A (36.8%): Flood frequency (305 to 310' msl) * probability off-site power is available * probability of failing to install flood gates (cold shutdown achieved) * probability of failing to implement severe flood cooling,
- Sequence CD-D (35.7%): Flood frequency (305 to 310' msl) * probability off-site power is unavailable * probability that cold shutdown is not achieved prior to flood (off-site power not available) * probability of failing to install flood gates (cold shutdown not achieved) * probability of failing to implement severe flood cooling,
- Sequence CD-E (21.4%): Flood frequency (305 to 310' msl) * probability off-site power is unavailable * probability of on-site power failure * probability of failing to implement severe flood cooling.

A common failure of sequences CD-A and CD-D is the inability to implement the severe flooding cooling strategy that was designed for floods over 310 feet msl. While this cooling strategy was intended to mitigate only the most severe floods, it can be used for any flooding events where Turbine Building flooding occurs given that the secondary side submersible pump uses the flood water in the Turbine Building as a suction source (the primary cooling pump suction source is the SFP and it is potentially available for any condition). For floods with elevations between 305 and 310 feet msl, damage to plant safety equipment requires failure of the flood gates. This requirement implies that the time available to implement the severe flooding cooling strategy is less than for the scenarios where flood elevations must rise to greater than 310 feet msl. As a result, the human error probability associated with this action is larger than for the scenarios with flood elevations over 310 feet msl. The IPEEE assumed an HEP of 5.0E-01 for implementing the severe flooding cooling alignment for the 305 to 310 foot msl floods. The improvements to the severe flooding mitigation strategy suggested for floods greater than 310 feet msl (SAMA 32) would also reduce the human error probability for sequences CD-A and CD-D and is considered to be an effective SAMA for these flood events.

Another common failure between sequences CD-A and CD-D is related to flood gate installation. The IPEEE assessment concluded that human error was the dominant factor related to flood gate installation failure and only human error was included in the failure probability. The HEPs for flood gate installation failure used in the IPEEE ranged from 5.6E-02 to 6.3E-02 based on the contemporary flood gate design. Since that evaluation, TMI-1 replaced the seal system on the Unit 1 class 1 buildings. The changes were considered to have improved seal reliability, made the seals easier to maintain, and made the seals/gates more convenient to use. These changes may have improved the reliability of flood gate installation in some way; however, the HEPs were not re-quantified to reflect the gate enhancements. Further changes to the gates could be made to improve their ease of use, such as replacing all gates with permanently installed swinging gates that could be secured with a handwheel. While such a change may make the flood gates easier to use, it would be difficult to justify a large difference in the HEP associated with the improved gate system and the current design given the long period of time that is available to properly install the gates. Based on an onsite review of the gates and discussions with the flooding engineer, no changes to the gates are suggested to improve their installation mechanisms.

Sequence CD-E appears to be a simplified evaluation of the cases in which both on-site and off-site AC power fail. From the information in the IPEEE submittal, the flooding event tree shows that core damage occurs for floods between 305 and 310 feet msl elevation if off-site power fails in conjunction with on-site AC power. However, the total CDF from the event tree is multiplied by the 0.5 failure probability for severe flooding cooling alignment to obtain the final CDF for floods with elevations between 305 feet msl and 310 feet msl. This implies that core damage does not occur before flood waters reach a level where the submersible pump could be used for secondary side cooling. No discussion is provided to describe the timing of off-site power loss relative to the flood height. This is important because the accident would evolve differently depending on whether it is caused by a hurricane or by flooding of the site transformers. For the case of a hurricane induced flood, offsite power could be lost early and on-site power would therefore be challenged at that time. An early failure in on-site power would result in core damage before flood water reaches the turbine building and no credit should be taken for the existing severe flooding cooling alignment. Quantitative resolution of this issue would require a more detailed analysis than what was performed for the IPEEE, but this uncertainty could be addressed through implementation the alternate secondary side suction source that is part of the SAMA 11 design. This provides a means of initiating both primary and secondary side makeup at any time during an accident.

A lower frequency sequence, CD-F, is based on the failure to provide an early flood warning to the plant. The early flood warning was assumed to be the cue instigating the initiation of the required flood procedures. While no credit was taken for installing the flood gates in time to prevent flooding of site buildings, the IPEEE credited implementation of the severe flooding cooling alignment. No discussion was identified that described why credit was taken for the severe flooding cooling alignment under this circumstance, but sequence CD-F would only comprise about 1 percent of the external flooding CDF if credit for the alignment were disallowed. Due to the low contribution of sequence CD-F relative to the other sequences, no SAMAs are considered to be required.

E.5.1.6.4.3 Floods with Elevations Below 305 Feet msl

In order for floods in this category to impact the site, the dike on the northern tip of the island is required to fail in conjunction with the flood event. The frequency of these events, which are required to cause site flooding, were determined to be less than 3 percent of the total flooding frequency alone. The conditional CDF given this type of flood event was estimated to be less than 0.1, which would correspond to a contribution of less than 0.3 percent of the total external flooding CDF.

No detailed CDF sequences were developed for these floods in the IPEEE and no specific failure contributions were identified other than dike failure. Improvements could be made to the dike, but even with dike failure, the buildings housing safety equipment would not flood. The only potential issue identified is the flooding of the EDG building cable vaults, which is addressed by SAMA 33. No other SAMAs are suggested to address this flood category.

E.5.1.6.4.4 External Flooding SAMA Identification Summary

Based on the review of the TMI-1 external flooding analysis, two external flooding related SAMAs have been identified:

- Prestage Severe Flooding Equipment (SAMA 32),
- Increase the Flood Protection Height (SAMA 33)

E.5.1.6.5 Transportation and Nearby Facility Accidents

Transportation and nearby facility accidents were included in the TMI-1 IPEEE to account for human errors or equipment failures that may occur in events not directly related to the power generation process at the plant. The types of hazards explicitly evaluated for the site include:

- Aircraft Impact
- Hazardous Chemical Release

E.5.1.6.5.1 Accidental Aircraft Impact

At the time the IPEEE was performed, available information related to military, commercial, and general aviation traffic was used to estimate the frequency of a release of radionuclides caused by aircraft impact. Given the information and conditions present at the time of the analysis, the frequency was determined to be 3.95E-07 per year and further analysis was not considered warranted.

It is recognized that the types of credible threats to nuclear facilities by aircraft have changed since the time the IPEEE was published. While this is true, efforts are underway within the industry to address this issue in conjunction with other forms of sabotage. Based on the fact that this topic is currently being analyzed in another forum and due to the complexity of the issue, intentional aircraft impact events are considered to be out of the scope of the SAMA analysis. The analysis performed in the IPEEE is used to provide insights related to accidental aircraft impact.

No potential plant improvements related to the risk of accidental aircraft impacts were identified in the IPEEE as the events were screened from detailed analysis based on low frequency of occurrence. For the purposes of the SAMA analysis, an estimate of the cost-risk corresponding to accidental aircraft impact can be used to determine if any cost beneficial changes could be identified for the site. The cost-risk corresponding to accidental aircraft impacts is determined using the following assumptions:

- Internal and external events risk are approximately equal (excluding external flooding),
- The external events CDFs are directly proportional to the cost-risk associated with a given external event.

For TMI-1, the internal events maximum averted cost-risk is $3,271,711, which implies that the non-external flood based external events contribution is also $3,271,711. For any given external event type, the corresponding cost-risk can then calculated by multiplying the total external event cost-risk by the ratio of the specific external event CDF to the total external events CDF (excluding external flooding). For example, for seismic events:

seismic cost-risk = total external events cost-risk * (seismic CDF / total external events CDF)

seismic cost-risk = $3,271,711 * (8.43E-05 / 1.07E-04) = $2,577,454

The following table summarizes the results for the non-flooding external events:

External Events Cost-Risk Summary

External Event	CDF	Ratio of CDF to Total External Event CDF	Corresponding Cost-Risk[3]
Seismic[1]	8.43E-05	7.88E-01	$2,577,454
Fire	2.16E-05	2.02E-01	$660,886
High Winds	7.77E-07	7.26E-03	$23,753
Aircraft Impact[2]	3.95E-07	3.69E-03	$12,073
Hazardous Chemicals	1.60E-07	1.50E-03	$4,908

1 Based on the NUREG-1488 seismic hazard curves.
2 Intentional aircraft impact is treated outside of SAMA and is not accounted for here due to the specific nature of the threat. The CDF quantified in the IPEEE is used to address the potential for accidental impact.
3 These cost-risks are calculated by multiplying the external events based cost-risk (see section E.4.6) by the percent contribution of the external event type.

The cost-risk associated with aircraft impact is only $12,073, which is less than the minimum expected cost of implementation of $50,000 (see section E.5.1). As a result, it is unlikely that any cost-beneficial SAMAs could be found to reduce the risk of accidental aircraft impact events.

It should be noted that the accidental aircraft impact assessment from the IPEEE was based on air traffic assumptions relevant to the initial license period. That assessment assumed a continuous “aircraft movement” growth for Harrisburg International Airport that was two to four times larger than the national average growth observed for the years 1979 to 1988. This resulted in an estimate of 177,000 aircraft movements per year for the midpoint of the original license period (1994). In order for the minimum cost SAMA (a procedure change of $50,000) to be potentially cost effective, the aircraft movement frequency would have to increase by a factor of 4.5. Even an order of magnitude increase in the aircraft movement would only yield a potential averted cost-risk of $120,730 for a completely effective SAMA. Based on the small impact of large changes in aircraft activity, any changes to aircraft movement frequency that may occur over the license renewal period are not expected to increase accidental aircraft impact risk to the point where potential SAMAs would become cost-effective. No SAMAs are suggested to address accidental aircraft impact for TMI-1.

E.5.1.6.5.2 Accidental Hazardous Chemical Release

Similar to the aircraft impact assessment performed for the IPEEE, the hazardous chemical release assessment was based on non-intentional events. Threats related to intentional chemical releases are credible; however, the specialized nature of security threats requires that they are treated in a separate forum and they are not addressed as part of the SAMA analysis.

For accidental releases, the IPEEE considered stationary and transient hazardous chemical sources that could pose a threat to TMI-1 if a release were to occur. As shown in the accidental aircraft impact discussion above, the cost-risk associated with hazardous chemical releases is only $4,908 assuming that the conditions present at the time of the IPEEE are applicable. Some variation may occur in the characteristics of the chemical loads near the site or transported on the rail lines close to the site over the course of the license renewal period. While it is not possible to accurately predict what these changes could be, an order of magnitude increase in the risk that was estimated in the IPEEE would only increase the associated cost-risk to $49,080. Given that an order of magnitude increase in the hazardous chemical release risk would still not be likely to yield any cost beneficial plant changes, no SAMAs are suggested to address these types of threats.

E.5.2 PHASE I SCREENING

The initial list of SAMA candidates is presented in Table E.5-3. The process used to develop the initial list is described in Section E.5.1.

The purpose of the Phase I analysis is to use high-level knowledge of the plant and SAMAs to preclude the need to perform detailed cost-benefit analyses on them. The following screening criteria were used:

- Applicability to the Plant: If a proposed SAMA does not apply to the TMI-1 design, it is not retained.

- Implementation Cost Greater than Screening Cost: If the estimated cost of implementation is greater than the modified Maximum Averted Cost-Risk, the SAMA cannot be cost beneficial and is screened from further analysis.

Table E.5-3 provides a description of how each SAMA was dispositioned in the Phase I analysis. All SAMAs that were found to be applicable to the TMI-1 design and to have a cost of implementation less than the MACR were passed to the Phase II analysis for a more detailed evaluation (Section E.6).

E.6 PHASE II SAMA ANALYSIS

Not all of the Phase II SAMA candidates require detailed analysis. The Phase II process allows for the screening of SAMAs known to be related to non-risk significant systems or to components/functions with low importance rankings. Due to the nature of the PRA based process used to develop the TMI-1 SAMA list, there are limited avenues for SAMAs of this type to be included in the list. However, potential pathways do exist:

- Inclusion of unresolved proposed plant changes from previous TMI-1 risk analyses,
- Inclusion of SAMAs based on the results of conservative modeling methods.

While no calculations are required for eliminating a SAMA that is linked to a non-risk significant system or components, some quantitative efforts are usually required to screen SAMAs that were developed to address risk contributors based on conservative modeling techniques. These cases are identified in Table E.5-4 and discussed in detail in the SAMA specific subsections of E.6.

For the SAMAs requiring detailed analysis, a more detailed conceptual design was prepared to allow the proposed SAMA to be modeled in the PRA. The results of the model changes were used in conjunction with the estimated implementation costs to evaluate whether or not the SAMA is cost beneficial.

The final cost based screening method is defined by the following equation:

Net Value = Averted cost-risk – cost of implementation

Where:

Averted cost-risk = (baseline maximum averted cost-risk – maximum averted cost-risk with SAMA implemented)

If the net value of the SAMA is negative, the cost of implementation is larger than the benefit associated with the SAMA and the SAMA is not considered beneficial. The baseline MACR was derived using the methodology presented in Section E.4. The MACR with the SAMA implemented is determined in the same manner with the exception that the PRA results used as input reflect implementation of the SAMA.

The calculation of the averted cost-risk for a SAMA must account for external events contributions. In some cases, representing the impact of a SAMA's impact on external events is complex. The method adopted in the SAMA analysis to address this issue is dependent on the type of SAMA to be quantified:

- For SAMAs that were not specifically developed to address external events issues, the multiplier defined in Section E.4.6.3 is used on the internal events averted cost-risk to provide an estimate of the non-external flooding external events benefit. This serves only as a gross approximation of the true benefit given that a SAMA may not impact both internal and external events risk in the same way. The external flooding model is quantified separately.

- For SAMAs that were specifically developed to address external events, the external events models are used to extract quantitative insights that can be used to provide bounding estimates of potential averted cost-risks. In these cases, the specific external events benefit calculations generally supercede the multiplier and the multiplier is not used. The details of the quantification process vary for each SAMA and are described in the SAMA specific discussions of Section E.6.

The implementation costs used in the Phase II analysis include both TMI-1 specific estimates developed by plant personnel and estimates taken from other SAMA submittals for those SAMAs that were determined to be highly similar. It should be noted that the TMI-1 specific implementation costs do not specifically include contingency costs for unforeseen difficulties nor do they account for any replacement power costs that may be incurred due to consequential shutdown time.

Sections E.6.1 – E.6.33 describe the detailed cost-benefit analysis that was used for each of the remaining candidates.

E.6.1 SAMA NUMBER 1: ENHANCE THE SBO EDG WITH AUTO START AND LOAD CAPABILITY

The availability of an auto start and load function for the SBO EDG will reduce the time required to restore power to the RCP seal cooling systems when the AC power has been lost and the "A" and "B" EDGs fail. Procedures should be reviewed to ensure that they will allow the operators to establish at least one form of seal cooling within 13 minutes of the initial loss of cooling. This is critical given that restoring RCP seal cooling after the 13 minute limit is considered to cause damage to the seals that will exacerbate seal leakage. The benefit of this SAMA would be enhanced if the auto start/load logic were capable of backing up either division of power for single EDG failures and selecting a single division to support in the event that both the “A” and “B” EDGs fail.

The SBO EDG is described in the plant manuals as being capable of accepting a load within 10 minutes of an SBO, but no credit is taken in the PRA for preventing seal damage due to the uncertainty in this performance time and the time required to ensure seal cooling is established. Some additional margin may be possible through procedure optimization, but the time window for action is so short that the most reliable way ensuring seal cooling is re-established before the 13 minute limit is reached is through automation of the start and load process for the SBO EDG.

E.6.1.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA’s averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In order to represent this SAMA in the PRA, it was necessary to perform both basic event data changes and event tree/fault tree structure modifications given that the LOOP-SBO event tree is structured to force a seal LOCA when the “A” and “B” EDGs are unavailable. Specifically, the operator action to start the SBO EDG was reduced by a factor of 10 to represent automation of the start function. Further, it was necessary to adjust the joint human error probabilities (JHEPs) that included the action to start the SBO EDG given that the manual start action is essentially eliminated by the SAMA. In this case, it is appropriate to eliminate all JHEPs associated with the SBO EDG start action as the automated start removes the human action from the dependence chain. With respect to the impact on seal LOCAs, the LOOP-SBO tree logic was changed to allow the SBO EDG to prevent a seal LOCA. The following table summarizes the model changes that were made:

SAMA 1 - Model Changes

Gate and / or Basic Event ID and Description	Description of Change
GSHEO1A----HDGOA: OPERATOR FAILS TO START SBO DG	The basic event probability was changed from 2.66E-02 to 2.66E-03.
JHHNSHOTHEOHEPOA: JHHNS10HOT1HEPOA AND GSHEO1A----HDGOA (dependence with tripping the RCPs)	The basic event probability was changed from 3.60E-05 to 0.0.
JHHNS10HEO1HEPOA: NRHNS10_HERHP1OA AND GSHEO1A----HDGOA (dependence with restarting NSRW pumps after a loop)	The basic event probability was changed from 3.10E-04 to 0.0.
LOOP-030 through LOOP-052	These gates were removed from the model as they are no longer required. The gates were previously used to model sequences in which a seal LOCA developed when only the SBO EDG was available.
RCP-LOOP-100	This gate was removed from the model as it was previously used to delineate cases where only the SBO EDG was available. These cases would previously result in seal LOCAs, but the SAMA implementation eliminates this condition.

It should be noted that the modeling strategy outlined above conservatively forces SAMA 1 to mitigate all seal LOCA cases with successful EFW operation when 4kV AC power has been lost to a single AC bus. There are scenarios in which core damage will occur for these conditions with SAMA 1 in place, but the impact is minor and would not change the conclusions for this SAMA. The results of the quantification are summarized below:

SAMA 1 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	1.88E-05	27.51	$98,718
Percent Change	-20.7%	-15.6%	-12.1%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 1 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.56E-07	1.59E-06	1.81E-07	1.27E-08	4.21E-11	4.21E-11	1.90E-10	2.40E-10	1.14E-08	1.24E-08	1.03E-09	2.88E-07	5.55E-07	1.34E-07	1.68E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.03	0.04	0.00	0.84	3.41	0.82	0.05
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,677	$44,202	$3,367	$236	$2	$2	$7	$9	$102	$111	$9	$2,589	$11,211	$2,707	$159

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	7.00E-08	6.41E-09	1.68E-07	2.58E-09	6.48E-07	9.53E-08	2.21E-06	1.07E-05	1.66E-08	1.63E-06	1.59E-08	1.88E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.20	0.02	0.23	0.00	0.87	0.13	4.91	2.85	0.00	0.44	0.00	27.51
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$662	$61	$642	$10	$2,475	$364	$13,879	$2,798	$4	$427	$4	$98,718

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 1 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$2,790,086	$481,625	2.0	$963,250

E.6.1.2 EXTERNAL FLOODING EVALUATION

This SAMA can have an impact on any scenario requiring the operation of the SBO EDG. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310’ msl: In these scenarios, the SBO EDG is flooded and this SAMA has no impact on the risk.

- Floods between 305’ and 310’ msl: Most of the sequences are not impacted by the enhanced capabilities of the SBO EDG as core damage is caused by failure of the flood gates (the SBO EDG is flooded) or because a flood warning is not provided and no preparations are made for the flood (the SBO EDG is flooded). Flood sequence “E” represents cases where the flood gates are correctly installed, but a loss of all AC power leads to core damage. Given that a loss of all power implies failure of the SBO EDG, SAMA 1 would provide no benefit to Sequence “E”.

- Floods below 305’ msl: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. While the inclement weather conditions that would likely exist in flood scenarios would provide an indication that a LOOP may occur, the operators would not start and prepare the SBO EDG for loading before the onset of loss of AC conditions. As a result, these scenarios are assumed to be impacted in the same way as the internal events LOOP events are.

In order to quantify the flooding benefits, it was necessary to characterize the impact of SAMA 1 on the internal events LOOP sequences. Once this is completed, the frequency of floods below 305’ msl can be reduced by the same percentage.

Because SAMA 1 predominantly impacts LOOP events, the absolute reduction in LOOP CDF can be calculated by subtracting the CDF for SAMA 1 from the base CDF:

Absolute LOOP CDF Reduction = 2.37E-05 - 1.88E-05 = 4.90E-06

The total base LOOP CDF can be approximated by multiplying the Fussell-Vesely value of the LOOP initiating event (%AC) by the base CDF:

Base LOOP CDF = 3.26E-1 * 2.37E-05 = 7.72E-06

The percent reduction in the LOOP CDF can then easily be determined:

Percent Reduction in LOOP CDF = (Absolute LOOP CDF Reduction / Base LOOP CDF) * 100

Percent Reduction in LOOP CDF = (4.90E-06 / 7.72E-06) * 100 = 63.5%

Based on these results, the CDF for the floods below 305’ msl was reduced by 63.5%.

The following tables summarize the results of these changes:

SAMA 1 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.09E-05	176.92	$541,385
Percent Change	-0.2%	-0.1%	-0.1%

A further breakdown of this information is provided below according to release category.

SAMA 1 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	9.13E-08	8.09E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.13	176.92
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$445	$541,385

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 1 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,520,578	$22,895

E.6.1.3 COST OF IMPLEMENTATION

The cost of this SAMA was estimated to be $3,125,000 (Exelon 2007c).

E.6.1.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 1 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$963,250	$22,895	$986,145	$3,125,000	-$2,138,855

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.2 SAMA NUMBER 2: INSTALL DAMAGE RESISTANT HIGH TEMPERATURE RCP SEALS WITH A PORTABLE 480V AC GENERATOR FOR EXTENDED EFW OPERATION

RCP seals have been developed that are capable of preventing seal LOCAs on loss of seal cooling events. The Flowserve N-9000 seals are reported to limit seal leakage to about 1 gpm per RCP seal even when cooling to the seals is completely lost, which is essentially considered to eliminate the seal LOCA evolution. In SBO cases, prevention of a seal LOCA will allow for extended operation if level instrumentation can be supplied using the vital 120V AC system. Powering the station battery chargers with a portable 480V AC generator would provide this capability and allow control of the TD EFW system to be retained in the MCR.

In order to maintain control of the TD EFW system from the MCR, power must be supplied for multiple loads, including:

- Level instrumentation,
- Control of EF-V-30 valves, and
- Instrument air for EF-V-30 valves.

The 480V AC generator should be capable of providing these loads as long as the correct connections are made and the loads are managed properly. Cooling water is another concern for the instrument air compressors, but IA-P-1A and IA-P-1B can be cooled from the Altitude Tank. Plant documentation indicates that this connection is linked to the Fire Service system, so it is also assumed that Fire Service water could be used in an SBO based on the availability of the diesel driven fire pump.

In the event that one of these support systems fails, it is also possible to operate the EF-V-30 valves locally, without any support other than power for SG level instrumentation.

E.6.2.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

To simulate the installation of a new RCP seal package that prevents the onset of a RCP seal LOCA, a recovery event was appended to cutsets using QRECOVER32 that satisfied the gate logic for RCP-LOOP-100, "RCP SEAL FAILURE". This process captures all of the seal LOCAs contributors and multiplies them by the probability of the recovery event, which in this case was set to 1.0E-01. While the new seals may be capable of preventing a seal LOCA with a reliability greater than 90% when cooling is lost, the existing PRA model is not configured to analyze the probability of core damage after a seal LOCA is prevented. Ten percent of the original seal LOCA contribution is retained to represent:

- The CDF from cases where the new seals fail and a seal LOCA occurs,
- The CDF from cases where the new seals prevent a seal LOCA, but the core is damaged due to other failures.

In order to account for the reduction in CDF due to the availability of a spare 480V AC diesel generator to supply backup 480V AC power, the HEP event EFHEF1_OPERH2HOA was reduced by a factor of 10. The CDF reduction is primarily due to the improved performance shaping factors related to the ability of the operator to use the MCR controls for EFW, but there may also be some improvement in the HEP related to the reduced manipulation time for the action. In the TMI-1 model, the relevant operator actions include the independent event discussed above as well as joint human error events. In this case, allowing for continued control of EFW in the MCR would not eliminate the dependence with other actions as the mechanism of dependence is primarily cognitive, but it could impact the JHEP probabilities. Depending on the nature of the JHEP calculation, the actual impact on the JHEP probabilities could range from a percent or two all the way to a factor of 10. Rather than recalculate the JHEPs, they were conservatively eliminated for convenience. No HEP is included for failure to align the portable 480V AC generator. For this evaluation, it is assumed that the operators will always be able to align the charger before depletion of the batteries and that the generator will always run.

No model requantification was performed for this SAMA. All of these operations were performed on the existing base cutset files through basic event data changes and cutset recovery. The following table summarizes the changes that were made to the basic event data and a brief description of the recovery file used to modify the seal LOCA contributors:

SAMA 2 - Model Changes

Gate and / or Basic Event ID and Description	Description of Change
EFHEF1_OPERH2HOA: OPERATOR FAILS TO MANUALLY OPERATE EF-V-30 AFTER LOSS OF INSTRUMENT AIR	The basic event probability was changed from 2.00E-03 to 2.00E-04.
JHHEF1-HBW1HEPOA: EFHEF1_OPERH2HOA AND BWHBW1-----HP2OA (dependence between EF-V-30 operation and manual HPI initiation)	The basic event probability was changed from 1.00E-04 to 0.0.
JHHAM2-HEF1HEPOA: AMHAM2-----HC1OA AND EFHEF1_OPERH2HOA (dependence between EF-V-30 operation and manual start of air compressors after a LOOP)	The basic event probability was changed from 4.61E-03 to 0.0.
JHHAMHEFHBWHEPOA: JHHAM2-HEF1HEPOA AND BWHBW1-----HP2OA (dependence between EF-V-30 operation, manual start of air compressors after a LOOP, and manual initiation of HPI)	The basic event probability was changed from 2.40E-04 to 0.0.
JHHAM1-HEF1HEPOA: AMHAM1-----HC1OA AND EFHEF1_OPERH2HOA (dependence between EF-V-30 operation and failure to bypass IA dryer transfer valve)	The basic event probability was changed from 1.81E-02 to 0.0.
JHHAMHEFHB2HEPOA: JHHAM1-HEF1HEPOA AND BWHBW1-----HP2OA (dependence between EF-V-30 operation, failure to bypass IA dryer transfer valve, and manual initiation of HPI)	The basic event probability was changed from 4.90E-05 to 0.0.
RCP-SEAL-IMPROVE.CAF	New recovery fault tree with top gate “Recoveries” used to apply a recovery event (RCP-SEAL-IMPROVE) to all cutsets including seal LOCAs. The new gates include: • RECOVERIES (Equivalence gate connected to new gate RCP-SEAL-IMPROVE) • RCP-SEAL-IMPROVE (Equivalence gate connected to existing gate RCP-LOOP-100)

Note that the action EFHEF2_OPERHFCOA and its JHEPs are not included in the model changes tabulated above as they have no measurable impact on the CDF. The results of the quantification are summarized below:

SAMA 2 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	1.13E-05	15.24	$56,521
Percent Change	-53.3%	-53.3%	-49.7%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 2 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.18E-07	9.21E-07	1.80E-07	9.32E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.26E-09	1.25E-09	4.86E-11	2.76E-08	3.56E-07	4.98E-08	5.87E-09
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.39	5.27	0.91	0.05	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.08	2.19	0.31	0.02
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$11,620	$25,604	$3,348	$173	$0	$0	$0	$0	$65	$11	$0	$248	$7,191	$1,006	$55

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.43E-11	0.00E+00	6.57E-09	1.43E-09	6.77E-08	4.09E-10	7.20E-08	3.75E-08	6.73E-07	8.14E-06	5.45E-09	3.18E-07	8.19E-10	1.13E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.02	0.00	0.09	0.00	0.10	0.05	1.49	2.17	0.00	0.08	0.00	15.24
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$0	$0	$62	$14	$259	$2	$275	$143	$4,226	$2,133	$1	$83	$0	$56,521

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 2 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$1,595,737	$1,675,974	2.0	$3,351,948

E.6.2.2 EXTERNAL FLOODING EVALUATION

This SAMA can have an impact on any SBO scenario as well as any seal LOCA scenario. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310' msl: In these scenarios, all safety equipment is flooded and the EFW system would not be available. Installation of the damage resistant RCP seals, which is part of this SAMA, would preclude the need to align the primary side makeup/seal injection pump. This would reduce the operator workload slightly improve the reliability of the flood mitigation actions, but the existing HEP is considered to be representative of the difficult set of actions that remain to align secondary side cooling and no reduction of the extreme flood CDF is assumed to occur based on the installation of the N-9000 seals.

- Floods between 305' and 310' msl: Most of the sequences are not impacted by this SAMA as core damage is caused by failure of the flood gates (the SBO EDG is flooded) or because a flood warning is not provided and no preparations are made for the flood (the SBO EDG is flooded). Flood sequence "E" represents cases where the flood gates are correctly installed, but a loss of all AC power leads to core damage. These SBO cases are assumed to be completely mitigated by this SAMA

- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. As a result, these flooding sequences would be impacted in the same way as the internal events LOOP events. In order to simplify the calculations, SAMA 2 is assumed to eliminate all risk from this flooding sequence. Given the low contribution of these sequences relative to the entire flooding contribution, the impact of this conservative assumption is minimal.

The following tables summarize the results of these changes:

SAMA 2 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	7.72E-05	166.08	$508,082
Percent Change	-4.8%	-6.3%	-6.3%

A further breakdown of this information is provided below according to release category.

SAMA 2 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	0.00E+00	8.65E-08	0.00E+00	7.72E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	0.00	0.25	0.00	166.08
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$0	$778	$0	$508,082

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 2 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$14,598,420	$945,053

E.6.2.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $7,300,000 by the TMI staff (Exelon 2007c).

E.6.2.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 2 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$3,351,948	$945,053	$4,297,001	$7,300,000	-$3,002,999

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.3 SAMA NUMBER 3: USE NSCCW AS AN ALTERNATE COOLING SOURCE FOR THE DHR HEAT EXCHANGERS (DH-C-1A/B)

For LOCAs requiring heat removal with the RHR system, DHRW and DHCCW failures are large contributors to loss of the primary cooling function. Providing the ability to cross-tie the NSCCW system to the DHR heat exchangers would diversify the plant's heat removal capability and eliminate the failures associated with loss of DHRW or DHCCW flow. The hard piped connections are assumed to be sized to allow enough flow to remove decay heat (not just pump cooling loads) and that each division is provided with a cross-connection to NSCCW.

E.6.3.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In order to represent this SAMA in the PRA, the NSCCW system was modeled to supply a backup cooling water source in the event that either of the DHCCW trains fails to provide cooling to the DHR heat exchangers. In the event that the DHCCW system is unavailable to provide cooling water on the shell side of either of the DHR heat exchangers, an operator action is required to restore cooling flow via cross-connecting the NSCCW header with the applicable DHR heat exchanger via a remotely operated MOV from within the MCR. The affected model logic was OR gate LPRG0007 for DHR heat exchanger train A and OR gate LPRG0019 for DHR train B. Specifically, the DHCCW train A system top event HA under gate LPRG0007 was replaced with a new AND gate named LPRG0007-1. The inputs to LPRG0007-1 are system top event HA and a new OR gate named NS-1A. The inputs to gate NS-1A are similar to the inputs under the nominal NSCCW system top event NS, with the addition of an MOV event for DHR heat exchanger DH-C-1A and an HEP event that represents operator failure to restore cooling water flow. Likewise, system top event HB under gate LPRG0019 was replaced with a new AND gate named LPRG0019-1. The inputs to LPRG0019-1 are system top event HB and a new OR gate named NS-1B. The inputs to gate NS-1B are similar to the inputs under the nominal NSCCW system top event NS, with the addition of an MOV event for DHR heat exchanger DH-C-1B and the same HEP event described above for restoration of cooling water flow.

In addition, all affected logic described above that is modeled within the logic structure for post-LOOP recovery scenarios was also modified, with gate names appended with the characters "-R".

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 3 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.01E-05	29.97	$105,253
Percent Change	-15.2%	-0.3%	-0.3%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 3 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.54E-07	1.52E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	4.34E-09	3.09E-07	7.28E-07	1.26E-07	2.20E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.60	8.69	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.01	0.91	4.48	0.77	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,621	$42,256	$3,367	$236	$3	$3	$7	$11	$351	$131	$39	$2,778	$14,706	$2,545	$208

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.21E-10	2.08E-11	7.97E-08	8.08E-09	2.24E-07	2.51E-09	7.38E-07	1.82E-07	2.78E-06	1.05E-05	1.69E-08	2.15E-06	1.78E-08	2.01E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.02	0.30	0.00	1.00	0.25	6.17	2.80	0.00	0.57	0.00	29.97
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$753	$76	$856	$10	$2,819	$695	$17,458	$2,748	$4	$563	$5	$105,253

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 3 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$2,995,414	$276,297	2.0	$552,594

E.6.3.2 EXTERNAL FLOODING EVALUATION

This SAMA has a very limited impact on external flooding scenarios. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310' msl: In these scenarios, flood waters fail the DHR system and the SAMA has zero impact.

- Floods between 305' and 310' msl: Most of the sequences are not impacted by the enhanced cooling capabilities of the DHR system as core damage is caused by failure of the flood gates (safety equipment flooded, SBO) or because a flood warning is not provided and no preparations are made for the flood (safety equipment flooded, SBO). Flood sequence "E" represents cases where the flood gates are correctly installed, but a loss of all AC power leads to core damage. These conditions will cause a seal LOCA and for the small fraction of the scenarios in which power is recovered, the cross-ties could be used to mitigate certain failures. The impact of this SAMA can be approximated by using the baseline internal events model to determine the percent contribution of the "power recovered" SBO sequences to the total SBO contribution. Then, if it is assumed that the relative distribution of "power recovered" sequences for the "E" flood sequence as the same as for the internal events model, the portion of the flood sequence "E" CDF impacted can be calculated. For this evaluation, it is assumed that implementation of this SAMA will eliminate all SBO "power recovered" risk and that the "power recovered" fraction is the same for flood events as it is for internal events SBOs (likely optimistic for the flood case).

- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. For simplicity, the CDF for this sequence is assumed to be completely eliminated.

Based on the internal events model, SBO sequences contribute a CDF of 3.25E-06/yr while the power recovered SBO sequences contribute only 2.21E-08/yr. This indicates that the "power recovered" SBO evolutions contribute only 0.7 percent of the SBO CDF (2.21E-08 / 3.25E-06/yr * 100 = 0.7). For flood sequence "E", the expected CDF reduction would then be 2.56E-08 (7.0E-03 * 3.66E-06 = 2.56E-08).

The following tables summarize the results of quantification strategy:

SAMA 3 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.08E-05	176.71	$540,710
Percent Change	-0.3%	-0.3%	-0.3%

A further breakdown of this information is provided below according to release category.

SAMA 3 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.63E-06	8.65E-08	0	8.08E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.63	0.25	0.00	176.71
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,628	$778	$0	$540,710

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 3 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,501,141	$42,332

E.6.3.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $2,450,000 by the TMI staff (Exelon 2007c).

E.6.3.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 3 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$552,594	$42,332	$594,926	$2,450,000	-$1,855,074

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.4 SAMA NUMBER 4: PROVIDE ALTERNATE POWER TO HPI PUMP MINIMUM FLOW RECIRCULATION VALVES MU-V-36 AND MU-V-37

The current PRA model logic correctly assumes isolation of HPI minimum flow recirculation valves MU-V-36 and 37 on an ESAS, but it does not include the AC power dependences for the "close" action. However, the logic related to opening the minimum flow valves does include the power dependencies, which can result in the generation of cutsets that include the failure to open a flow path that was never isolated. This is critical for the HPI pumps in cases where the HPI flow to the RCS is very low due to the small size of the RCS break/leak. Based on system review and discussions with plant personnel, the only events that could cause the MU-V-36 or MU-V-37 valves to be "stranded closed" are those in which an ESAS based closure occurs when power is available to one or both valves and then one or both of the divisions of valve power fails before the valve(s) can be re-opened to support HPI minimum flow recirculation.

A quantification of the contribution from scenarios of this type would require a dynamic PRA model, which is not available to TMI-1. However, an approximation can be performed to show that risk associated with the MU-V-36/37 design is low and that no SAMAs are required to modify the power supplies to the valves.

The current model assumes that power is always available to isolate MU-V-36/37 and if this assumption is accepted for this evaluation, a time weighted probability can be used for power failures to the valves that will approximate the CDF related to “stranding” them closed. In this case, once an ESAS has registered and the HPI pumps are running, 45 minutes are assumed to be available for establishing the minimum flow path before pump failure occurs. For "valve stranding" to be an issue, the loss of power to the valve would have to occur between the time of the ESAS and the time to pump failure. Power failures before the ESAS would not present a problem for minimum flow recirculation because MU-V-36/37 fail "as-is". Power failures after pump failure are not a concern because the pump will already have failed. Therefore, the pertinent portion of the valve power failure probability is for only 0.75 hours out of 24. Assuming that the likelihood of failure is constant over the 24 hour mission time, this correlates to a fraction of only 3.12E-02.

If this fraction is applied to the power inputs for the minimum flow recirculation valve failure logic, a more representative base case will be established with respect to CDF. From this model configuration, the importance of the power supplies for the minimum flow recirculation valves can then be calculated. As mentioned above, this approximation method assumes that power is initially available to isolate the MU-V-36/37 valves, which will not always be the case and overestimates the importance of the power failures.

The following table summarizes the changes that were made to the PRA model to establish the new "baseline" used to calculate the importance of the MU-V-36/37 power supply gates:

SAMA 4 – Model Changes

Gate and / or Basic Event ID and Description	Description of Change
MRG0001 (existing gate): MR (makeup pump recirculation path)	The following inputs were removed from this gate: • ED1AESV (existing gate): 480V MCC 1A ESV FAILS • EE1BESV (existing gate): 480V MCC 1B ESV FAILS The following inputs were added to this gate: • Gate MCC1A-FRACTION • Gate MCC1B-FRACTION
MCC1A-FRACTION (new AND gate)	The following inputs were included: • ED1AESV (existing gate): 480V MCC 1A ESV FAILS • RECIRC-FRACTION (new basic event: FRACTION OF TIME THAT FAILURE IS CRITICAL FOR MIN FLOW RECIRC

SAMA 4 – Model Changes

Gate and / or Basic Event ID and Description	Description of Change
RECIRC-FRACTION: FRACTION OF TIME THAT FAILURE IS CRITICAL FOR MIN FLOW RECIRC	New basic event representing the fraction of time that a failure of power to the MU-V-36 or 37 valves would result in a “Stranded” valve given that the valve has already closed (3.12E-02).
MCC1B-FRACTION (new AND gate)	The following inputs were included: • EE1BESV (existing gate): 480V MCC 1B ESV FAILS • RECIRC-FRACTION (new basic event: FRACTION OF TIME THAT FAILURE IS CRITICAL FOR MIN FLOW RECIRC
Similar changes were made to the LOOP recovered set of logic. The LOOP recovered logic is a reproduction of the base logic without power dependences that is used after power is recovered in a LOOP sequence.	

In this case, the RRW value for RECIRC-FRACTION, which captures the importance of both power supplied to the MU-V-36 and 37 valves for both the base and “power recovered” logic, is only 1.006 based on CDF and 1.002 for the Level 2 results, which is below the SAMA screening criteria of 1.01 and demonstrates that changes to the MU-V-36/37 power supply configuration would not be cost beneficial.

E.6.5 SAMA NUMBER 5: ENHANCE VALVES MU-V-76A/B AND MU-V-77A/B TO ALLOW FOR RAPID ALIGNMENT CHANGES IN ACCIDENT CONDITIONS

The current MU-V-76A/B and MU-V-77A/B valve configurations do not allow for rapid re-alignment during accident conditions. These valves are used to manipulate the flowpath for the “B” HPI pump between the seal injection and makeup flowpaths, but they also inherently determine whether the “A” or “C” pump can be aligned to the seal injection flowpath. For TMI-1, the capability to quickly align the "C" HPI pump for seal injection would reduce the risk of prominent accident sequences in which thermal barrier cooling has failed in conjunction with the "A" and "B" HPI pumps. Replacing MU-V-76A/B and MU-V-77A/B with MOVs operable from the main control room would allow TMI-1 to use the "C" HPI pump for seal injection and prevent seal LOCAs when the normal cooling methods are unavailable.

The normal conditions of the plant, which are reflected in the PRA model, show that the “C” pump is the important pump for establishing alternate seal injection and that the benefit is derived from changes to the MU-V-76A/B. However, plant operating practices can change and alterations to the normal alignment of the HPI system could shift the importance to the “A” division. In order to address alternate plant configurations and to provide maximum flexibility, both sets of valves are assumed to require modification.

E.6.5.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA’s averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In order to represent this SAMA in the PRA, cutset changes were made to address the impact of replacing the MU-V-76A/B and MU-V-77A/B valves with MOVs. This method was chosen given that the valve alignment capability can easily be modified through the manipulation of an existing human failure event. In the TMI-1 model, the relevant basic event is the independent HEP INHINJ2_MUHHMUOA, which is set to 1.0 in the baseline model to reflect the inability to locally manipulate the valve in time to support seal injection. In this case, providing the capability to remotely operate the valve is considered to reduce the failure probability to at least 1.0E-02, which is reflected in the cutsets by changing the failure probability of the independent HEP from 1.0 to 1.00E-02. This action is present in a large number of cutsets with multiple other HEPs. Typically, these cases are reviewed as part of the HRA dependency analysis, but for this case, the base probability is 1.0 and the action is not included in any JHEPs because the action always fails due to timing concerns. Setting the probability to something other than 1.0 would normally require inclusion of the action in the dependency analysis to limit the credit taken when dependent conditions exist. No dependency analysis was performed for this SAMA quantification. In this case, excluding the dependency analysis maximizes the benefit of the SAMA and is conservative relative to the identification of cost beneficial SAMAs. The following table summarizes the model changes that were made:

SAMA 5 - Model Changes

Gate and / or Basic Event ID and Description	Description of Change
INHINJ2_MUHHMUOA: OPERATOR OPENS CROSS CONNECT VALVES MU-V-76A/B AND STARTS MU-P-1C	The basic event probability was changed from 1.0 to 1.00E-02.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 5 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.22E-05	31.49	$109,455
Percent Change	-6.3%	-3.4%	-2.5%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 5 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	4.86E-11	4.86E-11	1.90E-10	2.46E-10	3.31E-08	1.41E-08	8.34E-09	3.16E-07	6.57E-07	1.63E-07	1.69E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.10	0.04	0.02	0.93	4.04	1.00	0.05
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$44,202	$3,367	$236	$2	$2	$7	$9	$298	$127	$75	$2,841	$13,271	$3,293	$160

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	7.99E-08	1.43E-08	1.75E-07	2.75E-09	7.43E-07	2.89E-07	3.12E-06	1.20E-05	1.69E-08	2.33E-06	1.91E-08	2.22E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.24	0.00	1.00	0.39	6.93	3.19	0.00	0.62	0.01	31.49
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$755	$135	$669	$11	$2,838	$1,104	$19,594	$3,134	$4	$610	$5	$109,455

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 5 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,157,717	$113,994	2.0	$227,988

E.6.5.2 EXTERNAL FLOODING EVALUATION

This SAMA has a very limited impact on external flooding scenarios. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310' msl: In these scenarios, the MU-V-76A/B and MU-V-77A/B are not used and the SAMA has zero impact.

- Floods between 305' and 310' msl: Most of the sequences are not impacted by the enhanced capabilities of the MU-V-76A/B and MU-V-77A/B valves as core damage is caused by failure of the flood gates (SBO case) or because a flood warning is not provided and no preparations are made for the flood (SBO case). Flood sequence "E" represents cases where the flood gates are correctly installed, but a loss of onsite power leads to core damage. These cases will cause a seal LOCA, which is the event this SAMA is primarily designed to prevent. As power recovery could not be performed rapidly enough for SAMA 5 to restore seal cooling and prevent the seal LOCA, the impact of this SAMA on sequence E sequence is negligible and is it is assumed to have no impact on the CDF.

- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. The CDF for this sequence is assumed to be reduced by the same fraction as the internal events CDF.

The following tables summarize the results of quantification strategy:

SAMA 5 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.10E-05	177.14	$542,081
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 5 - External Flooding Contributions by Release Ca

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.34E-07	8.10E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.35	177.14
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,141	$542,081

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 5 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,541,298	$2,175

E.6.5.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $3,150,000 by the TMI staff (Exelon 2007c).

E.6.5.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 5 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$227,988	$2,175	$230,163	$3,150,000	-$2,919,837

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.6 SAMA NUMBER 6: ADD CROSS-TIES WITHIN THE TRAINS OF COOLING SYSTEMS - DHR, DHCCW, DHRW

Some failure combinations that eliminate both trains of the DHR related cooling systems could be mitigated if cross-ties were available between trains of the DHR, DHRW, and DHCCW systems (not between the systems). For example, these cross-ties would be helpful in conditions where the flow path fails in one train while a pump failure or maintenance event disables the opposite train. To ensure the DHR cross-ties can be implemented in a timely manner for LPI requirements, the associated valves should be operable from the main control room.

The use of MOVs in the DHR cross-tie line is beneficial due to the relatively rapid response time required to support low pressure injection; therefore, the MOVs are suggested as part of the design. For the DHCCW and DHRW systems, which support the containment heat removal function of DHR, the time available to respond is much longer. Manual valves could be used for these cross-tie lines and the cross-tie reliability would not be greatly impacted.

E.6.6.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

Cross-tie capability for the DHRW system was modeled by adding an AND gate under the gate HAG0001 for train A that was labeled HAG0001-1 and has top event RA (DHRW train A) and gate HAG0001-2 as its inputs. HAG0001-2 is an OR gate that accounts for failure of a proposed crosstie MOV (SAMA6XTMOV1-VAFD), operator failure to perform the crosstie operation (SAMA6-XTIE-HVAOA), failure of a proposed AC power dependency (top event MC, which represents MCC 1C ESV), and the top event for DHRW train B (RB). Similar logic changes were also applied to the model for DHRW train B under gate HBG0001.

For DHCCW, the model logic changes for crosstie capability between trains A and B were applied to gates that affected cooling support dependencies for the reactor building spray pumps, the makeup pumps, and DHR pumps. The affected gates for train A systems were

CSG0018 (reactor building spray pump BS-P-1A), HPGPUMPACOOLSUP1 (makeup pump MU-P-1A), and LPRG0007 (decay heat pump DH-P-1A). The crosstie logic for DHCCW train A, with train B being used as the backup source, is contained under the AND gate HPGPUMPACOOLSUP1-1. This AND gate contains system top event HA and OR gate HPGPUMPACOOLSUP1-2 as its inputs. HPGPUMPACOOLSUP1-2 contains system top HB, the common operator failure event SAMA6-XTIE-HVAOA, gate MC for AC power dependency, and a proposed crosstie MOV (SAMA6XTMOV2-VAFD). Logic for DHCCW train B was revised in a similar fashion for the following affected gates for ECCS train B components:

CSG00017	reactor building spray pump BS-P-1B
HQGPUMPCCOOLIN	makeup pump MU-P-1C
LPRG0019	decay heat pump DH-P-1B

The AND gate HQGPUMPCCOOLIN-1 (DHCCW train B and train A as backup fail) was used as the cooling support dependency for these three gates identified for train B ECCS components. The inputs to HQGPUMPCCOOLIN-1 are system top HB (DHCCW train B) and the OR gate HQGPUMPCCOOLIN-2 (DHCCW train A fails as backup). The inputs to gate HQGPUMPCCOOLIN-2 are system top HA, the common operator failure event SAMA6-XTIE-HVAOA, gate MC for AC power dependency, and the proposed crosstie MOV (SAMA6XTMOV2-VAFD).

For the DHR system, two system top events representing different functions of this system were affected, namely gate LPI (LPI trains A and B fail), and gate DHR (DHR trains A and B fail). LPI is an AND gate with two inputs: AND gate LPIA-1 and AND gate LPIB-1. Inputs to LPIA-1 include OR gate LPIA for failure of LPI train A and OR gate LPIA-2, which represents failure of LPI train B to backup train A. LPIA-2 contains the operator failure to perform cross-tie operations (SAMA6-XTIE-HVAOA), power dependency gate MC, gate LPIB for failure of LPI train B, and crosstie MOV failure event SAMA6XTMOV3-VAFD. Likewise, AND gate LPIB-1 contains OR gate LPIB for failure of LPI train B and OR gate LPIB-2, which represents failure of LPI train A to backup train B. LPIB-2 contains the operator failure to perform cross-tie operations (SAMA6-XTIE-HVAOA), power dependency gate MC, gate LPIA for failure of LPI train A, and crosstie MOV failure event SAMA6XTMOV3-VAFD. Identical logic changes were made to system top DHR, which involved AND gate DHRA-1 and AND gate DHRB-1. The only difference is that system top DHRA was used in place of LPIA and DHRB was used in place of LPIB. Similarly, DHRA-1 and DHRA-2 were used in place of LPIA-1 and LPIA-2; and DHRB-1 and DHRB-2 were used in place of LPIB-1 and LPIB-2.

In addition, all affected logic described above that is modeled within the logic structure for post-LOOP recovery scenarios was also modified, with gate names appended with the characters "-R".

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 6 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.06E-05	31.00	$108,864
Percent Change	-13.1%	-4.9%	-3.0%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 6 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	4.86E-11	4.86E-11	1.90E-10	2.46E-10	3.57E-08	1.42E-08	7.69E-09	3.19E-07	6.39E-07	1.57E-07	1.60E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.10	0.04	0.02	0.93	3.93	0.97	0.04
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$44,202	$3,367	$236	$2	$2	$7	$9	$321	$128	$69	$2,868	$12,908	$3,171	$151

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.40E-08	1.42E-08	1.96E-07	2.75E-09	7.81E-07	2.62E-07	3.14E-06	1.03E-05	1.69E-08	2.33E-06	1.91E-08	2.06E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.24	0.04	0.26	0.00	1.05	0.35	6.97	2.76	0.00	0.62	0.01	31.00
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$794	$134	$749	$11	$2,983	$1,001	$19,719	$2,705	$4	$610	$5	$108,864

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 6 Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,093,415	$178,296	2.0	$356,592

E.6.6.2 EXTERNAL FLOODING EVALUATION

This SAMA has a very limited impact on external flooding scenarios. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310' msl: In these scenarios, flood waters fail the DHR system and the SAMA has zero impact.

- Floods between 305' and 310' msl: Most of the sequences are not impacted by the addition of the DHR system cross-ties as core damage is caused by failure of the flood gates (safety equipment flooded, SBO) or because a flood warning is not provided and no preparations are made for the flood (safety equipment flooded, SBO). Flood sequence "E" represents cases where the flood gates are correctly installed, but a loss of onsite power leads to core damage. These cases will cause a seal LOCA and for the small fraction of the scenario in which power is recovered, the cross-ties could be used to mitigate certain failures. The impact of this SAMA can be approximated by using the baseline internal events model to determine the percent contribution of the "power recovered" SBO sequences to the total SBO contribution. Then, if it is assumed that the relative distribution of "power recovered" sequences for the "E" flood sequence as the same as for the internal events model, the portion of the flood sequence "E" CDF impacted can be calculated. For this evaluation, it is assumed that SAMA implementation will eliminate all SBO "power recovered" risk.

- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. For simplicity, the CDF for this sequence is assumed to be completely eliminated.

Based on the internal events model, SBO sequences contribute a CDF of 3.25E-06/yr while the power recovered SBO sequences contribute only 2.21E-08/yr. This indicates that the "power recovered" SBO evolutions contribute only 0.7 percent of the SBO CDF (2.21E-08 / 3.25E-06/yr * 100 = 0.7). For flood sequence "E", the expected CDF reduction would then be 2.56E-08 (7.0E-03 * 3.66E-06 = 2.56E-08).

The following tables summarize the results of quantification strategy:

SAMA 6 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.08E-05	176.71	$540,710
Percent Change	-0.3%	-0.3%	-0.3%

A further breakdown of this information is provided below according to release category.

SAMA 6 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.63E-06	8.65E-08	0	8.08E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.63	0.25	0.00	176.71
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,628	$778	$0	$540,710

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 6 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,501,141	$42,332

E.6.6.3 COST OF IMPLEMENTATION

The cost of installing the powered DHR cross-tie was estimated to be $2,750,000 by the TMI staff (Exelon 2007c). The cross-ties for the DHCCW and DHRW systems are not required to be MOVs due to the longer times available for performing the cross-tie and while there would be a substantial additional cost related to the addition of these cross-ties, only the DHR cross-tie cost of $2,750,000 is used here based on the availability of information.

E.6.6.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 6 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$356,592	$42,332	$398,924	$2,750,000	-$2,351,076

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.7 SAMA NUMBER 7: USE FIRE SERVICE WATER AS AN ALTERNATE COOLING SOURCE FOR THE ICCW HEAT EXCHANGERS

For cases in which NSRW is unavailable due to hardware failures (e.g., flow diversion), the Fire Service Water system could be used to directly cool the ICCW heat exchangers for thermal barrier cooling support. Given that the ICCW pumps would be available for the relevant cases, a local, manual valve could be used for the alignment as time should be available for such an action.

E.6.7.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

For this model revision, the fire service water system was used to provide a backup cooling water source in the event that NSRW is unavailable to supply cooling water to the ICCW heat exchangers, which in turn renders thermal barrier cooling for the RCP seals unavailable. A new input was added to existing gate SEG0005, which was an AND gate labeled SEG0005-1. Inputs to this gate included the top event for unavailability of the NSRW system (top event NR) and OR gate SEG0005-2. Inputs to gate SEG0005-2 include the top event for unavailability of the fire service water system (top event FS), a basic event representing mechanical failures associated with this alternate alignment (SAMA7-MECHANICAL), and a HEP event (SAMA7-FSW-HVHOA), which was assigned an assumed failure probability of 0.1 since actions are performed outside the MCR. As a simplification, the failure probability for SAMA7-MECHANICAL was assigned an assumed unavailability of 1.0E-3. Model logic changes were not required for post-LOOP recovery scenarios as seal cooling is not applicable to those accident scenarios.

Similar model changes were performed under gate SEG0004 to credit this SAMA for ICCW "B" train cooling.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 7 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.07E-05	30.62	$107,565
Percent Change	-12.7%	-6.1%	-4.2%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 7 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	4.86E-11	4.86E-11	1.90E-10	2.46E-10	3.37E-08	1.41E-08	8.34E-09	3.15E-07	6.13E-07	1.52E-07	1.65E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.10	0.04	0.02	0.92	3.77	0.93	0.05
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$44,202	$3,367	$236	$2	$2	$7	$9	$303	$127	$75	$2,832	$12,383	$3,070	$156

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	7.99E-08	1.43E-08	1.70E-07	2.75E-09	7.43E-07	2.85E-07	3.06E-06	1.06E-05	1.69E-08	2.31E-06	1.91E-08	2.07E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.23	0.00	1.00	0.38	6.79	2.83	0.00	0.62	0.01	30.62
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$755	$135	$649	$11	$2,838	$1,089	$19,217	$2,778	$4	$605	$5	$107,565

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 7 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,064,992	$206,719	2.0	$413,438

E.6.7.2 EXTERNAL FLOODING EVALUATION

This SAMA can potentially impact scenarios in which AC power is available and the safety equipment has not been flooded. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310' msl: In these scenarios, all safety equipment is flooded and this SAMA has no impact on the risk.

- Floods between 305' and 310' msl: Most of the sequences could not be impacted by this SAMA as core damage is caused by failure of the flood gates (safety equipment is flooded) or because a flood warning is not provided and no preparations are made for the flood (safety equipment is flooded). Flood sequence "E" represents cases where the flood gates are correctly installed, but a loss of onsite power leads to core damage. In these cases, the ensuing SBO results in a seal LOCA, which is the event SAMA 7 was designed to prevent when power is available. Given that a seal LOCA will occur for sequence "E" whether or not SAMA 7 is implemented, it has no impact on the sequence "E" CDF.

- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. In order to simplify the quantification of this SAMA, it is assumed that the SAMA 7 eliminates all risk from these floods.

The following tables summarize the results of these changes:

SAMA 7 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.08E-05	176.79	$540,940
Percent Change	-0.3%	-0.2%	-0.2%

A further breakdown of this information is provided below according to release category.

SAMA 7 External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	0.00E+00	8.08E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.00	176.79
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$0	$540,940

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 7 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,507,657	$35,816

E.6.7.3 COST OF IMPLEMENTATION

Palisades estimated $2.9 million for Fire water cooling to CCW HXs (NMC 2005), Calvert Cliffs estimated $565k for alt DHR cooling (BGE 1998), and Brown's Ferry estimated $1 million for Fire Water to DHR HXs (TVA 2003). The Brown's Ferry estimate is used for TMI.

E.6.7.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 7 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$413,438	$35,816	$449,254	$1,000,000	-$550,746

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.8 SAMA NUMBER 8: AUTOMATE REACTOR COOLANT PUMP TRIP ON HIGH MOTOR BEARING COOLING TEMPERATURE

Seal LOCAs resulting from operator failures to trip the RCPs on loss of motor bearing cooling could be reduced if high temperature sensors were installed on motor bearing cooling water lines to provide automatic trip signals.

E.6.8.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

To simulate the improved capability of tripping the RCPs upon loss of NSCCW cooling to the motor and pump bearings, the HEP event OTHOT1_RCPTHP1OA was reduced by a factor of 10, from a failure probability of 1.44E-2 to 1.44E-3. Also, to account for the automation of the RCP trip function, all JHEPs including OTHOT1_RCPTHP1OA were set to 0.0.

While the installation of additional trip logic would introduce a previously non-existing source of spurious RCP trip signals that would increase plant risk, no reliable means of estimating the increase in the RCP trip frequency has been identified. As a result, no strategy to quantify the potential increase in risk related to implementation of this SAMA was developed for this quantification.

No requantification of the PRA model was required given that all of the changes outlined above could be performed in the cutset files.

The following table summarizes the data changes that were made:

SAMA Number 8 Model Changes

Gate and / or Basic Event ID and Description	Description of Change
OTHOT1_RCPTHP1OA: OPERATOR FAILS TO TRIP REACTOR COOLANT PUMP ON LOSS OF NSCCW	The basic event probability was changed from 1.44E-02 to 1.44E-03.
JHHEML-HOT1HEPOA: NSHEML_HER-HP2OA AND OTHOT1_RCPTHP1OA	This basic event probability was set to 0.0.
JHHNS10HOT1HEPOA: NSHNS6-----HHXOA AND OTHOT1_RCPTHP1OA	This basic event probability was set to 0.0.
JHHNS6-HOT1HEPOA: NSHNS6-----HHXOA AND OTHOT1_RCPTHP1OA	This basic event probability was set to 0.0.
JHHNSHOTHEOHEPOA: JHHNS10HOT1HEPOA AND GSHEO1A----HDGOA	This basic event probability was set to 0.0.
JHHNSHOTHMRHEPOA: JHHNS10HOT1HEPOA AND MRHMR1-----HMUOA	This basic event probability was set to 0.0.
JHHOT1-HMR1HEPOA: OTHOT1_RCPTHP1OA AND MRHMR1-----HMUOA	This basic event probability was set to 0.0.
JHHOT1-XTIEHEPOA: OTHOT1_RCPTHP1OA AND NR-NRSRXTIEHVAOA	This basic event probability was set to 0.0.
JHHOTHMRXTIHEPOA: OTHOT1_RCPTHP1OA; MRHMR1-----HMUOA; NR-NRSRXTIEHVAOA	This basic event probability was set to 0.0.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 8 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.06E-5	25.28	$91,111
Percent Change	-13.2%	-22.5%	-18.8%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 8 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
$Freq.(/yr)_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
$Freq. (/yr)_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.78E-08	1.46E-08	8.54E-09	3.16E-07	6.00E-07	1.60E-07	2.05E-08
$Dose\text{-}Risk_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06

SAMA 8 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Dose-Risk$_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	3.69	0.98	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$340	$131	$77	$2,841	$12,120	$3,232	$194

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.07E-07	2.75E-09	7.45E-07	2.89E-07	3.06E-07	1.32E-05	1.69E-08	2.32E-06	1.91E-08	2.06E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.28	0.00	1.01	0.39	0.68	3.52	0.00	0.62	0.01	25.28
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$791	$11	$2,846	$1,104	$1,922	$3,459	$4	$608	$5	$91,111

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 8 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$2,654,373	$617,338	2.0	$1,234,676

E.6.8.2 EXTERNAL FLOODING EVALUATION

This SAMA has no impact on external flooding scenarios. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310’ msl: In these scenarios, flood waters fail the safety equipment and the SAMA has zero impact.
- Floods between 305’ and 310’ msl: Most of the sequences could not be impacted by this SAMA as core damage is caused by failure of the flood gates (safety equipment is flooded) or because a flood warning is not provided and no preparations are made for the flood (safety equipment is flooded). Flood sequence “E” represents cases where the flood gates are correctly installed, but a loss of onsite power leads to core damage. In these cases the LOOP trips the RCPs so the auto trip function is not required. In addition, the ensuing SBO results in a seal LOCA, which is the event SAMA 8 was designed to prevent. Given that a

seal LOCA will occur for sequence "E" whether or not SAMA 8 is implemented, it has no impact on the sequence "E" CDF.

- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. Given that a LOOP event will trip the RCPs, SAMA 8's auto trip function is not required and it has no impact on these flood sequences.

In summary, this SAMA has no measurable impact on the external flooding contributors, as shown in the following tables:

SAMA 8 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	177.16	$542,159
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 8 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 8 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,543,473	$0

E.6.8.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $145,000 by the TMI staff (Exelon 2007c).

E.6.8.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 8 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$1,234,676	$0	$1,234,676	$145,000	$1,089,676

Given that the cost of implementation is less than the averted cost-risk for this SAMA, the net value is positive.

E.6.9 SAMA NUMBER 9: PROCEDURALIZE LOCAL ADV OPERATION

TMI-1 has procedures to perform the local ADV operations that are not credited in the PRA model (the failure probability is set to 1.0). If the available procedures are credited and used to allow local operation of the ADVS for cooldown/depressurization after loss of remote capability, the RRW value of the operator action would be reduced below the SAMA review threshold. This SAMA is used demonstrate that the RRW for this operator action would be below the SAMA review threshold if appropriate credit were taken and that no SAMAs are required to address local ADV operations.

For this case, an HEP of 0.1 is assumed for the action (AV-LOCADV--HCDOA). The model does not contain any JHEPs that include AV-LOCADV--HCDOA; therefore, no additional changes are required. This change was made directly in the cutsets and no model requantification was required, as summarized below:

SAMA 9 - Model Changes

Gate and / or Basic Event ID and Description	Description of Change
AV-LOCADV--HCDOA: OPERATOR ACTION FAILURE TO LOCALLY OPERATE ADVS ON LOSS OF AIR	Basic event probability changed from 1.0 to 1.00E-01.

In this case, the RRW value for AV-LOCADV--HCDOA was reduced to 1.005 for CDF and 1.004 for the Level 2 results. As these are both below the SAMA screening criteria of 1.01, this assessment demonstrates that enhancing local ADV operation would not be cost beneficial.

E.6.10 SAMA NUMBER 10: AUTOMATE BWST REFILL

Failure to refill the BWST is a large contributor to some SGTR sequences, especially those in which the main steam ADVs fail to operate (including operator errors). Automating the refill function would improve the reliability of this process and reduce the contributions from prominent SGTR sequences by providing a long term high pressure injection source. While isolation of the break is a more desirable approach to mitigating SGTR events, providing long term primary side injection is a potential means of preventing core damage and is considered to result in a success path by providing time to cool down the RCS and to recover isolation capability.

Automation of the BWST refill function will require linking tank level sensors/transmitters with logic that will start the transfer pumps, open the valves in the flowpath, and return the system to standby when the tank is refilled. This SAMA also requires that an adequate volume of boron will be available for at least 24 hours (without operator intervention) given the largest expected leak rate for SGTR initiating events.

It is possible that refill of the BWST would be capable of mitigating some ISLOCA events, but because an evaluation of Auxiliary Building flooding from ISLOCA flow has not been performed, no credit is taken for ISLOCA cases.

E.6.10.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of SAMA 10's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In order to represent this SAMA in the PRA, cutset changes were made to address the impact of automating the BWST refill function. This method was chosen given that BWST refill reliability can easily be modified through the manipulation of existing human failure events. In the TMI-1 model, the relevant basic events include an independent event as well as joint human error events. In this case, automating operation of the refill system (with human backup) is considered to reduce the failure probability to at least 1.0E-04, which is reflected by changing the failure probability of the independent HEP from 2.65E-02 to 1.0E-04. Because automation of the function basically removes it from the joint human error events, those events are set to 0.0. If the combinations of the remaining actions are important to the model, they would be treated in separate events and the development of new combinations is not required. The following table summarizes the model changes that were made:

SAMA 10 - Model Changes

Gate and / or Basic Event ID and Description	Description of Change
BWST-HRE27-HTKOA: FAILURE TO REFILL BWST (SPLIT FRAC REV)	The basic event probability was changed from 2.65E-02 to 1.0E-04.
JHAHCD4RE27HEPOA: AVHCD4_FF--HCDOA AND BWST-HRE27-HTKOA (JHEP addressing BWST refill and cooldown via secondary side)	The basic event probability was changed from 9.17E-05 to 0.0.
JHHRE27HL1AHEPOA: BWST-HRE27-HTKOA AND DLHHL1A----HVHOA (JHEP addressing BWST refill and opening drop line for DHR cooling)	The basic event probability was changed from 2.00E-04 to 0.0.
JHHEF2HRE27HEPOA: AVHEF2_FF--HCDOA AND BWST-HRE27-HTKOA (JHEP addressing BWST refill and manually initiating cooldown using the OTSG)	The basic event probability was changed from 1.3E-03 to 0.0.
JHHCD5HRE27HEPOA: DPHCD5-FF--HDPOA AND BWST-HRE27-HTKOA (JHEP addressing BWST refill and manual pressurization with the RCPs unavailable)	The basic event probability was changed from 1.90E-04 to 0.0.
JHHIGHREHHLHEPOA: IGHIG1_HER-HSGOA, BWST-HRE27-HTKOA, and DLHHL1A----HVHOA (JHEP addressing BWST refill, failure to isolate a SGTR, and opening drop line for DHR cooling)	The basic event probability was changed from 5.0E-07 to 0.0. (Event was not in cutsets)

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 10 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.29E-05	28.06	$90,062
Percent Change	-3.4%	-14.0%	-19.8%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 10 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	5.86E-08	1.19E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	0.34	6.81	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$1,629	$33,082	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.29E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	28.06
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$90,062

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 10 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$2,780,687	$491,024	2.0	$928,048

E.6.10.2 EXTERNAL FLOODING EVALUATION

This SAMA is of importance in SGTR events where RCS inventory leaves the containment and is unavailable for recirculation from the sump. For the external flooding cases, this is not an issue as the reactor is tripped by a manual shutdown rather than an SGTR event. While LOCAs are likely in external flooding scenarios due to SBO induced seal LOCAs, the sump would be available if AC power was subsequently recovered. No measurable risk reduction is believed to result from implementation of this SAMA for external flooding, as shown below:

SAMA 10 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	177.16	$542,159
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 10 - External Flooding Contributions by Release Ca

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	1.33E+02	1.31E+01	1.90E-01	1.89E+00	1.79E+01	1.07E+01	2.50E-01	3.70E-01	1.77E+02
SAMA Dose-Risk	1.33E+02	1.31E+01	1.90E-01	1.89E+00	1.79E+01	1.07E+01	2.50E-01	3.70E-01	1.77E+02
Base OECR	4.06E+05	4.01E+04	5.98E+02	5.77E+03	5.48E+04	3.29E+04	7.78E+02	1.22E+03	$542,159
SAMA OECR	4.06E+05	4.01E+04	5.98E+02	5.77E+03	5.48E+04	3.29E+04	7.78E+02	1.22E+03	$542,159

The external flooding component of the averted cost-risk for this SAMA is, therefore, $0:

SAMA 10 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,543,473	$0

E.6.10.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $3,800,000 by the TMI staff (Exelon 2007c).

E.6.10.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 10 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$982,048	$0	$982,048	$3,800,000	-$2,817,952

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.11 SAMA NUMBER 11: ENHANCE EXTREME EXTERNAL FLOODING MITIGATION EQUIPMENT TO ADDRESS SBO AND LOSS OF SEAL COOLING SCENARIOS

Making the extreme flooding equipment proposed in SAMA 32 useful for SBO conditions, especially those with TD EFW failure, would require permanently mounting the submersible pumps so that the suctions could easily be swapped from a piped water source to the flood water source. Permanently installing the portable generator and the pumps so that they could be auto aligned (and manually aligned from the MCR should auto alignment fail) to support seal cooling would address both SBO and non-SBO loss of seal cooling cases through the ability to rapidly align alternate seal cooling.

It is recognized that the requirements of this SAMA are extreme, but in order to mitigate an SBO with EFW failures, it is necessary to provide alternate power to support a means of heat removal. Long term heat removal can be accomplished either by maintaining primary integrity (through RCP seal protection) and using the secondary side systems for heat removal, or through some form of a feed and bleed method. However, a feed and bleed method requires a DHR system that will allow recirculation in order to prevent containment overfill. The added complexity of installing an SBO capable DHR system is considered to be at least as difficult as automating the 480V AC generator alignment, which is proposed by this SAMA. While this SAMA has been retained on the SAMA list due to flooding considerations, the simpler solution to providing long term SBO survivability given EFW failure for internal event initiators is considered in SAMA 24.

E.6.11.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

To simulate implementation of this SAMA, the cutsets from SAMA 1 were used as a starting point as they addressed the ability to prevent a seal LOCA given failure of the "A" and "B" EDGs. In order to capture the additional SAMA 11 capabilities of providing core cooling in an SBO even with turbine driven EFW failure, the important EDG and AFW equipment failures were set to zero. Setting these events to zero simulates recovery from these failures by the SAMA 11 equipment. The following table lists the basic event data changes that were made to the SAMA 1 cutset file to quantify the impact of this SAMA:

SAMA 11 - Model Changes

Gate and / or Basic Event ID and Description	Description of Change
EFEF-P-1----P7FS: TURBINE-DRIVEN PUMP EF-P-1 FAILS TO START	The basic event probability was changed from 4.66E-03 to 0.0.
EFEFP1------P7FR: TURBINE-DRIVEN PUMP EF-P-1 FAILS TO RUN	The basic event probability was changed from 5.06E-02 to 0.0.
EF-CCFEFW-LETHAL: LETHAL SHOCK TO THE EFW SYSTEM DUE TO COMMON CAUSE FAILURES	The basic event probability was changed from 4.25E-04 to 0.0.
GA1ADG------DGFS: DIESEL GENERATOR 1A FAILS TO START	The basic event probability was changed from 1.13E-02 to 0.0.
GA-EDG-1A---DGFR: DIESEL 1A FAILS TO RUN	The basic event probability was changed from 2.07E-02 to 0.0.
GA-EG-Y-1A--DGMM: Emergency Diesel Generator 1A in Maintenance	The basic event probability was changed from 1.61E-02 to 0.0.
GB1BDG------DGFS: DIESEL GENERATOR 1B FAILS TO START	The basic event probability was changed from 1.13E-02 to 0.0.
GB-EDG-1B---DGFR: DIESEL 1B FAILS TO RUN	The basic event probability was changed from 2.07E-02 to 0.0.
GB-EG-Y-1B--DGMM: Emergency Diesel Generator 1B in Maintenance	The basic event probability was changed from 1.61E-02 to 0.0.
GSEG-Y-4----DGFS: STATION BLACKOUT DG FAILS TO START	The basic event probability was changed from 1.13E-02 to 0.0.
GS-SBODG----DGFR: SBO DIESEL FAILS TO RUN	The basic event probability was changed from 2.07E-02 to 0.0.
GS-EG-Y-4---DGMM: SBO Diesel Generator in Maintenance	The basic event probability was changed from 1.30E-2 to 0.0.
GA-1A1BSBO-CDGFR: EDG CCF Run DG-1A;DG-1B;DG-SBO	The basic event probability was changed from 1.53E-04 to 0.0.
GAEDG-STARTCDGFS: EDG Fail to Start CCF DG-All 3	The basic event probability was changed from 5.25E-05 to 0.0.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 11 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	1.57E-05	24.43	$87,640
Percent Change	-33.8%	-25.1%	-21.9%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 11 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.47E-07	1.22E-06	1.80E-07	1.16E-08	4.21E-11	4.21E-11	2.37E-11	6.68E-11	1.11E-08	1.10E-08	3.35E-10	2.28E-07	5.18E-07	7.85E-07	1.22E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.56	6.98	0.91	0.06	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.67	3.19	4.83	0.03
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,427	$33,916	$3,348	$216	$2	$2	$1	$3	$100	$99	$3	$2,050	$10,464	$15,857	$115

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	3.41E-11	0.00E+00	8.41E-09	8.11E-10	1.24E-07	4.24E-10	7.80E-08	1.32E-08	8.26E-07	1.09E-05	1.25E-08	3.38E-07	4.81E-10	1.57E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.02	0.00	0.17	0.00	0.11	0.02	1.83	2.90	0.00	0.09	0.00	24.43
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$0	$0	$79	$8	$474	$2	$298	$50	$5,187	$2,849	$3	$89	$0	$87,640

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 11 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$2,452,029	$819,682	2.0	$1,639,364

E.6.11.2 EXTERNAL FLOODING EVALUATION

The severe flooding guidelines were originally credited in the IPEEE for both floods above 310' msl as well as for floods between 305' and 310' msl. Due to a more limited preparation time for the 305' to 310' msl floods, the failure probability was assumed to be 0.5 rather than the 0.255 used for the 310' msl floods. For floods below 305' msl, no credit was taken for the severe flooding guidelines as the submersible pumps used for secondary side makeup require flood water in the turbine building for a suction source. Given that this SAMA includes provisions for an alternate secondary side pump suction source, it is assumed that credit could be taken for the floods below 305', as well. The credit taken for this SAMA will be the same for all flood scenarios given that the proposed changes will reduce the manipulation time to a point where it is short (within 13 minutes for auto alignments cause by undervoltage) in comparison to the available time for all of the scenarios (on the order of 18-24 hours from the action cue). This factor reduces the impacts of time stress on the alignment failure probability.

For the purposes of this analysis, implementation of this SAMA is assumed to reduce the HEP for alignment of the external flooding measures from 1.1E-01 to 1.0E-04. The large reduction is based on the fact that SAMA 11 automates the system response and no operator action is required. As a result, there is no need to consider operator dependence factors for the initiation failure probability. In addition, the availability of the diverse, alternate portable AC generator is considered to reduce the failure probability of the flood-safe AC power source from 1.43E-01 to 2.04E-02 (1.43E-01 * 1.43E-01 = 2.04E-2, which assumes completely independent generators). This results in a total failure probability of 2.05E-02 (1.0E-04 + 2.04E-02 = 2.05E-02) for the severe flooding mitigation strategy.

Because the severe flooding guidelines were credited differently in each of the flood ranges, three separate strategies are required to obtain the revised core damage frequencies for the flooding scenarios:

- Floods >310' msl: The CDF for this scenario was calculated in the IPEEE as the product of the flood frequency and the failure probability for the alignment of the severe flooding mitigation strategy. As a result, the revised frequency can be obtained by multiplying the base CDF by the ratio of SAMA based severe flood mitigation failure probability to the baseline severe flood mitigation failure probability (2.05E-02 / 2.55E-01 = 8.03E-02).

- Floods between 305' and 310' msl: In the IPEEE, a multiplier of 0.5 was applied to each of the sequences in the flooding event tree to represent the potential to avert the flood using the severe flooding guidelines. The CDFs for these sequences can be made to reflect implementation of this SAMA by multiplying each sequence specific CDF by the ratio of SAMA based severe flood mitigation failure probability to the baseline severe flood mitigation failure probability (2.05E-02 / 5.0E-01 = 4.10E-02).

- Floods below 305' msl: No credit was taken for the severe flooding guidelines for these cases in the IPEEE and as a result, the CDF can be directly multiplied by 2.05E-02.

The results of this process are summarized below:

SAMA 11 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	5.81E-06	12.45	$38,036
Percent Change	-92.8%	-93.0%	-93.0%

A further breakdown of this information is provided below according to release category.

SAMA 11 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	5.12E-06	2.53E-07	2.67E-09	3.63E-08	2.45E-07	1.47E-07	3.47E-09	5.13E-09	5.81E-06
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	10.66	0.53	0.01	0.08	0.72	0.43	0.01	0.01	12.45
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$32,598	$1,610	$24	$231	$2,199	$1,318	$31	$25	$38,036

The external flooding based averted cost-risk for this SAMA is shown below:

SAMA 11 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$1,094,145	$14,449,328

E.6.11.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $4,250,000 by the TMI staff (Exelon 2007c).

E.6.11.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 11 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$1,639,364	$14,449,328	$16,088,692	$4,250,000	$11,838,692

Given that the cost of implementation is less than the averted cost-risk for this SAMA, the net value is positive.

E.6.12 SAMA NUMBER 12: USE THE DHR SYSTEM AS AN ALTERNATE SUCTION SOURCE FOR HPI

Failures of the BWST suction path (MU-V-14A/B) to the HPI pumps will lead to core damage in scenarios requiring early makeup. Through implementation of procedure changes, the DHR system could be aligned to take suction from the BWST and supply flow to the HPI system to allow injection in these cases.

While the events that will cause failure of the HPI suction path are low probability events, the options to prevent core damage in those cases are extremely limited. The existing DHR and HPI piping provide an alternate path that could be used and credited if plant procedures and training were modified.

E.6.12.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMAs averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In order to represent this SAMA in the PRA, the PRA model was changed to accommodate existing logic for valves DH-V-7A/B in the HPI system injection path logic. A new human error probability (HEP) event was added with a screening value of 0.1 (SAMA12-DHMUHVAOA) in conjunction with valve hardware failure events and power dependencies. Logic representing the dependence on the DHR system itself was not included in the DH-V-7A/B suction path. Inclusion of the DHR dependence would reduce the averted cost-risk calculated for this SAMA, but the impact is estimated to be small given that the alternate suction path failures would be dominated by the 0.1 failure probability of the operator action and the common valve power dependences. The changes made to the model are summarized in the following table:

SAMA 12 - Model Changes

Gate and / or Basic Event ID and Description	Description of Change
Gate HPG00MAC: NO FLOW FROM PUMP MU-P1A	Deleted the following gate: • Gate HPG00MBK: NO FLOW FROM MU-V-14AOR MU-V-14B Added the following gate: • Gate HPG00MBK-1 (new): NO SUCTION SOURCE FOR HPI
Gate HPG00MBK-1: NO SUCTION SOURCE FOR HPI	New AND gate representing the availability of both the BWST and the DHR heat exchangers as injection suction sources. The gate includes the following input: • Gate HPG00MBK (existing): NO FLOW FROM MU-V-14AOR MU-V-14B • Gate HPG00MBK-2 (new): HPI SUCTION VIA DH-V-7 MOVS
Gate HPG00MBK-2: HPI SUCTION VIA DH-V-7 MOVS	New OR gate representing the DHR system suction path for HPI. The gate includes the following input: • Gate HL (existing): HL (DH-V-7A/B failures)
Basic event SAMA12-DHMUHVAOA: OPERATOR FAILS TO ALIGN DHR TO MAKEUP PUMP SUCTION	New basic event representing the probability that the operators will fail to align the DHR system as the suction injection mode suction source for HPI. Failure probability = 0.1.
Similar changes have been made to the “power recovered” logic. The “power recovered” logic is used in portions of the LOOP tree in which offsite power has been restored and the power dependencies of the logic are removed to preclude failure of OSP from disabling equipment.	
Similar changes were also made to credit the MU-P-1B and MU-P-1C pumps with the alternate injection suction alignment from the DHR system.	

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 12 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.27E-05	31.64	$109,292
Percent Change	-4.2%	-3.0%	-2.6%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 12 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.47E-07	1.56E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	6.80E-07	1.63E-07	2.06E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.56	8.92	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.18	1.00	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,427	$43,368	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$13,736	$3,293	$195

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.11E-07	2.75E-09	7.44E-07	2.89E-07	3.14E-06	1.24E-05	1.68E-08	2.33E-06	1.91E-08	2.27E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.28	0.00	1.00	0.39	6.97	3.31	0.00	0.62	0.01	31.64
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$806	$11	$2,842	$1,104	$19,719	$3,251	$4	$610	$5	$109,292

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 12 - Non-External Flooding Averted Cost

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,172,492	$99,219	2.0	$198,438

E.6.12.2 EXTERNAL FLOODING EVALUATION

This SAMA is of importance in LOCA events where RCS inventory makeup is required using the HPI system suction from the BWST. For the external flooding cases, this is not an issue as the reactor is tripped by a manual shutdown (or a LOOP) rather than a LOCA event. While LOCAs are likely in external flooding scenarios due to SBO induced seal LOCAs, the HPI system would be unavailable in those cases during the SBO. There is some potential for this SAMA to provide a benefit in the flood induced SBO scenarios where AC power is recovered prior to core damage, but the likelihood of recovering power in the short amount of time to prevent core damage in believed to be very low for flood conditions and this SAMA is assumed to provide zero benefit. As a point of reference, the SBO sequences from the base model were quantified and the resulting cutsets were reviewed to determine the contribution of BWST suction failures after power recovery. There was no measurable contribution from suction path failures. The sequences quantified included those in which AC power was both recovered and not recovered, specifically:

- LOOP-055
- LOOP-057
- LOOP-058
- LOOP-059
- LOOP-062
- LOOP-064
- LOOP-066
- LOOP-067
- LOOP-068
- LOOP-069

As a result, this SAMA would not yield a measurable risk reduction for the external flooding events, as shown below:

SAMA 12 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	177.16	$542,159
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 12 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159

The external flooding component of the averted cost-risk for this SAMA is, therefore, $0:

SAMA 12 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,543,473	$0

E.6.12.3 COST OF IMPLEMENTATION

Procedure changes are estimated to be $50,000 (CPL 2004).

E.6.12.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 12 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$198,438	$0	$198,438	$50,000	$148,438

Given that the cost of implementation is less than the averted cost-risk for this SAMA, the net value is positive.

E.6.13 SAMA NUMBER 13: CHANGE IA SYSTEM LOGIC TO AUTOMATICALLY START IA-P-1A/B AFTER A LOW VOLTAGE TRIP IN CONJUNCTION WITH AN ESAS

The current IA system logic requires the operators to re-load the IA compressors on emergency power after a low voltage trip when an ESAS is registered. Automating the re-loading of these compressors would remove the requirement for the operators to perform this task in accident conditions. The scenarios of interest for this SAMA are turbine building steam line breaks that cause both a LOOP (due to adverse environmental conditions) and an ESAS, which will require the operators to reload the IA compressors. The importance of automating this action is driven by the short time that is available to prevent loss of seal cooling due to closure of MU-V-20, IC-V-3, and IC-V-4. The PRA indicates that the air supplies for these valves will deplete in 20 minutes after loss of IA and will go closed. While recovery may be possible after the initial closure, no credit is taken for such recovery actions in the model.

E.6.13.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

The HEP event for failure to manually start the air compressors using emergency power from the station diesel generators (AMHAM2-----HC1OA) was changed from a failure probability of 8.88E-2 to 1.00E-05 to simulate the improved reliability due to proposed automatic restart logic. In addition, the JHEPs including AMHAM2-----HC1OA were set to zero to account for the removal of the operator from the dependence chain. The following table summarizes the changes that were made to the basic event data:

SAMA 13 - Model Changes

Gate and / or Basic Event ID and Description	Description of Change
AMHAM2-----HC1OA:	Basic event probability changed from 8.88E-02 to 1.00E-05.
JHHAM2-HEF1HEPOA: AMHAM2-----HC1OA AND EFHEF1_OPERH2HOA	Basic event probability set to 0.0.
JHHAM2HINJ1HEPOA: AMHAM2-----HC1OA AND INHINJ1_MUHHMUOA	Basic event probability set to 0.0.
JHHAM2HINJ4HEPOA: AMHAM2-----HC1OA AND INHINJ4_MUHHVCOA	Basic event probability set to 0.0.
JHHAMHEFHBWHEPOA: JHHAM2-HEF1HEPOA AND BWHBW1-----HP2OA	Basic event probability set to 0.0.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 13 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.30E-05	31.17	$106,172
Percent Change	-3.0%	-4.4%	-5.4%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 13 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.00E-07	1.47E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.89E-08	1.46E-08	8.54E-09	3.16E-07	7.00E-07	1.64E-07	2.15E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.29	8.41	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.31	1.01	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$11,120	$40,866	$3,367	$236	$3	$3	$7	$11	$350	$131	$77	$2,841	$14,140	$3,313	$203

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.19E-07	2.75E-09	7.44E-07	2.89E-07	3.16E-06	1.28E-05	1.40E-08	2.34E-06	1.91E-08	2.30E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.30	0.00	1.00	0.39	7.02	3.41	0.00	0.62	0.01	31.17
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$837	$11	$2,842	$1,104	$19,845	$3,349	$4	$613	$5	$106,172

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 13 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,119,064	$152,647	2.0	$305,294

E.6.13.2 EXTERNAL FLOODING EVALUATION

This SAMA will have no measurable benefit for external flooding cases given that equipment is either flooded, an SBO and subsequent seal LOCA occurs (the main goal of this SAMA is to prevent seal LOCAs), or a LOOP will occur without an ESAS signal, as summarized below:

Floods over 310’ msl: In these scenarios, all safety equipment is flooded and this SAMA has no impact on the risk.

Floods between 305’ and 310’ msl: Most of the sequences are not impacted by this SAMA as core damage is caused by failure of the flood gates (safety equipment if flooded) or because a flood warning is not provided and no preparations are made for the flood (safety equipment is flooded). Flood sequence “E” represents cases where the flood gates are correctly installed, but a loss of onsite power leads to core damage. These scenarios will result in an SBO and a subsequent seal LOCA independent of the implementation status of SAMA 13.

Floods below 305’ mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. Given that IA will not require manual reload without a coincident ESAS and that an ESAS is not expected for a LOOP without a seal LOCA, implementation of SAMA 13 for seal LOCA prevention will not be beneficial.

Consequently, this SAMA would not yield a measurable risk reduction for the external flooding events, as shown below:

SAMA 13 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	177.16	$542,159
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 13 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 13 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,543,473	$0

E.6.13.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $950,000 by the TMI staff (Exelon 2007c).

E.6.13.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 13 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$305,647	$0	$305,647	$950,000	-$644,706

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.14 SAMA NUMBER 14: REPLACE HPI PUMP COOLING ALIGNMENT VALVES WITH MOVS

In the event that the normally aligned cooling source to a HPI pump fails, the current plant configuration requires local operation of the valves to swap the pump to the alternate cooling source. The time required to perform this action is considered to preclude it as a means of both preventing seal LOCAs in loss of seal cooling evolutions and for providing high pressure makeup. Replacing the valves with MOVs would allow the operators to rapidly align the alternate cooling source from the MCR in time to prevent a seal LOCA or provide high pressure injection.

E.6.14.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

The ability to cross-connect cooling systems for the makeup pumps necessitated a change to the model logic for all three makeup pumps depending upon their ESAS alignments. The following paragraphs outline the model changes for each of the makeup pumps:

Makeup Pump A Aligned to ESAS Train A:

The system top event HA under AND gate HPGPUMPACOOLSUP1 was replaced with an AND gate named HPGPUMPACOOLSUP1-1, which contained top event HA and an OR gate named HPGPUMPACOOLSUP1-2 as its inputs. The inputs to HPGPUMPACOOLSUP1-2 were a new

HEP event (SAMA14-HEP-HVAOA), a basic event that accounted for combined mechanical and electrical failures (SAMA14AMECH-ELEC), and system top event NS for unavailability of the NSCCW system. The HEP event was assigned a failure probability of 0.01, which was based on assuming all actions required for realigning cooling water were capable of being performed from inside the main control room. The event SAMA14AMECH-ELEC was estimated to have an unavailability of 0.01, based on a generic combination of mechanical and electrical support dependency failures unique to makeup pump MU-P-1A.

Makeup Pump A Aligned for RCP Seal Injection:

The system top event NS under AND gate HPGPUMPACOOLSUP2 was replaced with an AND gate named HPGPUMPACOOLSUP2-1, which contained the system top event NS and a new OR gate named HPGPUMPACOOLSUP2-2. This new OR gate contained the HEP event SAMA14-HEP-HVAOA and basic event SAMA14AMECH-ELEC, which were both described above, and the system top event HA, simulating the loss of DHCCW train A.

Makeup Pump B Cooling Water Dependency:

The physical arrangement of the MU-P-1B cooling piping is such that complex back feeding and the installation of multiple, additional MOVs would be required to allow DHCCW to be used for pump cooling in place of NSRW. Exelon's cost estimate for this SAMA does not include the costs associated with these types of changes; however, credit is taken in this evaluation for alternate MU-P-1B cooling. This conservative approach was used in order to provide a bounding assessment of the benefit related to alternate HPI pump cooling without expending the additional resources that would be required to fully develop the costs of providing DHCCW to MU-P-1B.

The system top event NS under OR gate HPGPUMPBCOOL was replaced with an AND gate named HPGPUMPBCOOL-1, which contained the system top event NS and a new OR gate named HPGPUMPBCOOL-2. This new OR gate contained the HEP event SAMA14-HEP-HVAOA described above and a new basic event SAMA14BMECH-ELEC, which was assigned an unavailability of 0.01, based on a generic combination of mechanical and electrical support dependency failures unique to makeup pump MU-P-1B. In addition, HPGPUMPBCOOL-2 also contained the system top event HA, simulating the loss of DHCCW train A.

Makeup Pump C Aligned to ESAS Train B:

The system top event HB under OR gate HQGPUMPCCOOLIN was replaced with an AND gate named HQGPUMPCCOOLIN-1, which contained top event HB and a new OR gate named HQGPUMPCCOOLIN-2 as its inputs. The inputs to HQGPUMPCCOOLIN-2 were the HEP event SAMA14-HEP-HVAOA described above, a basic event that accounted for combined mechanical and electrical failures unique to makeup pump MU-P-1C (SAMA14CMECH-ELEC), and system top event NS for unavailability of the NSCCW system.

In addition, all affected logic described above that is modeled within the logic structure for post-LOOP recovery scenarios was also modified, with gate names appended with the characters "-R".

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 14 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	1.97E-05	29.86	$105,634
Percent Change	-16.9%	-8.4%	-5.9%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 14 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
$Freq.(/yr)_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
$Freq. (/yr)_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	4.86E-11	4.86E-11	1.90E-10	2.46E-10	3.29E-08	1.42E-08	7.69E-09	3.19E-07	5.34E-07	1.57E-07	1.60E-08
$Dose\text{-}Risk_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
$Dose\text{-}Risk_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.10	0.04	0.02	0.93	3.28	0.97	0.04
$OECR_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
$OECR_{SAMA}$	$12,705	$44,202	$3,367	$236	$2	$2	$7	$9	$296	$128	$69	$2,868	$10,787	$3,171	$151

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
$Freq.(/yr)_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
$Freq.\ (/yr)_{SAMA}$	2.36E-10	2.08E-11	8.40E-08	1.42E-08	1.63E-07	2.75E-09	7.81E-07	2.62E-07	3.01E-06	9.70E-06	1.69E-08	2.32E-06	1.91E-08	1.97E-05
$Dose\text{-}Risk_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
$Dose\text{-}Risk_{SAMA}$	0.00	0.00	0.24	0.04	0.22	0.00	1.05	0.35	6.69	2.59	0.00	0.62	0.01	29.86
$OECR_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
$OECR_{SAMA}$	$2	$0	$794	$134	$623	$11	$2,983	$1,001	$18,928	$2,542	$4	$608	$5	$105,634

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 14 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$2,987,676	$284,035	2.0	$568,070

E.6.14.2 EXTERNAL FLOODING EVALUATION

This SAMA will have limited benefit for external flooding cases given that equipment is either flooded, an SBO occurs, or the combined probability of the flood initiators with loss of HPI pump cooling evolutions is so low that the SAMA will not provide a measurable risk reduction, as summarized below:

Floods over 310’ msl: In these scenarios, all safety equipment is flooded and this SAMA has no impact on the risk.

Floods between 305’ and 310’ msl: Most of the sequences are not impacted by this SAMA as core damage is caused by failure of the flood gates (safety equipment if flooded) or because a flood warning is not provided and no preparations are made for the flood (safety equipment is flooded). Flood sequence “E” represents cases where the flood gates are correctly installed, but a loss of onsite power leads to core damage. These are SBO scenarios in which SAMA 14 would not typically provide a benefit. In the event that AC power is recovered before core damage occurs, SAMA 14 could be beneficial if HPI pump cooling was also lost in the evolution; however, review of the baseline SBO sequence importance list shows that the largest RRW for any DHCCW or DHRW event is 1.001 and all NSCCW events fell below the truncation limit of the quantification and are not even included in the importance list. Therefore, no credit is taken for this SAMA in flood sequence “E”.

Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. There is some potential for SAMA 14 to provide a benefit for these cases and for the purposes of simplifying the quantification, SAMA 14 is assumed to eliminate all risk for these flood evolutions.

The following tables summarize the results of quantification strategy:

SAMA 14 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.08E-05	176.79	$540,940
Percent Change	-0.3%	-0.2%	-0.2%

A further breakdown of this information is provided below according to release category.

SAMA 14 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	0.00E+00	8.08E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.00	176.79
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$0	$540,940

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 14 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,507,657	$35,816

E.6.14.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $3,150,000 by the TMI staff (Exelon 2007c).

E.6.14.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 14 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$568,070	$35,816	$603,886	$3,150,000	-$2,546,114

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.15 SAMA NUMBER 15: AUTOMATIC SWAP TO RECIRCULATION MODE

The operator action to swap to recirculation mode is a key action for LOCA scenarios. Automating this function would improve the reliability of this action, especially in the rapidly evolving events where other actions are competing for the attention of the operators.

This SAMA should provide the capability to automatically align high or low pressure recirculation mode, depending on the conditions of the plant.

E.6.15.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMAs averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

To simulate the automatic swapover from injection to recirculation, the HEP events SAHSR1-----HSROA (for large LOCAs) and SAHSR2-----HSROA (for non-large LOCAs) were set to 1.00E-05 to simulate automation of the action. The corresponding JHEP was set to 0.0 to capture the removal of the recirculation action from the dependence chain. Given that these changes include only the modification of basic event probabilities, the changes were made to the cutset files and no model requantification was required. The cutset changes are summarized in the following table:

SAMA 15 - Model Changes

GATE AND / OR BASIC EVENT ID AND DESCRIPTION	DESCRIPTION OF CHANGE
SAHSR1-----HSROA: OPERATOR FAILS TO TAKE PROPER ACTION WITHIN ONE MINUTE	The basic event probability was changed from 1.71E-02 to 1.00E-05.
SAHSR2-----HSROA: OPERATOR FAILS TO TAKE PROPER ACTION WITHIN TEN MINUTE	The basic event probability was changed from 1.30E-04 to 1.00E-05.
JHHHL1AHSR2HEPOA: DLHHL1A----HVHOA AND SAHSR2-----HSROA (dependence between failure to swap to recirculation mode and failure to open dropline for DHR)	The basic event probability was changed from 2.00E-04 to 0.0.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 15 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.26E-05	31.65	$109,449
Percent Change	-4.6%	-2.9%	-2.5%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 15 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.55E-07	1.56E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	6.78E-07	1.63E-07	2.07E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.60	8.92	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.17	1.00	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,649	$43,368	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$13,696	$3,293	$196

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	7.99E-08	1.43E-08	2.12E-07	2.75E-09	7.44E-07	2.89E-07	3.14E-06	1.23E-05	1.67E-08	2.33E-06	1.91E-08	2.26E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.29	0.00	1.00	0.39	6.97	3.28	0.00	0.62	0.01	31.65
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$755	$135	$810	$11	$2,842	$1,104	$19,719	$3,223	$4	$610	$5	$109,449

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 15 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,172,617	$99,094	2.0	$198,188

E.6.15.2 EXTERNAL FLOODING EVALUATION

This SAMA is of importance in LOCA events when the entire volume of the BWST has been injected and the only source of borated water for continued core cooling is the water that has collected in the containment sump. For the external flooding cases, this is not an issue as the reactor is tripped by a manual shutdown (or a LOOP) rather than a LOCA event. While LOCAs are likely in external flooding scenarios due to SBO induced seal LOCAs, the primary side injection systems would be unavailable in those cases during the SBO. There is some potential for this SAMA to provide a benefit in the flood induced SBO scenarios where AC power is recovered prior to core damage, but the likelihood of recovering power in the short amount of time to prevent core damage is very low for flood conditions and this SAMA will provide an extremely limited benefit.

To investigate this further, the SBO sequences from the base model were quantified and the resulting cutsets were reviewed to determine the contribution of manual recirculation alignment failures after power recovery. The sequences quantified included those in which AC power was both recovered and not recovered, specifically:

- LOOP-055
- LOOP-057

- LOOP-058
- LOOP-059
- LOOP-062
- LOOP-064
- LOOP-066
- LOOP-067
- LOOP-068
- LOOP-069

The only event identified in the cutsets was the JHEP event “JHHHL1AHSR2HEPOA” which accounted for only 0.1 percent of the SBO CDF. For the external flooding cases, the only two potential sequences that could be impacted by SAMA 15 are:

- Floods between 305’ and 310’ msl, sequence E: Most of the sequences are not impacted by this SAMA as core damage is caused by failure of the flood gates (the SBO EDG is flooded) or because a flood warning is not provided and no preparations are made for the flood (the SBO EDG is flooded). Flood sequence “E” represents cases where the flood gates are correctly installed, but a loss of onsite power leads to core damage. These SBO cases are considered to be similar to the internal events SBO cases.

- Floods below 305’ mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. While only a fraction of these cases would actually be SBOs, they are assumed to be 100% SBO cases for this evaluation.

Assuming that SAMA 15 can remove all of the 0.1 percent risk attributed to manual recirculation failures results in a 0.1 percent reduction of the sequences identified above. The change in risk is trivial compared with the overall external flooding contributions, as summarized below:

SAMA 15 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	177.15	$542,125
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 15 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.65E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.70	0.25	0.37	177.15
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,826	$778	$1,217	$542,125

The external flooding component of the averted cost-risk for this SAMA is, therefore, $910:

SAMA 15 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,542,563	$910

E.6.15.3 COST OF IMPLEMENTATION

Multiple SAMA analyses have included estimates for this type of change, but the estimates vary by over a factor of 3.5:

- Oconee estimated the cost at over $1 million per unit (Duke 1998)
- Point Beach estimated the cost at over $1 million per unit (NMC 2004)
- Catawba estimated the cost at over $1 million (Duke 2001)
- Turkey Point estimated the cost to be about $450,000 (per unit) (FPL 2000)
- H.B. Robinson $265,000 (single unit) (CPL 2002)

For TMI-1, the $450,000 estimate from Turkey Point is used as it is in the middle range of the industry estimates identified.

E.6.15.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 15 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$198,188	$910	$199,098	$450,000	-$250,902

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.16 SAMA NUMBER 16: AUTOMATE HPI INJECTION ON LOW PRESSURIZER LEVEL

Providing an automatic signal to initiate HPI on low pressurizer level would improve the reliability of HPI initiation. The current initiation logic will not start HPI until low pressure (1600 psig) is reached in the RCS or high reactor building pressure (4 psig) is registered. This is adequate for LOCAs where the pressure drops with RCS level, but for loss of secondary side heat removal cases where the RCS pressure remains high while the level falls, no automated signal is available. HPI initiation is not a complicated action, but high workloads can divert attention from required tasks and providing an automated response to reduced level would prevent core uncovery in the event that a manual initiation is not performed.

Pressurizer level instrumentation already exists for other purposes and the low level signal could be used as a means to start the HPI system.

E.6.16.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMAs averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In order to represent this SAMA in the PRA, cutset changes were made to address the impact of automating initiation of the HPI system. This method was chosen given that HPI initiation reliability can easily be modified through the manipulation of existing human failure events. In the TMI-1 model, the relevant basic events include an independent event as well as joint human error events. In this case, automating the initiation of HPI (with human backup) is considered to reduce the failure probability to at least 1.0E-04, which is reflected by changing the failure probability of the independent HEP from 2.18E-03 to 1.0E-04. Because automation of the function basically removes it from the joint human error events, those events are set to 0.0. Any combinations of the remaining actions important to the model are treated in separate events and the development of new combinations is not required. The following table summarizes the model changes that were made:

SAMA 16 - Model Changes

GATE AND / OR BASIC EVENT ID AND DESCRIPTION	DESCRIPTION OF CHANGE
BWHBW1-----HP2OA: OPERATOR FAILS TO INITIATE HPI	The basic event probability was changed from 2.18E-03 to 1.00E-04.
JHHMR1-HBW1HEPOA: MRHMR1-----HMUOA AND BWHBW1-----HP2OA (dependence between failure to initiate HPI and failure to establish a min flow path for the HPI pumps)	The basic event probability was changed from 1.40E-03 to 0.0.
JHHAMHEFHBWHEPOA: JHHAM2-HEF1HEPOA AND BWHBW1-----HP2OA(dependence between failure to initiate HPI, failure to start IA on emergency power, and failure to operate EF-V-30 locally after loss of IA)	The basic event probability was changed from 2.40E-04 to 0.0.
JHHEF1-HBW1HEPOA: EFHEF1_OPERH2HOA AND BWHBW1-----HP2OA (dependence between failure to initiate HPI and failure to locally operate the EFW flow control valves)	The basic event probability was changed from 1.00E-04 to 0.0.
JHHEF3-HBW1HEPOA: EFHEF3_OPERH2HOA AND BWHBW1-----HP2OA (dependence between failure to initiate HPI and failure to locally operate the EFW flow control valves after 2 hour bottle depletion)	The basic event probability was changed from 4.10E-04 to 0.0.
JHHEF8-HBW1HEPOA: EFHEF8_OPERHBVOA AND BWHBW1-----HP2OA (dependence between failure to initiate HPI and failure to close EFW flow control block valve)	The basic event probability was changed from 5.70E-05 to 0.0.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 16 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.24E-05	24.27	$78,253
Percent Change	-5.5%	-25.6%	-30.3%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 16 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.55E-07	8.66E-07	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	6.93E-08	1.64E-07	2.13E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.60	4.95	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	0.43	1.01	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,649	$24,075	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$1,400	$3,313	$201

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.17E-07	2.69E-09	7.44E-07	2.89E-07	3.15E-06	1.34E-05	4.40E-09	2.34E-06	1.89E-08	2.24E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.29	0.00	1.00	0.39	6.99	3.58	0.00	0.62	0.01	24.27
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$829	$10	$2,842	$1,104	$19,782	$3,509	$1	$613	$5	$78,253

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 16 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$2,476,374	$795,337	2.0	$1,590,674

E.6.16.2 EXTERNAL FLOODING EVALUATION

This SAMA is of importance primarily in loss of secondary side heat removal cases where low level can occur in the primary side without an RCS low pressure signal. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310' msl: In these scenarios, all safety equipment is flooded and this SAMA has no impact on the risk.
- Floods between 305' and 310' msl: Most of the sequences are not impacted by this SAMA as core damage is caused by failure of the flood gates (the SBO EDG is flooded) or because a flood warning is not provided and no preparations are made for the flood (the SBO EDG is flooded). Flood sequence "E" represents cases where the flood gates are correctly installed, but a loss of onsite power leads to core damage. In these cases, an SBO will occur that will lead to seal damage, the majority of which will be of the larger size leaks. For these leaks, loss of inventory through the break will eventually result in a low pressure signal and an automatic HPI initiation if power is recovered. No benefit is considered available for these cases.
- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. For this evaluation, it is assumed that these sequences are impacted in the same manner as the internal events sequences, which are primarily loss of secondary side heat removal cases. The CDF for this flood sequence is reduced by the same percent as the internal events CDF based on SAMA 16 implementation.

The following tables summarize the results of these changes on external flooding risk:

SAMA 16 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.10E-05	177.14	$542,092
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 16 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.36E-07	8.10E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.35	177.14
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,152	$542,092

The external flooding component of the averted cost-risk for this SAMA is summarized below:

SAMA 16 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,541,516	$1,957

E.6.16.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $1,100,000 by the TMI staff (Exelon 2007c).

E.6.16.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 16 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$1,590,674	$1,957	$1,592,631	$1,100,000	$492,631

Given that the cost of implementation is less than the averted cost-risk for this SAMA, the net value is positive.

E.6.17 SAMA NUMBER 17: AUTO ISOLATE STEAM GENERATORS ON HIGH STEAM LINE FLOW

For steam line breaks downstream of the MSIVs, failure to isolate the relevant steam generator is an important contributor to core damage. The addition of logic to isolate the steam generator on high steam line flow would reduce the core damage contribution from isolation failures. The steam line break contributors for TMI typically include multiple operator actions such that further procedure changes to direct mitigation of the event will have a limited impact due to operator dependence issues. The most effective solution was considered to be automation of a mitigating function. For the steam line break contributors, auto isolation of the MSIV was a straightforward change with the potential to impact a majority of the postulated scenarios.

E.6.17.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMAs averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

To simulate the automatic isolation of steam generators during a steamline break scenario, the HEP event SIHSI1-----HSGOA was reduced by a factor of 10 and any associated JHEP events set to 0.0 using previously generated cutsets. The new cutset probabilities for CDF and the various release categories were then summed and used to determine an estimate for the averted cost risk. Therefore, no new logic changes were made to the PRA model and no fault tree requantifications were performed. The following table summarizes the model changes that were made:

SAMA 17 - Model Changes

GATE AND / OR BASIC EVENT ID AND DESCRIPTION	DESCRIPTION OF CHANGE
SIHSI1-----HSGOA: OPERATOR ERROR TO ISOLATE OTSG (BREAK DOWNSTREAM MSIV)	The basic event probability was changed from 1.50E-02 to 1.50E-03.
JHHSI1-HEF3HEPOA: SIHSI1-----HSGOA AND EFHEF3_OPERH2HOA (dependence between break isolation and failure to locally operate EF-V-30 after 2 hour air bottle depletion)	The basic event probability was changed from 1.50E-02 to 0.0.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 17 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.34E-05	32.37	$111,518
Percent Change	-1.3%	-0.7%	-0.7%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 17 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.57E-07	1.58E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.24E-07	1.65E-07	2.19E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.04	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.45	1.01	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$43,924	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,625	$3,333	$207

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.23E-07	2.75E-09	7.45E-07	2.89E-07	3.18E-06	1.30E-05	1.68E-08	2.35E-06	1.91E-08	2.34E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.06	3.46	0.00	0.63	0.01	32.37
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$852	$11	$2,846	$1,104	$19,970	$3,395	$4	$616	$5	$111,518

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 17 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,245,717	$25,994	2.0	$51,988

E.6.17.2 EXTERNAL FLOODING EVALUATION

This SAMA does not have an impact on external flooding given that it impacts only steam line break initiating events. For the external flooding cases, this is not an issue as the reactor is tripped by a manual shutdown (or a LOOP) rather than a steam line break event. No measurable risk reduction is believed to result from implementation of this SAMA for external flooding, as shown below:

SAMA 17 - External Flooding Results

	CDF (/YR)	DOSE-RISK (PERSON-REM/YR)	OECR ($/YR)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	177.16	$542,159
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 17 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159

The external flooding component of the averted cost-risk for this SAMA is, therefore, $0:

SAMA 17 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,543,473	$0

E.6.17.3 COST OF IMPLEMENTATION

This SAMA is considered to be similar in scope to SAMA 13 and the same cost of implementation ($950,000) is used for this SAMA.

E.6.17.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 17 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$51,988	$0	$51,988	$950,000	-$898,012

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.18 SAMA NUMBER 18: PROVIDE THE CAPABILITY TO ALIGN THE STANDBY BATTERY CHARGER AND THE 1A/1B DC CROSS-TIE FROM THE MCR

TMI has a spare 125V DC battery charger for each division that can be aligned to either battery bank within a division in the event that a normally operating battery charger fails. Currently, the alignment requires local actions. There is typically adequate time to align the charger in the event of a failure given that the batteries will last at least four hours, but additional changes could be made to allow rapid alignment of the spare charger from the MCR to reduce the manipulation time and improve the man-machine interface.

A divisional cross-tie exists that can be used to tie the DC buses together, if required. Providing the capability to remotely operate the cross-tie would provide an additional means of maintaining DC power to required loads.

E.6.18.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMAs averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

To simulate alignment of a spare battery charger from the MCR, the HEP event DABATTCHGR-HBCOA, which assumed manipulations performed outside the MCR, was lowered by a factor of 10. There were no applicable JHEP events; therefore, no additional basic event data changes were required.

No changes were made to the cutsets to explicitly represent the improvements to the cross-division DC cross-tie, but not modeling this capability does not have a meaningful impact on the results for the following reasons:

- The baseline model does not credit the existing, proceduralized action to cross-tie the DC buses. Given that there is ample time to perform the cross-tie, the base model over-emphasizes the importance of the DC power supplies.
- The HEP representing alignment of the spare battery chargers (DABATTCHGR-HBCOA) is currently assigned a screening value of 0.1. Like the DC cross-tie, spare battery charger alignment is proceduralized and ample time is available for completing the action. If reasonable credit was assigned to DABATTCHGR-HBCOA, the importance of the DC power supplies would be reduced.
- Even with the low credit for DABATTCHGR-HBCOA, the RRW for the action is only 1.001 when SAMA 18 is implemented. This implies that further reductions to the DC power supplied would provide limited benefit.

As a result, the changes made to HEP DABATTCHGR-HBCOA are considered to provide a reasonable assessment of the benefits related to SAMA 18. The following table summarizes the changes that were made to the cutsets:

SAMA 18 - Model Changes

GATE AND / OR BASIC EVENT ID AND DESCRIPTION	DESCRIPTION OF CHANGE
DABATTCHGR-HBCOA:	The basic event probability was changed from 1.00E-01 to 1.00E-02.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 18 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.33E-05	32.54	$112,239
Percent Change	-1.7%	-0.2%	-0.0%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 18 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
$Freq.(/yr)_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
$Freq.\ (/yr)_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.24E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.64E-08	1.35E-08	8.54E-09	2.87E-07	7.25E-07	1.65E-07	2.19E-08
$Dose\text{-}Risk_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
$Dose\text{-}Risk_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.84	4.46	1.01	0.06
$OECR_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
$OECR_{SAMA}$	$12,705	$44,202	$3,367	$231	$3	$3	$7	$11	$327	$121	$77	$2,580	$14,645	$3,333	$207

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
$Freq.(/yr)_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
$Freq.\ (/yr)_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	2.79E-08	2.88E-07	5.41E-09	7.86E-07	3.71E-07	3.17E-06	1.25E-05	1.69E-08	2.55E-06	1.91E-08	2.33E-05
$Dose\text{-}Risk_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
$Dose\text{-}Risk_{SAMA}$	0.00	0.00	0.22	0.08	0.39	0.01	1.06	0.50	7.04	3.33	0.00	0.68	0.01	32.54
$OECR_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
$OECR_{SAMA}$	$2	$0	$756	$264	$1,100	$21	$3,003	$1,417	$19,908	$3,272	$4	$668	$5	$112,239

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 18 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,259,138	$12,573	2.0	$25,146

E.6.18.2 EXTERNAL FLOODING EVALUATION

This SAMA is potentially of importance in any event where power to the battery chargers is available. For the external flooding cases, the only two potential sequences that could be impacted by SAMA 18 are:

- Floods between 305' and 310' msl, sequence E: Most of the sequences in the 305' to 310' msl range are not impacted by this SAMA as core damage is caused by failure of the flood gates (all safety equipment is flooded) or because a flood warning is not provided and no preparations are made for the flood (all safety equipment is flooded). Flood sequence “E” represents cases where the flood gates are correctly installed, but a loss of onsite power leads to core damage. This SAMA would provide benefit for flood sequence “E” when 1) battery depletion is the eventual cause of onsite power failure and alignment of the standby charger would prevent loss of DC power, and 2) when offsite AC power is recovered after loss of all on-site AC power and alignment of the standby charger would restore DC power. For this evaluation, the characteristics of the SBO contributors in flooding sequence “E” are assumed to be the same as the internal events SBO contributors. This is considered to be reasonable given that the flood gates prevent damage to plant safety equipment and offsite power recovery is a minor contributor to the internal events SBO evolutions (implies the potentially longer offsite AC recovery times for flood events are not a factor).
- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. For LOOP cases, improved DC reliability can impact the CDF.

As mentioned above, there is some potential for this SAMA to provide a benefit in the flood induced SBO scenarios (flood sequence “E”), but the circumstances in which the SAMA could be used are rare and it will provide an extremely limited benefit.

To investigate this further, the SBO sequences from the base model were quantified and the resulting cutsets were reviewed to determine the contribution of manual alignment of the spare battery chargers. The sequences quantified included those in which AC power was both recovered and not recovered, specifically:

- LOOP-055
- LOOP-057

- LOOP-058
- LOOP-059
- LOOP-062
- LOOP-064
- LOOP-066
- LOOP-067
- LOOP-068
- LOOP-069

Basic event “DABATTCHGR-HBCOA” accounted for only 0.8 percent of the SBO CDF, which implies that of all SBO cases, only 0.8 percent of the contribution includes conditions in which SAMA 18 could provide any benefit. Assuming that SAMA 18 can remove all of the 0.8 percent of the risk attributed to manual battery charger alignment failures results in a 0.8 percent reduction of 305’ to 310’ flood sequence E CDF.

For external floods below 305’ mls, the impact could be larger than for SBO scenarios given that that the need to recover or retain some form of AC power is not a precondition for credit (AC power is already available to the chargers). In these cases, the CDF is considered to behave more like the overall internal events model rather than the SBO subset of the CDF. To represent this behavior, the CDF for external floods below 305’ msl is reduced in proportion to the internal events model based on SAMA 18 implementation.

The results of these processes are summarized below:

SAMA 18 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.10E-05	177.06	$541,876
Percent Change	0.0%	0.1%	0.1%

A further breakdown of this information is provided below according to release category.

SAMA 18 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.63E-06	8.65E-08	2.46E-07	8.10E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.62	0.25	0.36	177.06
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,596	$778	$1,1198	$541,876

The external flooding component of the averted cost-risk for this SAMA is summarized below:

SAMA 18 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,535,359	$8,114

E.6.18.3 COST OF IMPLEMENTATION

No plant specific implementation cost was developed for this SAMA. Based on the low impact of the SAMA, the $100,000 minimum cost of a hardware modification (Exelon 2003) is used as the implementation cost.

E.6.18.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 18 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$25,146	$8,114	$33,260	$100,000	-$66,740

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.19 SAMA NUMBER 19: INSTALL BATTERY BACKED HYDROGEN IGNITORS OR A PASSIVE HYDROGEN IGNITION SYSTEM

The addition of hydrogen igniters would provide a means of preventing catastrophic combustible gas burns, which may lead to containment failure, by continuously burning these gases before they reach critical levels. Providing battery backup power would increase the likelihood that this system would be available in LOOP events. Use of a passive system would also function in LOOP as well as long term SBO scenarios.

E.6.19.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMAs averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

To simulate installation of hydrogen ignitors, a new basic event (SAMA19-H2IGNITER) was created to simulate the installation of a proposed hydrogen ignition system to minimize the concentration of hydrogen buildup within containment from various hydrogen producing mechanisms, such as corium-concrete interaction. Addition of this basic event to the Level 2 model necessitated inserting a new level of logic above the existing gate H2BURNS. Specifically, a new AND gate named H2BURNS-1 was inserted as an input to the Containment Event Tree nodal top event EARLY. The two inputs to gate H2BURNS-1 are gate H2BURNS and the new basic event SAMA19-H2IGNITER, with an assumed unavailability of 1.0E-02. This estimate is based on estimating an overall unavailability of a proposed system without identifying any particular design features or support dependencies (consistent with a passive design or an independent battery support system), and also represents a number that is not overly conservative or one that would tend to exaggerate the success of such a proposed system.

In addition, hydrogen burns are potential contributors to containment late; however, review of the cutsets shows that these evolutions are probabilistically insignificant (no cutsets exist that include late containment failure cause by hydrogen burns). All accident sequences including late hydrogen burns result in an intact containment and hydrogen igniters would not impact the results. Consequently, no model changes were included in this quantification to address late hydrogen burns to simplify the modeling process.

The model changes identified above yielded a reduction in the Dose-risk and Offsite Economic cost-risk, but did not impact the CDF, as summarized below:

SAMA 19 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.37E-05	29.11	$100,376
Percent Change	0.0%	-10.7%	-10.6%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 19 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
$Freq.(/yr)_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
$Freq. (/yr)_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	1.76E-07	1.33E-07	2.20E-08
$Dose\text{-}Risk_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
$Dose\text{-}Risk_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	1.08	0.82	0.06
$OECR_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
$OECR_{SAMA}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$3,555	$2,687	$208

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
$Freq.(/yr)_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
$Freq. (/yr)_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.38E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
$Dose\text{-}Risk_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
$Dose\text{-}Risk_{SAMA}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.69	0.00	0.63	0.01	29.11
$OECR_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
$OECR_{SAMA}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,617	$4	$618	$5	$100,376

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 19 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$2,987,716	$283,995	2.0	$567,990

E.6.19.2 EXTERNAL FLOODING EVALUATION

This SAMA can impact many of the external flooding evolutions given that a passive hydrogen ignition system could be available even in extreme flooding conditions. The circumstances related to each flood range are discussed below:

- Floods over 310' msl: For these floods, water level increases until it pours over the top of the existing flood barriers. Once core damage has occurred, the containment response is similar to an SBO scenario where water is not on the containment floor. The early containment failure frequency is assumed to be reduced in proportion to the early containment failures of the internal events model for this SAMA.

- Floods between 305' and 310' msl: Scenarios “A” through “D” are the result of flood gate failures. In these scenarios, no credit would be available for those cases where containment isolation was successfully performed (containment isolation failure will remain as containment isolation failures). In scenarios “A” and “C”, cold shutdown is achieved and containment isolation is successful, therefore credit is taken for these cases. For sequences “B” and “D”, no credit can be taken for hydrogen ignitors as these sequences represent cases where transition to cold shutdown has not occurred and the containment is not isolated. In sequence “E”, the flood gates hold, but EDG failures cause an SBO and prevent a transition to cold shutdown, which results in containment isolation failure and no credit is taken for SAMA 19. For sequence “F”, the operators have no warning of the impending flood and the plant is also not transitioned to cold shutdown before flood damage occurs, which implies containment isolation failure and no credit for SAMA 19.

- Floods below 305' mls: These are similar to internal events LOOP scenarios and early containment failures are assumed to be reduced in proportion to those in the internal events model.

Based on the qualitative descriptions above, the following quantitative structure was developed to represent the implementation of this SAMA:

External Flood Sequence Identifier	Quantification Method
>310 Feet	Reduce the “EARLY” release category (RC5) frequency contribution by the same fraction that this SAMA reduced the internal events RC5 frequency. Increase the “Late-SM” release category (RC7) frequency by the amount this SAMA reduced the RC5 frequency to simulate the shift of the release from RC group 5 to RC group 7.
305 to 310 feet Sequence “A”	Reduce the “EARLY” release category (RC5) frequency contribution by the same fraction that this SAMA reduced the internal events RC5 frequency. Increase the “Late-SM” release category (RC7) frequency by the amount this SAMA reduced the RC5 frequency to simulate the shift of the release from RC group 5 to RC group 7.
305 to 310 feet Sequence “B”	No change is made to this sequence’s distribution.
305 to 310 feet Sequence “C”	Reduce the “EARLY” release category (RC5) frequency contribution by the same fraction that this SAMA reduced the internal events RC5 frequency. Increase the “Late-SM” release category (RC7) frequency by the amount this SAMA reduced the RC5 frequency to simulate the shift of the release from RC group 5 to RC group 7.
305 to 310 feet Sequence “D”	No change is made to this sequence’s distribution.
305 to 310 feet Sequence “E”	No change is made to this sequence’s distribution.
305 to 310 feet Sequence “F”	No change is made to this sequence’s distribution.
<305 feet	Reduce the “EARLY” release category (RC5) frequency contribution by the same fraction that this SAMA reduced the internal events RC5 frequency. Increase the “Late-SM” release category (RC7) frequency by the amount this SAMA reduced the RC5 frequency to simulate the shift of the release from RC group 5 to RC group 7.

Due to the relatively large early containment failure component of the external events model, this SAMA has a large impact on the external flooding risk, as summarized below:

SAMA 19 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	145.71	$434,849
Percent Change	0.0%	-17.8%	-19.8%

A further breakdown of this information is provided below according to release category.

SAMA 19 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	104.56	10.34	0.19	1.49	17.87	10.71	0.25	0.30	145.71
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$309,750	$30,635	$598	$4,401	$54,839	$32,858	$778	$991	$434,849

The corresponding external flooding component of the averted cost-risk is shown below:

SAMA 19 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$12,983,587	$2,559,886

E.6.19.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $760,000 in the Calvert Cliffs SAMA analysis (BGE 1998).

E.6.19.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 19 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$567,990	$2,559,886	$3,127,876	$760,000	$2,367,876

Given that the cost of implementation is less than the averted cost-risk for this SAMA, the net value is positive.

E.6.20 SAMA NUMBER 20: EXTEND THE HIGH PRESSURE BOUNDARY THROUGH DHR VALVE DH-V-3 FOR ISLOCA ISOLATION

The highest frequency ISLOCA core damage scenario for TMI-1 is through two valves in the DHR suction line. While the frequency is relatively low in terms of CDF, the release frequency is relatively high given that primary containment is bypassed by definition. No effective mitigating actions are considered to be available in these cases because 1) the break may occur upstream of DH-V-3 or additional breaks in the low pressure boundary may occur after closure of a low pressure isolation valve, 2) reduction of primary system pressure may reduce the flow out of the break, but it would not stop it, and 3) refill of the BWST does not place the plant in a stable state and the impacts of auxiliary building flooding would have to be addressed before a successful endstate could be assigned to this type of action. Extending the pressure boundary through DH-V-3 would provide an additional isolation point in these cases.

This SAMA would provide an effective means of terminating the ISLOCA event and the reliability would be limited primarily by the ability of the operators to diagnose the event. Maintaining DH-V-3 as a motor operated valve will ensure that the break can be isolated quickly and without exposing the operators to potentially hazardous conditions.

E.6.20.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of SAMA 20's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In order to represent this SAMA in the PRA, cutset changes were made to address the impact of extending the high pressure boundary of the DHR suction line. This method was chosen given that ISLOCA events are modeled in a single cutset and are easily manipulated within the cutsets. While the lumped event includes more than one ISLOCA contributor, most of the risk is due to the DHR suction line scenario, so it is assumed that manipulation of the ISLOCA cutset can be used to represent changes to the DHR suction line scenario frequency. For the purposes of this analysis, implementation of this SAMA is assumed to eliminate ISLOCA risk completely. The following table summarizes the changes that were made to the cutsets:

SAMA 20 - Cutset Changes

GATE AND / OR BASIC EVENT ID AND DESCRIPTION	DESCRIPTION OF CHANGE
%ISL: INTERFACING SYSTEM LOCA	The initiating event probability was changed from 1.80E-07 to 0.0.

The change identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 20 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.35E-05	31.65	$108,733
Percent Change	-0.8%	-2.9%	-3.1%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 20 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.57E-07	1.59E-06	6.31E-10	3.66E-09	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.09	0.00	0.02	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$44,202	$12	$68	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.35E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.52	0.00	0.63	0.01	31.65
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,459	$4	$618	$5	$108,733

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 20 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,184,724	$86,987	2.0	$173,974

E.6.20.2 EXTERNAL FLOODING EVALUATION

This SAMA does not have an impact on external flooding given that it impacts only ISLOCA events and dual of importance in SGTR events where RCS inventory leaves the containment and is unavailable for recirculation from the sump. For the external flooding cases, this is not an issue as the reactor is tripped by a manual shutdown (or LOOP) rather than an ISLOCA event. While LOCAs are likely in external flooding scenarios due to SBO induced seal LOCAs, the sump would be available if AC power was subsequently recovered. No measurable risk reduction is believed to result from implementation of this SAMA for external flooding, as summarized below:

SAMA 20 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	177.16	$542,159
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 20 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	1.33E+02	1.31E+01	1.90E-01	1.89E+00	1.79E+01	1.07E+01	2.50E-01	3.70E-01	1.77E+02
SAMA Dose-Risk	1.33E+02	1.31E+01	1.90E-01	1.89E+00	1.79E+01	1.07E+01	2.50E-01	3.70E-01	1.77E+02
Base OECR	4.06E+05	4.01E+04	5.98E+02	5.77E+03	5.48E+04	3.29E+04	7.78E+02	1.22E+03	$542,159
SAMA OECR	4.06E+05	4.01E+04	5.98E+02	5.77E+03	5.48E+04	3.29E+04	7.78E+02	1.22E+03	$542,159

The external flooding component of the averted cost-risk for this SAMA is, therefore, $0:

SAMA 20 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,543,473	$0

E.6.20.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $3,030,000 by the TMI staff (Exelon 2007c).

E.6.20.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 20 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$173,974	$0	$173,974	$3,030,000	-$2,856,026

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.21 SAMA NUMBER 21: INSTALL CONCRETE SHIELDS TO BLOCK DIRECT PATHWAYS FROM THE RPV TO THE CONTAINMENT WALL AND/OR DIRECT CONTAINMENT FLOODING EARLY IN EXTERNAL FLOODING SCENARIOS

This SAMA is based on a failure mode identified in the Level 2 analysis that indicates core debris ejection during reactor vessel failure could result in dispersal of debris such that it could directly interact with the containment wall and cause a failure of the wall (early containment failure). Quantitatively, the largest contributor comes from low pressure melt cases where the core debris flows over the containment floor to contact the containment wall. This type of interaction could be prevented through the installation of concrete barriers to contain the core debris away from the outer containment wall.

Another option for this SAMA, which is important for external flooding cases, is to direct flooding of the containment early so that water would be on the floor of the containment before core damage/vessel failure. For internal events evolutions, the SAMGs direct containment flooding when there are indicators of the onset of core damage (e.g., high core temperatures, hydrogen in the reactor building), which adequately addresses the sequences of concern. For external flooding cases, however, the ability to initiate containment sprays will be lost before there are any indicators of core damage such that the existing SAMGs cannot be credited for directing containment flooding.

Both the installation of concrete barriers and the procedure changes for external flooding cases are discussed in more detail in the following subsections.

E.6.21.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component this SAMA's averted cost-risk associated with the internal events and the non-external flooding external events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In order to represent this SAMA in the PRA, cutset changes were made to address the impact of installing the concrete barriers. This method was chosen given that the containment wall/core debris interaction events are represented by two basic events and can easily be changed. In the TMI-1 model, there is a low pressure melt case (CWNOLIMITLPME) and a high pressure melt case (CWNOLIMITHPME). The low pressure melt case is by far the more significant contributor of the two to the early containment failure frequency. The high pressure melt case, while already a low contributor, is linked to the failure to locally operate the ADVs, which is currently assigned a value of 1.0. Procedures exist at TMI-1 to operate the ADVs locally, but the model does not currently credit the procedures. As a result, the importance of CWNOLIMITHPME is artificially inflated. CWNOLIMITHPME could be excluded from consideration in this SAMA, but for completeness, both CWNOLIMITHPME and CWNOLIMITLPME are included in the modeling changes.

While this SAMA does reduce the early containment failure frequency, it does not necessarily eliminate the release and it must be re-distributed to prevent over crediting this SAMA. The concrete barrier will prevent core debris attack on the containment wall, but basemat failure could still occur depending on the availability of water on the containment floor and the coolability of the core debris. Based on a review of the cutsets containing events CWNOLIMITLPME and CWNOLIMITHPME, containment spray is available about 50 percent of the time. For the cases where it is not available, basemat failure is assumed. When containment spray is available, the debris is assumed to be coolable only 50 percent of the time, which is consistent with the TMI-1 Level 2 analysis. When spray is containment spray is available and the debris is coolable, it is assumed that containment heat removal is available and that these cases result in an intact containment (RC group 9) rather than a late overpressurization failure (RC group 7). The following table summarizes the model changes that were made:

SAMA 21 - Model Changes

GATE AND / OR BASIC EVENT ID AND DESCRIPTION	DESCRIPTION OF CHANGE
CWNOLIMITLPME: Plant Config and Layout Does Not Limit Material Reaching Cont. Wall With LPM	The basic event probability was changed from 1.00E-01 to 0.0 to account for the ability of the concrete barriers to prevent failure of the containment wall.
CWNOLIMITHPME: Plant Config and Layout Does Not Limit Material Reaching Cont. Wall With HPM	The basic event probability was changed from 1.00E-01 to 0.0 to account for the ability of the concrete barriers to prevent failure of the containment wall.
RC8 (Basemat failure) Frequency	Increase the frequency by 75 percent of the reduction in RC5 (Early containment failure). This accounts for both the cases in which containment spray is not available and those cases where containment spray is available, but the debris is not coolable. (0.5 * RC5 reduction + 0.5 * RC5 reduction * 0.5 = 0.75 * RC5 reduction)
RC9 (Intact) Frequency	Increase the frequency by 25 percent of the reduction in RC5 (Early containment failure). This accounts for the cases in which containment spray is available and the core debris is coolable. (0.5 * RC5 reduction * 0.5 = 0.25 * RC5 reduction)

The model changes identified above yielded no change in the CDF, but did reduce the Dose-risk and Offsite Economic cost-risk, as summarized below:

SAMA 21 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.37E-05	31.5	$108,333
Percent Change	0.0%	-3.4%	-3.5%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 21 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	5.94E-07	5.65E-08	2.20E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	3.65	0.35	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$11,999	$1,141	$208

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.38E-06	1.32E-05	8.05E-08	2.36E-06	1.91E-08	2.37E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.51	3.53	0.02	0.63	0.01	31.50
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$21,232	$3,461	$21	$618	$5	$108,333

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 21 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,179,284	$92,427	2.0	$184,854

E.6.21.2 EXTERNAL FLOODING EVALUATION

The typical external flooding evolution is one in which the plant is stable until flood waters breach the flood gates and fail safety equipment. Alone, the concrete barriers would shift containment failure and the corresponding release from the "Early" release category (RC group 5) to the "basemat failure" category (RC group 8), assuming the containment is isolated. Flooding the containment floor can prevent core/concrete attack 50 percent of the time and in conjunction with the concrete barriers, the containment failure mode would be a long term overpressurization failure with a release that would be categorizes as “Late-small” (RC group 8). For the internal events model, an “intact” containment state was assumed to be possible given the potential for heat removal to be available, but for the external flooding cases, heat removal is not assumed to be available due to SBO conditions and a late overpressurization failure is considered to be more appropriate. For the 50 percent of the cases in which core-concrete attack is not prevented, basemat failure is assumed (RC group 8).

For many flood sequences, the loss of AC power will not be anticipated in time to initiate containment flooding, but in some cases, changes in the procedures could allow containment flooding as a means of reducing the release severity:

- Floods over 310’ msl: For these floods, water level increases until it pours over the top of the existing flood barriers. In these evolutions, there would likely be an interval when water level is rising between 305’ and 310’ msl when the determination could be made that the flood water will eventually top the barriers and that containment flooding should be performed as a precaution. Given that the flood gates are available and can be used to maintain the core in a safe state without risking further damage to the plant, flooding the containment floor to a depth where the water would remain available until vessel breach would be undesirable until absolutely necessary. While this is true, it is a credible means of reducing the probability of early containment failure and basemat failures. Containment spray is assumed to always be available before flood gate topping such that containment flooding will be successful, if directed.

- Floods between 305’ and 310’ msl: Scenarios “A” through “D” are the result of flood gate failures. In these scenarios, no credit would be available for performing early containment spray as core damage would not be anticipated and there would be no desirable cue to direct containment flooding. In scenarios “A” and “C”, credit could be taken for the concrete barriers as cold shutdown is achieved (implies containment isolation) and the barriers would prevent interaction with the containment wall. For sequences “B” and “D”, no credit can be taken for the concrete barriers as these sequences represent cases where transition to cold shutdown has not occurred and the containment is not isolated (these remain containment isolation failure cases). In sequence “E”, the flood gates hold, but EDG failures cause an SBO and no credit would be available for containment spray. Due to the AC power failures, the plant was not transitioned to cold shutdown and a containment isolation failure would occur (no credit for concrete barriers). For sequence “F”, the operators have no warning of the impending flood and the plant is also not transitioned to cold shutdown before flood damage occurs, which implies containment isolation failure.

- Floods below 305' mls: These are similar to LOOP scenarios and containment flooding is already addressed by the SAMGs. These cases are treated in the same manner as the internal events cases.

Based on the qualitative descriptions above, the following quantitative structure was developed to represent the implementation of this SAMA:

External Flood Sequence Identifier	Quantification Method
>310 Feet	• Reduce the "EARLY" release category (RC group 5) frequency contribution by the same fraction that this SAMA reduced the internal events RC group 5 frequency. • Increase the basemat failure frequency (RC group 8) by 50 percent of the reduction in RC group 5. This accounts for the cases where containment spray is available, but the debris is not coolable. Containment spray is assumed to always be available before topping of the flood gates. (0.5 * RC5 reduction) • Increase the late containment failure frequency (RC group 7) by 50 percent of the reduction in RC group 5. This accounts for the cases in which containment spray is available, the core debris is coolable, and lack of heat removal results in late containment failure. Containment spray is assumed to always be available before topping of the flood gates. (0.5 * RC5 reduction)
305 to 310 feet Sequence "A"	Reduce the "EARLY" release category (RC group 5) frequency contribution by the same fraction that this SAMA reduced the internal events RC5 frequency. Increase the "Basemat Failure" release category (RC8) frequency by the amount this SAMA reduced the RC5 frequency to simulate the shift of the release from RC group 5 to RC group 8.
305 to 310 feet Sequence "B"	No change is made to this sequence's distribution.
305 to 310 feet Sequence "C"	Reduce the "EARLY" release category (RC5) frequency contribution by the same fraction that this SAMA reduced the internal events RC5 frequency. Increase the "Basemat Failure" release category (RC8) frequency by the amount this SAMA reduced the RC5 frequency to simulate the shift of the release from RC group 5 to RC group 8.
305 to 310 feet Sequence "D"	No change is made to this sequence's distribution.
305 to 310 feet Sequence "E"	No change is made to this sequence's distribution.
305 to 310 feet Sequence "F"	No change is made to this sequence's distribution.
<305 feet	Treated in the same manner as the internal events model.

Due to the relatively large early containment failure component of the external events model, this SAMA has a large impact on the external flooding risk, as summarized below:

SAMA 21 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	165.06	$500,115
Percent Change	0.0%	-6.8%	-7.8%

A further breakdown of this information is provided below according to release category.

SAMA 21 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	121.80	12.15	0.19	1.75	17.87	10.71	0.25	0.34	165.06
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$367,957	$36,696	$598	$5,271	$54,839	$32,858	$778	$1,118	$500,115

The external flooding component of the averted cost-risk is summarized below:

SAMA 21 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$14,547,190	$1,181,137

E.6.21.3 COST OF IMPLEMENTATION

The cost of implementation is estimated to be $1,200,000 by the TMI staff (Exelon 2007c).

E.6.21.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 21 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$184,854	$996,283	$1,181,137	$1,200,000	-$18,863

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.22 SAMA NUMBER 22: INSTALL AN INDEPENDENT EFW SYSTEM

For TMI-1, loss of MFW after a trip coupled with loss of EFW can lead to large radionuclide releases in SGTR and induced SGTR scenarios due to the unavailability of water in the SGs for fission product scrubbing. A large contributor to EFW failure is estimated to be system wide common cause failures. An independent, motor driven, auxiliary feedwater system would be an effective means of addressing these cases. Power dependence is not a large issue for the cases addressed by this SAMA and the independent EFW pump is assumed to be powered by existing emergency power such that it would not be capable of mitigating SBO scenarios.

E.6.22.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMAs averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

New simplified model logic was added to the PRA model to represent an independent system that provides a backup to the existing EFW system. Requantification of the PRA model was then performed to determine new core damage and release category frequencies.

Specifically, for non-ATWS scenarios, a new level of logic was added above the gate EFNOATWS (EFW without ATWS conditions) consisting of a new AND gate named EFNOATWS-1 with two inputs. The two inputs to this new gate consisted of the original logic gate EFNOATWS and a new OR gate named ALT-EFW-NOATWS (failure of alternate EFW for non-ATWS conditions). The inputs to the OR gate
ALT-EFW-NOATWS consisted of the following inputs:

SAMA 22 NON-ATWS BASIC EVENTS	UNAVAILABILITY	EVENT DESCRIPTION
SAMA22ELECNOATWS	1.00E-02	NON-ATWS ALTERNATE EFW ELECTRICAL POWER DEPENDENCY FAILURES
SAMA22MECHNOATWS	1.00E-03	NON-ATWS ALTERNATE EFW MECHANICAL DEPENDENCY FAILURES
SAMA22HEP-NOATWS	1.00E-01	NON-ATWS ALTERNATE EFW HEP FAILURES
SAMA22JHEPNOATWS	5.00E-02	NON-ATWS ALTERNATE EFW JHEP FAILURES

The electrical event unavailability was based on the assumption that electrical dependencies require several other dependencies and control signals to function properly, thus resulting in a higher unavailability relative to assumed mechanical failures. The mechanical unavailability event was arbitrarily represented as 0.001, since most mechanical failures are typically of this order of magnitude. The independent HEP event was arbitrarily assigned an unavailability of 0.1, since this was based on the assumption that several actions would need to be performed outside the MCR. The JHEP event was estimated as having a high dependence for failure of a second related event, meaning that failure of the second HEP event was highly dependent on failure of the HEP event SAMA22HEP-NOATWS.

For ATWS scenarios, the fault tree logic for gate EFATWS was modified in the same manner as described above. In addition, the unavailabilities for the added basic events discussed above were increased by a factor of 3 (half a decade based on a logarithmic scale) to account for ATWS environmental stress factors and a greater sense of urgency. These events are identified in the table below:

SAMA 22 ATWS BASIC EVENTS	UNAVAILABILITY	EVENT DESCRIPTION
SAMA22ELEC--ATWS	3.00E-02	ATWS ALTERNATE EFW ELECTRICAL POWER DEPENDENCY FAILURES
SAMA22MECH--ATWS	3.00E-03	ATWS ALTERNATE EFW MECHANICAL POWER DEPENDENCY FAILURES
SAMA22HEP---ATWS	3.00E-01	ATWS ALTERNATE EFW HEP FAILURES
SAMA22JHEP--ATWS	1.50E-01	ATWS ALTERNATE EFW JHEP FAILURES

All affected logic described above that is modeled within the logic structure for post-LOOP recovery scenarios was also modified, with applicable gate names appended with the characters “-R”. This was only necessary for the logic involving non-ATWS scenarios.

The model changes identified above yielded a reduction in the Dose-risk and Offsite Economic cost-risk, but did not impact the CDF, as summarized below:

SAMA 22 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.22E-05	27.05	$85,423
Percent Change	-6.3%	-17.0%	-23.9%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 22 Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.21E-07	6.49E-07	1.80E-07	9.45E-09	9.07E-11	9.07E-11	1.90E-10	3.46E-10	3.81E-08	2.43E-08	8.54E-09	5.12E-07	6.88E-07	1.70E-07	2.14E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.41	3.71	0.91	0.05	0.00	0.00	0.00	0.00	0.11	0.07	0.03	1.50	4.23	1.05	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$11,704	$18,042	$3,348	$176	$3	$3	$7	$13	$343	$218	$77	$4,603	$13,898	$3,434	$202

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.72E-10	0.00E+00	8.02E-08	1.49E-08	2.18E-07	2.86E-09	7.47E-07	2.90E-07	3.14E-06	1.26E-05	2.70E-09	2.34E-06	3.08E-09	2.22E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.23	0.04	0.29	0.00	1.01	0.39	6.97	3.37	0.00	0.62	0.00	27.05
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$3	$0	$758	$141	$833	$11	$2,854	$1,108	$19,719	$3,311	$1	$613	$1	$85,423

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 22 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$2,662,735	$608,976	2.0	$1,217,952

E.6.22.2 EXTERNAL FLOODING EVALUATION

This SAMA will have a limited impact for external flooding scenarios given that many of the scenarios result in flooding the plant's safety equipment, which would render the proposed equipment inoperable. Even if the independent EFW system were located in a flood safe zone, the floods cause an SBO and subsequent seal LOCA that would result in core damage regardless of the operability of an alternate EFW system. The circumstances related to each flood range are discussed below:

- Floods over 310' msl: For these floods, water level increases until it pours over the top of the existing flood barriers. Flooding of safety equipment occurs and the subsequent seal LOCA will lead to core damage with or without SAMA 22. No credit is taken for this SAMA for this flood scenario.

- Floods between 305' and 310' msl: Scenarios "A" through "D" are the result of flood gate failures. In these scenarios, the result is the same as for floods over 310' msl and no credit is taken for SAMA 22. In sequence "E", the flood gates hold, but EDG failures cause an SBO. Alternate EFW could be beneficial if AC power was recovered to provide primary side makeup, but review of the LOOP/SBO model and the baseline SBO cutsets shows that EFW operability is only important to prolonging the time to core damage to allow AC power recovery. For floods of this magnitude, the normal AC power recovery credits are not considered to be applicable and the benefit of delaying core damage for a matter of a couple of hours would be minimal. No credit is taken for this SAMA for sequence "E". For sequence "F", the operators have no warning of the impending flood and the flood gates are not installed in time to prevent flooding of the safety equipment. As with the other, similar sequences, no credit is taken for SAMA 22 for sequence "F".

- Floods below 305' mls: These are similar to internal events LOOP scenarios and the availability of an alternate EFW system would be beneficial. In order to simplify the modeling for this sequence, SAMA 22 is assumed to eliminate all risk from these flood scenarios.

Implementation of this SAMA would result in only a limited risk reduction, as summarized below:

SAMA 22 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.08E-05	176.79	$540,940
Percent Change	-0.3%	-0.2%	-0.2%

A further breakdown of this information is provided below according to release category.

SAMA 22 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	0.00E+00	8.08E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.00	176.79
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$0	$540,940

The corresponding external flooding component of the averted cost-risk is shown below:

SAMA 22 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,507,657	$35,816

E.6.22.3 COST OF IMPLEMENTATION

Calvert Cliffs estimated the cost of installing an additional HPSI pump with a dedicated diesel to be between $5 million and $10 million. This type of enhancement is similar is scope to the changes required for this SAMA and the lower bound estimate of $5 million is used for this SAMA as the independent diesel is not required for this SAMA.

E.6.22.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 22 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$1,217,952	$35,816	$1,253,768	$5,000,000	-$3,746,232

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.23 SAMA NUMBER 23: DEVELOP ALARM RESPONSE PROCEDURES TO DIRECT OPERATION OF RR-V-5 ON LOW RBEC FLOW

Failure of RR-V-6 to open results in the loss of RBEC flow to the reactor building coolers, which can be diagnosed using the system flow indicators in the main control room; however, no alarm response procedures exist to specifically direct operation of the bypass valve (RR-V-5). If this procedure was developed, it may reduce the diagnosis time and improve the reliability of this operator action in an accident conditions.

E.6.23.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMAs averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events based averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

To model a more improved procedure regarding loss of RBEC flow from failure of RR-V-6 and recovery via MOV RR-V-5, the HEP event CFHRR1-----HVAOA was reduced by a factor of 10, from 7.79E-01 to 7.79E-02. There were no applicable JHEP events. The new cutset probabilities for the various Level 2 release categories were then summed and used to determine an estimate for the averted cost risk. Therefore, no new logic changes were made to the PRA model and no fault tree requantifications were performed. The following table summarizes the changes that were made to the model:

SAMA 23 - Model Changes

GATE AND / OR BASIC EVENT ID AND DESCRIPTION	DESCRIPTION OF CHANGE
CFHRR1-----HVAOA: OPERATOR FAILS TO OPEN MOV RR-V-5	The basic event probability was changed from 7.79E-1 to 7.79E-02.

The model changes identified above yielded a reduction in the Dose-risk and Offsite Economic cost-risk, but did not impact the CDF, as summarized below:

SAMA 23 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.37E-05	32.42	$111,626
Percent Change	0.0%	-0.6%	-0.6%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 23 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	1.36E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.04
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$129

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	7.72E-08	1.43E-08	1.42E-07	2.69E-09	7.13E-07	2.89E-07	3.17E-06	1.34E-05	1.69E-08	2.34E-06	1.91E-08	2.37E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.19	0.00	0.96	0.39	7.04	3.57	0.00	0.62	0.01	32.42
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$730	$135	$542	$10	$2,724	$1,104	$19,908	$3,505	$4	$613	$5	$111,626

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 23 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,256,480	$15,231	2.0	$30,462

E.6.23.2 EXTERNAL FLOODING EVALUATION

This SAMA will have a limited impact for external flooding scenarios given that many of the scenarios result in flooding the plant's safety equipment, which would render the reactor building coolers inoperable. For cases in which power is available, there would be some benefit. The circumstances related to each flood range are discusses below:

- Floods over 310' msl: For these floods, water level increases until it pours over the top of the existing flood barriers. Flooding of safety equipment occurs and the subsequent damage to the plant would result in a permanent loss of AC power. No credit is taken for this SAMA for this flood scenario.

- Floods between 305' and 310' msl: Scenarios "A" through "D" are the result of flood gate failures. In these scenarios, the result is the same as for floods over 310' msl and no credit is taken for SAMA 23. In sequence "E", the flood gates hold, but EDG failures cause an SBO. This SAMA could be useful if power was recovered and there was a failure of the RR-V-6 valve to open. Given that only 0.7 percent of the internal events SBO contributors are "power recovered" cases (flooding cases are less likely to recover power due to extreme weather), that RR-V-6 failures contribute to less that 2.0 percent to the release frequency even when power is available, and that the total Sequence "E" frequency is only 3.66E-06, the impact of this SAMA would not be measurable. No credit is taken for this SAMA for sequence "E". For sequence "F", the operators have no warning of the impending flood and the flood gates are not installed in time to prevent flooding of the safety equipment. As with the other, similar sequences, no credit is taken for SAMA 23 for sequence "F".

- Floods below 305' mls: These are similar to internal events LOOP scenarios and the recovery of RB cooling could be beneficial. The dose-risk and OECR of this flood sequence are assumed to be reduced in proportion to the internal events dose-risk and OECR.

Implementation of this SAMA would result in only a limited risk reduction, as summarized below:

SAMA 23 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	8.11E-05	177.16	$542,152
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category.

SAMA 23 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,212	$542,152

The corresponding external flooding component of the averted cost-risk is shown below:

SAMA 23 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$15,543,306	$167

E.6.23.3 COST OF IMPLEMENTATION

Procedure changes are estimated to be $50,000 (CPL 2004).

E.6.23.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 23 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$30,462	$167	$30,629	$50,000	-$19,371

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.24 SAMA NUMBER 24: INSTALL DAMAGE RESISTANT HIGH TEMPERATURE RCP SEALS WITH A DIESEL ENGINE AS AN ALTERNATE DRIVE FOR AN EFW PUMP AND A PORTABLE 480V AC GENERATOR FOR EXTENDED EFW OPERATION

For SBOs in which EFW has failed, neither primary nor secondary side cooling is available. Installing the enhanced RCP seals will prevent seal LOCAs and use of a portable generator would allow the turbine driven EFW pump to be used for extended periods in an SBO, as suggested in SAMA 2. However, in the event that the turbine driven EFW pump fails, there would be no means of providing secondary side makeup. Turbine driven EFW failures could be mitigated if an engine was available to drive one of the EFW pumps. Other industry SAMA applications have suggested similar strategies, but they typically suggest the turbine driven pumps as the best option for connection to the engine based on ease of connection. For scenarios with turbine driven EFW failure, however, the initial TD EFW pump failure may prevent its further use even with an alternate motive source. As a result, this SAMA, in addition to the requirements of SAMA 2, requires that the diesel engine be connected to one of the motor driven EFW pumps.

E.6.24.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the internal events and the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events based averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

To simulate the availability of a proposed alternate diesel-driven EFW pump, the cutsets from SAMA 2 were further adjusted by setting the turbine-driven EFW pump start and run failures to zero, i.e., EFEF-P-1----P7FS and EFEFP1------P7FR, respectively. Other contributors exist related to turbine driven EFW failures, but these are the major contributors and removing them from the cutsets is considered to adequately represent the benefits this SAMA. The new cutset probabilities for CDF and the various release categories were then summed and used to determine an estimate for the averted cost risk. Therefore, no new logic changes were made to the PRA model and no fault tree requantifications were performed. The following table summarizes the changes that were made to the basic event data:

SAMA 24 - Model Changes

Gate and / or Basic Event ID and Description	Description of Change
EFEF-P-1----P7FS: TURBINE-DRIVEN PUMP EF-P-1 FAILS TO START	The basic event probability was changed from 4.66E-03 to 0.0.
EFEFP1------P7FR: TURBINE-DRIVEN PUMP EF-P-1 FAILS TO RU	The basic event probability was changed from 5.06E-02 to 0.0.

The model changes identified above yielded a reduction in the CDF, Dose-risk, and Offsite Economic cost-risk, as summarized below:

SAMA 24 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	1.11E-05	14.68	$54,017
Percent Change	-53.2%	-55.0%	-51.9%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 24 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.18E-07	8.46E-07	1.80E-07	9.29E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.15E-09	1.25E-09	4.86E-11	2.67E-08	3.54E-07	4.88E-08	5.81E-09
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.39	4.84	0.91	0.05	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.08	2.18	0.30	0.02
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$11,620	$23,519	$3,348	$173	$0	$0	$0	$0	$64	$11	$0	$240	$7,151	$986	$55

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.43E-11	0.00E+00	5.24E-09	1.33E-09	6.66E-08	3.81E-10	5.57E-08	3.54E-08	6.34E-07	8.12E-06	4.86E-09	2.81E-07	7.97E-11	1.11E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.01	0.00	0.09	0.00	0.08	0.05	1.41	2.17	0.00	0.08	0.00	14.68
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$0	$0	$50	$13	$254	$1	$213	$135	$3,982	$2,127	$1	$74	$0	$54,017

Based on these results, the averted cost-risk for all non-external flooding contributors can be calculated using the 2.0 multiplier on the internal events results:

SAMA 24 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$1,536,137	$1,735,574	2.0	$3,471,148

E.6.24.2 EXTERNAL FLOODING EVALUATION

This SAMA can have an impact on any SBO, seal LOCA, or EFW failure scenario. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310' msl: In these scenarios, all safety equipment is flooded and this SAMA has no impact on the risk. No provisions are made for flood proofing the EFW pump in this SAMA. SAMA 32 addresses flood proof secondary side makeup capabilities.
- Floods between 305' and 310' msl: Most of the sequences are not impacted by this SAMA as core damage is caused by failure of the flood gates (the safety equipment is flooded) or because a flood warning is not provided and no preparations are made for the flood (the safety equipment is flooded). Flood sequence "E" represents cases where the flood gates are correctly installed, but a loss of all AC power leads to core damage. These SBO cases are assumed to be completely mitigated by this SAMA.
- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. As a result, these flooding sequences would be impacted in the same way as the internal events LOOP events. In order to simplify the calculations, SAMA 24 is assumed to eliminate all risk from this flooding sequence.

The following tables summarize the results of these changes:

SAMA 24 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	7.72E-05	166.08	$508,082
Percent Change	-4.8%	-6.3%	-6.3%

A further breakdown of this information is provided below according to release category.

SAMA 24 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	0.00E+00	8.65E-08	0.00E+00	7.72E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	0.00	0.25	0.00	166.08
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$0	$778	$0	$508,082

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 24 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$14,598,420	$945,053

E.6.24.3 COST OF IMPLEMENTATION

The cost of implementation for this SAMA is estimated to be a combination of SAMA 2 ($7,300,000) and the $1.1 million estimate for a direct drive diesel injection pump from Palisades (NMC 2005). The total implementation cost is $8,400,000.

E.6.24.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 24 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$3,471,148	$945,053	$4,416,201	$8,400,000	-$3,983,799

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.25 SAMA NUMBER 25: INSTALL AN ADDITIONAL EDG

An additional source of AC power is a potential means of supplying an entire division of safety equipment in the event that on-site AC power is lost in a LOOP. While additional EDGs are expensive, they can be cost effective at some plants, especially those with a large LOOP/SBO contribution to CDF.

However, for TMI-1, the SBO EDG is available at the site and a less costly solution to reducing risk through AC power improvements would be to implement SAMA 1 rather than to install an additional EDG. Without auto alignment capability, the benefit of a new EDG would not be maximized and installing an additional EDG with auto alignment capability would be illogical when the existing SBO EDG could be upgraded first. Therefore, installation of an additional EDG would imply that SAMA 1 must already be installed. In this case, the benefit of installing an additional EDG is approximated assuming previous installation of SAMA 1, but the cost of SAMA 1 is not included in the SAMA 25 implementation cost.

E.6.25.2 NON-EXTERNAL FLOODING EVALUATION

Rather than perform a full scale model change to evaluate this SAMA, PRA insights from the SAMA 1 results can be used to show that adding an additional EDG after implementing SAMA 1 would not be cost effective. The RRW values for the SBO EDG “fail to start”, “fail to run”, and maintenance terms based on both CDF and Level 2 are provided in the table below from the SAMA 1 importance lists. These are the main contributors to SBO EDG failures:

BASIC EVENT	CDF BASED RRW VALUE	LEVEL 2 BASED RRW VALUE
GSEG-Y-4----DGFS: STATION BLACKOUT DG FAILS TO START	1.010	1.025
GS-SBODG----DGFR: SBO DIESEL FAILS TO RUN	1.019	1.049
GS-EG-Y-4---DGMM: SBO Diesel Generator in Maintenance	1.011	1.029
Equivalent RRW Value of Events =	1.04	1.103

For independent events such as these, the RRW values can be combined to obtain a total RRW factor. Of the “equivalent” RRW values above, the Level 2 value is the larger of the two results and if the larger 1.103 RRW is assumed to apply to both the CDF and the Level 2 results, the impact of eliminating SBO EDG failures can be estimated. This is done by dividing the SAMA 1 internal events MACR of $5,580,172 by 1.103 and subtracting the result from the SAMA 1 internal events MACR, which yields $521,086 ($5,580,172 - ($5,580,172 / 1.103) = $521,086).

This can be done because the relationship between the MACR and the frequencies is linear and because the larger of the two "equivalent" RRW values was used to represent both the Level 1 and Level 2 results.

E.6.25.3 EXTERNAL FLOODING EVALUATION

This SAMA can have an impact on any scenario requiring the operation of the SBO EDG. For the external flooding cases, the three flood regimes are impacted differently:

- Floods over 310' msl: In these scenarios, the safety equipment is flooded and the addition of another EDG would have no impact on risk.

- Floods between 305' and 310' msl: Most of the sequences would not be impacted by the addition of another EDG as core damage is caused by failure of the flood gates (the safety equipment is flooded) or because a flood warning is not provided and no preparations are made for the flood (the safety equipment is flooded). Flood sequence "E" represents cases where the flood gates are correctly installed, but a loss of all AC power leads to core damage. In these cases, the installation of another EDG could provide a large benefit. For the purposes of this evaluation, it is assumed that SAMA 25 will eliminate all of the contribution from Sequence "E".

- Floods below 305' mls: The only impact these flood scenarios have on the plant is the potential to cause a loss of offsite power. SAMA 25 would have an impact on these SAMAs and for the purposes of this analysis, all risk from this flood sequence is assumed to be eliminated.

The following tables summarize the results of these changes:

SAMA 25 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	7.72E-05	166.08	$508,082
Percent Change	-4.8%	-6.3%	-6.3%

A further breakdown of this information is provided below according to release category.

SAMA 25 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	0.00E+00	8.65E-08	0.00E+00	7.72E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	132.75	13.13	0.19	1.89	17.87	0.00	0.25	0.00	166.08
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$405,951	$40,149	$598	$5,767	$54,839	$0	$778	$0	$508,082

Based on these results, the external flooding component of the averted cost-risk can then be calculated:

SAMA 25 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$14,598,420	$945,053

E.6.25.3 COST OF IMPLEMENTATION

Browns Ferry estimated the cost of installing an additional EDG to be $6 million. While there are estimates as high as $25 million used in SAMA analyses for the installation of additional EDGs, the Browns Ferry estimate is used for TMI-1.

E.6.25.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 25 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$521,086	$945,053	$1,466,139	$6,000,000	-$4,533,861

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.26 SAMA NUMBER 26: REROUTE CABLES SO THAT THEY DO NOT PASS OVER IGNITION SOURCES IN FIRE ZONE CB-FA-2E (WEST INVERTER ROOM) OR WRAP THEM IN FIRE PROOF MATERIAL

The TMI-1 IPEEE fire analysis identified that cables important to control functions for essential AC panels (including Bus 1E) were routed over potential ignition sources in fire zone CB-FA-2E. Some of the risk from this fire zone could be averted if these cables were protected or rerouted such that battery charger/inverter fires would not result in damage to the cables. While these changes would not eliminate the risk corresponding to the ignition source fires, the cables are the dominant risk contributors for the zone. Two potential methods of mitigating the fire risk in CB-FA-2E have been identified for this SAMA

- Method A: Rerouting the cables so that they do not pass over the battery chargers or inverters or,
- Method B: Providing fire barriers capable of preventing fire propagation and damage to the overhead cables.

Both of these changes are assumed to be capable of preventing damage to the overhead cables. Rerouting the cables has the potential to completely eliminate the risk of cable damage while use of fire barriers has some non-zero failure rate associated with the barriers, but for this analysis, both approaches are assumed to completely eliminate the risk of cable damage.

The impact of these types of changes has been estimated using available information from the fire model and engineering judgment. No model quantification was performed for this evaluation.

It is assumed that if the portion of the fire CDF and release consequences related to cable damage in fire zone CB-FA-2E can be identified, then an averted cost-risk can be calculated for this SAMA. The steps used to perform this calculation are provided below:

- Determine the component of the overall modified MACR attributable to non-external flooding external events,
- Determine the component of the non-external flooding external events cost-risk attributable to fire events,
- Determine the component of the fire based cost-risk attributable to fire zone CB-FA-2E,

- Determine the component of the fire based cost-risk attributable to the AC panel control cables located in fire zone CB-FA-2E,
- Calculate the percent reduction in the fire CB-FA-2E CDF that would occur if the SAMA is implemented and reduce the cost-risk for the fire zone by the same percent. The reduction in cost-risk is the averted cost-risk for this SAMA.

The baseline assumption for non-external flooding external events contributions in the TMI-1 SAMA is that they are approximately equal to the internal events contributions. Given that the internal events MACR is $3,271,711, the same value is assigned to external events.

The relative contribution of fire events to the total external events CDF is difficult to determine due to the fact that the methods of analysis for each of the external events types are not necessarily compatible. If the comparison is made strictly on the basis of the calculated CDFs, the fire contribution would only be 20.1%:

External Events Contribution Summary

External Event	CDF	Percent of Total Non-External Flooding External Events CDF
Seismic (based on LLNL seismic hazard curves)	8.43E-05/yr	78.6%
Fire*	2.16E-05/yr	20.1%
High Winds	7.77E-07/yr	0.7%
Aircraft Impact**	3.95E-07/yr	0.4%
Hazardous Chemicals	1.60E-07/yr	0.1%
Total	**1.07E-04/yr**	

*Includes the error in the IPEEE that results in overestimation of the CB-FA-2E fire zone frequency.

**This includes the contribution from accidental aircraft impact only. Intentional aircraft impact is addressed in separate plant programs and is beyond the scope of the SAMA analysis.

For seismically stable regions, the fire CDF is typically greater than the seismic CDF and for TMI-1, a larger value than the 20 percent identified in the table above is considered to be appropriate. For the purposes of this calculation, the fire CDF is assumed to be 85 percent of the total non-external flooding external events CDF. This corresponds to a cost-risk of $2,780,954 ($3,271,711 * 0.85 = $2,780,954).

The cost-risk associated with fire zone CB-FA-2E can then be determined based on its relative contribution to the total fire CDF by assuming the fire zone specific MACR is directly proportional to the CDF. For this calculation, the error identified in the IPEEE related to the CB-FA-2E CDF has been corrected:

Fire Area/Scenario	Description	CDF[1]	Percent of Total Fire CDF	Fire Zone Specific MACR
CB-FA-2d	East Inverter Room	4.94E-06/yr	26.17%	$727,776
CB-FA-2e	West Inverter Room	3.09E-06/yr	16.31%	$453,574
CB-FA-3a	1D Switchgear Room	3.94E-06/yr	20.87%	$580,385
CB-FA-3b	1E Switchgear Room	4.96E-06/yr	26.27%	$730,557
CB-FA-4b	Control Room – Console CR	1.96E-06/yr	10.38%	$288,663
	Total	1.89E-05/yr	100%	$2,780,955

The risk reduction possible for fire zone CB-FA-2E is a fraction of the total based on the potential capabilities of the changes proposed in this SAMA. Neither change (barriers or cable rerouting) is considered to be capable of preventing damage to the equipment in the cabinet where the fire starts; however, both changes are assumed to prevent damage to overhead cables. The averted cost-risk for these changes, therefore, is based on the difference between the CDF when cable damage occurs and the CDF when cable damage is eliminated.

The quantification of the CDF change due to this SAMA's implementation was performed using information from the IPEEE documentation. The IPEEE indicates that the CDF for fire zone CB-FA-2E is composed of two cases that are separated based on the location of the two batteries and two inverters in the zone. One battery and one inverter are located below the AC panel control cables and the other battery and inverter are not located below the AC power control cables. Fires in the battery or inverter below the AC control cables damage essential AC power (and are assumed to fail bus 1E), but fires in the battery or inverter located away from the AC panel control cables do not damage the AC control panel cables. The fire zone CDF for the existing plant configuration is summarized in the following table:

[1] The CB-2A-FE fire zone CDF reported in the IPEEE appears to have been overestimated due to computational errors. The correct CDF calculation for fire zone CB-FA-2E is shown here and used in the remainder of this calculation.

Current CB-FA-2E Fire Contributions

	Conditional CDF	IE Frequency	Fraction of IE Frequency Applicable	CDF
Case 1 (fires not resulting in cable failures)	1.16E-04	4.91E-03	5.00E-01	2.85E-07
Case 2 (fires resulting in cable failures)	1.14E-03	4.91E-03	5.00E-01	2.80E-06
			Total	**3.08E-06**

To represent implementation of the SAMA, Case 2 is adjusted such that the conditional CDF is equal to the conditional CDF for Case 1, which implies that the AC control cables are not damaged and that the consequences of failing either battery/inverter set are the same. The CDF results are shown below:

POST SAMA CB-FA-2E FIRE CONTRIBUTIONS

	CONDITIONAL CDF	IE FREQUENCY	FRACTION OF IE FREQUENCY APPLICABLE	CDF
Case 1 (fires not resulting in cable failures)	1.16E-04	4.91E-03	5.00E-01	2.85E-07
Case 2 (fires resulting in cable failures)	1.16E-04	4.91E-03	5.00E-01	2.85E-07
			Total	**5.70E-07**

The result is a CDF of 5.70E-7, which is 18.5 percent of the base CB-FA-2E CDF. This corresponds to a revised fire zone MACR of $83,911 ($453,574 * 0.185 = $83,911).

The difference between the baseline MACR for fire zone CB-FA-2E and MACR assuming SAMA implementation is the averted cost-risk for this SAMA: $453,574 - $83,911 = $369,663.

Of the two potential mitigation methods identified, cable wrapping (Method B) was determined to be the more cost effective approach. The cost of performing the cable wrapping in CB-FA-2e was estimated to be $900,000 by the TMI staff (Exelon 2007c).

Results

The results of the fire area analysis and the implementation cost estimates are used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

SAMA 26 - Net Value

Averted Cost-Risk	Cost of Implementation	Net Value
$369,663	$900,000	-$530,337

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.27 SAMA NUMBER 27: IMPROVE THE 480V AC LOAD CENTER WELDS

The IPEEE determined that the existing 480V AC load centers had the lowest seismic fragilities in the TMI-1 AC distribution system. Adding reinforcements to the welds on the load center framework would improve the seismic durability of the structure and increase the likelihood that the system would be available after a seismic event. The specific components considered to be addressed are 480V AC load centers 1P, 1R, 1S, and 1T, which are the components critical to improving the AC power system's seismic ruggedness. The other low seismic capacity components of the AC distribution system, the EDG air receivers, were enhanced subsequent to the completion of the IPEEE.

The ability to quantify the impact of improving the seismic capacity of the load centers is limited due to the small amount of information provided in the IPEEE related to the importance of the load centers over the four different seismic ranges evaluated. However, a process has been developed to approximate the potential benefit of increasing the HCLPF for the load centers from 0.12g to 0.30g through improvements to the welds. The revised HCLPF capacity value of 0.30g was chosen because it was used in industry seismic margins analyses as the threshold for components to be considered adequately durable. All of the calculations are based on information available in the IPEEE, the current PRA, and engineering judgment. No seismic model quantification was performed for this evaluation.

It is assumed that if the portion of the seismic CDF and release consequences related to the failures of the 480V AC load centers can be identified, then an averted cost-risk can be calculated for this SAMA. The steps used to perform this calculation are provided below:

- Determine the component of the overall modified MACR attributable to non-external flooding external events,
- Determine the component of the non-external flooding external events cost-risk attributable

to seismic events,

- Determine the component of the seismic based cost-risk attributable to 480V AC load centers 1P, 1R, 1S, and 1T,

- Calculate the percent reduction in seismic CDF that would occur if the SAMA is implemented and reduce the cost-risk for the load centers by the same percent. The reduction in cost-risk is the averted cost-risk for this SAMA.

The baseline assumption for non-external flooding external events contributions in the TMI-1 SAMA is that they are approximately equal to the internal events contributions. Given that the internal events MACR is $3,271,711, the same value is assigned to external events.

The relative contribution of seismic events to the total external events CDF is difficult to determine due to the fact that the methods of analysis for each of the external events types are not necessarily compatible. If the comparison is made strictly on the basis of the calculated CDFs, the seismic contribution would be 78.6%:

External Events Contribution Summary

External Event	CDF	Percent of Total Non-External Flooding External Events CDF
Seismic (based on LLNL seismic hazard curves)	8.43E-05/yr	78.6%
Fire*	2.16E-05/yr	20.1%
High Winds	7.77E-07/yr	0.7%
Aircraft Impact**	3.95E-07/yr	0.4%
Hazardous Chemicals	1.60E-07/yr	0.1%
Total	**1.07E-04/yr**	

*Includes the error in the IPEEE that results in overestimation of the CB-FA-2E fire zone frequency.

**This includes the contribution from accidental aircraft impact only. Intentional aircraft impact is addressed in separate plant programs and is beyond the scope of the SAMA analysis.

For seismically stable regions, the fire CDF is typically greater than the seismic CDF, but for TMI-1, this is not the case when the NUREG 1488 LLNL hazard curves are used. While it may be inconsistent with many industry examples in which the fire risk outweighs the seismic risk, the 78.6 percent seismic contribution is retained for this evaluation. This corresponds to a cost-risk of $2,571,565 ($3,271,711 * 0.786 = $2,571,565).

The cost-risk associated with the 480V AC load centers can then be determined based on the overall seismic Fussell-Vesely (F-V) value for the load centers and the assumption that the overall seismic F-V value is constant over the seismic spectrum. This is typically not true, but when used over the entire seismic spectrum, it will provide a reasonable answer.

Two separate F-V values have been identified for the 480V AC load centers, which are part of the FRAG15 component group (based on the NUREG-1488 seismic hazard curve results):

- GW: offsite power available cases (F-V = 0.4),
- GY: offsite power failure cases (F-V = 0.15).

The CDF corresponding to the FRAG15 component group (the 480V load centers) can be estimated by multiplying the F-V values by the CDF for each range in the seismic spectrum, as summarized below:

GW FRAG15 Specific CDF

Initiating Event	CDF	CDF Related to FRAG15
SEIS1 (0.15g) (range = 0.052g - 0.2g)	1.26E-05	5.04E-06
SEIS2 (0.25g) (range = 0.2g - 0.3g)	2.61E-05	1.04E-05
SEIS3 (0.4g) (range = 0.3g - 0.5g)	3.25E-05	1.30E-05
SEIS4 (0.6g) (range = 0.5g - 1.01g)	1.31E-05	5.24E-06
Totals=	**8.43E-05**	**3.37E-05**

GY FRAG15 Specific CDF

Initiating Event	CDF	CDF Related to FRAG15
SEIS1 (0.15g) (range = 0.052g - 0.2g)	1.26E-05	1.89E-06
SEIS2 (0.25g) (range = 0.2g - 0.3g)	2.61E-05	3.92E-06
SEIS3 (0.4g) (range = 0.3g - 0.5g)	3.25E-05	4.88E-06
SEIS4 (0.6g) (range = 0.5g - 1.01g)	1.31E-05	1.97E-06
Totals=	**8.43E-05**	**1.26E-05**

Assuming the MACR is directly proportional to the CDF provides a means of determining the MACR for FRAG15 over the seismic spectrum given the total seismic MACR of $2,571,565:

GW FRAG15 Specific MACR

Initiating Event	CDF Related to FRAG15	MACR Related to FRAG15
SEIS1 (0.15g) (range = 0.052g - 0.2g)	5.04E-06	$153,745
SEIS2 (0.25g) (range = 0.2g - 0.3g)	1.04E-05	$318,471
SEIS3 (0.4g) (range = 0.3g - 0.5g)	1.30E-05	$396,564
SEIS4 (0.6g) (range = 0.5g - 1.01g)	5.24E-06	$159,846
Totals=	**3.37E-05**	**$1,028,626**

GY FRAG15 SPECIFIC MACR

INITIATING EVENT	CDF RELATED TO FRAG15	MACR RELATED TO FRAG15
SEIS1 (0.15g) (range = 0.052g - 0.2g)	1.89E-06	$57,654
SEIS2 (0.25g) (range = 0.2g - 0.3g)	3.92E-06	$119,427
SEIS3 (0.4g) (range = 0.3g - 0.5g)	4.88E-06	$148,711
SEIS4 (0.6g) (range = 0.5g - 1.01g)	1.97E-06	$59,942
Totals=	**1.26E-05**	**$385,735**

The quantification of the CDF change due to this SAMA's implementation was performed using information from the IPEEE documentation. The IPEEE indicates that the HCLPF capacity for FRAG15 is 0.12g and the failure probabilities for each seismic range are explicitly provided for FRAG15. In addition, the failure probabilities are explicitly provided for the BWST (FRAG21), which has a HCLPF capacity of 0.3g. It is assumed that if the 480V AC load center welds are improved, the failure probabilities can be represented by those documented for FRAG21. From these assumptions the revised CDFs, and therefore the MACRs, can be calculated. More specifically, the ratio of the post-SAMA FRAG15 failure probability to the baseline FRAG15 failure probability will be equivalent to the ratio of the post-SAMA FRAG15 CDF to the baseline FRAG15 CDF. Finally, the FRAG15 MACR is proportional to the CDF, so once the FRAG15 CDF ratio is known, the post-SAMA FRAG15 MACR can be calculated by multiplying the FRAG15 ratio by the baseline FRAG15 MACR for each seismic hazard range. The following tables summarize the results:

GW FRAG15 Specific MACR Post SAMA Implementation

Initiating Event	Baseline FRAG15 Failure Probability	Post-SAMA FRAG15 Failure Probability (0.3g HCLPF)	CDF (or FRAG15) Ratio	Baseline FRAG15 MACR	Post-SAMA FRAG15 MACR (0.3g HCLPF)
SEIS1 (0.15g) (range = 0.052g - 0.2g)	1.25E-02	2.15E-06	1.72E-04	$153,745	$26
SEIS2 (0.25g) (range = 0.2g - 0.3g)	2.67E-01	3.95E-03	1.48E-02	$318,471	$4,711
SEIS3 (0.4g) (range = 0.3g - 0.5g)	6.61E-01	4.78E-02	7.23E-02	$396,564	$28,677
SEIS4 (0.6g) (range = 0.5g - 1.01g)	9.50E-01	2.82E-01	2.97E-01	$159,846	$47,449
			Total =	**$1,028,626**	**$80,864**

GY FRAG15 SPECIFIC MACR POST SAMA IMPLEMENTATION

Initiating Event	Baseline FRAG15 Failure Probability	Post-SAMA FRAG15 Failure Probability (0.3g HCLPF)	CDF Ratio	Baseline FRAG15 MACR	Post-SAMA FRAG15 MACR (0.3g HCLPF)
SEIS1 (0.15g) (range = 0.052g - 0.2g)	1.58E-02	2.15E-06	1.36E-04	$57,654	$8
SEIS2 (0.25g) (range = 0.2g - 0.3g)	3.60E-01	3.95E-03	1.10E-02	$119,427	$1,310
SEIS3 (0.4g) (range = 0.3g - 0.5g)	8.44E-01	4.78E-02	5.66E-02	$148,711	$8,422
SEIS4 (0.6g) (range = 0.5g - 1.01g)	9.98E-01	2.82E-01	2.83E-01	$59,942	$16,938
			Total =	**$385,735**	**$26,678**

The averted cost-risk is the difference between the base FRAG15 MACRs and the post-SAMA implementation MACRs for both GW and GY, which is $1,306,819 (($1,028,626 - $80,864) + ($385,735 - $26,678) = $1,306,819).

E.6.27.1 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $575,000 by the TMI staff (Exelon 2007c).

E.6.27.2 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is only the seismic averted cost-risk in this case, and the cost of implementation. The following table summarizes these results:

SAMA 27 - Net Value

Total Averted Cost-Risk	Cost of Implementation	Net Value
$1,306,819	$575,000	$731,819

Given that the cost of implementation is less than the averted cost-risk for this SAMA, the net value is positive.

E.6.28 SAMA NUMBER 28: IMPROVE THE DECAY HEAT SERVICE COOLER (DC-C-2A/B) ANCHORAGES

The IPEEE determined that the existing Decay heat service coolers (DC-C-2A/B) lacked sufficiently durable anchorages. Replacing the anchorages with more robust anchorages would improve the seismic durability of the structure and increase the likelihood that the heat exchangers would be available after a seismic event.

The ability to quantify the impact of improving the seismic capacity of the heat exchanger anchorages is limited due to the small amount of information provided in the IPEEE related to the importance of DC-C-2A/B over the four different seismic ranges evaluated. However, a process has been developed to approximate the potential benefit of increasing the HCLPF for the heat exchangers from 0.09g to 0.30g through improvements to the anchorages. The revised HCLPF capacity value of 0.30g was chosen because it was used in industry seismic margins analyses as the threshold for components to be considered adequately durable. All of the calculations are based on information available in the IPEEE, the current PRA, and engineering judgment. No seismic model quantification was performed for this evaluation.

It is assumed that if the portion of the seismic CDF and release consequences related to the failures of DC-C-2A/B can be identified, then an averted cost-risk can be calculated for this SAMA. The steps used to perform this calculation are provided below:

- Determine the component of the overall modified MACR attributable to non-external flooding external events,

- Determine the component of the non-external flooding external events cost-risk attributable to seismic events,
- Determine the component of the seismic based cost-risk attributable to Decay Heat Service Coolers DC-C-2A/B,
- Calculate the percent reduction in seismic CDF that would occur if the SAMA is implemented and reduce the cost-risk for the heat exchangers by the same percent. The reduction in cost-risk is the averted cost-risk for this SAMA.

The baseline assumption for non-external flooding external events contributions in the TMI-1 SAMA is that they are approximately equal to the internal events contributions. Given that the internal events MACR is $3,271,711, the same value is assigned to external events.

The relative contribution of seismic events to the total external events CDF is difficult to determine due to the fact that the methods of analysis for each of the external events types are not necessarily compatible. If the comparison is made strictly on the basis of the calculated CDFs, the seismic contribution would be 78.6%:

External Events Contribution Summary

External Event	CDF	Percent of Total Non-External Flooding External Events CDF
Seismic (based on LLNL seismic hazard curves)	8.43E-05/yr	78.6%
Fire*	2.16E-05/yr	20.1%
High Winds	7.77E-07/yr	0.7%
Aircraft Impact**	3.95E-07/yr	0.4%
Hazardous Chemicals	1.60E-07/yr	0.1%
Total	**1.07E-04/yr**	

*Includes the error in the IPEEE that results in overestimation of the CB-FA-2E fire zone frequency.

**This includes the contribution from accidental aircraft impact only. Intentional aircraft impact is addressed in separate plant programs and is beyond the scope of the SAMA analysis.

For seismically stable regions, the fire CDF is typically greater than the seismic CDF, but for TMI-1, this is not the case when the NUREG 1488 LLNL hazard curves are used. While it may be inconsistent with many industry examples in which the fire risk outweighs the seismic risk, the 78.6 percent seismic contribution is retained for this evaluation. This corresponds to a cost-risk of $2,571,565 ($3,271,711 * 0.786 = $2,571,565).

The cost-risk associated with DC-C-2A/B can then be determined based on the overall seismic Fussell-Vesely (F-V) value for the heat exchangers and the assumption that the overall seismic F-V value is constant over the seismic spectrum. This is typically not true, but when used over the entire seismic spectrum, it will provide a reasonable answer. The overall seismic F-V value for component group FRAG11, which includes DC-C-2A/B, is 2.00E-02 (based on the NUREG-1488 seismic hazard curve results).

The CDF corresponding to the FRAG11 component group (the Decay Heat Service Coolers) can be estimated by multiplying the FRAG11 F-V value by the CDF for each range in the seismic spectrum. The following table summarizes the results:

FRAG11 Specific CDF

Initiating Event	CDF	CDF Related to FRAG11
SEIS1 (0.15g) (range = 0.052g - 0.2g)	1.26E-05	2.52E-07
SEIS2 (0.25g) (range = 0.2g - 0.3g)	2.61E-05	5.22E-07
SEIS3 (0.4g) (range = 0.3g - 0.5g)	3.25E-05	6.50E-07
SEIS4 (0.6g) (range = 0.5g - 1.01g)	1.31E-05	2.62E-07
Totals=	8.43E-05	1.69E-06

Assuming the MACR is directly proportional to the CDF provides a means of determining the MACR for FRAG11 over the seismic spectrum given the total seismic MACR of $2,571,565:

FRAG11 Specific MACR

Initiating Event	CDF Related to FRAG11	MACR Related to FRAG11
SEIS1 (0.15g) (range = 0.052g - 0.2g)	2.52E-07	$7,687
SEIS2 (0.25g) (range = 0.2g - 0.3g)	5.22E-07	$15,924
SEIS3 (0.4g) (range = 0.3g - 0.5g)	6.50E-07	$19,828
SEIS4 (0.6g) (range = 0.5g - 1.01g)	2.62E-07	$7,992
Totals=	1.69E-06	$51,431

The quantification of the CDF change due to this SAMA's implementation was performed using information from the IPEEE documentation. The IPEEE provides the seismic range specific failure probabilities for top event RX, which are driven by FRAG11 given that the HCLPF capacity is 0.09g while the only other contributing component has a HCLPF capacity of 0.43g. In addition, the failure probabilities are explicitly provided for the BWST (FRAG21), which has a HCLPF capacity of 0.30g. It is assumed that if the DC-C-2A/B anchorages are improved, the failure probabilities can be represented by those documented for FRAG21 (HCLPF for DC-C-2A/B improved to 0.30g). From these assumptions, the revised CDFs and the corresponding MACRs can be calculated using the ratio of the revised CDFs to the original CDFs. The following tables summarize the results:

FRAG11 Specific MACR Post SAMA Implementation

Initiating Event	Base FRAG11 Failure Probability (From top event RX)	FRAG11 Failure Probability After SAMA Implementation (0.3g HCLPF)	CDF Ratio	Baseline FRAG11 MACR	Post-SAMA FRAG11 MACR (0.3g HCLPF)
SEIS1 (0.15g) (range = 0.052g - 0.2g)	3.46E-02	2.15E-06	6.21E-05	$7,687	$0
SEIS2 (0.25g) (range = 0.2g - 0.3g)	4.82E-01	3.95E-03	8.20E-03	$15,924	$130
SEIS3 (0.4g) (range = 0.3g - 0.5g)	8.42E-01	4.78E-02	5.68E-02	$19,828	$1,126
SEIS4 (0.6g) (range = 0.5g - 1.01g)	9.87E-01	2.82E-01	2.86E-01	$7,992	$2,284
			Total =	**$51,431**	**$3,540**

The averted cost-risk is the difference between the base FRAG11 specific MACRs and the FRAG11 specific MACRS after SAMA implementation, which is $47,891 ($51,431 - $3,540 = $47,891).

E.6.28.1 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $575,000 by the TMI staff (Exelon 2007c).

E.6.28.2 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is only the seismic averted cost-risk in this case, and the cost of implementation. The following table summarizes these results:

SAMA 28 - Net Value

Total Averted Cost-Risk	Cost of Implementation	Net Value
$47,891	$575,000	-$527,109

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.29 SAMA NUMBER 29: REPLACE EDG GROUND RESISTORS

Failure of the EDG ground resistors results in failure of the EDGs, which will lead to core damage in the event that off-site power is not available. Given that the HCLPF capacity for these components was estimated at 0.25g compared with 0.09g capacities of off-site power components (such as the 1/A and 1/B distribution buses or the aux transformers), it is likely that core damage will ensue due to long term loss of power if the EDG ground resistors fail from seismic shock. Replacing the resistors with more durable versions would improve the reliability of the EDGs in seismic events.

The ability to quantify the impact of improving the seismic capacity of the EDG ground resistors is limited due to the small amount of information provided in the IPEEE related to the importance of these components over the four different seismic ranges evaluated. However, a process has been developed to approximate the potential benefit of increasing the HCLPF capacity of the EDG ground resistors from 0.25g to a theoretical limit where it would never fail. All of the calculations are based on information available in the IPEEE, the current PRA, and engineering judgment. No seismic model quantification was performed for this evaluation.

It is assumed that if the portion of the seismic CDF and release consequences related to the failures of the EDG ground resistors can be identified, then an averted cost-risk can be calculated for this SAMA. The steps used to perform this calculation are provided below:

- Determine the component of the overall modified MACR attributable to non-external flooding external events,
- Determine the component of the non-external flooding external events cost-risk attributable to seismic events,
- Determine the component of the seismic based cost-risk attributable to the EDG ground resistors,
- Assume that implementation of this SAMA would eliminate all risk related to the EDG ground resistors such that the averted cost-risk would be the total cost-risk related to the EDG ground resistors.

The baseline assumption for non-external flooding external events contributions in the TMI-1 SAMA is that they are approximately equal to the internal events contributions. Given that the internal events MACR is $3,271,711, the same value is assigned to external events.

The relative contribution of seismic events to the total external events CDF is difficult to determine due to the fact that the methods of analysis for each of the external events types are not necessarily compatible. If the comparison is made strictly on the basis of the calculated CDFs, the seismic contribution would be 78.6%:

External Events Contribution Summary

External Event	CDF	Percent of Total Non-External Flooding External Events CDF
Seismic (based on LLNL seismic hazard curves)	8.43E-05/yr	78.6%
Fire*	2.16E-05/yr	20.1%
High Winds	7.77E-07/yr	0.7%
Aircraft Impact**	3.95E-07/yr	0.4%
Hazardous Chemicals	1.60E-07/yr	0.1%
Total	1.07E-04/yr	

*Includes the error in the IPEEE that results in overestimation of the CB-FA-2E fire zone frequency.

**This includes the contribution from accidental aircraft impact only. Intentional aircraft impact is addressed in separate plant programs and is beyond the scope of the SAMA analysis.

For seismically stable regions, the fire CDF is typically greater than the seismic CDF, but for TMI-1, this is not the case when the NUREG 1488 LLNL hazard curves are used. While it may be inconsistent with many industry examples in which the fire risk outweighs the seismic risk, the 78.6 percent seismic contribution is retained for this evaluation. This corresponds to a cost-risk of $2,571,565 ($3,271,711 * 0.786 = $2,571,565).

The cost-risk associated with the EDG ground resistors can then be determined based on the overall seismic Fussell-Vesely (F-V) value for the EDG ground resistors and the assumption that the overall seismic F-V value is constant over the seismic spectrum. This is typically not true, but when used over the entire seismic spectrum, it will provide a reasonable answer. The overall seismic F-V value for FRAG17, which represents the EDG ground resistors, is 1.00E-02 (based on the NUREG-1488 seismic hazard curve results).

The CDF corresponding to the FRAG17 component group (the EDG ground resistors) can be determined by multiplying the FRAG-17 F-V value by the CDF for each range in the seismic spectrum. The following table summarizes the results:

FRAG17 Specific CDF

Initiating Event	CDF	CDF Related to FRAG17
SEIS1 (0.15g) (range = 0.052g - 0.2g)	1.26E-05	1.26E-07
SEIS2 (0.25g) (range = 0.2g - 0.3g)	2.61E-05	2.61E-07
SEIS3 (0.4g) (range = 0.3g - 0.5g)	3.25E-05	3.25E-07
SEIS4 (0.6g) (range = 0.5g - 1.01g)	1.31E-05	1.31E-07
Totals=	8.43E-05	8.43E-07

Assuming the MACR is directly proportional to the CDF provides a means of determining the MACR for FRAG17 over the seismic spectrum given the total seismic MACR of $2,571,565:

FRAG17 Specific MACR

Initiating Event	CDF Related to FRAG17	MACR Related to FRAG17
SEIS1 (0.15g) (range = 0.052g - 0.2g)	1.26E-07	$3,844
SEIS2 (0.25g) (range = 0.2g - 0.3g)	2.61E-07	$7,962
SEIS3 (0.4g) (range = 0.3g - 0.5g)	3.25E-07	$9,914
SEIS4 (0.6g) (range = 0.5g - 1.01g)	1.31E-07	$3,996
Totals=	8.43E-07	$25,716

Following the assumption that implementation of this SAMA can eliminate all risk related to the EDG ground resistors, the averted cost-risk is the total MACR for FRAG17, which is $25,716.

E.6.29.1 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $800,000 by the TMI staff (Exelon 2007c).

E.6.29.2 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is only the seismic averted cost-risk in this case, and the cost of implementation. The following table summarizes these results:

SAMA 29 - Net Value

Total Averted Cost-Risk	Cost of Implementation	Net Value
$25,716	$800,000	-$774,284

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.30 SAMA NUMBER 30: IMPROVE DIESEL FIRE PUMP FUEL OIL TANK AND BATTERY RACK SUPPORTS

The Fire Service Water system provides cooling to the SBO EDG, backup cooling the DHCCW heat exchangers, and backup cooling to the "1A" and "1B" Instrument Air compressors. While seismic failures to the systems FSW supports would likely limit the benefit of improving the fuel oil tank and battery racks, some benefit may be available through improvements to the diesel fire pump's reliability.

The ability to quantify the impact of improving the seismic capacity of the diesel fire pump is limited due to the small amount of information provided in the IPEEE related to the importance of the fire system. The motor driven pump (FS-P-2) appears to be explicitly included in the mode, but the diesel driven pumps (FS-P-1, FS-P-3) are not. However, a process has been developed to approximate the potential benefit of increasing the HCLPF capacity of the diesel driven pumps to a theoretical limit where they would never fail based on the seismic F-V value of the lowest contributor. All of the calculations are based on information available in the IPEEE, the current PRA, and engineering judgment. No seismic model quantification was performed for this evaluation.

It is assumed that if the portion of the seismic CDF and release consequences related to the failures of the diesel driven fire pump can be identified, then an averted cost-risk can be calculated for this SAMA. The steps used to perform this calculation are provided below:

- Determine the component of the overall modified MACR attributable to non-external flooding external events,
- Determine the component of the non-external flooding external events cost-risk attributable to seismic events,
- Determine the component of the seismic based cost-risk attributable to the lowest reported

seismic component group (EDG ground resistors),

- Assume that the seismic importance of the diesel driven fire pumps is equivalent to the EDG ground resistors,
- Assume that implementation of this SAMA would eliminate all risk related to the diesel driven fire pumps such that the averted cost-risk would be the total cost-risk related to the diesel driven fire pumps (equivalent to the MACR for the EDG ground resistors).

Because neither the fire water system nor any fire water component was included in the seismic “system” or “component” importance lists, it is assumed that the MACR for the diesel fire driven pumps could not exceed that of the lowest component on the importance list. The IPEEE indicates that the lowest seismic F-V contributor is FRAG17, which represents the EDG ground resistors. Given that the MACR for FRAG17 was calculated in Section E.6.29, the calculations are not reproduced here, but the result was determined to be $25,716. This is considered to be the MACR for the diesel driven fire pumps.

E.6.30.1 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $150,000 by the TMI staff (Exelon 2007c).

E.6.30.2 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is only the seismic averted cost-risk in this case, and the cost of implementation. The following table summarizes these results:

SAMA Number 30 Net Value

Total Averted Cost-Risk	Cost of Implementation	Net Value
$25,716	$150,000	-$124,284

Given that the cost of implementation is greater than the averted cost-risk for this SAMA, the net value is negative.

E.6.31 SAMA NUMBER 31: MODIFY SPECIFIC CONTAINMENT PENETRATION MOVS TO FAIL CLOSED

Most containment penetrations have AOV or SOV isolation valves that will fail closed on loss of air or power; however, there are cases in which MOVs are used instead. Those lines that do not include a pair of AOVs or SOVs that fail closed are typically below 1" in diameter or include at least one AOV or SOV that will fail closed on loss of air or power. However, the Nuclear Services Closed Cooling Water (NSCCW) and Reactor Building Normal Cooling (RBNC) systems include penetrations that only include MOVs:

- Valves NS-V-4, NS-V-15, NS-V-35 (NSCCW),
- Valves RB-V-2A, RB-V-7 (RBNC)

While these are closed cooling systems that would not normally provide a credible release path, heat exchanger breaks in seismic events could provide containment bypass routes given that a break occurs in the reactor building as well. Changing one of the valves in each of these paths to fail closed is a means of increasing the isolation probability over what is available from manual action.

Further review of the seismic design of the NSCCW and RBNC systems showed that while the heat exchangers linked to the penetrations in question were relatively weak, the piping and equipment associated with these lines within the reactor building were screened in the IPEEE as high capacity components. This indicates that failure of the piping and components within the reactor building would not occur except under the most extreme seismic conditions. In those cases, other integrity issues would likely exist and preventing a break in the NSCCW and RBNC lines would not provide any benefit. For reference purposes, an estimate of the cost required to replace the existing isolation valves with “fail closed”, solenoid operated AOVs was prepared and determined to be $4,100,000 (Exelon 2007c), which is greater than the entire baseline external events cost-risk of $3,271,711. This SAMA is screened from further consideration.

E.6.32 SAMA NUMBER 32: PRE-STAGE SEVERE EXTERNAL FLOODING EQUIPMENT

The existing severe flooding guidelines, which address external floods greater than 309’ msl (stillwater level, 310’ msl assumed wave action level), provide the TSC with information and guidance to help it direct the installation of “flood safe” primary and secondary side makeup systems. The guidance currently requires a large number of tasks in potentially challenging environmental conditions to prepare the plant for extreme flooding conditions. Review of the guidelines has resulted in the identification of several areas that could be improved to reduce the time required to implement the procedures and to improve the reliability of the process.

While the details of the enhancements have not yet been developed, the following high level improvements have been established as desirable for inclusion:

- Fully proceduralize guidelines: Upgrade the guidelines so that they provide step by step instructions on all aspects of the implementation process. For example, the guidelines currently direct connections to power and air sources without specifying the steps required to complete the connection. The details for these types of tasks must be provided,
- Permanently mount the power cables between the generator and pump staging areas,
- Permanently mount the emergency seal injection pump with a suction source from the fuel transfer tubes and use it in place of the submersible injection pumps to take advantage of its capability of injecting at normal operating pressure (rather than the 1200 psig available from the submersible pumps). The pump must be positioned at a flood-safe height,
- Permanently mount injection lines required for primary and secondary side makeup (may not be practical for the secondary side pump that takes suction from flood water in the turbine building),
- Consider an alternate secondary side suction source given that flood waters may recede well before an alternate secondary side makeup source will become available when AC power is re-established to the site,
- Ensure the power cables have all required connectors attached or stored in the staging areas,
- Pre-manufacture any required air supply or fuel oil connectors and store them in the staging areas,
- Store the portable generator on the turbine deck,
- Install a normally empty fuel oil tank for EG-Y-6 on the turbine deck that can be filled when it is required using power from EG-Y-6, if necessary.

Based on the IPEEE evaluation, one of the larger contributors to the severe flooding mitigation strategy is the reliability of EG-Y-6. For the 48 hour mission time evaluated in the relevant external flooding scenarios, the failure probability for EG-Y-6 is nearly 1.5E-01. This estimate is based on the use of the failure probabilities established for the large 4kV EDGs used to power the emergency buses at TMI. While the use of the EDG failure data for EG-Y-6 is believed to be conservative, component specific failure data for EG-Y-6 is not available. As a result, the design of this SAMA requires the purchase of an alternate, diverse portable generator to serve as a backup AC power source.

E.6.32.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In this case, the changes to the extreme flooding mitigation strategy are not expected to impact internal events or non-flooding external events risk. This is because the primary injection alignment cannot be performed before RCP seal heatup/damage in SBO events or other scenarios that lead to loss of seal cooling. For a majority of the external flooding cases, the severe flooding primary injection strategy could be aligned before the loss of on-site AC power such that seal cooling would never be lost. For the internal events model, there is no adequate warning that would allow such an early alignment and the only result from using the severe flooding primary injection method would likely be thermal shock to the RCP seals.

Based on the discussion above, this SAMA does not reduce internal events risk, as summarized below:

SAMA 32 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.37E-05	32.61	$112,259
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 32 - Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259

The non-external flooding external events contribution is typically calculated using the 2.0 multiplier on the internal events results, but in this case, the averted cost-risk is $0, so the non-external flooding external events contribution is also $0:

SAMA 32 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,271,711	$0	2.0	$0

E.6.32.2 EXTERNAL FLOODING EVALUATION

The severe flooding guidelines were originally credited in the IPEEE for both floods above 310’ msl as well as for floods between 305’ and 310’ msl. Due to a more limited preparation time for the 305’ to 310’ msl floods, the failure probability was assumed to be 0.5 rather than the 0.255 used for the 310’ msl floods. For floods below 305’ msl, no credit was taken for the severe flooding guidelines as the submersible pumps used for secondary side makeup require flood water in the turbine building for a suction source. While this SAMA includes provisions for an alternate secondary side pump suction source, the expected alignment time of approximately 2 hours would likely preclude it from being an effective means of preventing core damage in a flood induced loop. In these cases, the alignment of the severe flood equipment would not begin in time to establish cooling before core melt.

For the purposes of this analysis, implementation of this SAMA is assumed to reduce the HEP for alignment of the external flooding measures from 1.1E-01 to 1.0E-02. In addition, the availability of the diverse, alternate portable AC generator is considered to reduce the failure probability of the flood-safe AC power source from 1.43E-01 to 2.04E-02 (1.43E-01 * 1.43E-01 = 2.04E-2, which assumes completely independent generators). This results in a total failure probability of 3.04E-02 (1.0E-02 + 2.04E-02 = 3.04E-02) for the severe flooding mitigation strategy.

Because the severe flooding guidelines were credited differently in each of the flood ranges, three separate strategies are required to obtain the revised core damage frequencies for the flooding scenarios:

- Floods >310' msl: The CDF for this scenario was calculated in the IPEEE as the product of the flood frequency and the failure probability for the alignment of the severe flooding mitigation strategy. As a result, the revised frequency can be obtained by multiplying the base CDF by the ratio of SAMA based severe flood mitigation failure probability to the baseline severe flood mitigation failure probability (3.04E-02 / 2.55E-01 = 1.19E-01).

- Floods between 305' and 310' msl: In the IPEEE, a multiplier of 0.5 was applied to each of the sequences in the flooding event tree to represent the potential to avert the flood using the severe flooding guidelines. The increase in the failure probability over the >310' msl case was made to account for the decreased time available in the 305' and 310' msl cases. For this evaluation, it is assumed that the failure to implement SAMA 32 is dominated by operator dependence. Non-negligible dependence exists between the actions to install the flood gates and to implement SAMA 32; however, the dependence is cognitive. As execution failure would be the majority contributor to the flood HEPs and because the execution and cognitive contributors are not separated for the flood actions, it could be overly conservative to use the dependence factors based on the available HEPs, especially given that the appropriate dependence level would likely be "high". To simulate the results of a true dependence assessment where the cognitive and execution components of the HEP are explicitly provided, a moderate dependence factor is used rather than a high dependence factor. As a result, the base event tree failure probabilities are multiplied by 0.14 (which is obtained from equation 10-16 of NUREG/CR-1278 (NRC 1983)) rather than 0.5 to get the new frequencies. In order to obtain the post-SAMA frequencies for these sequences, the flood frequencies reported in the IPEEE are multiplied by 0.28

(0.14/0.5=0.28) to account for the original 0.5 failure probability assigned to the contemporary severe flooding guidelines. Sequence “F” represents failure of the early flood warning and precluded the use of the flood panels in the IPEEE; however, credit was taken for the severe flood guidelines in the same manner as for the other sequences. For consistency with the IPEEE, the same credit taken for SAMA 32 in the other 305’ to 310’ msl sequences is also taken for Sequence “F”. Given that Sequence “F” is a minimal contributor, this assumption has no meaningful impact on the results.

- Floods below 305’ msl: While there are provisions to use a non-floodwater suction source for SAMA 32, the 2 hour alignment time may make it ineffective to prevent CD after flood induced LOOP. No credit is taken for SAMA 32 for these floods.

The results of this process are summarized below:

SAMA 32 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	1.26E-05	28.5	$87,324
Percent Change	-84.4%	-83.6%	-83.9%

A further breakdown of this information is provided below according to release category.

SAMA 32 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	7.58E-06	1.76E-06	1.86E-08	2.53E-07	1.71E-06	1.02E-06	2.42E-08	2.50E-07	1.26E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	15.80	3.68	0.05	0.53	5.00	3.00	0.07	0.37	28.50
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$48,308	$11,242	$167	$1,615	$15,355	$9,200	$218	$1,219	$87,324

The external flooding based averted cost-risk for this SAMA is shown below:

SAMA 32 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$2,491,451	$13,052,022

E.6.32.3 COST OF IMPLEMENTATION

The cost of implementation is estimated to be $1,700,000 (Exelon 2007c).

E.6.32.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 32 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$0	$13,052,022	$13,052,022	$1,700,000	$11,352,022

Given that the cost of implementation is less than the averted cost-risk for this SAMA, the net value is positive.

E.6.33 SAMA NUMBER 33: INCREASE THE FLOOD PROTECTION HEIGHT

The current configuration protects to the design basis limit of 310 feet msl and levels any higher result in topping of the existing flood doors and flooding of sensitive areas. Raising the height of the flood doors (completely sealing the doors, raising required air intakes/exhaust ducts, as required) would prevent water incursion and allow for continued operation of the normal safety equipment. The goal of this SAMA is to increase the flood protection height to a point where the extreme flooding CDF would be comparable to the internal events CDF of 2.37E-05/yr. In this case, the goal is assumed to be a CDF of 1.0E-05/yr and the assumption is made that when the flood waters exceed the flood protection height, core damage occurs (no credit taken for existing extreme flooding guidance). The exceedance frequency of 1E-05/yr corresponds to a level of 320.3’ msl (stillwater level). Protecting the plant against these floods would require modifications to match the stillwater of 320.3’ msl plus the wave setup height, which was determined to be up to 4’ (GPU 1990). The total flood protection height required is, therefore, 324.3’ msl, which is rounded up to 324.5’ msl.

Based on a review of plant documentation, the following changes would be required to protect the plant up to 324.5’ msl:

- EDG Building, GATE D1: Raise the flood gate to completely seal the door.
- EDG Building, GATE D2: Sealed by security changes, no additional changes are required.
- EDG Building, GATE D3: Raise the flood gate to completely seal the door.
- EDG Building, GATE D4: The gates must be extended from 311’-0” to 324.5’.
- EDG Building, Air Vent Valve: A 2-1/2” diameter penetration is located at elevation 311’-2” in the north wall and one in the west wall at elevation 312’-4” for fuel oil day tank air vent valves. Both penetrations must be waterproofed and the outlets must be extended to 324.5’.
- Air Intake Structure, Access Door: The bottom of the door is at 312’-0” and has no flood protection. The door should be completely sealed.
- Air Intake Structure, Air Vents: The bottoms of the intake louvers are a 312’. These must be completely sealed.
- Intermediate Building, Gate C-1: The tops of the existing gates are at 311’-6” and leave about 3 feet open to the top of the doorway. The door should be completely sealed and fitted with an entry hatch.
- Control Building, Gate B-1: The tops of the existing gates are at 311’ and leave an additional 10 feet open to the top of the doorway. The doors should be sealed and fitted with an entry hatch. Covering the entire doorway may not be required, but the conservative modification would be to provide complete protection.
- Control Building, Gate B-2: The tops of the existing gates are at 311’ and leave an additional 2 feet open to the top of the doorway. The door should be completely sealed and fitted with an entry hatch.

- Intake Screen Pumphouse, Gate E-1: The tops of the existing gates are at 311' and leave an additional 4 feet open to the top of the doorway. The door should be completely sealed and fitted with an entry hatch.
- Intake Screen Pumphouse, Gate E-4: The tops of the existing gates are at 311' and leave an additional 6 feet open to the top of the doorway. The door should be completely sealed and fitted with an entry hatch.
- Intake Screen Pumphouse, Gate E-2: The tops of the existing gates are at 311' and leave an additional 4 feet open to the top of the doorway. The door should be completely sealed and fitted with an entry hatch.
- Intake Screen Pumphouse, Gate E-3: The tops of the existing gates are at 311' and leave an additional 4 feet open to the top of the doorway. The door should be completely sealed and fitted with an entry hatch. In addition, two penetrations exist at 311'-4" and 312'-8" and an exhaust penetration exists in the west wall. These penetrations must be sealed and communication with the atmosphere must be provided at a level of at least 324.5'.

In addition, there is concern that the cable vaults holding the cables that connect the EDGs to the emergency buses are not waterproof. These cable vaults must be waterproofed so that the EDG output cables do not short out in the event that the cables have lost integrity.

E.6.33.1 INTERNAL EVENTS AND NON-EXTERNAL FLOODING EVALUATION

This subsection describes the calculation of the component of this SAMA's averted cost-risk associated with the non-external flooding events. As described in Section E.4.6.3, the external events risk, excluding external flooding, is considered to be equal to the internal events risk. Quantitatively, this is accounted for by multiplying the internal events averted cost-risk by a factor of 2.0. This process is described below and is one of the two components that comprise the total averted cost-risk for a SAMA.

In this case, the changes to the extreme flooding protection height will not impact internal events or non-flooding external events risk and this SAMA will not reduce the CDF, dose risk, or OECR, as summarized below:

SAMA 33 - Internal Events Results

	CDF (/yr)	Dose-Risk	OECR
Base Results	2.37E-05	32.61	$112,259
SAMA Results	2.37E-05	32.61	$112,259
Percent Change	0.0%	0.0%	0.0%

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

SAMA 33 Internal Events Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{SAMA}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{SAMA}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{SAMA}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{SAMA}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{SAMA}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{SAMA}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259

The non-external flooding external events contribution is typically calculated using the 2.0 multiplier on the internal events results, but in this case, the averted cost-risk is $0, so the non-external flooding external events contribution is also $0:

SAMA 33 - Non-External Flooding Averted Cost-Risk

Base Case Internal Events Cost-Risk	SAMA Case Internal Events Cost-Risk	Internal Events Averted Cost-Risk	Non-Flood External Events Multiplier	Total Non-Flood Averted Cost-Risk
$3,271,711	$3,271,711	$0	2.0	$0

E.6.33.2 EXTERNAL FLOODING EVALUATION

This SAMA only has the potential of reducing the risk of the extreme floods, those which result in flood waters exceeding 310’ msl. The lesser floods are already protected by dikes or flood gates and for those cases where flood gate installation fails, this SAMA would also fail.

For the purposes of this analysis, implementation of this SAMA is assumed to eliminate extreme flooding risk if installed properly. The same failure probability used in the IPEEE for installing the flood doors for the 305’ to 310’ msl floods is used for the floods over 310’ (HSL1 at 5.62E-02). In this case, no credit is taken for the implementing the existing severe flooding guidelines in the event that SAMA 33 is implemented and fails. SAMA 33 impacts neither the 305’ to 310’ msl floods nor the floods below 305’ msl. The results of this assumption are summarized below:

SAMA 33 - External Flooding Results

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
SAMA Results	3.14E-5	73.59	$225,428
Percent Change	-61.3%	-58.5%	-58.4%

A further breakdown of this information is provided below according to release category.

SAMA 33 - External Flooding Contributions by Release Category

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
SAMA Frequency	1.40E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	3.14E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
SAMA Dose-Risk	29.18	13.13	0.19	1.89	17.87	10.71	0.25	0.37	73.59
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
SAMA OECR	$89,220	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$225,428

The external flooding based averted cost-risk for this SAMA is shown below:

SAMA 33 - External Flooding Averted Cost-Risk

Base Case External Flooding Cost-Risk	SAMA Case External Flooding Cost-Risk	External Flooding Averted Cost-Risk
$15,543,473	$6,401,188	$9,142,285

E.6.33.3 COST OF IMPLEMENTATION

The cost of this enhancement was estimated to be $2,700,000 by the TMI staff (Exelon 2007c).

E.6.33.4 NET VALUE

The net value for this SAMA is the difference between the total averted cost-risk, which is the sum of the external flooding and non-external flooding based averted cost-risks, and the cost of implementation. The following table summarizes these results:

SAMA 33 - Net Value

Non-External Flooding Based Averted Cost-Risk	External Flooding Based Averted Cost-Risk	Total Averted Cost-Risk	Cost of Implementation	Net Value
$0	$9,142,285	$9,142,285	$2,700,000	$6,442,285

Given that the cost of implementation is less than the averted cost-risk for this SAMA, the net value is positive.

E.7 UNCERTAINTY ANALYSIS

Sensitivity cases were run for the following conditions to assess their impact on the overall SAMA evaluation:

Use the 95th percentile PRA results in place of the mean PRA results.

Assume no baseline BWST Refill capability

- Use alternate MACCS2 input variables for selected cases.
- Assume no credit for extreme external flooding guidance

E.7.1 95TH PERCENTILE PRA RESULTS

The results of the SAMA analysis can be impacted by implementing conservative values from the PRA's uncertainty distribution. If the best estimate failure probability values were consistently lower than the "actual" failure probabilities, the PRA model would underestimate plant risk and yield lower than "actual" averted cost-risk values for potential SAMAs. Re-assessing the cost benefit calculations using the high end of the failure probability distributions is a means of identifying the impact of having consistently underestimated failure probabilities for plant equipment and operator actions included in the PRA model. This sensitivity uses the 95th percentile results to examine the impact of uncertainty in the PRA model.

For TMI-1, the UNCERT32 software code was used to perform the Level 1 internal events model uncertainty analysis. The results of the calculation are provided below:

Parameter	Value
Mean	4.10E-05
5 percent	8.98E-06
50 percent	1.81E-05
95 percent	6.51E-05
Standard Deviation	9.36E-04

The PRA uncertainty calculation identifies the 95th percentile CDF as 6.51E-05 per year. This is a factor of 2.75 greater than the CDF point estimate produced by the TMI-1 PRA.

E.7.1.1 PHASE I IMPACT

For Phase I screening, use of the 95th percentile PRA results will increase the MACR and for some sites, it may prevent the screening of some of the higher cost modifications. In the event that a SAMA is retained based on use of the 95th percentile MACR, it would be unlikely to impact the SAMA conclusions. This is due to the fact that the benefit gleaned from the implementation of those SAMAs must be extremely large in order to be cost beneficial. For TMI-1, no SAMAs were screened in Phase I, so use of the 95th percentile PRA results does not impact the Phase I analysis. However, the 95th percentile PRA results MACR is calculated here for completeness.

As discussed above, the 95th PRA results are approximately a factor of 2.75 greater than the point estimate CDF. The uncertainty analyses that are available for the Level 1 models are not available for Level 2 and 3 PRA models. In order to simulate the use of the 95th percentile results for the Level 2 and 3 models, the same scaling factor calculated for the Level 1 results was assumed to apply to the Level 2 and 3 models. Because the MACR calculations scale linearly with the CDF, dose-risk, and offsite economic cost-risk, the 95th percentile MACR can be calculated by multiplying the base case MACR by 2.75. This results in a 95th percentile MACR of $60,739,250.

E.7.1.2 PHASE II IMPACT

As mentioned above, the 95th percentile PRA results are not available for the Level 2 and 3 models. In order to estimate the impact of using the 95th percentile PRA results in the Phase II SAMA analysis, the same process used to calculate the revised MACR was applied to each of the Phase II SAMAs (the averted cost-risk for each SAMA was increased by a factor of 2.75 over the base case).

The following table provides a summary of the impact of using the 95th percentile PRA results in the detailed cost-benefit calculations that have been performed.

Results Summary for the 95th Percentile PRA Results

SAMA ID	Cost of Implement-ation	Averted Cost- Risk (Base)	Net Value (Base)	Averted Cost- Risk (95th Percentile)	Net Value (95th Percentile)	Change in Cost Effective-ness?
SAMA 1	$3,125,000	$986,145	-$2,138,855	$2,711,899	-$413,101	No
SAMA 2	$7,300,000	$4,297,001	-$3,002,999	$11,816,753	$4,516,753	Yes
SAMA 3	$2,450,000	$594,926	-$1,855,074	$1,636,047	-$813,954	No
SAMA 5	$3,150,000	$230,163	-$2,919,837	$632,948	-$2,517,052	No
SAMA 6	$2,750,000	$398,924	-$2,351,076	$1,097,041	-$1,652,959	No
SAMA 7	$1,000,000	$449,254	-$550,746	$1,235,449	$235,449	Yes
SAMA 8	$145,000	$1,234,676	$1,089,676	$3,395,359	$3,250,359	No
SAMA 10	$3,800,000	$982,048	-$2,817,952	$2,700,632	-$1,099,368	No
SAMA 11	$4250,000	$16,088,692	$11,838,692	$44,243,903	$39,993,903	No
SAMA 12	$50,000	$198,438	$148,438	$545,705	$495,705	No
SAMA 13	$950,000	$305,294	-$644,706	$839,559	-$110,442	No
SAMA 14	$3,150,000	$603,886	-$2,546,114	$1,660,687	-$1,489,314	No
SAMA 15	$450,000	$199,098	-$250,902	$547,520	$97,520	Yes
SAMA 16	$1,100,000	$1,592,631	$492,631	$4,379,735	$3,279,735	No
SAMA 17	$950,000	$51,988	-$898,012	$142,967	-$807,033	No
SAMA 18	$100,000	$33,260	-$66,740	$91,465	-$8,535	No
SAMA 19	$760,000	$3,127,876	$2,367,876	$8,601,659	$7,841,659	No
SAMA 20	$3,030,000	$173,974	-$2,856,026	$478,429	-$2,551,572	No
SAMA 21	$1,200,000	$1,181,137	-$18,863	$3,248,127	$2,048,127	Yes
SAMA 22	$5,000,000	$1,253,768	-$3,746,232	$3,447,862	-$1,552,138	No
SAMA 23	$50,000	$30,629	-$19,371	$84,230	$34,230	Yes
SAMA 24	$8,400,000	$4,416,201	-$3,983,799	$12,144,553	$3,744,553	Yes
SAMA 25	$6,000,000	1,466,139	-$4,533,861	$4,031,882	-$1,968,118	No
SAMA 26	$900,000	$369,663	-$530,337	$1,016,573	$116,573	Yes
SAMA 27	$575,000	$1,306,819	$731,819	$3,593,752	$3,018,752	No
SAMA 28	$575,000	$47,891	-$527,109	$131,701	-$443,299	No
SAMA 29	$800,000	$25,716	-$774,284	$70,719	-$729,281	No
SAMA 30	$150,000	$25,716	-$124,284	$70,719	-$79,281	No
SAMA 32	$1,700,000	$13,052,022	$11,352,022	$35,893,061	$34,193,061	No
SAMA 33	$2,700,000	$9,142,285	$6,442,285	$25,141,284	$22,441,284	No

Of the SAMAs classified as “not cost beneficial” in the baseline Phase II analysis, seven SAMAs (2, 7, 15, 21, 23, 24, and 26) were found to be cost beneficial when the 95th percentile PRA results were applied. The use of the 95th percentile PRA results is not considered to provide the most realistic assessment of the cost effectiveness of a SAMA; however, these seven additional SAMAs could be considered for implementation to address the uncertainties inherent in the SAMA analysis.

E.7.2 BWST REFILL CAPABILITY

A recent inspection at TMI questioned the viability of preventing core damage in SGTR scenarios by refilling the BWST. Specifically, it is not certain whether the BWST can be refilled at a rate that will completely make up for the inventory being lost through the tube rupture. Analysis has shown that in certain scenarios (e.g., no RCS cooldown and depressurization), the current BWST refill capability will only delay core damage, but not prevent it. Because SGTR events are large contributors to the TMI-1 dose-risk and OECR, changes to the assumptions related to BWST refill capabilities can have a significant impact on the accident consequence analysis given that successful BWST refill is assumed to avert core damage. While the results of the BWST refill analysis have not yet been finalized, this sensitivity has been developed to determine how the SAMA 10 evaluation (automated BWST refill) could be impacted by the assumption that manual BWST refill is not capable of preventing core damage for SGTR events at TMI-1.

Currently, the PRA model assumes that manual refill of the BWST will support continuous makeup to the primary system, thus preventing core damage in SGTR scenarios. The importance list review showed that further improving the reliability of this function would have a meaningful impact on both the Level 1 and Level 2 results. The cost benefit results provided for SAMA 10 in Section E.6.10 are predicated on the assumption that the current BWST refill capability prevents core damage; however, if the current capability only delayed core damage to allow other recovery actions rather than prevent core damage, the impact of implementing SAMA 10 would be greater than what is shown in the baseline assessment. The averted cost-risk for the SAMA would be estimated using the difference in the MACR for the plant configuration in which BWST refill always fails and the MACR for the plant configuration in which BWST is fully automated. This is a bounding assessment since assuming no refill capability is conservative. However, detailed modeling of partial success via manual BWST refill would be very complicated and may only reduce the averted cost-risk by a small amount.

Because SAMA 10 already evaluated the plant configuration in which BWST refill is fully automated, the information required to obtain the MACR for that plant configuration is already available and is the sum of the “SAMA case external flooding cost risk” and 2 times the “SAMA case internal events cost-risk” (multiplier of 2 required to account for the non-external flooding external events contribution). As documented in Section E.6.10, the “SAMA case external flooding cost risk" is $15,543,473 and the "SAMA case internal events cost-risk" is $2,763,004. The total MACR would therefore be $21,069,481 ($15,543,473 + 2 * $2,763,004).

In order to obtain the revised baseline MACR in which BWST refill always fails, the basic event representing the independent operator action for BWST refill is set to 1.0. Because failure of the BWST refill action is a physical limitation, the JHEPs are eliminated from the results. The changes made to the cutset file to obtain the "revised baseline" results are summarized in the table below:

BWST Refill Sensitivity Model Changes

Gate and / or Basic Event ID and Description	Description of Change
BWST-HRE27-HTKOA: FAILURE TO REFILL BWST (SPLIT FRAC REV)	The basic event probability was changed from 2.65E-02 to 1.0.
JHAHCD4RE27HEPOA: AVHCD4_FF--HCDOA AND BWST-HRE27-HTKOA (JHEP addressing BWST refill and cooldown via secondary side)	The basic event probability was changed from 9.17E-05 to 0.0.
JHHRE27HL1AHEPOA: BWST-HRE27-HTKOA AND DLHHL1A----HVHOA (JHEP addressing BWST refill and opening drop line for DHR cooling)	The basic event probability was changed from 2.00E-04 to 0.0.
JHHEF2HRE27HEPOA: AVHEF2_FF--HCDOA AND BWST-HRE27-HTKOA (JHEP addressing BWST refill and manually initiating cooldown using the OTSG)	The basic event probability was changed from 1.3E-03 to 0.0.
JHHIGHREHHLHEPOA: IGHIG1_HER-HSGOA, BWST-HRE27-HTKOA, and DLHHL1A----HVHOA (JHEP addressing BWST refill, failure to isolate a SGTR, and opening drop line for DHR cooling)	The basic event probability was changed from 5.0E-07 to 0.0. (Event was not in cutsets)

The results of these changes are summarized in the tables below:

BWST Refill Sensitivity Results

	CDF (/YR)	DOSE-RISK	OECR
Sensitivity Results	2.75E-05	54.04	$216,329

A further breakdown of this information is provided below according to release category. Note that the results for the following RCs are not provided given that the frequencies are always zero: RC2-01, RC2-03, RC3-05, RC3-06, RC4-05, RC4-06, RC4-07, RC4-08, RC6-01, RC6-02, AND RC6-06.

BWST Refill Sensitivity Results By Release Category

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{Sens}$	2.33E-06	3.46E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Dose-Risk$_{Sens}$	13.33	19.79	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
OECR$_{Sens}$	$64,774	$96,188	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{Sens}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.33E-05	1.69E-08	2.36E-06	1.91E-08	2.75E-05
Dose-Risk$_{Sens}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.54	0.00	0.63	0.01	54.04
OECR$_{Sens}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,476	$4	$618	$5	$216,329

These results are converted into a cost-risk using the methods documented in Section E.4:

BWST Refill Sensitivity Non-External Flooding Cost-Risk

Sensitivity Case Internal Events Cost-Risk	Non-External Flooding External Events Multiplier	Total Non-Flood Cost-Risk
$5,578,084	2.0	$11,156,168

Assuming that the external flooding MACR is constant at $15,543,473, the total MACR for the case without BWST refill capability would be $26,699,641 ($15,543,473 + $11,156,168 = $26,699,641). It should be noted that the use of the multiplier of 2 to account for external events contributions for this case may be inappropriate because SGRT events are not considered in the external events scenarios.

Finally, the averted cost risk and net value for SAMA 10 assuming an initial configuration in which BWST refill is not credited can be recalculated:

BWST Sensitivity SAMA 10 Net Value

No BWST Refill Case MACR	Fully Automated BWST Refill MACR	Averted Cost-Risk	Cost of Implementation	Net Value
$26,699,641	$21,069,481	$5,630,160	$3,800,000	$1,830,160

Given that the net value is positive for this case, the implication is that if the actual TMI-1 conditions are best represented by no credit for BWST refill (a conservative assumption), SAMA 10 is a cost effective change.

E.7.3 MACCS2 INPUT VARIATIONS

The MACCS2 model was developed using the best information available for the Three Mile Island site; however, reasonable changes to modeling assumptions can lead to variations in the Level 3 results. In order to determine how certain assumptions could impact the SAMA results, a sensitivity analysis was performed on a group of parameters that has previously been shown to impact the Level 3 results. These parameters (and the associated sensitivity case identifiers) include:

- Meteorological data (TMI1999; TMI2000)
- Population estimates(TMI30INC; TMISIT00)
- Evacuation effectiveness (TMISLOW)
- Radionuclide release characteristics (TMIATM1; TMIATM2)
- Recovery, decontamination, and resettlement factors (Intermediate Phase) (TMICHR1, TMICHR2)

The risk metrics produced by MACCS2 that are evaluated in the sensitivity analyses are the 50 mile population dose and the 50 mile offsite economic cost. The following subsections discuss the changes in these results for each of the sensitivity cases that are shown below. The final subsection, E.7.3.6, correlates the worst case changes identified in the sensitivity runs to a change in the site's averted cost-risk and discusses the implications of the sensitivity analysis on the SAMA analysis.

CASE	DESCRIPTION	POP. DOSE RISK Δ BASE (%)	COST RISK Δ BASE (%)
TMI1998	Base Case (Year 1998 MET data)	--	--
TMI1999	Year 1999 MET data	-10.5%	-9.29%
TMI2000	Year 2000 MET data	-4.73%	-5.15%
TMI30INC	Year 2034 population values increased uniformly 30% over base case.	28.3%	29.5%
TMISit00	Year 2000 population based (Base Case is Year 2034)	-28.9%	-29.6%
TMISlow	Evacuation speed decreased 50% to 0.59 mph, 0.26 m/sec (Base Case is 1.18 mph).	15.3%	0%
TMIATM1	Release height set to ground level	-4.58%	-5.22%

CASE	DESCRIPTION	POP. DOSE RISK Δ BASE (%)	COST RISK Δ BASE (%)
TMIATM2	Plume thermal heat content set to ambient (i.e., buoyant plume rise not modeled)	1.65%	1.09%
TMICHR1	Long Term Phase starts immediately after the Early Phase is over (No Intermediate Phase; Base Case is 6 month Intermediate Phase)	16.8%	-36.9%
TMICHR2	1 Year Intermediate Phase following the Early Phase (Base Case is 6 month Intermediate Phase)	-8.84%	34.0%

E.7.3.1 METEOROLOGICAL SENSITIVITY

In addition to the base case meteorological data (year 1998), data is also analyzed for the years 1999 and 2000. Analysis of these alternate data sets yielded population dose-risks and offsite economic cost-risks that are lower than the 1998 data by at least 4.7 percent and by as much as 10.5 percent.

As no particular criteria have been defined by the industry related to determining which meteorological data set should be used as a base case for a site, the year 1998 data is conservatively chosen for Three Mile Island given that it yielded the largest results.

E.7.3.2 POPULATION SENSITIVITY

The population sensitivity cases (TMI30INC, TMISIT00) demonstrate a significant dependence on population estimates. This is expected given that the population dose and offsite economic costs are primarily driven by the regional population.

In case TMI30INC, the baseline 2034 population is uniformly increased by 30 percent in all sectors of the 50-mile radius. This change increased the estimated population dose-risk and offsite economic cost by over 28 percent each.

A second population based sensitivity (TMISIT00) is performed to determine the impact of using year 2000 census data rather than projecting to the end of the license renewal period (Year 2034). The baseline SAMA case is based on a population projection to year 2034 based on the population growth trends shown between the years 1990 and 2000. When year 2000 data is utilized, the overall dose-risk and OECR decrease, as expected. Specifically, the dose-risk and the OECR decreased by about 29 percent each.

E.7.3.3 EVACUATION SENSITIVITY

The evacuation sensitivity case (TMISLOW) demonstrates population dose-risk impacts associated with evacuation assumptions. While evacuation assumptions do impact the population dose-risk estimates, they do not impact MACCS2 offsite economic cost-risk estimates because MACCS2 calculated cost-risks are based on land contamination levels which remain unaffected by evacuation assumptions and the number of people evacuating.

For Three Mile Island, a slow evacuation assumption is used in the base case (1.18 mph). An additional 50 percent decrease in the evacuation speed to 0.59 mph increased the dose-risk by approximately 15 percent.

E.7.3.4 RADIOACTIVE RELEASE SENSITIVITY

The sensitivity cases TMIATM1 and TMIATM2 quantify the impact of the assumptions related to the height of the release and thermal energy of the plume, respectively. TMIATM1 assumes that the release occurs at ground level rather than at an elevation that could correspond to a release through the stack or a break high in the reactor building. The lower release height shows a decrease in dose-risk and OECR of approximately 5 percent. Reducing the thermal plume heat content to ambient conditions has a minimal impact. TMIATM2 shows an increase in the dose-risk and the OECR of about 1 percent.

E.7.3.5 INTERMEDIATE PHASE DURATION SENSITIVITY

The Intermediate Phase, as modeled by MACCS2, is the time period beginning after the early phase (one week emergency phase) and extends to the time when recovery actions such as decontamination and resettlement are started (long term phase). MACCS2 allows the habitation of land during the intermediate phase unless the projected dose criterion is exceeded. If the projected dose criterion is exceeded during the intermediate phase, the individual is relocated. MACCS2 allows an intermediate phase ranging from no intermediate phase to one (1) year. The Intermediate Phase related sensitivity cases (TMICHR1 and TMICHR2) show significant dependence in relation to economic impact, and are therefore discussed further:

- The No Intermediate Phase case (TMICHR1) is developed based on the NUREG-1150 modeling approach. However, the 37 percent reduction in economic cost estimates based on the approach are judged too optimistic in that the land decontamination efforts are modeled as starting one week after the accident (i.e., directly after the early phase ends) such that a significant portion of population relocation costs are omitted. For example, the costs associated with temporary housing while decontamination strategies are developed and decontamination teams are contracted are not accounted for without an intermediate phase. It is believed that NUREG-1150 studies omitted the intermediate phase because the MACCS2 intermediate phase coding was not validated at that time. A competing factor is that the population dose increases because people are allowed to re-occupy the land sooner (17 percent increase over the base case).

- The 1 Year Intermediate Phase case (TMICHR2) is developed based on the maximum length of time allowed by MACCS2 for the intermediate phase. A long intermediate phase can be unrealistic in that re-occupation of the contaminated land is not performed during this phase even if contamination levels decrease (by natural radioactive decay) to levels which would allow it (i.e., resettlement is evaluated as part of the long term phase, not the intermediate phase). Therefore, population relocation costs may be over estimated using a long (i.e., one year) intermediate phase. An Intermediate Phase of one year shows a 34 percent increase in the OECR estimates compared with the six month (base case) Intermediate phase. However, the population dose decreased by 9 percent with a longer Intermediate Phase due to later resettlement on decontaminated land.

The six month intermediate phase (base case) is judged to be a best estimate approach in that it provides a reasonable time for both decontamination efforts and resettlement to begin. The sensitivity cases demonstrate that this six month modeling approach is mid-range of the modeling choices available and is used as the base case.

E.7.3.6 IMPACT ON SAMA ANALYSIS

Several different Level 3 input parameters are examined as part of the Three Mile Island MACCS2 sensitivity analysis. The primary reason for performing these sensitivity runs is to identify any reasonable changes that could be made to the Level 3 input parameters that would impact the conclusions of the SAMA analysis. While the table in Section E.7.3 summarizes the changes to the dose-risk and OECR estimates for each sensitivity case, it is prudent to consider if any of these changes would result in the retention of the SAMAs that were screened using the baseline results.

Of all the MACCS2 sensitivity cases, the largest increase in the dose-risk is 28 percent in case TMI30INC while the largest increase in OECR is 34 percent in case TMICHR2. While these are separate cases, the Three Mile Island MACR is recalculated using these results to determine the impact of using the worst case for each parameter simultaneously. The resulting MACR is $28,048,743 (a factor of 1.27 increase over the base case), which is less than the $60,739,250 calculated in Section E.7.1 for the 95th percentile PRA results. The 95th percentile PRA results sensitivity is considered to bound this case and no SAMAs would be retained based on this sensitivity that were not already identified in Section E.7.1.

E.7.4 EXTREME FLOODING MITIGATION

The extreme flooding scenario (floods over 310' msl) accounts for 53% of the TMI-1 MACR. While this single sequence is highly important to site risk, the calculation of its CDF is simplified, using only the frequency of a flood exceeding 310' msl (stillwater level) and the failure probability of the severe flood mitigation strategy. In addition, the flooding sequences between 305' and 310' msl contribute a CDF of 1.71E-05/yr and are also based on simplified risk estimates. Typically, simplified estimates such as these include a conservative bias to prevent under predicting negative events; however, due to the large uncertainty in external flood scenarios, it is still possible that the quantification results underestimate the flooding risk. This sensitivity is intended to examine how an optimistic assessment of the flooding risk could impact the SAMA analysis. This sensitivity could be accomplished by modifying the flooding frequency for each of the flood ranges by a set factor, but in this case, the source of uncertainty was assumed to be in the likelihood of successfully implementing the extreme flooding mitigation strategy, which is credited for both floods over 310' msl and those between 305' and 310' msl. SAMA 32 investigates the cost benefit of improving the extreme flooding mitigation strategy, but this sensitivity will provide some insight on how the existing assumptions related to the response capability impact the other SAMA evaluations.

E.7.4.1 PHASE I IMPACT

In this sensitivity, no credit is taken for the use of the current TMI severe flood guidance. This pessimistic assumption changes the extreme flooding CDF from 6.37E-05/yr to 2.50E-04/yr. In addition, the CDFs for all of the sequences in the 305' msl to 310' msl range are increased by a factor of two, which mathematically eliminates the credit taken for the flood guidelines for those sequences. The following table summarizes the changes to the dose-risk and OECR corresponding to these changes in CDF:

Flooding Sensitivity: No Credit for Severe Flooding Guidance

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Base Ext. Flooding Results	8.11E-05	177.16	$542,159
Sensitivity Results	2.84E-04	609.47	$1,864,412
Percent Change	+250.2%	+244.0%	+243.9%

A further breakdown of this information is provided below according to release category.

Flooding Sensitivity: Contributions by Sequence

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Sensitivity Frequency	2.50E-04	1.26E-05	1.33E-07	1.81E-06	1.22E-05	7.31E-06	1.73E-07	2.50E-07	2.84E-04
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
Sensitivity Dose-Risk	521.00	26.26	0.39	3.77	35.75	21.42	0.51	0.37	609.47
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
Sensitivity OECR	$1,593,214	$80,298	$1,196	$11,535	$109,678	$65,717	$1,555	$1,219	$1,864,412

The corresponding external flooding component of the averted cost-risk is shown below:

Flooding Sensitivity: Revised External Flooding MACR

Base Case External Flooding MACR	Sensitivity Case External Flooding MACR	Difference (Sensitivity MACR - Base MACR)
$15,543,473	$53,604,345	$38,060,872

As can be seen, assuming no credit for TMI's current extreme flood mitigation capabilities results in a large increase in the external flooding MACR ($38,060,872 increase). Given that no SAMAs are screened in the Phase I analysis based on cost, the extreme flooding mitigation capabilities do not impact the Phase I analysis.

E.7.4.2 PHASE II IMPACT

If the same changes are made to the credit taken for the extreme flooding mitigation capabilities for each SAMA (i.e., no credit for the current mitigation strategies), the averted cost-risks are altered for those SAMAs that had some impact on the external flooding risk. The following table summarizes the changes to the cost benefit calculations when no credit is taken for the severe flooding mitigation capabilities:

Results Summary for the Extreme Flooding Capability Sensitivity

SAMA ID	Cost of Implement-ation	Averted Cost- Risk (Base)	Net Value (Base)	Averted Cost- Risk (Sensitivity)	Net Value (Sensitivity)	Change in Cost Effective-ness?
SAMA 1	$3,125,000	$986,145	-$2,138,855	$986,143	-$2,138,857	No
SAMA 2	$7,300,000	$4,297,001	-$3,002,999	$5,206,254	-$2,093,746	No
SAMA 3	$2,450,000	$594,926	-$1,855,074	$601,141	-$1,848,859	No
SAMA 5	$3,150,000	$230,163	-$2,919,837	$230,164	-$2,919,836	No
SAMA 6	$2,750,000	$398,924	-$2,351,076	$405,139	-$2,344,861	No
SAMA 7	$1,000,000	$449,254	-$550,746	$449,256	-$550,744	No
SAMA 8	$145,000	$1,234,676	$1,089,676	$1,234,676	$1,089,676	No
SAMA 10	$3,800,000	$982,048	-$2,817,952	$982,048	-$2,817,952	No
SAMA 11	$4250,000	$16,088,692	$11,838,692	$54,144,650	$49,894,650	No
SAMA 12	$50,000	$198,438	$148,438	$198,438	$148,438	No
SAMA 13	$950,000	$305,294	-$644,706	$305,294	-$644,706	No
SAMA 14	$3,150,000	$603,886	-$2,546,114	$603,888	-$2,546,112	No
SAMA 15	$450,000	$199,098	-$250,902	$200,003	-$249,997	No
SAMA 16	$1,100,000	$1,592,631	$492,631	$1,592,631	$492,631	No
SAMA 17	$950,000	$51,988	-$898,012	$51,988	-$898,012	No
SAMA 18	$100,000	$33,260	-$66,740	$40,379	-$59,621	No
SAMA 19	$760,000	$3,129,354	$2,369,354	$10,098,967	$9,338,967	No
SAMA 20	$3,030,000	$173,974	-$2,856,026	$173,974	-$2,856,026	No
SAMA 21	$1,200,000	$1,181,137	-$18,863	$3,908,256	$2,708,256	Yes
SAMA 22	$5,000,000	$1,253,768	-$3,746,232	$1,253,770	-$3,746,230	No
SAMA 23	$50,000	$30,629	-$19,371	$30,630	-$19,370	No
SAMA 24	$8,400,000	$4,416,201	-$3,983,799	$5,325,454	-$3,074,546	No
SAMA 25	$6,000,000	1,466,139	-$4,533,861	2,375,392	-$3,624,608	No
SAMA 26	$900,000	$369,663	-$530,337	$369,663	-$530,337	No
SAMA 27	$575,000	$1,306,819	$731,819	$1,306,819	$731,819	No
SAMA 28	$575,000	$47,891	-$527,109	$47,891	-$527,109	No
SAMA 29	$800,000	$25,716	-$774,284	$25,716	-$774,284	No
SAMA 30	$150,000	$25,716	-$124,284	$25,716	-$124,284	No
SAMA 32	$1,700,000	$13,052,022	$11,352,022	$51,109,295	$49,409,295	No
SAMA 33	$2,700,000	$9,142,285	$6,442,285	$43,403,546	$40,703,546	No

As demonstrated in the table above, of all the SAMAs evaluated, the “cost effectiveness” classification was only changed for SAMA 21. Given that the 95th percentile PRA results sensitivity presented in Section E.7.1 also identified this SAMA as potentially cost effective, it can be concluded that the results of the SAMA analysis are not impacted by making pessimistic assumptions related to external flooding risk at TMI-1.

E.7.5 SENSITIVITY ANALYSIS: IMPACT OF IMPLEMENTING SAMA 32

While the TMI-1 SAMA list is comprised of unique plant enhancements, it is not uncommon for one SAMA to address areas of risk that are also addressed by one or more other SAMAs. The implication is that implementing a SAMA may impact the net values of the non-implemented SAMAs. Depending on the nature of the SAMAs under consideration, implementation of any given SAMA may result in the reclassification of previously cost beneficial SAMAs as "not cost beneficial". Because SAMA 32 is a potential candidate for implementation at TMI-1, a sensitivity analysis has been performed to evaluate the impact of its implementation on the cost benefit analysis.

Because implementation of SAMA 32 results in a risk decrease, there is no mechanism that would allow a non-cost beneficial SAMA to become cost beneficial; therefore, this sensitivity analysis only addresses the SAMAs that were classified as cost beneficial in either the base case or the 95th percentile PRA results sensitivity case. Specifically, these SAMAs include: 2, 7, 8, 11, 12, 15, 16, 19, 21, 23, 24, 26, 27, and 33.

E.7.5.1 ANALYSIS PROCESS

The intent of this analysis is to quantify the net value of each SAMA assuming that SAMA 32 is already implemented at the site. In order to do this, it was necessary to define the PRA model configuration with SAMA 32 implemented as the new "base case". All model changes made to represent implementation of the other SAMAs were made using the new "base case" as the starting point. This allowed the risk reduction for each SAMA to be measured from the configuration in which SAMA 32 was implemented to the configuration in which SAMA 32 was implemented in conjunction with one additional SAMA.

Establishing SAMA 32 as the "base case" required no changes to the internal events model given that SAMA 32 did not impact internal events risk. Consequently, all of the internal events based risk reductions calculated for the cost beneficial SAMAs were unchanged from the original SAMA analysis. The same was true for the non-external flooding external events contributions given that they were directly derived from the internal events results through the use of a multiplier.

The external flooding results, however, were impacted by SAMA 32 and it was necessary to review the external flooding frequencies for each of the SAMAs and adjust them to account for the impacts of SAMA 32.

For all cases other than for SAMAs 11 and 33, the same quantification strategies described in Section E.6 were used to quantify the external flooding benefits of the SAMAs.

For SAMAs 11 and 33, additional work was required to define how multiple flood mitigation strategies would impact risk. The following table summarizes the assumptions used to perform the quantifications:

Quantification Strategy for Implementation of Multiple Flood Mitigation SAMAs

Case	Floods >310	Floods 305’ to 310’	Floods <305’
Implementation of SAMA 32 and SAMA 33	SAMA 33 would be the primary action with SAMA 32 as the backup. It is assumed that the failure probability for installing SAMA 33’s extended flood gates is the same as the IPEEE value of 5.62E-02 for the 305’ to 310’ floods (variable HSL1). Implementation of SAMA 32 is then addressed by a human dependence factor. Non-negligible dependence exists between the actions to install the flood gates and to implement SAMA 32, but the dependence is cognitive. As execution would be the majority contributor to the flood HEPs and because the execution and cognitive contributors are not separated for the flood actions, it would be overly conservative to use the dependence factors based on the available HEPs. To simulate the results of a true assessment, a moderate dependence factor (from equation 10-16 of NUREG/CR-1278 (NRC 1983)) is used rather than a high factor, which would likely be appropriate for the cognitive portion of the HEPs. The failure probability for SAMA 32 is, therefore, 0.14. The CDF for this sequence would be calculated as follows: CDF=2.5E-04*5.62E-02*0.14=1.97E-06	Having higher gates will not impact the installation failure probability significantly. With SAMA 32 implemented, the CDFs should be the same as with SAMA 32 alone.	This SAMA does not impact floods below 305’ msl. The CDF should be the same as with SAMA 32 alone.
Implementation of SAMA 32 and SAMA 11	The implementation of SAMA 11 would essentially result in a configuration that would supercede that established by SAMA 32. The CDF for this sequence would be calculated by multiplying the flooding frequency by the failure probability of SAMA 11 (2.05E-02): CDF=2.5E-04*2.05E-02=5.12E-06	The failure probabilities for SAMA 11 are dominated by hardware faults and use of a dependence factor is not required for addressing any potential dependence between installation of the flood panels and operation of SAMA 11. The CDF for these sequences should be obtained by multiplying the sequence CDFs by 2.05E-02. The 0.5 multiplier used in the IPEEE for the existing severe flood guidelines is disregarded and excluded from the calculation.	These sequences would be improved through implementation of SAMA 11. The original CDF, which is the same as the CDF with SAMA 32 implemented, should be multiplied by 2.05E-02.

Finally, the 95th percentile PRA results were used in the quantifications given that they are typically used in the final classification of a SAMA's cost benefit status.

E.7.5.2 RESULTS

The following table summarizes the results of the sensitivity analysis. As shown below, only one SAMA that was originally identified as potentially cost beneficial would be reclassified as "not cost beneficial" if SAMA 32 were implemented at the site (SAMA 21).

Results Summary for the SAMA 32 Implementation Sensitivity

SAMA ID	Cost of Implement-ation	Averted Cost- Risk (95th percentile PRA results)	Net Value (95th percentile PRA results	Averted Cost- Risk (SAMA 32 Implemented, 95th percentile PRA results)	Net Value (SAMA 32 Implemented, 95th percentile PRA results)	Change in Cost Effective-ness?
SAMA 2	$7,300,000	$11,816,753	$4,516,753	$10,016,562	$2,716,562	No
SAMA 7	$1,000,000	$1,235,449	$235,449	$1,235,451	$235,451	No
SAMA 8	$145,000	$3,395,359	$3,250,359	$3,395,359	$3,250,359	No
SAMA 11	$4,250,000	$44,243,903	$39,993,903	$8,339,832	$4,089,832	No
SAMA 12	$50,000	$545,705	$495,705	$545,705	$495,705	No
SAMA 15	$450,000	$547,520	$97,520	$545,562	$95,562	No
SAMA 16	$1,100,000	$4,379,735	$3,279,735	$4,379,738	$3,279,738	No
SAMA 19	$760,000	$8,601,659	$7,841,659	$2,528,235	$1,768,235	No
SAMA 21	$1,200,000	$3,248,127	$2,048,127	$921,330	-$278,670	Yes
SAMA 23	$50,000	$84,230	$34,230	$84,233	$34,233	No
SAMA 24	$8,400,000	$12,144,553	$3,744,553	$10,344,362	$1,944,362	No
SAMA 26	$900,000	$1,016,573	$116,573	$1,016,573	$116,573	No
SAMA 27	$575,000	$3,593,752	$3,018,752	$3,593,752	$3,018,752	No
SAMA 33	$2,700,000	$25,141,284	$22,441,284	$2,839,757	$139,757	No

For SAMAs 2, 11, 19, 21, 24, and 33, the averted cost-risk reductions were all over $1,000,000. A reduction of this magnitude indicates that a large portion of the risk originally intended to be addressed by these SAMAs was removed by SAMA 32 and implementation may not be appropriate. Final judgements related to these SAMAs would likely have to be made using insights outside of the PRA analysis.

The remaining SAMAs (7, 8, 12, 15, 16, 23, 26, and 27) are essentially independent of SAMA 32 and none of their averted cost-risk estimates were impacted by more than 1 percent. No changes to the conclusions related to these SAMAs would be expected based on implementation of SAMA 32.

E.7.6 SENSITIVITY ANALYSIS: IMPACT OF SECPOP ERROR CORRECTIONS

The SECPOP2000 code is used to process population and economic data to serve as input data for the Level 3 PRA code MACCS2 that is used to support SAMA evaluations. The SECPOP2000 code is sponsored by the NRC and is maintained by Sandia National Laboratory.

After completion of the TMI SAMA analysis, three SECPOP errors were identified that if uncorrected, result in MACCS2 utilizing incorrect data thereby impacting the SAMA cost benefit calculations. The TMI SAMA evaluation was not impacted by the first SECPOP error described in this discussion (i.e., Error #1), but the analysis is affected by the second and third errors (Error #2 and Error #3, respectively). All three errors are discussed below for completeness.

E.7.6.1 ERROR #1

In May 2007, a formatting error associated with the SECPOP2000 output file option (which generates a text file for use as an input file to MACCS2) was publicized throughout the industry. The error involves the formatting of the columns in the text file resulting in MACCS2 mis-reading the data. Exelon Risk Management was aware of this formatting error well before its publication throughout the industry. For the TMI SAMA analysis, Risk Management had manually corrected the alignment of the SECPOP2000 output for proper reading by MACCS2. As a result, the TMI SAMA evaluation is not impacted by this error.

E.7.6.2 ERROR #2

In mid-July 2007, an error associated with the formatting of the 1997 economic database file used by SECPOP2000 was discovered by a MACCS2 industry user. This error was discovered when the user attempted to update the database file with new data, and the SECPOP2000 output did not change. Investigation revealed that a formatting error in the database file resulted in SECPOP2000 processing incorrect economic and land use data (i.e., data is output for the wrong counties). The incorrect county selection results in incorrect data being used in MACCS2, ultimately influencing the SAMA cost benefit calculations. The magnitude of the error's impact on the results is different for each site as it depends on the relative difference between the correct county data and incorrect county data read by SECPOP2000, which varies for each county considered. As a result, a site-specific analysis is required to assess the impact on the cost benefit analysis.

E.7.6.3 ERROR #3

In early-August 2007, an additional SECPOP2000 error was identified related to the use of the 1997 economic database file. SECPOP2000 was written to process the county data based on a sequential county numbering system; however, there are gaps in the data file. The first gap appears at county number 955 and any county beyond 955 is handled incorrectly by SECPOP2000. This error was corrected by manipulating the county numbering system in the 1997 economic database file and re-running SECPOP2000.

The nature of Error #3 is similar to Error #2 in that its impact on the cost benefit analysis depends on the relative differences between the correct and incorrect county data. This varies for each county considered and as a result, obtaining an estimate of the impact of the error requires a site specific analysis.

E.7.6.4 IMPACT ON TMI MACR

Review of the TMI SAMA analysis indicates that correcting Error #2 and Error #3 results in a measurable change to both of the MACCS2 outputs that are used to quantify the TMI MACR:

- Dose
- Economic cost

After addressing the errors, the MACCS2 model was re-quantified and the revised results were used to update the MACR calculation. The following tables provide a summary of the corrected results compared with the base case. The designator "PE23" is used to identify the case in which both Error #2 and Error #3 have been corrected.

SECPOP2000 Error Corrections - Internal Events Results Overview

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
Internal Events Results - Base	2.37E-05	32.61	$112,259
Internal Event Results - Post Error Corrections (case PE23)	2.37E-05	32.33	$128,937
Percent Change	0.0%	-0.8%	14.8%

The following tables provide the release category specific results:

Release Category	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
Freq.(/yr)$_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Freq. (/yr)$_{PE23}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
Dose-Risk$_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
Dose-Risk$_{PE23}$	2.62	9.11	0.92	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.02	0.92	4.54	1.02	0.06
OECR$_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208
OECR$_{PE23}$	$14,670	$51,039	$3,873	$272	$4	$4	$8	$13	$398	$149	$87	$3,223	$17,071	$3,835	$242

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
Freq.(/yr)$_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Freq. (/yr)$_{PE23}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
Dose-Risk$_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
Dose-Risk$_{PE23}$	0.00	0.00	0.22	0.04	0.30	0.00	0.99	0.38	6.95	3.42	0.00	0.61	0.00	32.33
OECR$_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259
OECR$_{PE23}$	$3	$0	$880	$157	$981	$12	$3,248	$1,260	$22,904	$3,897	$5	$696	$6	$128,937

Based on these results, the revised non-external flooding cost-risk can be calculated using the methodology from Section E.4 and the 2.0 multiplier on the internal events results:

SECPOP2000 Error Corrections - Non-External Flooding Cost-Risk

PE23 Internal Events Cost-Risk	Non-Flood External Events Multiplier	Non-Ext. Flooding Cost-Risk
$3,514,124	2.0	$7,028,248

Because the Level 3 results are also used in the external flooding evaluation, the impact on the external flooding contribution must also be considered. The following tables summarize the changes to the external flooding results.

SECPOP2000 Error Corrections - External Flooding Results Overview

	CDF (/yr)	Dose-Risk (person-rem/yr)	OECR ($/yr)
External Flooding Results - Base	8.11E-05	177.16	$542,159
External Flooding Results - Post Error Corrections (PE23)	8.11E-05	175.86	$619,814
Percent Change	0.0%	-0.7%	14.3%

A further breakdown of this information is provided below according to flood sequence.

SECPOP2000 Error Corrections - External Flooding Contributions by Flood Sequence

Flood Category	>310'	305' to 310' sequence A	305' to 310' sequence B	305' to 310' sequence C	305' to 310' sequence D	305' to 310' sequence E	305' to 310' sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Freq. (/yr)$_{PE23}$	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
Dose-Risk$_{PE23}$	131.68	13.02	0.19	1.87	17.81	10.67	0.25	0.37	175.86
Base OECR	$405,951	$40,149	$598	$5,767	$54,839	$32,858	$778	$1,219	$542,159
OECR$_{PE23}$	$464,785	$45,968	$678	$6,603	$62,220	$37,281	$882	$1,397	$619,814

Based on these results, the revised external flooding cost-risk can be calculated using the methodology from Section E.4, which yields $16,672,271. Finally, the revised TMI MACR is the sum of the External Flooding and non-External Flooding contributors:

SECPOP2000 Error Corrections - MACR

PE23 Non-External Flooding Cost-Risk	PE23 External Flooding Cost-Risk	Total MACR (sum of Ext. Flood and Non-Ext. Flood)
$7,028,248	$16,672,271	$23,700,519

Given that the base case MACR was developed by rounding the results of the process documented in Section E.4 to the next highest thousand, the same is done here to obtain a MACR of $23,701,000. This result represents an increase over the base case of 7.3% (($23,701,000-$22,087,000)/ $22,087,000*100=7.3%).

Further investigations revealed that impacts on individual SAMA candidates may differ due to specific release category dependencies (i.e., some release categories may see increases while other release categories see decreases.) Therefore, changes to the averted cost-risk values for each SAMA candidate can not be readily predicted without a SAMA specific re-quantification, which is addressed in Section E.7.6.5.

E.7.6.5 IMPACT ON INDIVIDUAL SAMA CALCULATIONS

In addition to the impact on the MACR, the SECPOP errors also impacted the averted cost-risks and net values that were calculated for each of the SAMAs. The following table summarizes the impact of all SECPOP2000 error corrections (case PE23) in conjunction with the mean PRA results for the detailed cost-benefit calculations that were performed for the SAMA analysis.

Results Summary for SECPOP2000 Corrections (Case PE23, Mean PRA Results)

SAMA ID	Cost of Implement-ation	Averted Cost- Risk (Base)	Net Value (Base)	Averted Cost- Risk (PE23)	Net Value (PE23)	Change in Cost Effective-ness?
SAMA 1	$3,125,000	$986,145	-$2,138,855	$1,039,690	-$2,085,310	No
SAMA 2	$7,300,000	$4,297,001	-$3,002,999	$4,597,411	-$2,702,589	No
SAMA 3	$2,450,000	$594,926	-$1,855,074	$624,045	-$1,825,955	No
SAMA 5	$3,150,000	$230,163	-$2,919,837	$240,738	-$2,909,262	No
SAMA 6	$2,750,000	$398,924	-$2,351,076	$412,415	-$2,337,585	No
SAMA 7	$1,000,000	$449,254	-$550,746	$467,015	-$532,985	No
SAMA 8	$145,000	$1,234,676	$1,089,676	$1,318,032	$1,173,032	No
SAMA 10	$3,800,000	$982,048	-$2,817,952	$1,086,512	-$2,713,488	No
SAMA 11	$4250,000	$16,088,692	$11,838,692	$17,237,942	$12,987,942	No
SAMA 12	$50,000	$198,438	$148,438	$210,304	$160,304	No
SAMA 13	$950,000	$305,294	-$644,706	$333,154	-$616,846	No
SAMA 14	$3,150,000	$603,886	-$2,546,114	$630,447	-$2,519,553	No
SAMA 15	$450,000	$199,098	-$250,902	$209,632	-$240,368	No
SAMA 16	$1,100,000	$1,592,631	$492,631	$1,745,154	$645,154	No
SAMA 17	$950,000	$51,988	-$898,012	$55,242	-$894,758	No
SAMA 18	$100,000	$33,260	-$66,740	$32,229	-$67,771	No
SAMA 19	$760,000	$3,127,876	$2,367,876	$3,415,704	$2,655,704	No
SAMA 20	$3,030,000	$173,974	-$2,856,026	$189,934	-$2,840,066	No
SAMA 21	$1,200,000	$1,181,137	-$18,863	$1,292,074	$92,074	Yes
SAMA 22	$5,000,000	$1,253,768	-$3,746,232	$1,380,631	-$3,619,369	No
SAMA 23	$50,000	$30,629	-$19,371	$32,220	-$17,780	No
SAMA 24	$8,400,000	$4,416,201	-$3,983,799	$4,730,523	-$3,669,477	No
SAMA 25	$6,000,000	1,466,139	-$4,533,861	1,574,565	-$4,425,435	No
SAMA 26	$900,000	$369,663	-$530,337	$397,053	-$502,947	No
SAMA 27	$575,000	$1,306,819	$731,819	$1,403,645	$828,645	No
SAMA 28	$575,000	$47,891	-$527,109	$51,440	-$523,560	No
SAMA 29	$800,000	$25,716	-$774,284	$27,621	-$772,379	No
SAMA 30	$150,000	$25,716	-$124,284	$27,621	-$122,379	No
SAMA 32	$1,700,000	$13,052,022	$11,352,022	$14,000,044	$12,300,044	No
SAMA 33	$2,700,000	$9,142,285	$6,442,285	$9,807,683	$7,107,683	No

As demonstrated in the table, the SECPOP2000 error corrections had a relatively small impact on the averted cost-risk estimates and only one SAMA (SAMA 21) that was originally classified as "not cost beneficial" was re-classified as "cost beneficial" based on the use of the corrected input. Given that SAMA 21 was identified as potentially cost beneficial in the 95th percentile

PRA results sensitivity analysis that is documented in Section E.7.1, this change did not result in the identification of any new potentially cost beneficial SAMAs.

In addition to the review of the mean PRA results quantifications, it was necessary to examine how the 95th percentile PRA results quantifications were impacted given that they were also used to identify potentially cost beneficial SAMAs. The following table provides a summary of the cost benefit calculations using the results of the SECPOP2000 error corrections in conjunction with the 95th percentile PRA results. In this case, no SAMAs were identified as potentially cost beneficial that were not already identified in original 95th percentile PRA results sensitivity analysis documented in Section E.7.1.

Results Summary for SECPOP2000 Corrections (Case PE23, 95th Percentile PRA Results)

SAMA ID	Cost of Implement-ation	Averted Cost- Risk (Original 95th Percentile Results)	Net Value (Original 95th Percentile Results)	Averted Cost- Risk (PE23 with 95th Percentile Results)	Net Value (PE23 with 95th Percentile Results)	Change in Cost Effective-ness?
SAMA 1	$3,125,000	$2,711,899	-$413,101	$2,859,148	-$265,853	No
SAMA 2	$7,300,000	$11,816,753	$4,516,753	$12,642,880	$5,342,880	No
SAMA 3	$2,450,000	$1,636,047	-$813,954	$1,716,124	-$733,876	No
SAMA 5	$3,150,000	$632,948	-$2,517,052	$662,030	-$2,487,971	No
SAMA 6	$2,750,000	$1,097,041	-$1,652,959	$1,134,141	-$1,615,859	No
SAMA 7	$1,000,000	$1,235,449	$235,449	$1,284,291	$284,291	No
SAMA 8	$145,000	$3,395,359	$3,250,359	$3,624,588	$3,479,588	No
SAMA 10	$3,800,000	$2,700,632	-$1,099,368	$2,987,908	-$812,092	No
SAMA 11	$4250,000	$44,243,903	$39,993,903	$47,404,341	$43,154,341	No
SAMA 12	$50,000	$545,705	$495,705	$578,336	$528,336	No
SAMA 13	$950,000	$839,559	-$110,442	$916,174	-$33,827	No
SAMA 14	$3,150,000	$1,660,687	-$1,489,314	$1,733,729	-$1,416,271	No
SAMA 15	$450,000	$547,520	$97,520	$576,488	$126,488	No
SAMA 16	$1,100,000	$4,379,735	$3,279,735	$4,799,174	$3,699,174	No
SAMA 17	$950,000	$142,967	-$807,033	$151,916	-$798,085	No
SAMA 18	$100,000	$91,465	-$8,535	$88,630	-$11,370	No
SAMA 19	$760,000	$8,601,659	$7,841,659	$9,393,186	$8,633,186	No
SAMA 20	$3,030,000	$478,429	-$2,551,572	$522,319	-$2,507,682	No
SAMA 21	$1,200,000	$3,248,127	$2,048,127	$3,553,204	$2,353,204	No
SAMA 22	$5,000,000	$3,447,862	-$1,552,138	$3,796,735	-$1,203,265	No
SAMA 23	$50,000	$84,230	$34,230	$88,605	$38,605	No
SAMA 24	$8,400,000	$12,144,553	$3,744,553	$13,008,938	$4,608,938	No
SAMA 25	$6,000,000	$4,031,882	-$1,968,118	$4,330,055	-$1,669,945	No

Results Summary for SECPOP2000 Corrections (Case PE23, 95th Percentile PRA Results)

SAMA ID	Cost of Implement-ation	Averted Cost- Risk (Original 95th Percentile Results)	Net Value (Original 95th Percentile Results)	Averted Cost- Risk (PE23 with 95th Percentile Results)	Net Value (PE23 with 95th Percentile Results)	Change in Cost Effective-ness?
SAMA 26	$900,000	$1,016,573	$116,573	$1,091,894	$191,894	No
SAMA 27	$575,000	$3,593,752	$3,018,752	$3,860,024	$3,285,024	No
SAMA 28	$575,000	$131,701	-$443,299	$141,459	-$433,541	No
SAMA 29	$800,000	$70,719	-$729,281	$75,958	-$724,042	No
SAMA 30	$150,000	$70,719	-$79,281	$75,958	-$74,042	No
SAMA 32	$1,700,000	$35,893,061	$34,193,061	$38,500,121	$36,800,121	No
SAMA 33	$2,700,000	$25,141,284	$22,441,284	$26,971,128	$24,271,128	No

E.8 CONCLUSIONS

The benefits of revising the operational strategies in place at TMI-1 and/or implementing hardware modifications can be evaluated without the insight from a risk analysis. Use of the PRA in conjunction with cost-benefit analysis methodologies has, however, provided an enhanced understanding of the effects of the proposed changes relative to the cost of implementation and projected impact on offsite dose and economic impacts. The results of this study indicate that of the identified potential improvements that can be made at TMI-1, several are cost beneficial based on the methodology applied in this analysis.

The baseline Phase II analysis indicates that the following SAMAs are potentially cost beneficial:

- SAMA 8: Automate Reactor Coolant Pump Trip (on high motor bearing temperature)
- SAMA 11: Enhance Extreme External Flooding Mitigation Equipment to Address SBO and Loss of Seal Cooling Scenarios
- SAMA 12: Use the DHR System as an Alternate Suction Source for HPI
- SAMA 16: Automate HPI Injection on Low Pressurizer Level
- SAMA 19: Install Battery Backed Hydrogen Igniters or a Passive Hydrogen Ignition System
- SAMA 27: Improve the 480V AC load center welds
- SAMA 32: Pre-stage Severe Flooding Equipment
- SAMA 33: Increase the Flood Protection Height

In addition, when the 95th percentile PRA results are used in the analysis, the following additional SAMAs are potentially cost beneficial:

- SAMA 2: Install Damage Resistant, High Temperature RCP Seals with a Portable 480V Generator for Extended EFW Operation
- SAMA 7: Use Fire Service Water as an Alternate Cooling Source for the ICCW Heat Exchangers

- SAMA 15: Automate Swap to Recirculation Mode
- SAMA 21: Install Concrete Shields to Block Direct Pathways from the RPV to the Containment Wall and/or Direct Containment Flooding Early in External Flooding Scenarios
- SAMA 23: Develop Alarm Response Procedures to Direct Operation of RR-V-5 on Low RBEC Flow
- SAMA 24: Install Damage Resistant, High Temperature RCP Seals with a Diesel Engine as an Alternate Drive for an EFW Pump and a Portable Generator for Level Control Instrumentation
- SAMA 26: Reroute Cables so that They Do Not Pass Over Ignition Sources in Fire Area CB-FA-2e (West Inverter Room) or Wrap them in Fire Proof Material

While the identification of a SAMA as potentially “cost beneficial” indicates that it may be advantageous to implement the SAMAs from a PRA based risk reduction perspective, not all of the SAMAs should be designated as serious candidates for implementation. Some of the SAMAs address the same types of risk such that implementation of a given SAMA would significantly reduce or eliminate the benefit of another SAMA. In addition, there are differences in the level of uncertainty in the PRA bases that support the SAMA cost benefit calculations. While a particular SAMA may show a large potential risk reduction, it would be inappropriate to justify the expenditure of a large sum of money to address a risk that is likely overstated by pessimistic PRA assumptions or technical limitations. Table E.8.1 summarizes these considerations for the SAMAs that have been identified as potentially cost beneficial for TMI-1. In addition, this table provides the following information:

- The implementation cost for the SAMA
- Averted cost-risk (based on the 95th percentile PRA results),
- Net value (based on the 95th percentile PRA results), and
- The ratio of the averted cost-risk per dollar of implementation cost (identified as the “dollar per dollar” (DPD) ratio).

E.9 FIGURES

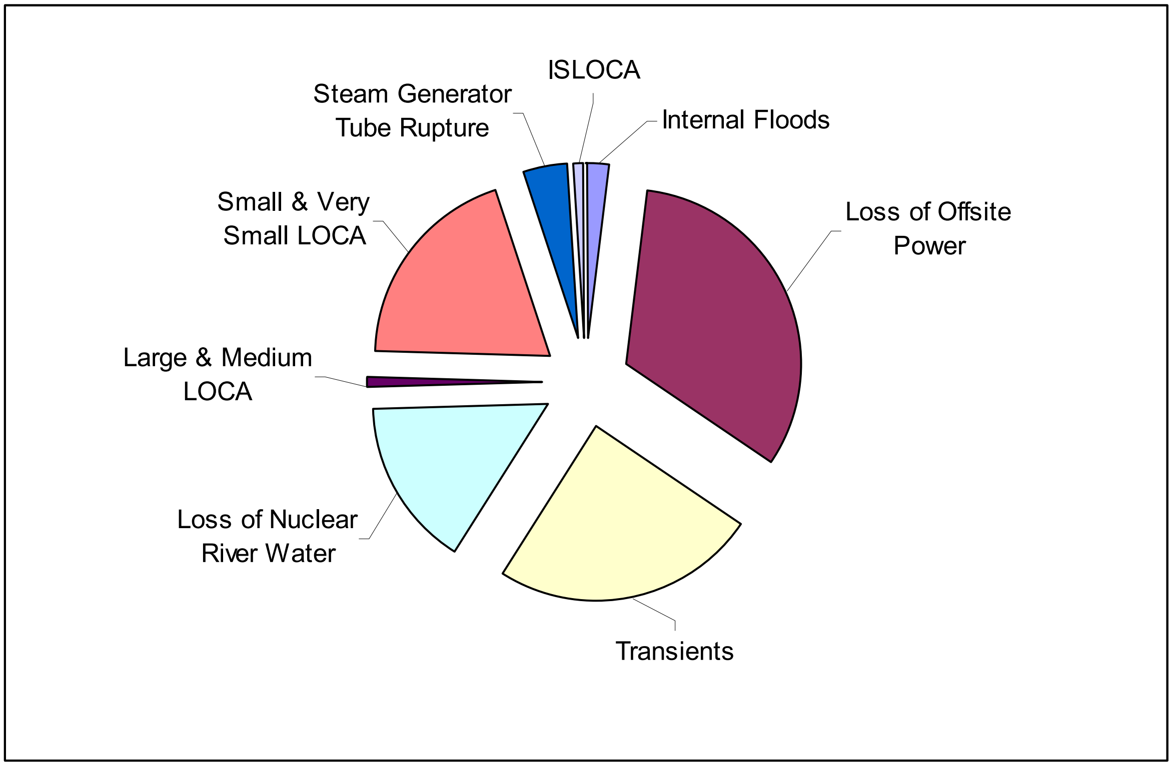


Figure E.2-1
TMI-1 Level 1 CDF Contributions

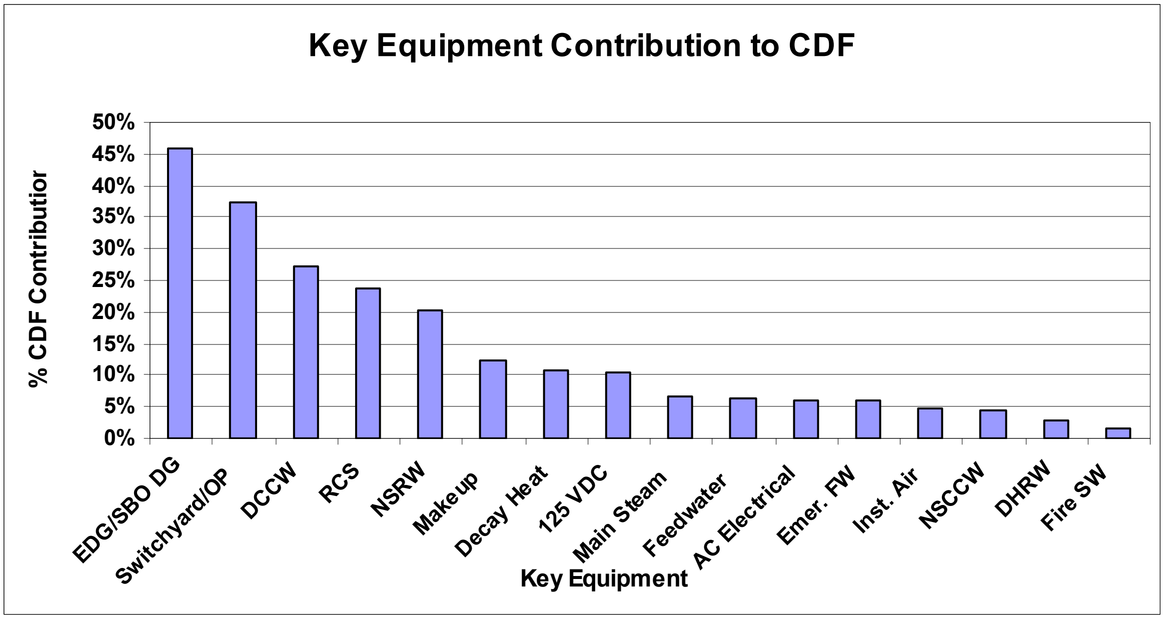


Figure E.2-2
TMI-1 System Importance Rankings

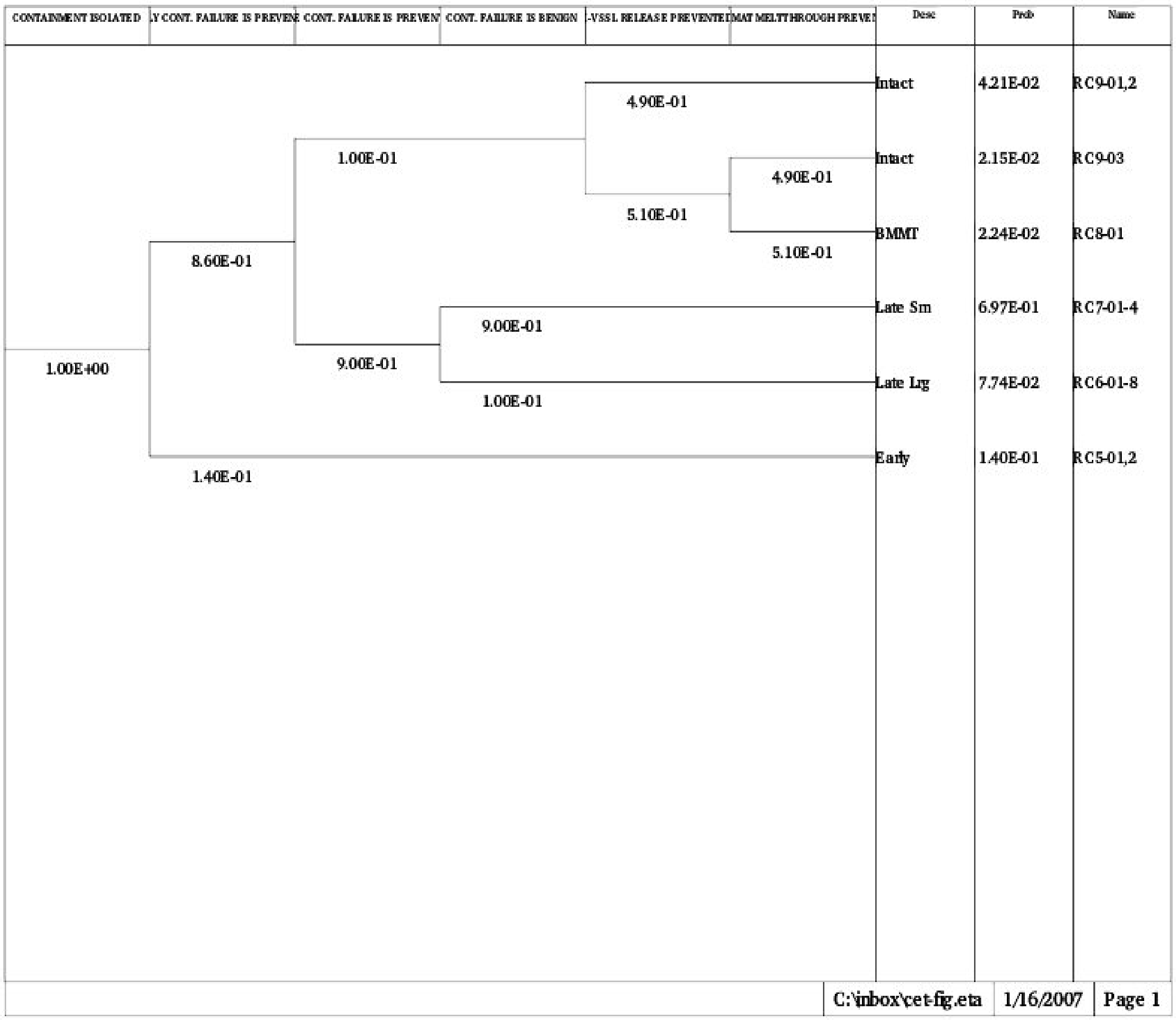


Figure E.2-3
Simplified CET Binning Logic for External Flooding Analysis

E.10 TABLES

TABLE E.2-1
THREE MILE ISLAND PRA MODEL SUMMARY

Model Revision Date	Model Name	Internal Events Excluding Internal Flooding (1/yr)	Seismic (1/yr)	Internal Flooding (1/yr)	Total CDF (1/yr)	Total LERF (1/yr)	Trunc. Limit (1/yr)	Notes
Nov. 1987	Original PRA	4.43E-4	2.70E-6	<1.0E-5	5.5E-4	NA	NR	1
Dec. 1992	IPE	4.19E-5	-	-	4.19E-5	NA	NR	2
Dec. 1994	IPEEE Update	-	3.21E-5	-	-	NA	-	3
Aug. 2000	2000 Update	3.74E-5	-	3.0E-06	4.1E-5	3.75E-6	NR	4
Nov. 2001	L2RV2	3.69E-5	-	2.56E-6	3.95E-5	2.70E-6	1E-12	5
Jul. 2003	ABSA	3.33E-5	-	3.5E-7	3.38E-5	1.39E-6	1E-14	6
Dec. 2004	2004 Rev. 0	3.07E-5	-	2.6E-7	3.09E-5	-	1E-11	7
Jun. 2005	2004 Rev. 1	3.32E-5	-	3.7E-7	3.36E-5	-	1E-11	8
June 2007	2004 Rev. 2	2.32E-5	-	4.5E-7	2.37E-5	3.02E-06	1E-11	9

Notes:

1. Original PRA for Three Mile Island Unit 1; Truncation limit not reported (NR). All sequences quantified but some are grouped with more severe support states. LERF not computed.
2. 1992 update for the IPE. Control building ventilation failures deleted from model based on physical testing of the system and rooms served. Truncation limit not reported. LERF not computed.
3. IPEEE update. Seismic results not modified since this report.
4. TMI RISKMAN® 2000 Update; Level 2 added to model for first time. Truncation limit not reported. Model reflects plant design as of 1998 (see Reference [9]).
5. TMI RISKMAN® L2RV2 model: Level 2 model directly linked with Level 1 sequences.
6. TMI RISKMAN® ABSA model: Revisions in support of responses to peer certification comments. Plant model reflects plant design as of January, 2003 (see Reference [8]).
7. TMI CAFTA® 2004, Rev. 0 model: Initial conversion of ABSA Level 1 model from RISKMAN® to CAFTA® software. This model was never officially implemented. Level 2 model not revised.
8. TMI CAFTA® 2004, Rev. 1 model: Implementation of various model changes and improvements since Revision 0 (see Reference [4]). Level 2 model not revised.
9. TMI CAFTA® 2004, Rev. 2 model: Implementation of various model changes and improvements since Revision 1 (see Reference [5]). New Level 2 model (see Reference [6]) developed using CAFTA® based on February 1993 Level 2 model (see Reference [3]).

TABLE E.2-2
CORE MELT BINS

BIN #	DESCRIPTION
1	Large LOCA, injection failure
2	Large LOCA, early recirculation failure
3	Large LOCA, late recirculation failure
4	Medium LOCA, injection failure
5	Medium LOCA, early recirculation failure
6	Medium LOCA, late recirculation failure
7	Small LOCA, injection failure, steam generators available
8	Small LOCA, recirculation failure, steam generators available
9	Small LOCA, injection failure, steam generators unavailable
10	Small LOCA, early recirculation failure, steam generators unavailable
11	Small LOCA, late recirculation failure, steam generators unavailable
12	Cycling relief valve, injection failure
13	Cycling relief valve, early recirculation failure
14	Cycling relief valve, late recirculation failure
15	Steam generator tube rupture, injection failure, steam generators unavailable
16	Steam generator tube rupture, early recirculation failure, steam generators unavailable
17	Steam generator tube rupture, late recirculation failure, steam generators unavailable
18	Steam generator tube rupture, steam generators available
19	Interfacing-systems LOCA

TABLE E.2-3
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 TRANSIENT CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
GT-004	13 or 14	Depending on time of recirculation failure.
GT-005	2	Based on PTS failures assuming to be a part of this core melt bin.
GT-006	12	

**TABLE E.2-4
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1
LOOP-SBO CORE DAMAGE STATES**

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
LOOP-002	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-004	13 or 14	Depending on time of recirculation failure.
LOOP-005	12	
LOOP-006	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-009	8	
LOOP-011	7	
LOOP-012	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-014	10 or 11	Depending on time of recirculation failure.
LOOP-015	9	
LOOP-016	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-018	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-021	13 or 14	Depending on time of recirculation failure.
LOOP-022	12	
LOOP-023	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-025	13 or 14	Depending on time of recirculation failure.
LOOP-026	12	
LOOP-027	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-030	8	
LOOP-032	7	
LOOP-033	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-036	8	
LOOP-038	7	
LOOP-039	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-042	8	
LOOP-044	7	
LOOP-046	10 or 11	Depending on time of recirculation failure.
LOOP-047	9	
LOOP-048	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-050	10 or 11	Depending on time of recirculation failure.
LOOP-051	9	

TABLE E.2-4
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 LOOP-SBO CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
LOOP-052	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-055	8	
LOOP-057	7	
LOOP-058	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-059	7	
LOOP-062	8	
LOOP-064	7	
LOOP-066	10 or 11	Depending on time of recirculation failure.
LOOP-067	9	
LOOP-068	2	Based on PTS failures assuming to be a part of this core melt bin.
LOOP-069	9	

TABLE E.2-5
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 VERY SMALL LOCA CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
VSL-004	8	Conservatively binned since depressurization was successful
VSL-006	8	
VSL-007	2	Based on PTS failures assuming to be a part of this core melt bin.
VSL-011	8	Conservatively binned since depressurization was successful
VSL-013	8	
VSL-014	2	Based on PTS failures assuming to be a part of this core melt bin.
VSL-016	10 or 11	Depending on time of recirculation failure.
VSL-017	2	Based on PTS failures assuming to be a part of this core melt bin.
VSL-018	10	
VSL-019	9	SSHR is assumed unavailable.

TABLE E.2-6
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 SMALL LOCA CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
SL-002	10 or 11	Depending on time of recirculation failure. SSHR is assumed unavailable.
SL-003	2	Based on PTS failures assuming to be a part of this core melt bin.
SL-005	8	
SL-006	2	Based on PTS failures assuming to be a part of this core melt bin.
SL-008	8	
SL-009	2	Based on PTS failures assuming to be a part of this core melt bin.
SL-010	10	Failure of early recirculation is assumed.
SL-011	9	SSHR is assumed unavailable.

TABLE E.2-7
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 MEDIUM LOCA CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
ML-002	5 or 6	Depending on time of recirculation failure.
ML-003	4	Injection failure is assumed, even though partial injection was successful.
ML-004	4	

TABLE E.2-8
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 LARGE LOCA CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
LL-002	2 or 3	Depending on time of recirculation failure.
LL-003	1	Injection failure is assumed, even though partial injection was successful.
LL-004	1	

TABLE E.2-9
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 SGTR CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
SGTR-004	18	
SGTR-006	18	
SGTR-010	18	
SGTR-012	18	
SGTR-013	16	Since SSHR is unavailable, water is assumed to be present in containment due to primary pressure relief.
SGTR-014	16	SSHR is assumed unavailable.
SGTR-015	15	SSHR is assumed unavailable.

TABLE E.2-10
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 STEAMLINE BREAKS UPSTREAM MSIVS CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
SLBI-003	13 or 14	Depending on time of recirculation failure.
SLBI-004	13	Conservative assumption due to failure of pressure relief.
SLBI-005	12	
SLBI-007	10 or 11	Depending on time of recirculation failure. SSHR is assumed unavailable.
SLBI-008	9	SSHR is assumed unavailable.
SLBI-010	13 or 14	Depending on time of recirculation failure.
SLBI-011	13	Conservative assumption due to failure of pressure relief.
SLBI-012	2	Based on PTS failures assuming to be a part of this core melt bin.
SLBI-013	12	

TABLE E.2-11
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 STEAMLINE BREAKS DOWNSTREAM MSIVS CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
SLBO-004	13 or 14	Depending on time of recirculation failure.
SLBO-005	13	Conservative assumption due to failure of pressure relief.
SLBO-006	2	Based on PTS failures assuming to be a part of this core melt bin.
SLBO-007	12	
SLBO-009	10 or 11	Depending on time of recirculation failure. SSHR is assumed unavailable.
SLBO-010	2	Based on PTS failures assuming to be a part of this core melt bin.
SLBO-011	9	SSHR is assumed unavailable.

TABLE E.2-12
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 ATWS CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
ATWS-002	14	Least conservative bin, since core damage may not result for this sequence.
ATWS-003	12	
ATWS-005	14	Least conservative bin, since core damage may not result for this sequence.
ATWS-006	12	
ATWS-007	12	Failure of injection is assumed
ATWS-008	12	Failure of injection is assumed
ATWS-009	1	Injection is assumed ineffective
ATWS-010	1	Injection is assumed ineffective

TABLE E.2-13
CORE MELT BIN ASSIGNMENTS FOR LEVEL 1 ISLOCA CORE DAMAGE STATES

SEQUENCE ID [6]	CORE MELT ASSIGNMENTS FROM TABLE E.2-2	COMMENTS
ISLOC-001	19	

TABLE E.2-14
CONTAINMENT SAFEGUARDS/ISOLATION STATE

STATE ID	DESCRIPTION
A	All safeguards available, containment isolated
B	Fans available, sprays available in injection mode; sprays unavailable in recirculation mode, containment isolated
C	Fans available; sprays unavailable in injection and recirculation modes, containment isolated
D	Sprays available in injection and recirculation modes; fans unavailable, containment isolated
E	Sprays in injection mode available; fans unavailable, sprays unavailable in recirculation mode, containment isolated
F	No safeguards available, containment isolated
G	All safeguards available, small isolation failure
H	Fans available, sprays available in injection mode; sprays unavailable in recirculation mode, small isolation failure
I	Fans available; sprays unavailable in injection and recirculation modes, small isolation failure
J	Sprays available in injection and recirculation modes; fans unavailable, small isolation failure
K	Sprays in injection mode available; fans unavailable, sprays unavailable in recirculation mode, small isolation failure
L	No safeguards available, small isolation failure
M	All safeguards available, large isolation failure
N	Fans available, sprays available in injection mode; sprays unavailable in recirculation mode, large isolation failure
O	Fans available; sprays unavailable in injection and recirculation modes, large isolation failure
P	Sprays available in injection and recirculation modes; fans unavailable, large isolation failure
Q	Sprays in injection mode available; fans unavailable, sprays unavailable in recirculation mode, large isolation failure
R	No safeguards available, large isolation failure

TABLE E.2-15
CONTAINMENT EVENT TREE TOP EVENTS

EVENT NODE/STATE	DESCRIPTION
A	**Containment Bypass**
Success	Containment is available as a barrier to fission product release
Failure	Containment is not available as a barrier to fission product release (SGTR, ISLOCA)
B	**Containment Isolation**
Success	Containment is isolated
Failure	Containment is not isolated
C	**Large Isolation Failure**
Success	Isolation failure is small
Failure	Isolation failure is large
D	**Auxiliary Building Release**
Success	Fission product release is through the Auxiliary Building
Failure	Fission product release does not go through the Auxiliary Building
E	**Early Containment Failure**
Success	Early containment failure does not take place
Failure	Early containment failure does occur
F	**Late Containment Failure**
Success	Late containment failure does not take place
Failure	Late containment failure does occur
G	**Benign Containment Failure**
Success	Containment failure is benign, i.e., leak before break
Failure	Containment failure is catastrophic
H	**Ex-Vessel Release of Fission Products**
Success	Ex-vessel release is prevented
Failure	Ex-vessel release is not prevented
I	**Containment Basemat Failure**
Success	Containment failure from basemat melt-through is prevented
Failure	Containment failure from basemat melt-through occurs
J	**Revaporization Release**
Success	Revaporization release does not take place
Failure	Revaporization release does occur
K	**Fission Product Scrubbing**
Success	Fission products are scrubbed in containment, steam generator, or Auxiliary Building
Failure	Fission products are not scrubbed

TABLE E.2-16
INDIVIDUAL RELEASE CATEGORY DEFINITIONS

RELEASE CATEGORY	DEFINITION	BASELINE FREQUENCY (/YR)
1.01	Containment bypass, outside the auxiliary building, with fission product scrubbing, release begins at approximately 4 hrs	4.57E-07
1.02	Containment bypass, outside the auxiliary building, without fission product scrubbing, release begins at approximately 3 hrs	1.59E-06
2.01	Containment bypass, to the auxiliary building, without ex-vessel release of fission products, with fission product scrubbing, release begins at approximately 4 hrs	0.0
2.02	Containment bypass, to the auxiliary building, without ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 3 hrs	1.81E-07
2.03	Containment bypass, to the auxiliary building, with ex-vessel release of fission products, with fission product scrubbing, release begins at approximately 4 hrs	0.0
2.04	Containment bypass, to the auxiliary building, with ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 3 hrs	1.27E-08
3.01	Large isolation failure, to the auxiliary building, without ex-vessel release of fission products, with fission product scrubbing, release begins at approximately 1.5 hrs	9.07E-11
3.02	Large isolation failure, to the auxiliary building, without ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 1.5 hrs	9.07E-11
3.03	Large isolation failure, to the auxiliary building, with ex-vessel release of fission products, with fission product scrubbing, release begins at approximately 1.5 hrs	1.90E-10
3.04	Large isolation failure, to the auxiliary building, with ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 1.5 hrs	2.88E-10
3.05	Large isolation failure, outside the auxiliary building, without ex-vessel release of fission products, release begins at approximately 1.5 hrs	0.0
3.06	Large isolation failure, outside the auxiliary building, with ex-vessel release of fission products, release begins at approximately 1.5 hrs	0.0
4.01	Small isolation failure, to the auxiliary building, without ex-vessel release of fission products, with fission product scrubbing, release begins at approximately 2.5 hrs	3.90E-08
4.02	Small isolation failure, to the auxiliary building, without ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 2.5 hrs	1.46E-08

TABLE E.2-16
INDIVIDUAL RELEASE CATEGORY DEFINITIONS

RELEASE CATEGORY	DEFINITION	BASELINE FREQUENCY (/YR)
4.03	Small isolation failure, to the auxiliary building, with ex-vessel release of fission products, with fission product scrubbing, release begins at approximately 2.5 hrs	8.54E-09
4.04	Small isolation failure, to the auxiliary building, with ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 2.5 hrs	3.16E-07
4.05	Small isolation failure, to the environment, without ex-vessel release of fission products, with fission product scrubbing, release begins at approximately 2.5 hrs	0.0
4.06	Small isolation failure, to the environment, without ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 2.5 hrs	0.0
4.07	Small isolation failure, to the environment, with ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 2.5 hrs	0.0
4.08	Small isolation failure, to the environment, with ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 2.5 hrs	0.0
5.01	Early containment failure, without ex-vessel fission product release, release begins at approximately 3.25 hrs	7.39E-07
5.02	Early containment failure, with ex-vessel fission product release, release begins at approximately 5.5 hrs	1.66E-07
6.01	Late overpressurization, with catastrophic containment failure, without ex-vessel fission product release, without revaporization, with fission product scrubbing, release begins at approximately 45 hrs	0.0
6.02	Late overpressurization, with catastrophic containment failure, without ex-vessel fission product release, without revaporization, without fission product scrubbing, release begins at approximately 45 hrs	0.0
6.03	Late overpressurization, with catastrophic containment failure, without ex-vessel fission product release, with revaporization, with fission product scrubbing, release begins at approximately 45 hrs	2.20E-08
6.04	Late overpressurization, with catastrophic containment failure, without ex-vessel fission product release, with revaporization, without fission product scrubbing, release begins at approximately 45 hrs	2.36E-10
6.05	Late overpressurization, with catastrophic containment failure, with ex-vessel release of fission products, without revaporization, with fission product scrubbing, release begins at approximately 45 hrs	2.08E-11
6.06	Late overpressurization, with catastrophic containment failure, with ex-vessel release of fission products, without revaporization, without fission product scrubbing, release begins at approximately 45 hrs	0.0

TABLE E.2-16
INDIVIDUAL RELEASE CATEGORY DEFINITIONS

RELEASE CATEGORY	DEFINITION	BASELINE FREQUENCY (/YR)
6.07	Late overpressurization, with catastrophic containment failure, with ex-vessel release of fission products, with revaporization, with fission product scrubbing, release begins at approximately 45 hrs	8.00E-08
6.08	Late overpressurization, with catastrophic containment failure, with ex-vessel release of fission products, with revaporization, without fission product scrubbing, release begins at approximately 45 hrs	1.43E-08
7.01	Late overpressurization, with benign containment failure, without ex-vessel fission product release, with fission product scrubbing, release begins at approximately 14.5 hrs	2.25E-07
7.02	Late overpressurization, with benign containment failure, without ex-vessel fission product release, without fission product scrubbing, release begins at approximately 14.5 hrs	2.75E-09
7.03	Late overpressurization, with benign containment failure, with ex-vessel release of fission products, with fission product scrubbing, release begins at approximately 14.5 hrs	7.45E-07
7.04	Late overpressurization, with benign containment failure, with ex-vessel release of fission products, without fission product scrubbing, release begins at approximately 14.5 hrs	7.89E-07
8.01	Containment failure from basemat melt-through, with ex-vessel release of fission products, release begins at approximately 36 hrs	3.19E-06
9.01	No containment failure, without ex-vessel fission product release, with fission product scrubbing, release begins at approximately 0.5 hrs	1.32E-05
9.02	No containment failure, without ex-vessel fission product release, without fission product scrubbing, release begins at approximately 2.5 hrs	1.69E-08
9.03	No containment failure, with ex-vessel fission product release, with fission product scrubbing, release begins at approximately 2.5 hrs	2.36E-06
9.04	No containment failure, with ex-vessel fission product release, without fission product scrubbing, release begins at approximately 2.5 hrs	1.91E-08

TABLE E.2-17
SUMMARY OF REPRESENTATIVE MAAP SEQUENCES FOR TMI-1 SOURCE TERMS

MAAP CASE	NAME	DESCRIPTION	EFW	SEAL LOCA?	SPRAYS ON?	FANS ON?	TCU HOURS	TCD HOURS	HLCR HOURS	TVF HOURS	TCF HOURS	TEND HOURS	NG FRACTION	CSI FRACTION
TM0034	INTACT	No cont failure, no exvessel rel, FP scrbbed	Y	Y	Y	Y	18.8	26.0	26.7	34.6	NA	48	1.2E-01	4.6E-04
TM0035	BMMT	Basemat melt w/o debris cooling	Y	Y	N	N	18.7	26.0	26.6	34.7	64.4	48	9.7E-01	8.7E-03
TM0036	LATE - SM	Small late containment failure	6 hrs	Y	N	N	8.2	9.0	9.9	16.5	52.1	72	7.0E-01	6.5E-03
TM0037	LATE-LRG	Large containment failure	Y	Y	N	N	18.8	26.0	26.6	34.8	70.8	72	1.0E+00	6.9E-02
TM0038	EARLY	Early containment failure at vessel breach	6 hrs	Y	N	N	8.2	9.3	NA	11.7	11.7	48	1.0E+00	6.0E-02
TM0039	ISO-SM	Containment isolation failure - small	N	Y	N	N	0.6	0.8	1.4	6.0	0.0	48	8.3E-01	3.4E-02
TM0040	ISO-LRG	Containment isolation failure - large	6 hrs	Y	N	N	8.5	9.4	10.0	16.0	0.0	48	1.0E+00	2.3E-01
TM0041	ISLOCA	.003 ft^2 break	N	N	N	N	15.0	15.8	16.8	24.3	NA	72	9.2E-01	1.8E-01
TM0042	SGTR	.0066 ft^2 break	N	N	N	N	12.7	13.5	16.6	18.3	NA	48	1.0E+00	6.5E-01

Notes to Table E.2-17:

EFW	Is EFW available for makeup?
Tcu	Time of core uncovery
Tcd	Time of core damage (max core > 1800F)
Tvf	Time of vessel failure
Tcf	Time of containment failure
Tend	End time of scenario run
NG	Noble Gas release
CsI	CsI release

TABLE E.2-18
TMI-1 SOURCE TERM SUMMARY

RELEASE CATEGORY	INTACT	BMMT	LATE-SM	LATE-LRG	EARLY	ISO-SM	ISO-LRG	ISLOCA	SGTR
MAAP Case ID	TM0034	TM0035	TM0036	TM0037	TM0038	TM0039	TM000040	TM0041	TM0042
Run Duration	48 hr	72 hr	72 hr	120	48 hr	48 hr	48 hr	72 hr	48 hr
Time after Scram when General Emergency is declared (3)	26 hr	26 hr	9 hr	26 hr	9.3 hr	0.8 hr	9.4 hr	15.8 hr	13.5 hr
Fission Product Group:									
1) Noble									
Total Plume 1 Release Fraction	1.25E-01	3.00E-01	7.00E-01	1.00E+00	1.00E+00	8.30E-01	1.00E+00	9.20E-01	1.00E+00
Start of Plume 1 Release (hr)	26.00	26.00	10.00	70.80	11.70	1.00	10.00	16.00	14.00
End of Plume 1 Release (hr)	48.00	64.00	72.00	70.80	11.70	48.00	20.00	20.00	16.00
Total Plume 2 Release Fraction[2]		1.00E+00							
Start of Plume 2 Release (hr)		64.00							
End of Plume 2 Release (hr)		64.00							
2) CsI									
Total Plume 1 Release Fraction	4.60E-04	8.70E-03	6.50E-03	7.00E-02	6.00E-02	3.40E-02	2.30E-01	1.80E-01	2.00E-02
Start of Plume 1 Release (hr)	26.00	26.00	10.00	70.80	11.70	1.00	10.00	16.00	14.00
End of Plume 1 Release (hr)	30.00	50.00	20.00	100.00	11.70	8.00	16.00	25.00	14.00
Total Plume 2 Release Fraction[2]									6.50E-01
Start of Plume 2 Release (hr)									34.00
End of Plume 2 Release (hr)									44.00
3) TeO2									
Total Plume 1 Release Fraction	4.60E-04	9.00E-03	9.00E-03	2.00E-02	3.80E-02	1.50E-02	2.00E-01	6.00E-02	1.00E-02
Start of Plume 1 Release (hr)	26.00	26.00	10.00	70.80	11.70	1.00	10.00	16.00	14.00
End of Plume 1 Release (hr)	30.00	50.00	20.00	100.00	11.70	8.00	16.00	20.00	14.00
Total Plume 2 Release Fraction[2]									4.00E-02
Start of Plume 2 Release (hr)									34.00
End of Plume 2 Release (hr)									44.00

TABLE E.2-18
TMI-1 SOURCE TERM SUMMARY

RELEASE CATEGORY	INTACT	BMMT	LATE-SM	LATE-LRG	EARLY	ISO-SM	ISO-LRG	ISLOCA	SGTR
4) SrO									
Total Plume 1 Release Fraction	7.00E-05	8.50E-04	4.00E-04	5.00E-06	4.50E-03	1.50E-03	1.00E-02	6.00E-03	9.00E-04
Start of Plume 1 Release (hr)	29.00	30.00	10.00	70.80	11.70	1.00	12.00	16.00	14.00
End of Plume 1 Release (hr)	32.00	40.00	20.00	70.80	20.00	8.00	20.00	20.00	24.00
Total Plume 2 Release Fraction[2]									
Start of Plume 2 Release (hr)									
End of Plume 2 Release (hr)									
5) MoO2									
Total Plume 1 Release Fraction	3.50E-04	4.00E-03	2.80E-03	2.00E-05	2.00E-02	2.00E-02	3.50E-02	3.00E-02	6.00E-03
Start of Plume 1 Release (hr)	29.00	30.00	10.00	70.80	11.70	1.00	10.00	16.00	14.00
End of Plume 1 Release (hr)	32.00	40.00	20.00	70.80	11.70	8.00	16.00	20.00	14.00
Total Plume 2 Release Fraction[2]									
Start of Plume 2 Release (hr)									
End of Plume 2 Release (hr)									
6) CsOH									
Total Plume 1 Release Fraction	4.50E-04	9.00E-03	5.50E-03	2.00E-02	3.00E-02	1.00E-02	1.50E-01	5.00E-02	2.00E-02
Start of Plume 1 Release (hr)	26.00	26.00	10.00	70.80	11.70	1.00	10.00	16.00	14.00
End of Plume 1 Release (hr)	30.00	50.00	20.00	100.00	11.70	8.00	16.00	20.00	14.00
Total Plume 2 Release Fraction[2]									9.00E-02
Start of Plume 2 Release (hr)									34.00
End of Plume 2 Release (hr)									44.00
7) BaO									
Total Plume 1 Release Fraction	1.80E-04	3.00E-03	1.00E-03	1.20E-05	5.00E-03	9.00E-03	1.50E-02	2.50E-02	2.00E-03
Start of Plume 1 Release (hr)	29.00	30.00	10.00	70.80	11.70	1.00	10.00	16.00	14.00
End of Plume 1 Release (hr)	32.00	40.00	20.00	70.80	20.00	8.00	16.00	20.00	14.00
Total Plume 2 Release Fraction[2]									
Start of Plume 2 Release (hr)									
End of Plume 2 Release (hr)									

TABLE E.2-18
TMI-1 SOURCE TERM SUMMARY

RELEASE CATEGORY	INTACT	BMMT	LATE-SM	LATE-LRG	EARLY	ISO-SM	ISO-LRG	ISLOCA	SGTR
8) La2O3									
Total Plume 1 Release Fraction	2.00E-06	5.50E-05	3.00E-05	5.50E-07	5.50E-04	1.00E-04	9.00E-04	2.50E-04	1.00E-04
Start of Plume 1 Release (hr)	29.00	30.00	10.00	70.80	11.70	1.00	14.00	16.00	14.00
End of Plume 1 Release (hr)	32.00	40.00	20.00	70.80	20.00	8.00	20.00	20.00	24.00
Total Plume 2 Release Fraction[2]									
Start of Plume 2 Release (hr)									
End of Plume 2 Release (hr)									
9) CeO2									
Total Plume 1 Release Fraction	1.00E-05	5.20E-04	5.00E-04	1.00E-05	1.50E-02	1.50E-03	2.00E-02	1.50E-03	2.00E-03
Start of Plume 1 Release (hr)	29.00	30.00	10.00	70.80	11.70	4.00	14.00	16.00	14.00
End of Plume 1 Release (hr)	32.00	50.00	20.00	70.80	20.00	10.00	20.00	26.00	24.00
Total Plume 2 Release Fraction[2]									
Start of Plume 2 Release (hr)									
End of Plume 2 Release (hr)									
10) Sb									
Total Plume 1 Release Fraction	4.00E-04	1.50E-02	8.00E-03	5.00E-02	1.80E-01	5.00E-02	1.50E-01	1.50E-01	7.00E-01
Start of Plume 1 Release (hr)	29.00	30.00	10.00	70.80	11.70	1.00	10.00	16.00	28.00
End of Plume 1 Release (hr)	32.00	40.00	20.00	120.00	20.00	8.00	20.00	20.00	30.00
Total Plume 2 Release Fraction[2]									
Start of Plume 2 Release (hr)									
End of Plume 2 Release (hr)									
11) Te2									
Total Plume 1 Release Fraction	0.00E+00	1.00E-04	3.00E-05	1.50E-03	2.00E-04	4.00E-03	7.00E-04	9.00E-05	2.00E-04
Start of Plume 1 Release (hr)		30.00	18.00	70.80	11.70	6.00	16.00	30.00	20.00
End of Plume 1 Release (hr)		40.00	20.00	70.80	20.00	16.00	20.00	40.00	24.00
Total Plume 2 Release Fraction[2]									
Start of Plume 2 Release (hr)									
End of Plume 2 Release (hr)									

TABLE E.2-18
TMI-1 SOURCE TERM SUMMARY

RELEASE CATEGORY	INTACT	BMMT	LATE-SM	LATE-LRG	EARLY	ISO-SM	ISO-LRG	ISLOCA	SGTR
12) UO2									
Total Plume 1 Release Fraction	0.00E+00	5.00E-06	2.80E-06	1.50E-06	1.20E-04	1.00E-05	2.00E-04	5.00E-06	1.00E-05
Start of Plume 1 Release (hr)		30.00	18.00	70.80	11.70	6.00	16.00	30.00	20.00
End of Plume 1 Release (hr)		50.00	20.00	70.80	20.00	16.00	20.00	40.00	24.00
Total Plume 2 Release Fraction[2]									
Start of Plume 2 Release (hr)									
End of Plume 2 Release (hr)									

Notes to Table E.2-18:

(1) Puff releases are denoted in the table by those entries with equivalent start and end times.
(2) Plume 2 release fraction is cumulative and includes the initial plume 1 release fraction
(3) General Emergency declaration based on time of core damage per Radiological Emergency Plant for TMI, EP-AA-1009 Revision 7

TABLE E.2-19
TMI-1 INITIATING EVENT CONTRIBUTIONS TO CDF

INITIATOR	PROBABILITY	%CDF
Loss of Offsite Power	7.73E-06	32.6%
Transients	5.80E-06	24.5%
Small & Very Small LOCA	4.66E-06	19.7%
Loss of Nuclear River Water	3.67E-06	15.5%
Steam Generator Tube Rupture	9.93E-07	4.2%
Internal Floods	4.50E-07	1.9%
Large & Medium LOCA	2.06E-07	0.9%
ISLOCA	1.80E-07	0.8%

TABLE E.2-20
TMI-1 TOP INITIATING EVENT CONTRIBUTIONS FOR EACH RELEASE CATEGORY

RELEASE CATEGORY GROUP	RELEASE CATEGORY FREQUENCY (1/YR)	PERCENT CONTRIBUTION OF TOP INITIATING EVENTS
1	2.04E-6	27.5%: Loss of Instrument Air 25.2%: "A" Division SGTR 25.2%: "B" Division SGTR
2	1.93E-7	97.8%: Interfacing System LOCA 1.0%: Loss of Offsite Power 0.3%: Loss of 4160V AC Bus
3	6.60E-10	80.9%: Loss of Offsite Power 19.1%: Loss of 4160V AC Bus
4	3.78E-7	87.7%: Loss of Offsite Power 4.1%: Loss of 4160V AC Bus 3.0%: Steam Line Break
5	9.05E-7	35.3%: Loss of Offsite Power 18.1%: Loss of Nuclear River Water 13.3%: Very Small LOCA
6	1.17E-7	89.7%: Loss of Offsite Power 4.3%: Loss of 4160V AC Bus 2.2%: Very Small LOCA
7	1.26E-6	90.1% Loss of Offsite Power 3.8%: Loss of 4160V AC Bus 2.0%: Very Small LOCA
8	3.19E-6	77.5%: Loss of Offsite Power 6.4%: Very Small LOCA 4.8%: Loss of Nuclear River Water
9	1.44E-5	36.5%: Loss of Offsite Power 18.9%: Loss of Nuclear River Water 10.2%: Very Small LOCA

TABLE E.2-21
EXTERNAL FLOODING CDF SUMMARY

SEQUENCE IDENTIFIER	LEVEL 1 SEQUENCE DESCRIPTION	FREQUENCY (/YR)*
>310 Feet	No detailed core damage progression information is available for these floods in the IPEEE. Based on the available text, successful installation of flood gates would delay the time to equipment damage, but not prevent it (SBO and core damage would still occur). The IPEEE indicates that there should be several hours available between a high water level warning and the onset of flooding, even for hurricane events. This is in addition to the warnings that would exist related to any incoming storm. As a result, it is assumed that the reactor is placed in cold shutdown prior to the onset of site flooding. Core damage ultimately occurs after the failure of the extreme flooding measures.	6.37E-05
305 to 310 feet Sequence “A”	Flood event occurs, Offsite power is available, Flood preparations fail given that transition to cold shutdown was successful.	6.30E-06
305 to 310 feet Sequence “B”	Flood event occurs, Offsite power is available, Transition to cold shutdown fails, Flood preparations fail given that transition to cold shutdown failed.	6.65E-08
305 to 310 feet Sequence “C”	Flood event occurs, Offsite power is unavailable (on-site power OK), Flood preparations fail given that transition to cold shutdown was successful.	9.05E-07
305 to 310 feet Sequence “D”	Flood event occurs, Offsite power is unavailable (on-site power OK), Transition to cold shutdown fails, Flood preparations fail given that transition to cold shutdown failed.	6.10E-06
305 to 310 feet Sequence “E”	Flood event occurs, Offsite power is unavailable, On-site power is unavailable.	3.66E-06
305 to 310 feet Sequence “F”	Flood event occurs, Early warning system fails.	8.65E-08
<305 feet	A site flood with river levels between 300 and 305 feet occurs only with a dike failure. All safety equipment appears to be contained in buildings that do not have penetrations below the 305 foot level. Offsite power equipment in the switchyard is not damaged until flood levels reach 307 feet, which would imply off-site power is available if the grid is energized (not likely in a hurricane induced event). The CDF estimated in the IPEEE is based on the flooding frequency, the probability of dam failure, and an assumed 0.1 conditional core damage probability. No details are available related to the core damage progression.	2.5E-07
TOTAL		8.11E-05

* Includes credit for current severe flooding guidelines.

TABLE E.2-22
CET NODE BINNING CHARACTERISTICS

CET NODE	BINNING CHARACTERISTIC
Early Containment Failure is Prevented	Used to identify “early” containment failures. Failure of the node denotes an early containment breach has occurred while success indicates that the containment remains intact or fails late.
Late Containment Failure is Prevented	Failure of the node implies a “late” containment overpressurization failure has occurred. The success path contains both “no containment failure” cases and basemat melt through cases.
Containment Failure is Benign	For late overpressurization failure cases, success of this node indicates that containment failure results in a “small” release pathway while failure of the node indicates a “large” release pathway has opened.
Ex-Vessel Release of Fission Products is Prevented	Release of the fission products from the vessel is used to determine whether or not a basemat failure could occur. If the corium is retained in the vessel (success of the node), no basemat failure is possible. Failure of the node requires a subsequent evaluation of the interaction between the corium and the containment floor.
Containment Failure From Basemat Melt through is Prevented	For those cases in which the fission products are not retained in the vessel, failure of this node implies that the containment basemat fails due to the interaction between the concrete and the corium. Success of the node implies that the containment remains intact.

TABLE E.2-23
FLOOD SEQUENCE SOURCE TERM FREQUENCIES

FLOOD SEQUENCE	SGTR (RC1)	ISLOCA (RC2)	ISO-LRG (RC3)	ISO-SM (RC4)	EARLY (RC5)	LATE-LRG (RC6)	LATE-SM (RC7)	BMMT (RC8)	INTACT (RC9)
>310' Flood Freq.(/yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.92E-06	4.93E-06	4.44E-05	1.43E-06	4.05E-06
305' to 310' Sequence A Freq. (/yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.82E-07	4.88E-07	4.39E-06	1.41E-07	4.01E-07
305' to 310' Sequence B Freq. (/yr)	0.00E+00	0.00E+00	0.00E+00	6.65E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
305' to 310' Sequence C Freq. (/yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.27E-07	7.00E-08	6.31E-07	2.03E-8	5.76E-08
305' to 310' Sequence D Freq. (/yr)	0.00E+00	0.00E+00	0.00E+00	6.10E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
305' to 310' Sequence E Freq. (/yr)	0.00E+00	0.00E+00	0.00E+00	3.66E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
305' to 310' Sequence F Freq. (/yr)	0.00E+00	0.00E+00	0.00E+00	8.65E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Floods <305' msl	1.68E-07	0.00E+00	0.00E+00	3.32E-09	2.11E-08	0.00E+00	1.09E-08	3.38E-08	1.64E-07

TABLE E.2-24
TMI PEER REVIEW SUMMARY OVERALL ASSESSMENT

PRA ELEMENT	GRADE BASED ON SUB-ELEMENTS
Initiating Events (IE)	3 (C)
Accident Sequence Evaluation (AS)	3
Thermal Hydraulic Analysis (TH)	2 (C)
Systems Analysis (SY)	3 (C)
Data Analysis (DA)	3 (C)
Human Reliability Analysis (HR)	2
Dependency Analysis (DE)	3
Structural Response (ST)	3
Quantification (QU)	3
Containment Performance Analysis (L2)	2 (C)
Maintenance and Update Process (MU)	2 (C)

Overall Assessment: The Three Mile Island PRA can be effectively used to support applications involving risk significant determinations supported by deterministic analysis, once the technical issues and recommendations for enhancements that are noted in the element summaries and Fact and Observation Sheets are addressed. When these enhancements are addressed for thermal hydraulics analysis, containment performance analysis, and the maintenance and update process, the current PRA elements are capable of supporting risk-ranking elements.

Areas Requiring Enhancement: Significant opportunities for enhancements to support applications involving risk significance determinations were identified for all PRA elements except for Accident Sequence Evaluation, Dependency Analysis, Structural Response, and Level 1 Sequence Quantification. The peer review process for TMI-1 resulted in one ‘A’, 29 ‘B’, 37 ‘C’, and 14 ‘D’ level F&O findings identified during the review. All ‘A’ and ‘B’ F&Os have been closed with the exception of SY-21. See Section E.2.4.

(C): This identifier is used to denote a grade that is conditional on the resolution of specific review comments; if the comment(s) is/are not resolved, a lower grade would be appropriate.

TABLE E.3-1
ESTIMATED POPULATION DISTRIBUTION WITHIN A 50-MILE RADIUS OF THREE MILE ISLAND, YEAR 2034

Sector	0-1 mile (1.00) [(1)]	1-2 miles (1.78) [(1)]	2-3 miles (1.00) [(1)]	3-4 miles (1.14) [(1)]	4-5 miles (1.22) [(1)]	5-10 miles (1.33) [(1)]	10-mile total
N	0	228	3110	9798	455	19442	33034
NNE	0	1226	267	684	899	24566	27642
NE	0	1930	465	667	440	4138	7639
ENE	46	228	79	706	1491	3663	6212
E	26	154	51	656	2652	27227	30766
ESE	25	411	230	547	1151	6719	9084
SE	0	1005	77	714	550	5184	7530
SSE	85	389	354	748	448	4606	6630
S	0	0	311	1693	1804	12795	16603
SSW	0	0	625	251	1061	6100	8036
SW	0	2136	567	1991	645	3262	8600
WSW	0	881	199	1785	1276	3569	7710
W	0	3090	448	2491	3593	8835	18456
WNW	0	3273	64	995	1751	17079	23162
NW	0	0	35	0	4158	46674	50867
NNW	0	0	892	1551	4192	32894	39529
Total	182	14950	7774	25277	26565	226752	301500

[(1)] Ten year radial population growth factor applied to year 2000 census data to develop year 2034 estimate.

TABLE E.3-2
ESTIMATED POPULATION DISTRIBUTION WITHIN A 50-MILE RADIUS OF THREE MILE ISLAND, YEAR 2034

Sector	0-10 miles	10-20 miles (1.09) [1]	20-30 miles (1.10) [1]	30-40 miles (1.12) [1]	40-50 miles (1.11) [1]	50-mile total
N	33034	16171	11115	12504	66687	139511
NNE	27642	21750	5535	23296	62672	140895
NE	7639	42789	76809	18906	88956	235099
ENE	6212	14482	23100	67848	300119	411762
E	30766	24171	110948	76620	66474	308978
ESE	9084	64191	201929	49553	84839	409596
SE	7530	30257	16040	25237	45943	125006
SSE	6630	69506	22672	26782	145000	270590
S	16603	127880	32539	35911	154350	367283
SSW	8036	54317	71630	37706	87671	259361
SW	8600	13149	31487	45963	36183	135382
WSW	7710	12601	15712	15080	41633	92736
W	18456	32360	56527	25691	33767	166801
WNW	23162	96481	26716	10568	7576	164503
NW	50867	113320	16415	17466	23171	221239
NNW	39529	65264	19006	14046	22665	160510
Total	301500	798690	738178	503178	1267705	3609252

(1) Ten year radial population growth factor applied to year 2000 census data to develop year 2034 estimate.

TABLE E.3-3
THREE MILE ISLAND MACCS2 CORE INVENTORY

ENTRY	NUCLIDE(2)	THREE MILE ISLAND MACCS2(1)	ENTRY	NUCLIDE(2)	THREE MILE ISLAND MACCS2(1)
1	Co-58	2.475E+16	31	Te-131m	3.774E+17
2	Co-60	1.890E+16	32	Te-132	3.774E+18
3	Kr-85	3.885E+16	33	I-131	2.645E+18
4	Kr-85m	8.620E+17	34	I-132	3.811E+18
5	Kr-87	6.067E+15	35	I-133	5.549E+18
6	Kr-88	1.702E+18	36	I-134	6.141E+18
7	Rb-86	2.397E+18	37	I-135	5.142E+18
8	Sr-89	2.900E+18	38	Xe-133	5.549E+18
9	Sr-90	3.126E+17	39	Xe-135	2.038E+18
10	Sr-91	3.959E+18	40	Cs-134	6.326E+17
11	Sr-92	4.144E+18	41	Cs-136	1.754E+17
12	Y-90	3.226E+17	42	Cs-137	4.255E+17
13	Y-91	3.548E+18	43	Ba-139	5.105E+18
14	Y-92	4.144E+18	44	Ba-140	4.920E+18
15	Y-93	4.624E+18	45	La-140	4.994E+18
16	Zr-95	4.587E+18	46	La-141	4.661E+18
17	Zr-97	4.661E+18	47	La-142	4.550E+18
18	Nb-95	4.587E+18	48	Ce-141	4.514E+18
19	Mo-99	5.031E+18	49	Ce-143	4.477E+18
20	Tc-99m	4.403E+18	50	Ce-144	3.626E+18
21	Ru-103	4.033E+18	51	Pr-143	4.403E+18
22	Ru-105	2.690E+18	52	Nd-147	1.839E+18
23	Ru-106	1.521E+18	53	Np-239	4.994E+19
24	Rh-105	2.538E+18	54	Pu-238	1.428E+16
25	Sb-127	2.767E+17	55	Pu-239	1.114E+15
26	Sb-129	8.361E+17	56	Pu-240	1.199E+15
27	Te-127	3.677E+16	57	Pu-241	4.957E+17
28	Te-127m	2.741E+17	58	Am-241	7.621E+14
29	Te-129	1.232E+17	59	Cm-242	1.794E+17
30	Te-129m	8.213E+17	60	Cm-244	1.454E+16

1. Core inventory obtained from TMI specific calculation C-1101-900-E-220-178
2. MACCS2 allows up to 60 nuclides input

TABLE E.3-4
MACCS2 RELEASE CATEGORIES VS. THREE MILE ISLAND RELEASE CATEGORIES

MACCS2 Release Categories	Three Mile Island Release Categories
1-Xe/Kr	Noble Gases
2-I	CsI
3-Cs	CsOH
4-Te	TeO2 (Sb(1) & Te2(2) are included)
5-Sr	SrO
6-Ru(Mo)	MoO2 (Mo is in Ru MACCS category)
7-La	La2O3
8-Ce	CeO2 (UO2(2) are included)
9-Ba	BaO

(1) The largest release fraction of the TeO2 and Sb category is used
(2) These release fractions are typically negligible.

TABLE E.3-5
MACCS2 BASE CASE MEAN RESULTS

SOURCE TERM (DESIGNATOR)	RELEASE CATEGORY	DOSE (P-SV)	DOSE (P-REM)	OFFSITE ECONOMIC COST ($)
1 (SGTR)	RC1-01 - RC1-02	5.72E+04	5.72E+06	2.78E+10
2 (ISLOCA)	RC2-01 - RC2-04	5.05E+04	5.05E+06	1.86E+10
3 (ISO-LRG)	RC3-01 - RC3-06	8.91E+04	8.91E+06	3.76E+10
4 (ISO-SM)	RC4-01 - RC4-08	2.93E+04	2.93E+06	8.99E+09
5 (EARLY)	RC5-01 - RC5-02	6.15E+04	6.15E+06	2.02E+10
6 (LATE-LRG)	RC6-01 - RC6-08	2.81E+04	2.81E+06	9.45E+09
7 (LATE-SM)	RC7-01 - RC7-04	1.35E+04	1.35E+06	3.82E+09
8 (BMMT)	RC8-01	2.22E+04	2.22E+06	6.28E+09
9 (INTACT)	RC9-01 - RC9-04	2.67E+03	2.67E+05	2.62E+08

TABLE E.3-6
RELEASE CATEGORY SPECIFIC MACCS2 BASE CASE MEAN RESULTS

RELEASE CATEGORY	RC1-01	RC1-02	RC2-02	RC2-04	RC3-01	RC3-02	RC3-03	RC3-04	RC4-01	RC4-02	RC4-03	RC4-04	RC5-01	RC5-02	RC6-03
$Freq.(/yr)_{BASE}$	4.57E-07	1.59E-06	1.81E-07	1.27E-08	9.07E-11	9.07E-11	1.90E-10	2.88E-10	3.90E-08	1.46E-08	8.54E-09	3.16E-07	7.39E-07	1.66E-07	2.20E-08
$Dose\text{-}Risk_{BASE}$	2.61	9.09	0.91	0.06	0.00	0.00	0.00	0.00	0.11	0.04	0.03	0.93	4.54	1.02	0.06
$OECR_{BASE}$	$12,705	$44,202	$3,367	$236	$3	$3	$7	$11	$351	$131	$77	$2,841	$14,928	$3,353	$208

Release Category	RC6-04	RC6-05	RC6-07	RC6-08	RC7-01	RC7-02	RC7-03	RC7-04	RC8-01	RC9-01	RC9-02	RC9-03	RC9-04	Sum of Annual Risk
$Freq.(/yr)_{BASE}$	2.36E-10	2.08E-11	8.00E-08	1.43E-08	2.25E-07	2.75E-09	7.45E-07	2.89E-07	3.19E-06	1.32E-05	1.69E-08	2.36E-06	1.91E-08	2.37E-05
$Dose\text{-}Risk_{BASE}$	0.00	0.00	0.22	0.04	0.30	0.00	1.01	0.39	7.08	3.53	0.00	0.63	0.01	32.61
$OECR_{BASE}$	$2	$0	$756	$135	$860	$11	$2,846	$1,104	$20,033	$3,461	$4	$618	$5	$112,259

TABLE E.3-7
EXTERNAL FLOODING BASE CASE MEAN RESULTS

Flood Category	>310'	305' to 310' Sequence A	305' to 310' Sequence B	305' to 310' Sequence C	305' to 310' Sequence D	305' to 310' Sequence E	305' to 310' Sequence F	<305' (uses LOOP RC distribution)	Total External Flood Frequency
Base Frequency	6.37E-05	6.30E-06	6.65E-08	9.05E-07	6.10E-06	3.66E-06	8.65E-08	2.50E-07	8.11E-05
Base Dose-Risk	132.75	13.13	0.19	1.89	17.87	10.71	0.25	0.37	177.16
Base OECR	4.06E+05	4.01E+04	5.98E+02	5.77E+03	5.48E+04	3.29E+04	7.78E+02	1.22E+03	$542,159

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
%AC	4.48E-02	1.484	LOSS OF OFFSITE POWER	The importance of the LOOP initiator flag provides limited information about plant risk given that the LOOP category is broad and includes several different contributors. These contributors are represented by other events in this importance list that better define specific failures that can be investigated to identify means of reducing plant risk. No credible means of reducing the TMI-1 LOOP frequency have been identified. Implementation of the Maintenance Rule is considered to address equipment reliability issues such that no measurable improvement is likely available based on enhancing maintenance practices. It may be possible to improve switchyard work planning and/or practices, but a reliable means of quantifying the impact of these types of changes is not available. No SAMAs suggested.
RECOVERY-LOOP-01	4.97E-01	1.216	NONRECOVERY OF OFFSITE POWER	This OSP recovery failure event is related to conditions in which only one EDG (potentially the SBO EDG) is available, EFW is successful, but a seal LOCA occurs due to loss of seal cooling. For these cases, auto alignment and load capability for the SBO EDG would allow recovery of emergency AC power in time to prevent seal damage (SAMA 1). Alternatively, damage resistant, high temperature seals could be installed to eliminate most of the seal leakage after loss of cooling and delay core damage long enough to align the SBO EDG or recover OSP. This SAMA also includes the use of a portable 480V AC generator to power a division of battery chargers and maintain MCR control of EFW (SAMA 2).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
%VSB	2.56E-03	1.177	VERY SMALL BREAK LOCA	Multiple failure types contribute, including failures of HPI, DHRW, and DHCCW. The DHRW and DHCCW failures may be eliminated by providing connections from the NSCCW system to the DHR heat exchangers (DH-C-1A/B) to provide emergency heat removal (SAMA 3). Some of the injection failures are caused by division "A" power failures related to "in-series" HPI minimum flow valves MU-V-36 and MU-V-37. These types of failures could be eliminated by powering these two valves from the MCC 1C ESV swing bus (SAMA 4). Alternatively, MU-V-76A and B (and MU-V-77A/B) could be replaced with MOVs to allow rapid alignment of the "C" pump to seal injection (eliminates pump damage from recirc path failures) (SAMA 5). Cross-ties between trains of the DHR related systems would also reduce risk (SAMA 6).
%LNR	3.42E-03	1.177	LOSS OF NUCLEAR RIVER WATER	A large majority of the contribution from this event corresponds to the non-recoverable NSRW failures. For many of these contributors, MU-V-76A and B (and MU-V-77A/B) could be replaced with MOVs to allow rapid alignment of the "C" pump to seal injection (eliminates pump damage from recirc path failures) (SAMA 5). For those contributors where DHRW or DHCCW fail, a hard piped connection to the FSW system could be used to cool the ICCW heat exchangers to provide backup cooling in the event that the normal supply is lost (SAMA 7).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
LOCA-SIZE-101	7.80E-01	1.164	PROBABILITY THAT RCP SEAL LOCA IS OF VSLOCA CATEGORY	Almost 40% of the contributors include hardware failures that would disable NSRW so that the cross-tie from SSRW would not be available. A hard-piped connection from the FSW could be used as a backup supply to the ICCW heat exchangers. This arrangement has the advantage over use of SSRW to NSRW that the integrity of the NSRW system does not need to be confirmed before cooling to the Thermal Barriers can be re-established through alignment of FSW to the ICCW heat exchangers. Given that the ICCW pumps would be available for the relevant cases, a local, manual valve could be used for the alignment as time should be available for such an action (SAMA 7). For other contributors, MU-V-76A and B (and MU-V-77A/B) could be replaced with MOVs to allow rapid alignment of the "C" pump to seal injection (eliminates pump damage from recirc path failures) (SAMA 5).
FLAG-SBOALIGN-1E	5.00E-01	1.103	SBO ALIGNED TO BUS 1E	The contributors containing this event lead to RCP seal LOCAs. These events could be mitigated using damage resistant, high temperature seals (SAMA 2). In addition, these events all include an unrecovered failure of the "A" AC division, which leads to failure of the HPI makeup pumps for this initiator due to loss of the "C" HPI pump minimum flow path. These failures could be addressed by powering valves MU-V-36 and MU-V-37 from MCC 1C ESV (SAMA 4). Even if the SBO EDG functions as designed, the time to align it to an emergency bus is longer that the time to assumed seal damage. If auto alignment and load capability were provided, it would reduce the seal LOCA contribution (SAMA 1).
RECOVERY-LOOP-03	8.11E-02	1.101	NONRECOVERY OF OFFSITE POWER	This power recovery event is used in cases where no EDGs are available and EFW is initially successful. Installing high temperature, damage resistant seals with a portable generator to power SG level instrumentation for EFW operation would allow long term SBO mitigation (SAMA 2).
RARB-STANDBYFLAG	5.00E-01	1.098	BOTH DHRW TRAINS A AND B IN STANDBY	The event is associated with loss of DHRW flow events. Use of the NSCCW system to cool the DHR heat exchangers (DH-C-1A/B) would provide alternate heat removal capabilities (SAMA 3).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
NON-RECOV-LNR-IE	2.70E-01	1.096	NON-RECOVERABLE FRACTION OF %LNR EVENTS	For many of the non-recoverable loss of NSRW contributors, MU-V-76A and B (and MU-V-77A/B) could be replaced with MOVs to allow rapid alignment of the "C" pump to seal injection (eliminates pump damage from recirc path failures) (SAMA 5). For those contributors where DHRW or DHCCW fail, a hard piped connection to the FSW system could be used to cool the ICCW heat exchangers to provide backup cooling in the event that the normal supply is lost (SAMA 7).
GB-EDG-1B---DGFR	2.07E-02	1.095	DIESEL 1B FAILS TO RUN	Most of the contributors containing this event lead to RCP seal LOCAs. These events could be mitigated using damage resistant, high temperature seals (SAMA 2). In addition, these events typically include an unrecovered failure of the "A" AC division, which leads to failure of the HPI makeup pumps for this initiator due to loss of the "C" HPI pump minimum flow path. These failures could be addressed by powering valves MU-V-36 and MU-V-37 from MCC 1C ESV (SAMA 4). Even if the SBO EDG is available, the time to align it to an emergency bus is longer that the time to assumed seal damage. If auto alignment and load capability were provided, it would reduce the seal LOCA contribution (SAMA 1).
GA-EDG-1A---DGFR	2.07E-02	1.081	DIESEL 1A FAILS TO RUN	Most of the contributors with EDG "A" failure result in seal LOCAs due to loss of power. A majority of the total is related to REC-LOOP-101 sequences in which EFW is available and the SBO EDG is aligned after seal damage. High temperature, damage resistant seals (SAMA 2) would address most of these cases. Alternatively, providing auto alignment and load capability for the SBO EDG would preclude initial seal damage (SAMA 1). In addition, some of these events include unrecovered failure of the "A" AC division, which leads to failure of all HPI makeup pumps for this initiator due to loss of the "C" HPI pump minimum flow path. These failures could be addressed by powering valves MU-V-36 and MU-V-37 from MCC 1C ESV (SAMA 4).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
%LNS	2.74E-03	1.079	LOSS OF NUCLEAR SERVICES CLOSED COOLING WATER	A large portion of the contributors including this event are related to the operator failure to trip the RCPs on loss of cooling. This contribution could be reduced if high temperature sensors on the motor bearing cooling water lines were installed and used to provide automatic trip signals for the pumps (SAMA 8).
RECOVERY--LNR-IE	7.30E-01	1.067	RECOVERABLE FRACTION OF %LNR EVENTS	Providing a hardpiped connection from the FSW system to the ICCW heat exchangers would provide an alternate cooling source for the ICCW system on loss of NSRW; however, the dependence between the operator action to perform this cross-tie and the one to SSRW would be high or complete and the benefit would be minimal. Enhancing the MU-V-76A/B valves so that they are operable from the MCR would allow the operators to provide a seal injection path for the "C" HPI pump in a timely manner based on different cues (SAMA 5). This option may provide slightly more benefit and would also prevent the seal LOCA that dominates the cutsets that include "RECOVERY--LNR-IE".
INHINJ2_MUHHMUOA	1.00E+00	1.067	OPERATOR OPENS CROSS CONNECT VALVES MU-V-76A/B AND STARTS MU-P-1C	MU-V-76A and B (and MU-V-77A/B) are the manual HPI swing pump valves, which require local manipulation to align. Providing motor operators to the valves with controls in the MCR would allow for rapid alignment of the "B" HPI pump to either division in accident conditions. This would also allow the "C" pump to be quickly aligned for seal injection (eliminates pump damage from recirc path failures). Provisions for allowing rapid alignment of the valve and pump power sources must also be made in order to make the SAMA fully functional (SAMA 5).
JHHOT1-XTIEHEPOA	5.10E-02	1.066	OTHOT1_RCPTHP1OA AND NR-NRSRXTIEHVAOA	The contribution from the failure of this JHEP could be reduced if high temperature sensors on the motor bearing cooling water lines were installed and used to provide automatic trip signals for the pumps (SAMA 8). The automation of the RCP trip action would remove the important dependence issue and is considered to be an effective means of addressing this dependent combination for TMI-1.

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
DABB1A------BYFD	4.84E-04	1.062	FAILURE OF BATTERY BANK 1A ON DEMAND	About 75% of these contributors are LOOP/seal LOCAs with initial EFW success. Installation of the damage resistant, high temperature seals would prevent loss of primary coolant while removing heat with EFW, which would allow for operation out to at least 24 hours and provide recovery opportunities (SAMA 2). Even if the SBO EDG is available, the time to align it to an emergency bus is longer than the time to assumed seal damage. If auto alignment and load capability were provided, it would reduce the seal LOCA contribution (SAMA 1).
AV-LOCADV--HCDOA	1.00E+00	1.052	OPERATOR ACTION FAILURE TO LOCALLY OPERATE ADVS ON LOSS OF AIR	A large majority of the contributors including AV-LOCADV--HCDOA result from conditions where RCP seal cooling and HPI makeup are lost due to IA valve and power failures. Multiple SAMAs could address these circumstances, including SAMAs 1, 2, 3, 4, 5, 6, and 7; however, TMI-1 has procedures to perform the local ADV operations that are not credited in the PRA model. If these procedures are credited, the RRW of the operator action is reduced below the review threshold. SAMA 9 is used as a surrogate to demonstrate this.
GB-EG-Y-1B--DGMM	1.61E-02	1.052	Emergency Diesel Generator 1B in Maintenance	Most of the contributors containing this event lead to RCP seal LOCAs. These events could be mitigated using damage resistant, high temperature seals (SAMA 2). In addition, these events typically include an unrecovered failure of the "A" AC division, which leads to failure of the HPI makeup pumps for this initiator due to loss of the "C" HPI pump minimum flow path. These failures could be addressed by powering valves MU-V-36 and MU-V-37 from MCC 1C ESV (SAMA 4). Even if the SBO EDG is available, the time to align it to an emergency bus is longer that the time to assumed seal damage. If auto alignment and load capability were provided, it would reduce the seal LOCA contribution (SAMA 1).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
GB1BDG------DGFS	1.13E-02	1.049	DIESEL GENERATOR 1B FAILS TO START	Most of the contributors containing this event lead to RCP seal LOCAs. These events could be mitigated using damage resistant, high temperature seals (SAMA 2). In addition, these events typically include an unrecovered failure of the "A" AC division, which leads to failure of the HPI makeup pumps for this initiator due to loss of the "C" HPI pump minimum flow path. These failures could be addressed by powering valves MU-V-36 and MU-V-37 from MCC 1C ESV (SAMA 4). Even if the SBO EDG is available, the time to align it to an emergency bus is longer that the time to assumed seal damage. If auto alignment and load capability were provided, it would reduce the seal LOCA contribution (SAMA 1).
%SBL	4.50E-04	1.049	SMALL BREAK LOCA	There are multiple failure types contributing to the cutsets including this initiating event and no single change other than the installation of an independent injection/heat removal system would address all of these events. As installation of such a system is known not to be cost effective, it is not suggested as a SAMA. A potential change that could reduce some of the risk would be to provide a means of using NSCCW to cool the DHR heat exchangers (DH-C-1A/B) (SAMA 3). Another potential enhancement would be to add inter-train cross-ties to the DHR related systems (DHR, DHRW, and DHCCW) (SAMA 6).
%LGA	1.23E-03	1.047	LOSS OF GA POWER	More than half of the contributions including this event are related to operator failure to align the "C" HPI pump for seal injection. If the cross-connect valves were enhance so that they could be controlled from the MCR, this action could be performed in time to prevent seal damage or at least in time to provide an excess flow path for the "C" pump during injection phase to mitigate the loss of the recirc path (SAMA 5). Alternatively, these failures could be addressed by powering valves MU-V-36 and MU-V-37 from MCC 1C ESV to provide a minimum flow path for the "C" HPI pump (SAMA 4).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
RECOVERY-LOOP-04	4.97E-01	1.047	NONRECOVERY OF OFFSITE POWER	This recovery term is used in SBO sequences with TD EFW failures. In these cases, there is neither primary nor secondary injection available. An approach similar to what is used to mitigate the extreme external flooding scenarios could be used to address these scenarios. Making it useful for SBO conditions would require permanently installing the portable generator, primary injection pump, and secondary pump so that they could be aligned from the MCR. The submersible pumps would have to be mounted so that the suctions could easily be swapped from a piped water source to the flood water source. This SAMA would also address non-SBO loss of seal cooling cases given the ability to rapidly align alternate seal cooling (SAMA 11).
HP-_14A_14BCVAFD	2.03E-04	1.045	HPI Train Fails MOV CCF Op MU-V-14A;14B	Failures of the HPI BWST suction path through valves 14A and 14B could be mitigated by proceduralizing the use of the LPI system to operate as the suction path for the HPI pumps in the injection mode (SAMA 12). Some interlock bypasses may be required.
GA-EG-Y-1A--DGMM	1.61E-02	1.043	Emergency Diesel Generator 1A in Maintenance	Most of the contributors with EDG "A" failures result in seal LOCAs due to loss of power. A majority of the total is related to REC-LOOP-101 sequences in which EFW is available and the SBO EDG is aligned after seal damage. High temperature, damage resistant seals (SAMA 2) would address most of these cases . Alternatively, providing the ability to rapidly align the SBO EDG would preclude initial seal damage (SAMA 1). In addition, some of these events include unrecovered failure of the "A" AC division, which leads to failure of all HPI makeup pumps for this initiator due to loss of the "C" HPI pump minimum flow path. These failures could be addressed by powering valves MU-V-36 and MU-V-37 from MCC 1C ESV (SAMA 4).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
GA1ADG------DGFS	1.13E-02	1.042	DIESEL GENERATOR 1A FAILS TO START	Most of the contributors with EDG "A" failures result in seal LOCAs due to loss of power. A majority of the total is related to REC-LOOP-101 sequences in which EFW is available and the SBO EDG is aligned after seal damage. High temperature, damage resistant seals (SAMA 2) would address most of these cases . Alternatively, providing the ability to rapidly align the SBO EDG would preclude initial seal damage (SAMA 1). In addition, some of these events include unrecovered failure of the "A" AC division, which leads to failure of all HPI makeup pumps for this initiator due to loss of the "C" HPI pump minimum flow path. These failures could be addressed by powering valves MU-V-36 and MU-V-37 from MCC 1C ESV (SAMA 4).
%SLT	4.22E-03	1.038	STEAM LINE BREAK IN TURBINE BUILDING	A large the contributor to TB steam line break scenarios is the failure of the operators to start the IA compressors on emergency power after a low voltage trip in conjunction with an ESAS. If the IA system logic were altered to automatically load the IA-P-1A/B compressors when power is restored after an ESAS, this would reduce the probability that IA would not be available (SAMA 13).
GA-1A1BSBO-CDGFR	1.53E-04	1.037	EDG CCF Run DG-1A;DG-1B;DG-SBO	The primary contribution from this event comes from SBO with initial success of the TD EFW pump. Installing the high temperature, damage resistant seals will prevent a significant seal LOCA and using a portable 480V AC generator to power a battery charger would allow long term operation of the TD EFW pump (SAMA 2).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
EFEFP1------P7FR	5.06E-02	1.036	TURBINE-DRIVEN PUMP EF-P-1 FAILS TO RUN	Most of the contribution related to this event comes from SBO sequences. In these cases, there is neither primary nor secondary injection available. An approach similar to what is used to mitigate the extreme external flooding scenarios could be used to address these scenarios. Making it useful for SBO conditions would require permanently installing the portable generator, primary injection pump, and secondary pump so that they could be aligned from the MCR. The submersible pumps would have to be mounted so that the suctions could easily be swapped from a piped water source to the flood water source. This SAMA would also address non-SBO loss of seal cooling cases given the ability to rapidly align alternate seal cooling (SAMA 11).
HP-MU-P-1B--P2MM	7.46E-03	1.036	Makeup Pump (Operating) 1B in Maintenance	Many of the contributors related to this event could be eliminated if the HPI pump cooling supply valves were replaced with MOVs controllable from the MCR. This would allow rapid alignment of an alternate cooling source to available pumps in the event that the normal supply is lost (SAMA 14).
JHHHL1AHSR2HEPOA	2.00E-04	1.035	DLHHL1A----HVHOA AND SAHSR2-----HSROA	This joint human error probability includes operator failure to perform swap to recirculation mode and failure to open the drop line. A potential change that could reduce some of the risk would be to automate the swap to recirculation mode when the BWST has been depleted (SAMA 15).
FLAG-SBOALIGN-1D	5.00E-01	1.034	SBO ALIGNED TO BUS 1D	The contributors containing this event lead to RCP seal LOCAs. If auto alignment and load capability were provided, it would reduce the seal LOCA contribution (SAMA 1). Alternatively, these events could be mitigated using damage resistant, high temperature seals (SAMA 2).
HA-P-1AP-1BCP2FS	1.50E-04	1.034	DH Clsd Cool Stdby Pmp CCF Strt P2-1A;1B	A majority of the CCF DHCCW pump failures are important because they fail the heat sink for DHR. Failures of the DHCCW pumps may be mitigated by providing a connection from the NSCCW system to the DHR (DH-C-1A/B) heat exchangers to provide emergency heat removal (SAMA 3)

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
%LAIR	5.23E-03	1.033	LOSS OF AIR INITIATING EVENT	A primary contributor related to this initiating event is related to the failure of operators to operate the EFW flow control valves after loss of air and a dependent operator failure to initiate HPI. Providing logic to auto-start HPI on low pressurizer level would reduce the risk of this scenario (SAMA 16). In addition, a connection to the plant Service Air system exists that is not currently credited in the model. Use of this system to recover IA is possible if the integrity of the IA system is not compromised by the IE. Crediting this cross-tie would also reduce the importance of this IE. Finally, a significant contributor is event "AV-LOCADV--HCDOA", which is addressed above.
JHHOTHMRXTIHEPOA	3.10E-03	1.033	OTHOT1_RCPTHP1OA; MRHMR1-----HMUOA; NR-NRSRXTIEHVAOA	This JHEP is important for cases where %LNR has failed thermal barrier cooling, contributed to loss of seal injection, created a small LOCA via loss of RCP bearing cooling, and failed the remaining HPI source. These types of scenarios would be reduced in frequency by automating RCP trip on high motor bearing coolant temperature (SAMA 8).
HADC-V-2A---VCFT	3.00E-03	1.031	DC-V2A FAILS TO REMAIN OPEN	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). It should be noted that while the ability to rapidly transfer the SBO EDG to the alternate division of power exists, no credit is taken for this capability in the model. As a result, equipment failures after SBO EDG alignment are not recovered while there is a chance that the SBO EDG could be aligned to the opposite division to support use of potentially available equipment.

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
HADC-V-65A--VCFT	3.00E-03	1.031	DC-V65A TRANSFERS TO DIFFERENT STATE	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). It should be noted that while the ability to rapidly transfer the SBO EDG to the alternate division of power exists, no credit is taken for this capability in the model. As a result, equipment failures after SBO EDG alignment are not recovered while there is a chance that the SBO EDG could be aligned to the opposite division to support use of potentially available equipment.
RB-RUNNING--FLAG	2.50E-01	1.026	DHRW TRAIN B RUNNING AND TRAIN A IN STANDBY	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3).
HA-DC-P-1A--P1MM	2.84E-03	1.026	Decay Heat Closed Cycle Cooling Water Pump 1A in Maintenance	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). It should be noted that while the ability to rapidly transfer the SBO EDG to the alternate division of power exists, no credit is taken for this capability in the model. As a result, equipment failures after SBO EDG alignment are not recovered while there is a chance that the SBO EDG could be aligned to the opposite division to support use of potentially available equipment.

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
LOCA-SIZE-100	2.20E-01	1.026	PROBABILITY THAT RCP SEAL LOCA IS OF SLOCA CATEGORY	About 50% of the contributors including LOCA-SIZE-100 result from the failure of NSRW to cool ICCW and to supply cooling to the running makeup pump in conjunction with failures that eliminate the remaining trains of seal injection. A hard-piped connection from the FSW could be used as a backup supply to the ICCW heat exchangers and maintain seal cooling. Given that the ICCW pumps would be available for the relevant cases, a local, manual valve could be used for the alignment as time should be available for such an action (SAMA 7).
OP-OPB-CONDITION	3.00E-01	1.026	POWER SUPPLY UNAVAILABLE GIVEN A TURBINE BYPASS SIGNAL	This event represents the probability that non-emergency electrical power will be lost due to damage from a steam line break in the turbine building. A large the contributor to these scenarios is the failure of the operators to start the IA compressors on emergency power after a low voltage trip in conjunction with an ESAS. If the IA system logic were altered to automatically load the IA-P-1A/B compressors when power is restored after an ESAS, this would reduce the probability that IA would not be available (SAMA 13).
NRHNS8A----HP1OA	5.37E-01	1.025	OPERATOR FAILS TO ISOLATE FAILED RW PUMP (POWER UNAVAILABLE)	A large majority of the contributors including event NRHNS8A----HP1OA include the operator failure to open valves MU-V-76A/B to allow seal injection with the "C" HPI pump. MU-V-76A and B (and MU-V-77A/B) are the manual HPI swing pump valves, which require local manipulation to align. Providing motor operators to the valves with controls in the MCR would allow for rapid alignment of the "B" HPI pump to either division in accident conditions. This would also allow the "C" pump to be quickly aligned for seal injection (eliminates pump damage from recirc path failures). Provisions for allowing rapid alignment of the valve and pump power sources must also be made in order to make the SAMA fully functional (SAMA 5).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
HADC-P-1A---P2FS	2.46E-03	1.025	DHCCW PUMP DC-P1A FAILS TO START	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). It should be noted that while the ability to rapidly transfer the SBO EDG to the alternate division of power exists, no credit is taken for this capability in the model. As a result, equipment failures after SBO EDG alignment are not recovered while there is a chance that the SBO EDG could be aligned to the opposite division to support use of potentially available equipment.
JHHEF1-HBW1HEPOA	1.00E-04	1.024	EFHEF1_OPERH2HOA AND BWHBW1-----HP2OA	Providing logic to auto-start HPI on low pressurizer level would reduce the risk of the scenarios including operator failures to initiate HPI (SAMA 16). It should be noted, however, that a connection to the plant Service Air system exists that is not currently credited in the model. Use of this system to recover IA is possible if the integrity of the IA system is not compromised by the IE.
INMU-P-1C--HMUOA	1.00E+00	1.024	OPERATOR FAILURE TO ALIGN AND START MU-P-1C	Alignment of the "C" HPI pump for seal injection cannot be accomplished in time to prevent RCP seal damage due to the local, manual valve actions required to get the cooling flow aligned. Providing the ability to perform the alignment rapidly from the MCR would allow this action to be taken in the required time frame (SAMA 5).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
NRNR-V-20A--VPFD	1.35E-03	1.024	CHECK VALVE NR-V20A FAILS TO RESEAT	These events are tied to loss of NSRW due to back flow of a tripped pump. The main contributors include loss of div "A" power so that only HPI pump "C" is available for seal injection/makeup. Because MU-V-76A/B require local operation to align the "C" pump for seal injection, time is not available to perform the alignment before a seal LOCA occurs and the loss of "A" power fails the min flow recirc path, so all HPI will be lost. Providing motor operators to the valves with controls in the MCR would allow the "C" pump to be quickly aligned for seal injection (eliminates pump damage from recirc path failures). Provisions for allowing rapid alignment of the valve and pump power sources must also be made in order to make the SAMA fully functional (SAMA 5). Alternatively, FSW could be used as an alternate cooling medium for the ICCW heat sinks to maintain thermal barrier cooling (SAMA 7).
TH-HPIOFF--HP2OA	1.00E+00	1.024	OPERATOR FAILS TO SECURE ALL MU/HPI PUMPS TO PREVENT OVERCOOLING	This action is primarily associated with steam line breaks. Inclusion of logic to auto isolate the steam generators on high steam line flow would reduce the isolation failure (SAMA 17).
NR-NRSRXTIEHVAOA	1.00E-01	1.024	OPERATOR FAILS TO PERFORM CROSS-TIE IN TIME TO PREVENT LOSS OF RCP SEAL COOLING	Many contributors including event "NR-NRSRXTIEHVAOA" also include failure to locally operate MU-V-76A and B (and MU-V-77A/B) to align the "C" HPI pump for seal injection. Providing motor operators to the valves with controls in the MCR would allow the "C" pump to be quickly aligned for seal injection (eliminates pump damage from recirc path failures). Provisions for allowing rapid alignment of the valve and pump power sources must also be made in order to make the SAMA fully functional (SAMA 5). In addition, other contributors include failure of both NSRW and DHCCW. In these cases, FSW could be used as an alternate cooling medium for the ICCW heat sinks to maintain thermal barrier cooling (SAMA 7).
JHAHCD4RE27HEPOA	9.17E-05	1.023	AVHCD4_FF--HCDOA AND BWST-HRE27-HTKOA	Automating BWST refill would effectively eliminate this JHEP and provide a reliable means of maintaining level in the BWST (SAMA 10).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
JHHNS6-HOT1HEPOA	3.00E-02	1.023	NSHNS6-----HHXOA AND OTHOT1_RCPTHP1OA	Automating Reactor Coolant Pump Trip on high motor bearing coolant temperature would eliminate this JHEP and reduce the probability of seal failures (SAMA 8).
HBDC-V-2B---VCFT	3.00E-03	1.023	DC-V2B FAILS TO REMAIN OPEN	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). In addition, some scenarios could be mitigated by enhancing the SBO DG so that it could be rapidly aligned to either division. This would benefit the cases where the SBO EDG is aligned to a particular division only to flow up with an equipment failure specific to that division (SAMA 1).
HBDC-V-65B--VCFT	3.00E-03	1.023	DC-V65B TRANSFERS TO DIFFERENT STATE	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). It should be noted that while the ability to rapidly transfer the SBO EDG to the alternate division of power exists, no credit is taken for this capability in the model. As a result, equipment failures after SBO EDG alignment are not recovered while there is a chance that the SBO EDG could be aligned to the opposite division to support use of potentially available equipment.
OP230KV-----OGFD	2.40E-03	1.022	LOSS OF 230KV TO AUX XFRMR 1A AND 1B	Many contributors to consequential LOOP events could be addressed by installing high temperature, damage proof seals in conjunction with a 480V AC generator to support continued EFW operation from the MCR (SAMA 2). Other contributors would benefit from changing the IA system logic so that it automatically reloads after power is restored (SAMA 13).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
RA-RUNNING--FLAG	2.50E-01	1.022	DHRW TRAIN A RUNNING	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3).
%TRIB	2.86E-03	1.021	INITIATING EVENT FOR SGTR ON OTSG B	Over 80% of the contribution from the cutsets including this initiating event include operator failures to refill the BWST. Automating refill of the BWST is a potential means of improving the reliability of the refill function (SAMA 10).
%TRIA	2.86E-03	1.021	INITIATING EVENT FOR SGTR ON OTSG A	Over 80% of the contribution from the cutsets including this initiating event include operator failures to refill the BWST. Automating refill of the BWST is a potential means of improving the reliability of the refill function (SAMA 10).
HB-DC-P-1B--P1MM	2.84E-03	1.021	Decay Heat Closed Cycle Cooling Water Pump 1B in Maintenance	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). It should be noted that while the ability to rapidly transfer the SBO EDG to the alternate division of power exists, no credit is taken for this capability in the model. As a result, equipment failures after SBO EDG alignment are not recovered while there is a chance that the SBO EDG could be aligned to the opposite division to support use of potentially available equipment.

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
RADR-V-1A---VAFD	3.28E-03	1.021	DR-V-1A FAILS TO OPEN ON DEMAND	Failure of DR-V-1A contributes to both long term recirculation failures and LOOP related seal LOCAs. Installing a cross-connect from NSCCW to the DHR heat exchangers would provide an alternate means of removing decay heat for many of the loss of DHR cases (SAMA 3). Alternatively, adding cross-ties between the DHR systems would allow the operators to establish DHR in cases where opposite trains of the DHR systems are failed for different reasons (SAMA 6). The LOOP induced seal LOCAs typically occur because the SBO EDG cannot be aligned in time to provide power for seal cooling. Enhancing the SBO EDG with auto alignment and load capability would reduce these contributions (SAMA 1).
EF-CCFEFW-LETHAL	4.25E-04	1.02	LETHAL SHOCK TO THE EFW SYSTEM DUE TO COMMON CAUSE FAILURES	There are multiple contributors to cutsets including lethal EFW CCF, but about 40% are related to operator failure to manually initiate HPI. Automating HPI initiation on low level would reduce the reliance on operator action to perform this function (SAMA 16).
GSHEO1A----HDGOA	2.66E-02	1.019	OPERATOR FAILS TO STARTSBODG	Over 90% of the cutsets including this event are SBO sequences and 65% are SBOs in which EFW is initially available. Auto start and load capability for the SBO EDG would essentially eliminate the contribution of these failures (SAMA 1). The scenarios with EFW available could be addressed by installing high temperature, damage resistant seals that would prevent seal LOCAs (SAMA 2).
HBDC-P-1B---P2FS	2.46E-03	1.018	DHCCW PUMP DC-P1A FAILS TO START	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). It should be noted that while the ability to rapidly transfer the SBO EDG to the alternate division of power exists, no credit is taken for this capability in the model. As a result, equipment failures after SBO EDG alignment are not recovered while there is a chance that the SBO EDG could be aligned to the opposite division to support use of potentially available equipment.

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
%LGB	1.23E-03	1.018	LOSS OF GB POWER	Many of the %LGB events are coupled with what are assumed to be non-recoverable electrical failures of the "A" division that fail "A" HPI. The result is a seal LOCA with no makeup capability. A potential mitigation method would be to permanently mount the extreme flooding equipment so that seal injection and secondary side cooling are available in SBO equivalent conditions (SAMA 11).
MRHMR1-----HMUOA	1.03E-02	1.018	OPERATOR FAILS TO RECOGNIZE AND ESTABLISH MIN FLOW RECIRC PATH	A large majority of the contributors containing this event are combined with the "INHINJ2_MUHHMUOA" operator action to cross-connect the "C" HPI pump for seal injection. Either "MRHMR1-----HMUOA" or "INHINJ2_MUHHMUOA" would provide a minimum flow path for the "C" pump, but the alignment of the pump for seal injection is a more visible and familiar cue that would prevent damage to the pump. Replacing the MU-V-76A/B valves (and 77A/B for easy swap of the "B" pump) would allow the operator to perform the alignment of the "C" pump in a timely manner and reduce the contribution from these scenarios (SAMA 5).
JHHAMHEFHBWHEPOA	2.40E-04	1.017	JHHAM2-HEF1HEPOA AND BWHBW1-----HP2OA	Nearly 80% of the contribution including this cutset is related to a steamline break that causes a trip of the off-site power source and subsequently requires the re-loading of IA onto emergency power. If the IA logic were modified to automatically re-load IA once emergency power is established, the requirement for the operator action would be removed (SAMA 13).
HADC-P-1A---P2FR	1.63E-03	1.016	DHCCW PUMP DC-P1A FAILS DURING OPERATION	Failure of HADC-P-1A---P2FR contributes to both long term recirculation failures and LOOP related seal LOCAs. Installing cross-connects from NSCCW to the DHR heat exchangers would provide an alternate means of removing decay heat for many of the loss of DHR cases (SAMA 3). Alternatively, adding cross-ties between the DHR systems would allow the operators to establish DHR in cases where opposite trains of the DHR systems are failed for different reasons (SAMA 6). The LOOP induced seal LOCAs typically occur because the SBO EDG cannot be aligned in time to provide power for seal cooling. Enhancing the SBO EDG with auto start and load capability would reduce these contributions (SAMA 1).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
GA-1A-1B---CDGFR	2.31E-04	1.016	EDG CCF Run DG-1A;DG-1B	Many of the contributors including this event could be mitigated by enhancing the SBO EDG auto start and load capability so that it can restore seal cooling in time to prevent a seal LOCA (SAMA 1). In other cases, the SBO EDG is failed and would not be available. In these cases, replacing the RCP seals with high temperature, damage resistant seals would allow the operators to maintain RCS integrity and remove heat with the EFW system. Typically, a portable 480V AC generator would be required to provide instrument and control power for EFW to improve the reliability of EFW operation (SAMA 2).
DABATTCHGR-HBCOA	1.00E-01	1.016	HEP FOR FAILURE TO ALIGN SPARE CHARGER 1E OR 1F	This action is proceduralized at the plant, but the time requirements and reliability of the action could be improved by providing controls in the MCR (SAMA 18).
RADR-V-1B---VAFD	3.28E-03	1.015	DR-V-1B FAILS TO OPEN ON DEMAND	Failure of DR-V-1B contributes to both long term recirculation failures and LOOP related seal LOCAs. Installing cross-connects from NSCCW to the DHR heat exchangers would provide an alternate means of removing decay heat for many of the loss of DHR cases (SAMA 3). Alternatively, adding cross-ties between the DHR systems would allow the operators to establish DHR in cases where opposite trains of the DHR systems are failed for different reasons (SAMA 6). The LOOP induced seal LOCAs typically occur because the SBO EDG cannot be aligned in time to provide power for seal cooling. Enhancing the SBO EDG with the capability to auto start and load would reduce these contributions (SAMA 1).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
GS-SBODG----DGFR	2.07E-02	1.015	SBO DIESEL FAILS TO RUN	More than half of the contributions including this event are related to SBO cases in which the EFW system is available. For these cases, installing damage resistant, high temperature seals could be installed to eliminate most of the seal leakage after loss of cooling and delay core damage long enough to align the SBO EDG or recover OSP. This SAMA also includes the use of a portable 480V AC generator to power a division of battery chargers and maintain MCR control of EFW (SAMA 2). An additional 25% of the cases are related to SBO events where the EFW system fails. The result is a seal LOCA with no makeup capability. A potential mitigation method would be to permanently mount the extreme flooding equipment so that seal injection and secondary side cooling are available in SBO equivalent conditions (SAMA 11).
HA-P-1AP-1BCP2FR	6.12E-05	1.013	DH Clsd Cool Stndby Pmp CCF Run P2-1A;1B	A majority of the CCF DHCCW pump failures are important because they fail the heat sink for DHR. Failures of the DHCCW pumps may be mitigated by providing connections from the NSCCW system to the DHR (DH-C-1A/B) heat exchangers to provide emergency heat removal (SAMA 3)
AMSC-V-52B--VCFD	6.38E-03	1.013	AIR OPERATED VALVE SC-V-52B FAILS TO OPEN/D	About 70% of the contributors including this event also include the event "AV-LOCADV--HCDOA", which is conservatively modeled in the TMI-1 PRA model. SAMA 9 demonstrates that when appropriate credit is taken for this action, the RRW is reduced below the SAMA review cutoff level.
AMSC-V-58---VCFD	6.38E-03	1.013	F.S. COOLING IA-P1A SC-V-58/D	About 70% of the contributors including this event also include the event "AMSC-V-58---VCFD", which is conservatively modeled in the TMI-1 PRA model. SAMA 9 demonstrates that when appropriate credit is taken for this action, the RRW is reduced below the SAMA review cutoff level.
FLAG----NRNORMAB	3.23E-01	1.013	FRACTION THAT NR PUMPS A AND B ARE NORMALLY RUNNING	A large majority of the contributors including this event also include the event "INHINJ2_MUHHMUOA", which represents the failure of the operators to align the "C" HPI pump for seal injection. Enhancing the MU-V-76A/B valves so that they are operable from the MCR would allow the operators to provide a seal injection path for the "C" HPI pump in a timely manner based on different cues (SAMA 5).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
JHHMR1-XTIEHEPOA	2.30E-03	1.013	MRHMR1-----HMUOA AND NR-NRSRXTIEHVAOA	A large majority of the contributors containing this event are combined with the "INHINJ2_MUHHMUOA" operator action to cross-connect the "C" HPI pump for seal injection. Either "MRHMR1-----HMUOA" or "INHINJ2_MUHHMUOA" would provide a minimum flow path for the "C" pump, but the alignment of the pump for seal injection is a more visible and familiar cue that would prevent damage to the pump. Replacing the MU-V-76A/B valves (and 77A/B for easy swap of the "B" pump) would allow the operator to perform the alignment of the "C" pump in a timely manner and reduce the contribution from these scenarios (SAMA 5).
RADR-P-1A---P5FR	1.51E-03	1.013	FAILURE OF DECAY HEAT RIVER WATER PUMP A (DR-P1A) TO RUN	Failure of DR-P1A contributes to both long term recirculation failures and LOOP related seal LOCAs. Installing cross-connects from NSCCW to the DHR heat exchangers would provide an alternate means of removing decay heat for many of the loss of DHR cases (SAMA 3). Alternatively, adding cross-ties between the DHR systems would allow the operators to establish DHR in cases where opposite trains of the DHR systems are failed for different reasons (SAMA 6). The LOOP induced seal LOCAs typically occur because the SBO EDG cannot be aligned in time to provide power for seal cooling. Enhancing the SBO EDG with the capability to auto start and load would reduce these contributions (SAMA 1).
RA-V-1AV-1BCVAFD	1.34E-04	1.012	DHRW MOV CCF Operate on Demand V-1A;1B	A large majority of the contributors including this event are related to failure of the DHRW system to provide long term heat removal. These contributors could be addressed by providing an alternate method of cooling the DHR heat exchangers (DH-C-1A/B) with NSCCW (SAMA 3).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
GAEDG-STARTCDGFS	5.25E-05	1.012	EDG Fail to Start CCF DG-All 3	About 69% of the contributions including this event are related to SBO cases in which the EFW system is available. For these cases, installing damage resistant, high temperature seals could be installed to eliminate most of the seal leakage after loss of cooling and delay core damage long enough to align the SBO EDG or recover OSP. This SAMA also includes the use of a portable 480V AC generator to power a division of battery chargers and maintain MCR control of EFW (SAMA 2). An additional 29% of the cases are related to SBO events where the EFW system fails. The result is a seal LOCA with no makeup capability. A potential mitigation method would be to permanently mount the extreme flooding equipment so that seal injection and secondary side cooling are available in SBO equivalent conditions (SAMA 11).
HBDC-P-1B---P2FR	1.63E-03	1.012	DHCCW PUMP DC-P1B FAILS DURING OPERATION	Providing cross-ties between the DHR cooling water systems (DHRW, DHCCW, and DHR) would provide a means of restoring cooling to the HPI pumps and the DHR heat exchangers in many cases (SAMA 6). In addition, some contributors could be addressed by providing an alternate means of flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). It should be noted that while the ability to rapidly transfer the SBO EDG to the alternate division of power exists, no credit is taken for this capability in the model. As a result, equipment failures after SBO EDG alignment are not recovered while there is a chance that the SBO EDG could be aligned to the opposite division to support use of potentially available equipment.
HPMU-P-1A---P2FS	2.46E-03	1.012	MAKEUP PUMP A FAILS TO START	Over half of the contribution from this event is related to seal LOCAs in which NSRW cooling to ICCW is lost. Providing an alternate means of cooling the ICCW heat exchangers would prevent the seal LOCAs in these sequences. FSW could be used as a backup cooling source for the ICCW heat exchangers. Given that the ICCW pumps would be available for the relevant cases, a local, manual valve could be used for the alignment as time should be available for such an action (SAMA 7).

TABLE E.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

EVENT NAME	PROB-ABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
HP-MU-P-1A--P2MM	2.21E-03	1.01	Makeup Pump (Standby) 1A in Maintenance	Over half of the contribution from this event is related to seal LOCAs in which NSRW cooling to ICCW is lost. Providing an alternate means of cooling the ICCW heat exchangers would prevent the seal LOCAs in these sequences. FSW could be used as a backup cooling source for the ICCW heat exchangers. Given that the ICCW pumps would be available for the relevant cases, a local, manual valve could be used for the alignment as time should be available for such an action (SAMA 7).
HL-V-7AV-7BCVAFD	2.03E-04	1.01	Line UP DHR HP Recrc MOV CCF Op V-7A;7B	The low position of this event in the importance list indicates that hardware changes to specifically address the CCF of the DHR to HPI suction valves (DH-V-7A/B) would not be cost beneficial. The dominant contributor for this event is when it is paired with a small break LOCA alone (38% of contribution). In this case, the only options for mitigation appear to be the installation of a bypass line or an alternate DHR method. A manually operated bypass would be effective assuming it was accessible, but a more appropriate approach for addressing this risk is believed to be through the seal LOCAs. Prevention of the seal/consequential LOCAs would preclude the need for HPR. The SAMAs suggesting the installation of high temperature, damage resistant seals (SAMA 2) and automated RCP trip logic (SAMA 8) would address the seal/consequential LOCAs contributors related to this event.
OTHOT1_RCPTHP1OA	1.44E-02	1.01	OPERATOR FAILS TO TRIP REACTOR COOLANT PUMP ON LOSS OF NSCCW	The contribution from the failure of this action could be reduced if high temperature sensors on the motor bearing cooling water lines were installed and used to provide automatic trip signals for the pumps (SAMA 8).
RA-P-1AP-1BCP5FR	5.35E-05	1.01	DHRW Standby RW Pump CCF Run P5-1A;1B	The event is associated with loss of DHRW flow scenarios. Use of the NSCCW system to cool the DHR heat exchangers (DH-C-1A/B) would provide alternate heat removal capabilities (SAMA 3).

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
%AC	4.48E-02	2.161	LOSS OF OFFSITE POWER	Addressed by a similar event the Level 1 importance list.
RECOFFSITEPWR	9.64E-01	1.698	OFFSITE POWER RECOVERED WITHIN 24 HOURS	About 80% of the contributors including RECOFFSITEPWR are SBO events, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for RECOFFSITEPWR. An additional insight is that 80% of the contributors including RECOFFSITEPWR belong to RC8-01. These sequences are characterized by ex-vessel releases of corium and basemat failure. Ex-vessel release occurs due to lack of containment spray early while basemat failure largely occurs in spite of late recovery of containment sprays, which implies that early recovery of AC power would allow containment spray to prevent the ex-vessel release.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
MELT	5.00E-01	1.668	Likelihood That Water Pool in Cavity Will Not Stop Concrete Attack	This event represents the probability that water will not prevent interaction between the core melt debris and the containment floor (containment has performed as designed, but the sprays cannot prevent containment damage). Over 50% of the cutset contributions including the event MELT are SBO events, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for MELT. An additional 20% to 25% of the contributors are cases where the SBO EDG is available, but cannot be aligned in time to prevent a seal LOCA. These cases are addressed by SAMA 1. No potentially cost effective containment structure changes have been identified to address this issue (installation of a flooded rubble bed was estimated to be over $18 million for the ABWR [GE 1994]).
RECSPRAYLT	9.99E-01	1.614	AVAILABILITY OF CONTAINMENT SPRAYS WITHOUT POWER DEPENDENCY	RECSPRAYLT is completely tied to event RECOFFSITEPWR, which is addressed separately in this table.
RECOVERY-LOOP-03	8.11E-02	1.355	NONRECOVERY OF OFFSITE POWER	Addressed by a similar event the Level 1 importance list.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
RBSPRAY	9.99E-01	1.263	RB SPRAY SYSTEM IS AVAILABLE	These cases are similar to RECSPRAYLT in that containment spray is ineffective at preventing containment failure. However, for these cases, AC power is available to support containment spray early. About 35% of the contributors including RECSPRAYLT also include the event MELT, which is addressed separately in this list. An additional 35% is related to containment over pressurization due to hydrogen burns. Installation of battery backed hydrogen igniters would reduce the contribution from these events (SAMA 19).
STREN1H2	5.00E-01	1.203	Likelihood That Cont Can Handle Comb. Gas Burn Press. W/ High Base Pressure	This event represents the cases where a hydrogen burn occurs, but the containment does not fail due to the burn event. Over 99.5% of these cases include the event MELT. As for the event MELT, over 50% of the cutset contributions including the event MELT are SBO events, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for MELT. An additional 20% to 25% of the contributors are cases where the SBO EDG is available, but cannot be aligned in time to prevent a seal LOCA. These cases are addressed by SAMA 1.
CTMT-F-BENIGN	9.00E-01	1.17	CONTAINMENT LEAK BEFORE BREAK	About 70% of the contributors including CTMT-F-BENIGN are related to hydrogen burns that fail containment. Installation of battery backed hydrogen igniters would reduce the contribution from these events (SAMA 19).
RECOVERY-LOOP-01	4.97E-01	1.158	NONRECOVERY OF OFFSITE POWER	Addressed by a similar event the Level 1 importance list.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
RECOVERY-LOOP-04	4.97E-01	1.141	NONRECOVERY OF OFFSITE POWER	Addressed by a similar event the Level 1 importance list.
GB-EDG-1B---DGFR	2.07E-02	1.136	DIESEL 1B FAILS TO RUN	Addressed by a similar event the Level 1 importance list.
DRYEFF	5.00E-01	1.127	Likelihood That Recombination Can Deplete Comb. Gas Given a Dry Cavity	This event represents the cases where the hydrogen recombiners are able to remove enough hydrogen to prevent a catastrophic burn. As a result, early containment failure does not occur, but subsequent evolutions result in loss of containment integrity. Over 99.5% of these cases include the event MELT. As for the event MELT, over 50% of the cutset contributions including the event MELT are SBO events, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for MELT. An additional 20% to 25% of the contributors are cases where the SBO EDG is available, but cannot be aligned in time to prevent a seal LOCA. These cases are addressed by SAMA 1.
GA-EDG-1A---DGFR	2.07E-02	1.127	DIESEL 1A FAILS TO RUN	Addressed by a similar event the Level 1 importance list.
NOSTREN1H2	5.00E-01	1.125	Likelihood That Cont Cannot Handle Comb. Gas Burn Press. W/ High Base Pressure	These contributors are related to hydrogen burns that fail containment (for late containment failure). Installation of battery backed hydrogen igniters would reduce the contribution from these events (SAMA 19).
GA-1A1BSBO-CDGFR	1.53E-04	1.118	EDG CCF Run DG-1A;DG-1B;DG-SBO	Addressed by a similar event the Level 1 importance list.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
EFEFP1------P7FR	5.06E-02	1.098	TURBINE-DRIVEN PUMP EF-P-1 FAILS TO RUN	Addressed by a similar event the Level 1 importance list.
NOEXSCRUBEFF	1.00E-01	1.096	Likelihood That Overlying Water Pool Will Not Scrub FPs Released From Corium	This event is completely linked to the event MELT; however, the population of MELT events that it is associated with are not SBO events. About 30% are related to RECOVERY-LOOP-01 for which SAMAs 1 and 2 would be useful. The remaining contributors are a diverse mixture of LOCAs and transients that would not be mitigated by a single SAMA outside of the installation of an additional, independent DHR/injection system. Based on the high cost of a new DHR/injection system and the low contribution of all non-SBO transients and non-ISLOCAs to the MACR, this type of change would not be cost beneficial. No additional SAMAs are suggested to address this event.
NODRYEFF	5.00E-01	1.09	Likelihood That Recombination Cannot Deplete Comb. Gas Given a Dry Cavity	These contributors are related to hydrogen burns that fail containment. Installation of battery backed hydrogen igniters would reduce the contribution from these events (SAMA 19).
NOAFTSTREN1	5.00E-01	1.08	Likelihood That Cont Cannot Handle Comb. Gas Burn Press. W/ High Base Pressure	These contributors are related to hydrogen burns that fail containment (for early containment failure). Installation of battery backed hydrogen igniters would reduce the contribution from these events (SAMA 19).
NOINERTAF	1.00E-01	1.08	Containment Has High Base Pressure Early After RV Failure Without Steam Inerting	These contributors are related to hydrogen burns that fail containment (for early containment failure). Installation of battery backed hydrogen igniters would reduce the contribution from these events (SAMA 19).

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
%LAIR	5.23E-03	1.08	LOSS OF AIR INITIATING EVENT	Addressed by a similar event the Level 1 importance list.
FLAG-SBOALIGN-1E	5.00E-01	1.074	SBO ALIGNED TO BUS 1E	Addressed by a similar event the Level 1 importance list.
JHHEF1-HBW1HEPOA	1.00E-04	1.073	EFHEF1_OPERH2HOA AND BWHBW1-----HP2OA	Addressed by a similar event the Level 1 importance list.
JHAHCD4RE27HEPOA	9.17E-05	1.07	AVHCD4_FF--HCDOA AND BWST-HRE27-HTKOA	Addressed by a similar event the Level 1 importance list.
%TRIB	2.86E-03	1.069	INITIATING EVENT FOR SGTR ON OTSG B	Addressed by a similar event the Level 1 importance list.
%TRIA	2.86E-03	1.069	INITIATING EVENT FOR SGTR ON OTSG A	Addressed by a similar event the Level 1 importance list.
GB-EG-Y-1B--DGMM	1.61E-02	1.069	Emergency Diesel Generator 1B in Maintenance	Addressed by a similar event the Level 1 importance list.
GB1BDG------DGFS	1.13E-02	1.066	DIESEL GENERATOR 1B FAILS TO START	Addressed by a similar event the Level 1 importance list.
GA-EG-Y-1A--DGMM	1.61E-02	1.065	Emergency Diesel Generator 1A in Maintenance	Addressed by a similar event the Level 1 importance list.
GA1ADG------DGFS	1.13E-02	1.062	DIESEL GENERATOR 1A FAILS TO START	Addressed by a similar event the Level 1 importance list.
WATEREFF	5.00E-01	1.061	Likelihood That Water in S/G Will Scrub Fission Products	This event is related to SGTR scenarios. The failure to provide makeup to the BWST (BWST-HRE27-HTKOA) contributes to over 85% of the cutsets including WATEREFF. Event BWST-HRE27-HTKOA is addressed in the Level 1 importance list.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
NONCGASHIGH	1.00E-01	1.057	Likelihood That Non Condensable Gas Production is Not High Given a Dry Cavity	This event is completely linked to the event MELT; however, the population of MELT events that it is associated with are not all SBO events. About 35% are related to RECOVERY-LOOP-03 and RECOVERY-LOOP-04, which are addressed by similar events in the Level 1 importance list. Some additional benefit (about 25%) could be gained through the use of the RBEC system to provide alternate flow to the DHR heat exchangers (DH-C-1A/B) (SAMA 3). The remaining contributors are a diverse mixture of LOCAs and transients that would not be mitigated by a single SAMA outside of the installation of an additional, independent DHR/injection system, which is known not to be cost effective. No additional SAMAs are suggested to address this event.
AV-LOCADV--HCDOA	1.00E+00	1.055	OPERATOR ACTION FAILURE TO LOCALLY OPERATE ADVS ON LOSS OF AIR	Addressed by a similar event the Level 1 importance list.
NOWATEREFF	5.00E-01	1.055	Likelihood That Water in S/G Will Not Scrub Fission Products	This event is related to SGTR scenarios. The failure to provide makeup to the BWST (BWST-HRE27-HTKOA) contributes to over 95% of the cutsets including WATEREFF. Event BWST-HRE27-HTKOA is addressed in the Level 1 importance list.
GSHEO1A----HDGOA	2.66E-02	1.051	OPERATOR FAILS TO STARTSBODG	Addressed by a similar event the Level 1 importance list.
LOCA-SIZE-101	7.80E-01	1.05	PROBABILITY THAT RCP SEAL LOCA IS OF VSLOCA CATEGORY	Addressed by a similar event the Level 1 importance list.
%VSB	2.56E-03	1.046	VERY SMALL BREAK LOCA	Addressed by a similar event the Level 1 importance list.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
%LNR	3.42E-03	1.044	LOSS OF NUCLEAR RIVER WATER	Addressed by a similar event the Level 1 importance list.
DABB1A------BYFD	4.84E-04	1.044	FAILURE OF BATTERY BANK 1A ON DEMAND	Addressed by a similar event the Level 1 importance list.
EF-CCFEFW-LETHAL	4.25E-04	1.043	LETHAL SHOCK TO THE EFW SYSTEM DUE TO COMMON CAUSE FAILURES	Addressed by a similar event the Level 1 importance list.
FLAG-SBOALIGN-1D	5.00E-01	1.041	SBO ALIGNED TO BUS 1D	Addressed by a similar event the Level 1 importance list.
NOHEATIML	1.00E-01	1.039	Prob. that Failure of the Primary System Does Not Occur Due to Heating	Over 86% of the contributors including this event are SBO scenarios, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for NOHEATIML.
GS-SBODG----DGFR	2.07E-02	1.038	SBO DIESEL FAILS TO RUN	Addressed by a similar event the Level 1 importance list.
GAEDG-STARTCDGFS	5.25E-05	1.037	EDG Fail to Start CCF DG-All 3	Addressed by a similar event the Level 1 importance list.
OP230KV-----OGFD	2.40E-03	1.034	LOSS OF 230KV TO AUX XFRMR 1A AND 1B	Addressed by a similar event the Level 1 importance list.
RARB-STANDBYFLAG	5.00E-01	1.034	BOTH DHRW TRAINS A AND B IN STANDBY	Addressed by a similar event the Level 1 importance list.
%LGA	1.23E-03	1.032	LOSS OF GA POWER	Addressed by a similar event the Level 1 importance list.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
INERTLT	1.00E-01	1.032	Sequence Late After RV Failure Has Low Base Pressure From Gas Generation	This event represents the cases where gas generation for the core melt process does not produce enough gas to create a high base pressure in the containment (related to evaluating consequences of a hydrogen burn). For the relevant cases (all RC8-01), the hydrogen burn does not cause containment failure, but subsequent evolutions result in loss of containment integrity. Over 99.8% of these cases include the event MELT. As for the event MELT, over 60% of the cutset contributions including the event MELT are SBO events, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for MELT. An additional 28% of the contributors are cases where the SBO EDG is available, but cannot be aligned in time to prevent a seal LOCA. These cases are addressed by SAMA 1.
INHINJ2_MUHHMUOA	1.00E+00	1.028	OPERATOR OPENS CROSS CONNECT VALVES MU-V-76A/B AND STARTS MU-P-1C	Addressed by a similar event the Level 1 importance list.
NON-RECOV-LNR-IE	2.70E-01	1.025	NON-RECOVERABLE FRACTION OF %LNR EVENTS	Addressed by a similar event the Level 1 importance list.
GADF-PALL6-CP2FS	3.62E-05	1.025	EDG Standby Pump CCF Start P2-ALL 6	Addressed by a similar event the Level 1 importance list.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
%ISL	1.80E-07	1.024	INTERFACING SYSTEM LOCA	For TMI-1, ISLOCA is dominated by DHR suction path failures after leak or rupture of valves DH-V-1 and DH-V-2. While the TMI-1 ISLOCA analysis does not take credit for any potentially mitigating actions, no actions that could reliably terminate the event are believed to be available. For example, 1) the isolation of DH-V-3 may not isolate the break or additional breaks may occur after isolation, 2) reduction of primary system pressure may reduce the flow out of the break, but it would not stop it, and 3) refill of the BWST does not place the plant in a stable state and the impacts of aux building flooding would have to be addressed. A potential SAMA would be to extend the high pressure boundary through valve DH-V-3 to allow an additional isolation point (SAMA 20).
ISLOCA--COREMELT	1.00E+00	1.024	CORE DAMAGE DUE TO INTERFACING SYSTEM LOCA	This event is completely tied to %ISL, which is treated separately on this list.
GA-1A-1B---CDGFR	2.31E-04	1.023	EDG CCF Run DG-1A;DG-1B	Addressed by a similar event the Level 1 importance list.
GS-EG-Y-4---DGMM	1.30E-02	1.023	SBO Diesel Generator in Maintenance	Addressed by a similar event the Level 1 importance list.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
CWNOLIMITLPME	1.00E-02	1.023	Plant Config and Layout Does Not Limit Material Reaching Cont. Wall With LPM	The contributors including this event are composed of a diverse set of accident scenarios that lead to low pressure core melts. No single SAMA has been identified that would effectively eliminate a majority of the core damage sequences. Several SAMAs identified in the Level 1 importance list are applicable to portions of the contributors, but these issues are addressed by the Level 1 review and no new insights are available from the Level 2 cutsets for the core damage evolutions. The event CWLIMITLPME represents the probability that corium will not spread to the containment wall after a low pressure melt, which is described as "almost certain" in the L2 analysis based on the cavity configuration. The event here, CWNOLIMITLPME, is the complement of CWLIMITLPME. A possible plant enhancement would be to identify pathways that corium could reach the containment wall and to install shields to block the pathways or to flood the containment early (SAMA 21).
MF-MFPT----EVENT	2.09E-02	1.022	MFPT (LEGACY EVENT)	These events are related to the loss of MFW flow in after a trip when overcooling events have not occurred. MFW and EFW availability are important to determining the status of fission product scrubbing for SGTR events and also for determining whether or not induced tube ruptures will occur. These events could be reduced in an independent AFW system were installed (SAMA 22).
%SLT	4.22E-03	1.022	STEAM LINE BREAK IN TURBINE BUILDING	Addressed by a similar event the Level 1 importance list.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
HP-_14A_14BCVAFD	2.03E-04	1.021	HPI Train Fails MOV CCF Op MU-V-14A;14B	Addressed by a similar event the Level 1 importance list.
%LNS	2.74E-03	1.021	LOSS OF NUCLEAR SERVICES CLOSED COOLING WATER	Addressed by a similar event the Level 1 importance list.
%FW	5.40E-02	1.02	LOSS OF FEEDWATER	These events are related to the loss of MFW flow in after a trip followed by failure of EFW and induced SGTR. MFW and EFW availability are important to determining the status of fission product scrubbing for SGTR events and also for determining whether or not induced tube ruptures will occur. These events could be reduced in an independent AFW system were installed (SAMA 22).
GSEG-Y-4----DGFS	1.13E-02	1.02	STATION BLACKOUT DG FAILS TO START	Over 99% of the contributors including this event are SBO scenarios, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for GSEG-Y-4----DGFS.
CFRR-V-6----VCFF	1.62E-02	1.018	RR-V6 FAILS TO OPERATE	This valve failure is related to the loss of RBEC return flow for containment cooling. The TMI-1 HRA documentation indicates that there are no alarm response procedures related to low flow on the system that would direct the operators to open the bypass valve (RR-V-5) when RR-V-6 fails to open. A potential SAMA would be to develop procedures to direct operation of the bypass valve when the normal return path fails (SAMA 23).

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
CFHRR1-----HVAOA	7.79E-01	1.018	OPERATOR FAILS TO OPEN MOV RR-V-5	This valve failure is related to the loss of RBEC return flow for containment cooling. The TMI-1 HRA documentation indicates that there are no alarm response procedures related to low flow on the system that would direct the operators to open the bypass valve (RR-V-5) when RR-V-6 fails to open. A potential SAMA would be to develop procedures to direct operation of the bypass valve when the normal return path fails (SAMA 23).
RECOVERY--LNR-IE	7.30E-01	1.018	RECOVERABLE FRACTION OF %LNR EVENTS	Addressed by a similar event the Level 1 importance list.
JHHRE27HL1AHEPOA	2.00E-04	1.017	BWST-HRE27-HTKOA AND DLHHL1A----HVHOA	Automating BWST refill would effectively eliminate this JHEP and provide a reliable means of maintaining level in the BWST (SAMA 10).
NORECOFFSITEPWR	3.60E-02	1.017	OFFSITE POWER NOT RECOVERED WITHIN 24 HOURS	Most of the contributors including this event result in late containment failure due to over pressurization. Over 70% of the contributors are SBO cases, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for NORECOFFSITEPWR.
BWHBW1-----HP2OA	2.18E-03	1.017	OPERATOR FAILS TO INITIATE HPI	Addressed in the Level 1 importance list through dependent operator action terms JHHEF1-HBW1HEPOA and JHHAMHEFHBWHEPOA.
JHHOT1-XTIEHEPOA	5.10E-02	1.017	OTHOT1_RCPTHP1OA AND NR-NRSRXTIEHVAOA	Automating RCP trip on high cooling water temperature would effectively eliminate this JHEP and provide a reliable means of preventing pump/seal damage (SAMA 8).

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
GEOMFREEZE	5.00E-01	1.016	Cavity Geometry Allows Enough Corium to Disperse For Freezing	Over 87% of the contributors including this event are SBO scenarios, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for GEOMFREEZE. No potentially cost effective containment structure changes to impact the dispersal of corium in the cavity have been identified.
JHHHL1AHSR2HEPOA	2.00E-04	1.016	DLHHL1A----HVHOA AND SAHSR2-----HSROA	Addressed by a similar event the Level 1 importance list.
BWST-HRE27-HTKOA	2.65E-02	1.015	FAILURE TO REFILL BWST (SPLIT FRAC REV)	Addressed in the Level 1 importance list through dependent operator action JHAHCD4RE27HEPOA.
INMU-P-1C--HMUOA	1.00E+00	1.014	OPERATOR FAILURE TO ALIGN AND START MU-P-1C	Addressed by a similar event the Level 1 importance list.
CTMT-F-NOTBENIGN	1.00E-01	1.014	PROBABILITY THAT CONTAINMENT FAILURE IS NOT BENIGN	This event represents the probability that containment failure due to over pressurization will be a failure that results in a rapid blowdown of containment. Over 80% of the contributors including CTMT-F-NOTBENIGN are failure due to hydrogen burns. Installation of battery backed hydrogen igniters would reduce the contribution from these events (SAMA 19).
%SBL	4.50E-04	1.014	SMALL BREAK LOCA	Addressed by a similar event the Level 1 importance list.
JHHAM2-HEF1HEPOA	4.61E-03	1.014	AMHAM2-----HC1OA AND EFHEF1_OPERH2HOA	This dependent operator action term is addressed by SAMA 13, which would automate operator action AMHAM2-----HC1OA and preclude the need for EFHEF1_OPERH2HOA. No additional SAMAs are required.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
HADC-V-2A---VCFT	3.00E-03	1.013	DC-V2A FAILS TO REMAIN OPEN	Addressed by a similar event the Level 1 importance list.
HADC-V-65A--VCFT	3.00E-03	1.013	DC-V65A TRANSFERS TO DIFFERENT STATE	Addressed by a similar event the Level 1 importance list.
HP-MU-P-1B--P2MM	7.46E-03	1.012	Makeup Pump (Operating) 1B in Maintenance	Addressed by a similar event the Level 1 importance list.
DXBATT1A1B-CBYFF	3.51E-06	1.012	Batteries 1A and 1B CCF Operate	The importance of this event is driven by its contribution to containment isolation failure in SBO cases (dominated by RECOVERY-LOOP-04), which is dependent on AC power. These sequences could be mitigated by preventing core damage in the same manner as suggested for RECOVERY-LOOP-04.
DX-1-ABCD--CBCFF	3.39E-06	1.012	Battery Charger CCF of 3/4 and 4/4	The importance of this event is driven by its contribution to containment isolation failure in SBO cases (dominated by RECOVERY-LOOP-04), which is dependent on AC power. These sequence could be mitigated by preventing core damage in the same manner as suggested for RECOVERY-LOOP-04.
JHHOTHMRXTIHEPOA	3.10E-03	1.011	OTHOT1_RCPTHP1OA; MRHMR1-----HMUOA; NR-NRSRXTIEHVAOA	Addressed by a similar event the Level 1 importance list.
%RT	4.82E-01	1.011	REACTOR TRIP	The importance of this event is driven by a diverse set of contributors that are addressed elsewhere in the importance lists, including OP230KV-----OGFD, MELT, RECOFFSITEPWR, and RECSPRAYLT. No single, potentially cost beneficial SAMA has been identified to mitigate all of the risk associated with the “reactor trip” initiating event.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
HA-P-1AP-1BCP2FS	1.50E-04	1.011	DH Clsd Cool Stdby Pmp CCF Strt P2-1A;1B	Addressed by a similar event the Level 1 importance list.
NRHNS8A----HP1OA	5.37E-01	1.011	OPERATOR FAILS TO ISOLATE FAILED RW PUMP (POWER UNAVAILABLE)	Addressed by a similar event the Level 1 importance list.
GADF-PALL6-CP2FR	1.60E-05	1.011	EDG Standby Pump CCF Run P2-ALL6	Over 99.5% of the contributors including this event are SBO scenarios, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for GADF-PALL6-CP2FR.
OP-OPB-CONDITION	3.00E-01	1.011	POWER SUPPLY UNAVAILABLE GIVEN A TURBINE BYPASS SIGNAL	Addressed by a similar event the Level 1 importance list.
NRNR-V-20A--VPFD	1.35E-03	1.011	CHECK VALVE NR-V20A FAILS TO RESEAT	Addressed by a similar event the Level 1 importance list.
HA-DC-P-1A--P1MM	2.84E-03	1.011	Decay Heat Closed Cycle Cooling Water Pump 1A in Maintenance	Addressed by a similar event the Level 1 importance list.
GSFS-V-646--VCFD	6.38E-03	1.01	AIR OPERATED VALVE FS-V-646 FAILS ON DEMAND	This event causes the failure of the cooling flow to the SBO EDG and over 99.5% of the contributors including this event are SBO scenarios, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed by similar events in the Level 1 importance list and the same SAMAs are applicable for GSFS-V-646--VCFD.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
GSFS-V-647--VCFD	6.38E-03	1.01	AIR OPERATED CONTROL VALVE FS-V-647 FAILS ON DEMAND	This event causes the failure of the cooling flow to the SBO EDG and over 99.5% of the contributors including this event are SBO scenarios, which are represented by events RECOVERY-LOOP-03 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for GSFS-V-647--VCFD.
HADC-P-1A---P2FS	2.46E-03	1.01	DHCCW PUMP DC-P1A FAILS TO START	Addressed by a similar event the Level 1 importance list.
HBDC-V-2B---VCFT	3.00E-03	1.01	DC-V2B FAILS TO REMAIN OPEN	Addressed by a similar event the Level 1 importance list.
HBDC-V-65B--VCFT	3.00E-03	1.01	DC-V65B TRANSFERS TO DIFFERENT STATE	Addressed by a similar event the Level 1 importance list.
JHHAMHEFHBWHEPOA	2.40E-04	1.01	JHHAM2-HEF1HEPOA AND BWHBW1-----HP2OA	Addressed by a similar event the Level 1 importance list.
SPARKAFT_1	1.00E-01	1.01	PROB THAT SPARK IS AVAILABLE EARLY AFTER RV FAILURE WITHOUT RB SPRAY	These cases are related to evolutions in which an ignition source is available and causes a non-catastrophic hydrogen burn. Containment failure occurs later due primarily to basemat failures. For the contributors including this event, most of the contribution results from core damage events that could have been mitigated if it were possible to swap the train to which the SBO EDG was aligned after equipment failure. This is addressed by SAMA 1.

TABLE E.5-2
LEVEL 2 IMPORTANCE LIST REVIEW

EVENT NAME	PROBABILITY	RED W	DESCRIPTION	POTENTIAL SAMAS
DABATTCHGR-HBCOA	1.00E-01	1.01	HEP FOR FAILURE TO ALIGN SPARE CHARGER 1E OR 1F	About 80% of the contributors including DABATTCHGR-HBCOA are LOOP events that include events RECOVERY-LOOP-01 and RECOVERY-LOOP-04. These events are addressed in the Level 1 importance list and the same SAMAs are applicable for DABATTCHGR-HBCOA.
CWNOLIMITHPME	1.00E-01	1.01	Plant Config and Layout Does Not Limit Material Reaching Cont. Wall With HPM	About 70% of the contribution from this event is linked to "AV-LOCADV--HCDOA", which is addressed by a similar event the Level 1 importance list. As discussed there, if existing procedures are credited, the contribution from AV-LOCADV--HCDOA will be greatly reduced, which implies that event CWNOLIMITHPME would not remain above the RRW review threshold of 1.01. However, SAMA 21 was developed for a similar event (CWNOLIMITLPME) and it addresses the same issues relevant to CWNOLIMITHPME.
HB-DC-P-1B--P1MM	2.84E-03	1.01	Decay Heat Closed Cycle Cooling Water Pump 1B in Maintenance	Addressed by a similar event the Level 1 importance list.
EF-EF-P-1---P1MM	6.57E-03	1.01	EFW Pump (Turbine Driven) 1 in Maintenance	About 90% of these events are SBO cases, represented by RECOVERY-LOOP-04. This event is addressed in the Level 1 importance list and the same SAMAs are applicable for EF-EF-P-1---P1MM.

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
1	Enhance the SBO EDG for Auto Alignment and Loading	The current capability of the SBO EDG is limited by manual actions to diagnose and respond to conditions requiring a start of the SBO EDG. While the time required to start and load the EDG is relatively short, it is close enough to the 13 minute limit for restoration of seal cooling after a total loss that no credit is taken for the SBO EDG to prevent seal LOCAs in LOOP evolutions with normal EDG failures. Automation of SBO EDG operation would reduce the time required to restore seal cooling and through this function, a large portion of the seal LOCA CDF could be eliminated.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $3,125,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.1).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
2	Install Damage Resistant, High Temperature RCP Seals with a Portable 480V Generator for Extended EFW Operation	Currently, alternate RCP pump seals are available that can effectively prevent seal LOCAs caused by loss of RCP seal cooling (Flowserve N-9000 seals). It is estimated that these seals will limit leakage flow to about 1 gpm per seal on loss of cooling, which is low enough to maintain core coverage in cases where seal LOCAs would normally result in core uncovery/core damage within the PRA's 24 hour mission time. The ability to prevent a seal LOCA will allow for extended operation in SBO conditions if level instrumentation can be supplied using the vital 120V AC system. Powering the station battery chargers with a portable 480V AC generator would provide this capability and allow control of the TD EFW system to be retained in the MCR.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $7,300,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.2).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
3	Use NSCCW as an Alternate Cooling Source for the DHR Heat Exchangers (DH-C-1A/B)	For LOCAs requiring heat removal with the RHR system, DHRW and DHCCW failures are large contributors to loss of the primary cooling function. Providing the ability to cross-tie the NSCCW system to the DHR heat exchangers would diversify the plant's heat removal capability and eliminate the failures associated with loss of DHRW or DHCCW flow. The hard piped connections are assumed to be sized to allow enough flow to remove decay heat (not just pump cooling loads) and that each division is provided with a cross-connection.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $2,450,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.3).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
4	Provide Alternate Power to HPI Pump Minimum Flow Recirculation Valves MU-V-36 and MU-V-37	The current PRA model logic correctly assumes isolation of valves MU-V-36 and 37 on an ESAS, but it does not include the AC power dependences for the "close" action. However, the logic related to opening the minimum flow valves does include the power dependences, which can result in the generation of cutsets that include the failure to open a flow path that was never isolated. If the appropriate power dependencies were accounted for in the isolation logic, the only events that could cause the MU-V-36 or MU-V-37 valves to be "stranded closed" are those in which an ESAS occurs when both divisions of power are available and then division "A" power fails before MU-V-36 can be opened.	Level 1 TMI-1 Importance List	Not Required (screened on PRA insights).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis(refer to Section E.6.4).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
5	Enhance Valves MU-V-76A/B and MU-V-77A/B to Allow for Rapid Alignment Changes in Accident Conditions	The current MU-V-76A/B and MU-V-77A/B valve configurations do not allow for rapid re-alignment during accident conditions. For TMI-1, the capability to quickly align the "C" HPI pump for seal injection would reduce the risk of prominent accident sequences in which thermal barrier cooling has failed in conjunction with the "A" and "B" HPI pumps. Replacing MU-V-76A/B and MU-V-77A/B with MOVs operable from the main control room would allow TMI-1 to use the "C" HPI pump for seal injection and prevent seal LOCAs when the normal cooling methods are unavailable.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $3,150,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.5).
6	Add Cross-ties Within the Trains of the Cooling Systems -DHR -DHRW -DHCCW	Some failure combinations that eliminate both trains of the DHR related cooling systems could be mitigated if cross-ties were available between trains of the DHR, DHRW, and DHCCW systems (not between the systems). For example, these cross-ties would be helpful in conditions where the flow path fails in one train while a pump failure or maintenance event disables the opposite train. To ensure the DHR cross-ties can be implemented in a timely manner for LPI requirements, the associated valves should be operable from the main control room.	Level 1 TMI-1 Importance List	The cost of installing the powered DHR cross-tie was estimated to be $2,750,000 by the TMI staff (Exelon 2007c). The cross-ties for the DHCCW and DHRW systems are not required to be MOVs due to the longer times available for performing the cross-tie and while there would be a substantial additional cost related to the addition of these cross-ties, only the DHR cross-tie cost of $2,750,000 is used here based on the availability of information.	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.6).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
7	Use Fire Service Water as an Alternate Cooling Source for the ICCW Heat Exchangers	For cases in which NSRW is unavailable due to hardware failures (e.g., flow diversion), the Fire Service Water system could be used to directly cool the ICCW heat exchangers for thermal barrier cooling support. Given that the ICCW pumps would be available for the relevant cases, a local, manual valve could be used for the alignment as time should be available for such an action.	Level 1 TMI-1 Importance List	Palisades estimated $2.9 million for Fire water cooling to CCW HXs (NMC 2005), Calvert Cliffs estimated $565k for alt DHR cooling (BGE 1998), and Brown's Ferry estimated $1 million for Fire Water to DHR HXs (TVA 2003). The Brown's Ferry estimate is used for TMI.	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.7).
8	Automate Reactor Coolant Pump Trip	Seal LOCAs resulting from operator failures to trip the RCPs on loss of motor bearing cooling could be reduced if high temperature sensors were installed on motor bearing cooling water lines to provide automatic trip signals.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $145,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.8).
9	Proceduralize Local ADV Operation	TMI-1 has procedures to perform the local ADV operations that are not credited in the PRA model (the failure probability is set to 1.0). If the available procedures are credited, the RRW value of the operator action would be reduced below the SAMA review threshold. This SAMA is used demonstrate the reduction in the RRW that would occur when a reasonable failure probability is applied to the operator action.	Level 1 TMI-1 Importance List	Not Required (screened on PRA insights).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.9).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
10	Automate BWST Refill	Failure to refill the BWST is a large contributor to some SGTR sequences, especially those in which the MS ADVs fail to operate. Automating the refill function would improve the reliability of this process and reduce the contributions from prominent SGTR sequences by providing a long term high pressure injection source. This SAMA requires a new pump with a flow rate of at least 400 gpm with a connection to a borated water source that will provide suction for 24 hours. In addition, the pump should be able to supply water from a non-borated water source for an indefinite periods of time after depletion of the borated water source.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $3,800,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.10).
11	Enhance Extreme External Flooding Mitigation Equipment to Address SBO and Loss of Seal Cooling Scenarios	Making the extreme flooding equipment useful for SBO conditions, especially those with TD EFW failure, would require permanently mounting the submersible pumps so that the suctions could easily be swapped from a piped water source to the flood water source. Permanently installing the portable generator and the pumps so that they could be aligned from the MCR would improve alignment capabilities and address non-SBO loss of seal cooling cases through the ability to rapidly align alternate seal cooling.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $4,250,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.11).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
12	Use the DHR System as an Alternate Suction Source for HPI	Failures of the BWST suction path to the HPI pumps will lead to core damage in scenarios requiring early makeup. Through implementation of procedure changes, the DHR system could be aligned to take suction from the BWST and supply flow to the HPI system to allow injection in these cases.	Level 1 TMI-1 Importance List	This change can be implemented at TMI-1 through only procedure changes as no interlocks are associated with the suggested alignment. Procedure changes are estimated to cost about $50,000 (CPL 2004).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.12).
13	Change IA System Logic to Automatically Start IA-P-1A/B After a Low Voltage Trip in Conjunction with an ESAS	The current IA system logic requires the operators to re-load the IA compressors on emergency power after a low voltage trip when an ESAS is registered. Automating the re-loading of these compressors would remove the requirement for the operators to perform this task in accident conditions.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $950,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.13).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
14	Replace HPI Pump Cooling Alignment Valves with MOVs	In the event that the normally aligned cooling source to a HPI pump fails, the current plant configuration requires local operation of the valves to swap the pump to the alternate cooling source. The time required to perform this action is considered to preclude it as a means of both preventing seal LOCAs in loss of seal cooling evolutions and for providing high pressure makeup. Replacing the valves with MOVs would allow the operators to rapidly align the alternate cooling source from the MCR in time to prevent a seal LOCA or provide high pressure injection.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $3,150,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.14).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
15	Automate Swap to Recirculation Mode	The operator action to swap to recirculation mode is a key action for LOCA scenarios. Automating this function would improve the reliability of this action, especially in the rapidly evolving events where other actions are competing for the attention of the operators.	Level 1 TMI-1 Importance List	Multiple SAMA analyses have included estimates for this type of change, but the estimates vary by over a factor of 3.5: - Oconee estimated the cost at over $1 million per unit (DUKE 1998)) - Point Beach estimated the cost at over $1 million per unit (NMC 2004) - Catawba estimated the cost at over $1 million (DUKE 2001) - Turkey Point estimated the cost to be about $450,000 (per unit) (FPL 2000) - H.B. Robinson $265,000 (single unit) (CPL 2002) For TMI-1, the $450,000 estimate from Turkey Point is used as it is in the middle range of the industry estimates identified.	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.15).
16	Automate HPI Injection on Low Pressurizer Level	Providing an automatic signal to initiate HPI on low pressurizer level would improve the reliability of HPI initiation.	Level 1 TMI-1 Importance List	The cost of this enhancement was estimated to be $1,100,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.16).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
17	Auto Isolate Steam Generators on High Steam Line Flow	For steam line breaks downstream of the MSIVs, failure to isolate the relevant steam generator is an important contributor to core damage. The addition of logic to isolate the steam generator on high steam line flow would reduce the core damage contribution from isolation failures.	Level 1 TMI-1 Importance List	This SAMA is considered to be similar in scope to SAMA 13 and the same cost of implementation ($950,000) is used for this SAMA.	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.17).
18	Provide the Capability to Align the Standby Battery Charger and the 1A/1B Cross-tie from the MCR	TMI has a spare 125V DC battery charger for each division that can be aligned to either battery bank within a division in the event that a normally operating battery charger fails. Currently, the alignment requires local actions. There is typically adequate time to align the charger in the event of a failure, but additional changes could be made to allow rapid alignment of the spare charger from the MCR to reduce the manipulation time and improve the man-machine interface.	Level 1 TMI-1 Importance List	No plant specific implementation cost was developed for this SAMA. Based on the low impact of the SAMA, the $100,000 minimum cost of a hardware modification (Exelon 2003) is used as the implementation cost.	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.18).
19	Install Battery Backed Hydrogen Igniters or a Passive Hydrogen Ignition System	The addition of igniters would provide a means of preventing catastrophic combustible gas burns by continuously burning these gases before they reach critical levels. Providing battery backup power would increase the likelihood that this system would be available in LOOP events. Use of a passive system would also function in LOOP as well as long term SBO scenarios.	Level 2 TMI-1 Importance List	The cost of this enhancement was estimated to be $760,000 in the Calvert Cliffs SAMA analysis (BGE 1998).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.19).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
20	Extend the High Pressure Boundary Through DHR Valve DH-V-3 for ISLOCA Isolation	The highest frequency ISLOCA scenario for TMI-1 is through two valves in the DHR suction line. While the scenario's CDF is low, the release frequency is relatively high given that primary containment is bypassed by definition. No effective mitigating actions are considered to be available in these cases because 1) the break may occur upstream of DH-V-3 or additional breaks in the low pressure boundary may occur after closure of a low pressure isolation valve, 2) reduction of primary system pressure may reduce the flow out of the break, but it would not stop it, and 3) refill of the BWST does not place the plant in a stable state and results in auxiliary building flooding. Extending the pressure boundary through DH-V-3 would provide an additional isolation point in these cases.	Level 2 TMI-1 Importance List	The cost of this enhancement was estimated to be $3.030,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.20).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
21	Install Concrete Shields to Block Direct Pathways from the RPV to the Containment Wall and/or Direct Containment Flooding Early in External Flooding Scenarios	This SAMA is based on a failure mode identified in the Level 2 analysis that indicates corium ejection during RV failure could result in dispersal of debris such that it could directly interact with the containment wall and cause a failure of the wall. For some external flooding scenarios, it may be possible to change the procedures to direct containment flooding early such that water would be available on the containment floor before loss of power.	Level 2 TMI-1 Importance List	The cost of this enhancement was estimated to be $1,200,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.21).
22	Install an Independent AFW System	For TMI-1, loss of MFW after a trip coupled with loss of EFW can lead to large radionuclide releases in SGTR and induced SGTR scenarios due to the unavailability of water in the SGs for fission product scrubbing. A large contributor to EFW failure is estimated to be system wide common cause failures. An independent, motor driven, auxiliary feedwater system would be an effective means of addressing these cases. Power dependence is not a large issue for the cases addressed by this SAMA and the independent EFW pump is assumed to be powered by existing emergency power such that it would not be capable of mitigating SBO scenarios.	Level 2 TMI-1 Importance List	Calvert Cliffs estimated the cost of installing an additional HPSI pump with a dedicated diesel to be between $5 million and $10 million (BGE 1998). This type of enhancement is similar is scope to the changes required for this SAMA and the lower bound estimate of $5 million is used for this SAMA as the diesel generator is not required for this SAMA.	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.22).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
23	Develop Alarm Response Procedures to Direct Operation of RR-V-5 on Low RBEC Flow	Failure of RR-V-6 to open results in the loss of RBEC flow to the reactor building coolers, which can be diagnosed using the system flow indicators in the main control room; however, no alarm response procedures exist to specifically direct operation of the bypass valve (RR-V-5). If this procedure was developed, it may reduce the diagnosis time and improve the reliability of this operator action in an accident conditions.	Level 2 TMI-1 Importance List	Procedure changes are estimated to be $50,000 (CPL 2004).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.23).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
24	Install Damage Resistant, High Temperature RCP Seals with a Diesel Engine as an Alternate Drive for an EFW Pump and a Portable Generator for Level Control Instrumentation	For SBOs in which EFW has failed, neither primary nor secondary side cooling is available. Installing the enhanced RCP seals will prevent seal LOCAs and use of a portable generator would allow the turbine driven EFW pump to be used for extended periods in an SBO, as suggested in SAMA 2. However, in the event that the turbine driven EFW pump fails, there would be no means of providing secondary side makeup. Turbine driven EFW failures could be mitigated if an engine was available to drive one of the EFW pumps. Other industry SAMA applications have suggested similar strategies, but they typically suggest the turbine driven pumps as the best option for connection to the engine based on ease of connection. For scenarios with turbine driven EFW failure, however, the initial TD EFW pump failure may prevent its further use even with an alternate motive source. As a result, this SAMA, in addition to the requirements of SAMA 2, requires that the diesel engine be connected to one of the motor driven EFW pumps.	Palisades SAMA Analysis (NMC 2005)	The cost of implementation for this SAMA is estimated to be a combination of SAMA 2 ($7,300,000) and the $1.1 million estimate for a direct drive diesel injection pump from Palisades (NMC 2005). The total implementation cost is $8,400,000.	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.24).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
25	Install an Additional EDG	An additional source of AC power is a potential means of supplying an entire division of safety equipment in the event that on-site AC power is lost in a LOOP. While additional EDGs are expensive, they can be cost effective at some plants, especially those with a large LOOP/SBO contribution to CDF.	Palisades SAMA Analysis (NMC 2005)	Brown's Ferry estimated the cost of installing an additional EDG to be $6 million (TVA 2003). While there are estimates as high as $25 million used in SAMA analyses for the installation of additional EDGs, the Browns Ferry estimate is used for TMI-1.	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.25).
26	Reroute Cables so that They Do Not Pass Over Ignition Sources in Fire Area CB-FA-2e (West Inverter Room) or Wrap them in Fire Proof Material	Some of the risk from fires in this room is from damage to cables that run over ignition sources. If the cable trays were re-routed away from the electrical equipment that they currently pass over, the consequences of equipment fires in the inverter room could be reduced.	TMI-1 IPEEE (Fire)	Of the two options, cable wrapping was determined to be the more cost effective approach. The cost of performing the cable wrapping in CB-FA-2e was estimated to be $900,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.26).
27	Improve the 480V AC load center welds	The IPEEE determined that the existing 480V AC load centers were among the weaker components in the TMI-1 AC distribution system. Adding reinforcements to the welds on the load center framework would improve the seismic durability of the structure and increase the likelihood that the system would be available after a seismic event. The other low seismic capacity components, the EDG air receivers, were enhanced subsequent to the completion of the IPEEE.	TMI-1 IPEEE (Seismic)	The cost of this enhancement was estimated to be $575,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.27).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
28	Improve the Decay Heat Service Cooler (DC-C-2A/B) Anchorages	The IPEEE determined that the existing Decay Heat Service Coolers (DC-C-2A/B) lacked sufficiently durable anchorages. Replacing the anchorages with more robust anchorages would improve the seismic durability of the structure and increase the likelihood that the heat exchangers would be available after a seismic event.	TMI-1 IPEEE (Seismic)	The cost of this enhancement was estimated to be $575,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.28).
29	Replace EDG Ground Resistors	Failure of the EDG ground resistors results in failure of the EDGs, which will lead to core damage in the event that off-site power is not available. Given that the HCLPF capacity for these components was estimated at 0.25g compared with 0.09g capacities of off-site power components (such as the 1/A and 1/B distribution buses or the aux transformers), it is likely that core damage will ensue due to long term loss of power if the EDG ground resistors fail from seismic shock. Replacing the resistors with more durable versions would improve the reliability of the EDGs in seismic events.	TMI-1 IPEEE (Seismic)	The cost of this enhancement was estimated to be $800,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.29).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
30	Improve Diesel Fire Pump Fuel Oil Tank and Battery Rack Supports	The Fire Service Water system provides cooling to the SBO EDG, backup cooling the DHCCW heat exchangers, and backup cooling to the "1A" and "1B" Instrument Air compressors. While seismic failures to the systems FSW supports would likely limit the benefit of improving the fuel oil tank and battery racks, some benefit may be available through improvements to the diesel fire pump's reliability.	TMI-1 IPEEE (Fire/Seismic)	The cost of this enhancement was estimated to be $150,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.30).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
31	Modify Specific Containment Penetration MOVs to “Fail Closed”	Most containment penetrations have AOV or SOV isolation valves that will fail closed on loss of air or power; however, there are cases in which MOVs are used instead. Those lines that do not include a pair of AOVs or SOVs that fail closed are typically below 1" in diameter or include at least one AOV or SOV that will fail closed on loss of air or power. However, the NSCCW and RBEC systems include penetrations that only include MOVs. While these are closed cooling systems that would not normally provide a credible release path, heat exchanger breaks in seismic events could provide containment bypass routes in the event that a failure also occurs in the reactor building. Changing one of the valves in each of these paths to fail closed is a means of increasing the isolation probability over what is available from manual action.	TMI-1 IPEEE (Seismic)	The cost of this enhancement was estimated to be $4,100,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.31).

TABLE E.5-3
PHASE I SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	COST ESTIMATE	PHASE I DISPOSITION
32	Pre-stage Severe Flooding Equipment	Pre-staging the equipment used to prevent core damage in severe flooding conditions would reduce sources of error in the alignment actions and reduce the time required to perform the task. Potential changes include: - Storing the portable EDG on the turbine deck - Adding a normally empty fuel oil tank for the portable EDG to the turbine deck - Permanently running power cable from the portable EDG to the pump areas A potential permutation of this SAMA would be to procure an additional portable EDG to reduce the failure contribution from the power source.	TMI-1 IPEEE (External Flooding)	The cost of implementation is estimated to be $1,700,000 (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.32).
33	Increase the Flood Protection Height	The current configuration protects to the design basis limit of 310 feet msl and levels any higher result in topping of the existing flood doors and flooding of sensitive areas. Raising the height of the flood doors (or completely sealing the doors) would prevent water incursion and allow for continued operation of the normal safety equipment.	TMI-1 IPEEE (External Flooding)	The cost of this enhancement was estimated to be $2,700,000 by the TMI staff (Exelon 2007c).	Cannot be screened on cost or applicability to the plant. Retain for Phase II analysis (refer to Section E.6.33).

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
1	Enhance the SBO EDG for Auto Alignment and Loading	The current capability of the SBO EDG is limited by manual actions to diagnose and respond to conditions requiring a start of the SBO EDG. While the time required to start and load the EDG is relatively short, it is close enough to the 13 minute limit for restoration of seal cooling after a total loss that no credit is taken for the SBO EDG to prevent seal LOCAs in LOOP evolutions with normal EDG failures. Automation of SBO EDG operation would reduce the time required to restore seal cooling and through this function, a large portion of the seal LOCA CDF could be eliminated.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
2	Install Damage Resistant, High Temperature RCP Seals with a Portable 480V Generator for Extended EFW Operation	Currently, alternate RCP pump seals are available that can effectively prevent seal LOCAs caused by loss of RCP seal cooling (Flowserve N-9000 seals). It is estimated that these seals will limit leakage flow to about 1 gpm per seal on loss of cooling, which is low enough to maintain core coverage in cases where seal LOCAs would normally result in core uncovery/core damage within the PRA's 24 hour mission time. The ability to prevent a seal LOCA will allow for extended operation in SBO conditions if level instrumentation can be supplied using the vital 120V AC system. Powering the station battery chargers with a portable 480V AC generator would provide this capability and allow control of the TD EFW system to be retained in the MCR.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
3	Use NSCCW as an Alternate Cooling Source for the DHR Heat Exchangers (DH-C-1A/B)	For LOCAs requiring heat removal with the RHR system, DHRW and DHCCW failures are large contributors to loss of the primary cooling function. Providing the ability to cross-tie the NSCCW system to the DHR heat exchangers would diversify the plant's heat removal capability and eliminate the failures associated with loss of DHRW or DHCCW flow. The hard piped connections are assumed to be sized to allow enough flow to remove decay heat (not just pump cooling loads) and that each division is provided with a cross-connection.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
4	Provide Alternate Power to HPI Pump Minimum Flow Recirculation Valves MU-V-36 and MU-V-37	The current PRA model logic correctly assumes isolation of valves MU-V-36 and 37 on an ESAS, but it does not include the AC power dependences for the "close" action. However, the logic related to opening the minimum flow valves does include the power dependences, which can result in the generation of cutsets that include the failure to open a flow path that was never isolated. If the appropriate power dependencies were accounted for in the isolation logic, the only events that could cause the MU-V-36 or MU-V-37 valves to be "stranded closed" are those in which an ESAS occurs when both divisions of power are available and then division "A" power fails before MU-V-36 can be opened.	Level 1 TMI-1 Importance List	Screened from analysis based on PRA insights as described in Section E.6.4.
5	Enhance Valves MU-V-76A/B and MU-V-77A/B to Allow for Rapid Alignment Changes in Accident Conditions	The current MU-V-76A/B and MU-V-77A/B valve configurations do not allow for rapid re-alignment during accident conditions. For TMI-1, the capability to quickly align the "C" HPI pump for seal injection would reduce the risk of prominent accident sequences in which thermal barrier cooling has failed in conjunction with the "A" and "B" HPI pumps. Replacing MU-V-76A/B and MU-V-77A/B with MOVs operable from the main control room would allow TMI-1 to use the "C" HPI pump for seal injection and prevent seal LOCAs when the normal cooling methods are unavailable.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
6	Add Cross-ties Within the Trains of the Cooling Systems -DHR -DHRW -DHCCW	Some failure combinations that eliminate both trains of the DHR related cooling systems could be mitigated if cross-ties were available between trains of the DHR, DHRW, and DHCCW systems (not between the systems). For example, these cross-ties would be helpful in conditions where the flow path fails in one train while a pump failure or maintenance event disables the opposite train. To ensure the DHR cross-ties can be implemented in a timely manner for LPI requirements, the associated valves should be operable from the main control room.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
7	Use Fire Service Water as an Alternate Cooling Source for the ICCW Heat Exchangers	For cases in which NSRW is unavailable due to hardware failures (e.g., flow diversion), the Fire Service Water system could be used to directly cool the ICCW heat exchangers for thermal barrier cooling support. Given that the ICCW pumps would be available for the relevant cases, a local, manual valve could be used for the alignment as time should be available for such an action.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
8	Automate Reactor Coolant Pump Trip	Seal LOCAs resulting from operator failures to trip the RCPs on loss of motor bearing cooling could be reduced if high temperature sensors were installed on motor bearing cooling water lines to provide automatic trip signals.	Level 1 TMI-1 Importance List	This SAMA's net value is positive and is classified as "cost beneficial".
9	Proceduralize Local ADV Operation	TMI-1 has procedures to perform the local ADV operations that are not credited in the PRA model (the failure probability is set to 1.0). If the available procedures are credited, the RRW value of the operator action would be reduced below the SAMA review threshold. This SAMA is used demonstrate the reduction in the RRW that would occur when a reasonable failure probability is applied to the operator action.	Level 1 TMI-1 Importance List	Screened from analysis based on PRA insights as described in Section E.6.9.

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
10	Automate BWST Refill	Failure to refill the BWST is a large contributor to some SGTR sequences, especially those in which the MS ADVs fail to operate. Automating the refill function would improve the reliability of this process and reduce the contributions from prominent SGTR sequences by providing a long term high pressure injection source. This SAMA requires a new pump with a flow rate of at least 400 gpm with a connection to a borated water source that will provide suction for 24 hours. In addition, the pump should be able to supply water from a non-borated water source for an indefinite periods of time after depletion of the borated water source.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
11	Enhance Extreme External Flooding Mitigation Equipment to Address SBO and Loss of Seal Cooling Scenarios	Making the extreme flooding equipment useful for SBO conditions, especially those with TD EFW failure, would require permanently mounting the submersible pumps so that the suctions could easily be swapped from a piped water source to the flood water source. Permanently installing the portable generator and the pumps so that they could be aligned from the MCR would improve alignment capabilities and address non-SBO loss of seal cooling cases through the ability to rapidly align alternate seal cooling.	Level 1 TMI-1 Importance List	This SAMA's net value is positive and is classified as "cost beneficial".
12	Use the DHR System as an Alternate Suction Source for HPI	Failures of the BWST suction path to the HPI pumps will lead to core damage in scenarios requiring early makeup. Through implementation of procedure changes, the DHR system could be aligned to take suction from the BWST and supply flow to the HPI system to allow injection in these cases.	Level 1 TMI-1 Importance List	This SAMA's net value is positive and is classified as "cost beneficial".

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
13	Change IA System Logic to Automatically Start IA-P-1A/B After a Low Voltage Trip in Conjunction with an ESAS	The current IA system logic requires the operators to re-load the IA compressors on emergency power after a low voltage trip when an ESAS is registered. Automating the re-loading of these compressors would remove the requirement for the operators to perform this task in accident conditions.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
14	Replace HPI Pump Cooling Alignment Valves with MOVs	In the event that the normally aligned cooling source to a HPI pump fails, the current plant configuration requires local operation of the valves to swap the pump to the alternate cooling source. The time required to perform this action is considered to preclude it as a means of both preventing seal LOCAs in loss of seal cooling evolutions and for providing high pressure makeup. Replacing the valves with MOVs would allow the operators to rapidly align the alternate cooling source from the MCR in time to prevent a seal LOCA or provide high pressure injection.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
15	Automate Swap to Recirculation Mode	The operator action to swap to recirculation mode is a key action for LOCA scenarios. Automating this function would improve the reliability of this action, especially in the rapidly evolving events where other actions are competing for the attention of the operators.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
16	Automate HPI Injection on Low Pressurizer Level	Providing an automatic signal to initiate HPI on low pressurizer level would improve the reliability of HPI initiation.	Level 1 TMI-1 Importance List	This SAMA's net value is positive and is classified as "cost beneficial".
17	Auto Isolate Steam Generators on High Steam Line Flow	For steam line breaks downstream of the MSIVs, failure to isolate the relevant steam generator is an important contributor to core damage. The addition of logic to isolate the steam generator on high steam line flow would reduce the core damage contribution from isolation failures.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
18	Provide the Capability to Align the Standby Battery Charger and the 1A/1B Cross-tie from the MCR	TMI has a spare 125V DC battery charger for each division that can be aligned to either battery bank within a division in the event that a normally operating battery charger fails. Currently, the alignment requires local actions. There is typically adequate time to align the charger in the event of a failure, but additional changes could be made to allow rapid alignment of the spare charger from the MCR to reduce the manipulation time and improve the man-machine interface.	Level 1 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
19	Install Battery Backed Hydrogen Igniters or a Passive Hydrogen Ignition System	The addition of igniters would provide a means of preventing catastrophic combustible gas burns by continuously burning these gases before they reach critical levels. Providing battery backup power would increase the likelihood that this system would be available in LOOP events. Use of a passive system would also function in LOOP as well as long term SBO scenarios.	Level 2 TMI-1 Importance List	This SAMA's net value is positive and is classified as "cost beneficial".
20	Extend the High Pressure Boundary Through DHR Valve DH-V-3 for ISLOCA Isolation	The highest frequency ISLOCA scenario for TMI-1 is through two valves in the DHR suction line. While the scenario's CDF is low, the release frequency is relatively high given that primary containment is bypassed by definition. No effective mitigating actions are considered to be available in these cases because 1) the break may occur upstream of DH-V-3 or additional breaks in the low pressure boundary may occur after closure of a low pressure isolation valve, 2) reduction of primary system pressure may reduce the flow out of the break, but it would not stop it, and 3) refill of the BWST does not place the plant in a stable state and results in auxiliary building flooding. Extending the pressure boundary through DH-V-3 would provide an additional isolation point in these cases.	Level 2 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
21	Install Concrete Shields to Block Direct Pathways from the RPV to the Containment Wall and/or Direct Containment Flooding Early in External Flooding Scenarios	This SAMA is based on a failure mode identified in the Level 2 analysis that indicates corium ejection during RV failure could result in dispersal of debris such that it could directly interact with the containment wall and cause a failure of the wall. For some external flooding scenarios, it may be possible to change the procedures to direct containment flooding early such that water would be available on the containment floor before loss of power.	Level 2 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
22	Install an Independent AFW System	For TMI-1, loss of MFW after a trip coupled with loss of EFW can lead to large radionuclide releases in SGTR and induced SGTR scenarios due to the unavailability of water in the SGs for fission product scrubbing. A large contributor to EFW failure is estimated to be system wide common cause failures. An independent, motor driven, auxiliary feedwater system would be an effective means of addressing these cases. Power dependence is not a large issue for the cases addressed by this SAMA and the independent EFW pump is assumed to be powered by existing emergency power such that it would not be capable of mitigating SBO scenarios.	Level 2 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".
23	Develop Alarm Response Procedures to Direct Operation of RR-V-5 on Low RBEC Flow	Failure of RR-V-6 to open results in the loss of RBEC flow to the reactor building coolers, which can be diagnosed using the system flow indicators in the main control room; however, no alarm response procedures exist to specifically direct operation of the bypass valve (RR-V-5). If this procedure was developed, it may reduce the diagnosis time and improve the reliability of this operator action in an accident conditions.	Level 2 TMI-1 Importance List	This SAMA's net value is negative and is classified as "not cost beneficial".

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
24	Install Damage Resistant, High Temperature RCP Seals with a Diesel Engine as an Alternate Drive for an EFW Pump and a Portable Generator for Level Control Instrumentation	For SBOs in which EFW has failed, neither primary nor secondary side cooling is available. Installing the enhanced RCP seals will prevent seal LOCAs and use of a portable generator would allow the turbine driven EFW pump to be used for extended periods in an SBO, as suggested in SAMA 2. However, in the event that the turbine driven EFW pump fails, there would be no means of providing secondary side makeup. Turbine driven EFW failures could be mitigated if an engine was available to drive one of the EFW pumps. Other industry SAMA applications have suggested similar strategies, but they typically suggest the turbine driven pumps as the best option for connection to the engine based on ease of connection. For scenarios with turbine driven EFW failure, however, the initial TD EFW pump failure may prevent its further use even with an alternate motive source. As a result, this SAMA, in addition to the requirements of SAMA 2, requires that the diesel engine be connected to one of the motor driven EFW pumps.	Palisades SAMA Analysis (NMC 2005)	This SAMA's net value is negative and is classified as "not cost beneficial".
25	Install an Additional EDG	An additional source of AC power is a potential means of supplying an entire division of safety equipment in the event that on-site AC power is lost in a LOOP. While additional EDGs are expensive, they can be cost effective at some plants, especially those with a large LOOP/SBO contribution to CDF.	Palisades SAMA Analysis (NMC 2005)	This SAMA's net value is negative and is classified as "not cost beneficial".

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
26	Reroute Cables so that They Do Not Pass Over Ignition Sources in Fire Area CB-FA-2e (West Inverter Room) or Wrap them in Fire Proof Material	Some of the risk from fires in this room is from damage to cables that run over ignition sources. If the cable trays were re-routed away from the electrical equipment that they currently pass over, the consequences of equipment fires in the inverter room could be reduced.	TMI-1 IPEEE (Fire)	This SAMA's net value is negative and is classified as "not cost beneficial".
27	Improve the 480V AC load center welds	The IPEEE determined that the existing 480V AC load centers were among the weaker components in the TMI-1 AC distribution system. Adding reinforcements to the welds on the load center framework would improve the seismic durability of the structure and increase the likelihood that the system would be available after a seismic event. The other low seismic capacity components, the EDG air receivers, were enhanced subsequent to the completion of the IPEEE.	TMI-1 IPEEE (Seismic)	This SAMA's net value is positive and is classified as "cost beneficial".
28	Improve the Decay Heat Service Cooler (DC-C-2A/B) Anchorages	The IPEEE determined that the existing Decay Heat Service Coolers (DC-C-2A/B) lacked sufficiently durable anchorages. Replacing the anchorages with more robust anchorages would improve the seismic durability of the structure and increase the likelihood that the heat exchangers would be available after a seismic event.	TMI-1 IPEEE (Seismic)	This SAMA's net value is negative and is classified as "not cost beneficial".

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
29	Replace EDG Ground Resistors	Failure of the EDG ground resistors results in failure of the EDGs, which will lead to core damage in the event that off-site power is not available. Given that the HCLPF capacity for these components was estimated at 0.25g compared with 0.09g capacities of off-site power components (such as the 1/A and 1/B distribution buses or the aux transformers), it is likely that core damage will ensue due to long term loss of power if the EDG ground resistors fail from seismic shock. Replacing the resistors with more durable versions would improve the reliability of the EDGs in seismic events.	TMI-1 IPEEE (Seismic)	This SAMA's net value is negative and is classified as "not cost beneficial".
30	Improve Diesel Fire Pump Fuel Oil Tank and Battery Rack Supports	The Fire Service Water system provides cooling to the SBO EDG, backup cooling the DHCCW heat exchangers, and backup cooling to the "1A" and "1B" Instrument Air compressors. While seismic failures to the systems FSW supports would likely limit the benefit of improving the fuel oil tank and battery racks, some benefit may be available through improvements to the diesel fire pump’s reliability.	TMI-1 IPEEE (Fire/Seismic)	This SAMA's net value is negative and is classified as "not cost beneficial".
31	Modify Specific Containment Penetration MOVs to “Fail Closed”	Most containment penetrations have AOV or SOV isolation valves that will fail closed on loss of air or power; however, there are cases in which MOVs are used instead. Those lines that do not include a pair of AOVs or SOVs that fail closed are typically below 1" in diameter or include at least one AOV or SOV that will fail closed on loss of air or power. However, the NSCCW and RBEC systems include penetrations that only include MOVs. While these are closed cooling systems that would not normally provide a credible release path, heat exchanger breaks in seismic events could provide containment bypass routes in the event that a failure also occurs in the reactor building. Changing one of the valves in each of these paths to fail closed is a means of increasing the isolation probability over what is available from manual action.	TMI-1 IPEEE (Seismic)	Screened from analysis based on PRA insights as described in Section E.6.31.

TABLE E.5-4
PHASE II SAMA

SAMA NUMBER	SAMA TITLE	SAMA DESCRIPTION	SOURCE	BASELINE PHASE II DISPOSITION
32	Pre-stage Severe Flooding Equipment	Pre-staging the equipment used to prevent core damage in severe flooding conditions would reduce sources of error in the alignment actions and reduce the time required to perform the task. Potential changes include: - Storing the portable EDG on the turbine deck - Adding a normally empty fuel oil tank for the portable EDG to the turbine deck - Permanently running power cable from the portable EDG to the pump areas A potential permutation of this SAMA would be to procure an additional portable EDG to reduce the failure contribution from the power source.	TMI-1 IPEEE (External Flooding)	This SAMA's net value is positive and is classified as "cost beneficial".
33	Increase the Flood Protection Height	The current configuration protects to the design basis limit of 310 feet msl and levels any higher result in topping of the existing flood doors and flooding of sensitive areas. Raising the height of the flood doors (or completely sealing the doors) would prevent water incursion and allow for continued operation of the normal safety equipment.	TMI-1 IPEEE (External Flooding)	This SAMA's net value is positive and is classified as "cost beneficial".

TABLE E.8-1
SUMMAY OF COST BENEFICIAL SAMAS

SAMA ID	SAMA Title	SAMA Implementation Cost	Averted Cost-Risk	Net Value	DPD Ratio*	Comments
SAMA 8	Automate Reactor Coolant Pump Trip	$145,000	$3,395,359	$3,250,359	23.4	This SAMA would complement the set of existing RCP protection signals to protect against potential cooling failures that appear to be critical to the RCPs. Given the relatively low implementation cost and the relatively large risk reduction associated with the change, this SAMA is a candidate for implementation.
SAMA 32	Pre-stage Severe Flooding Equipment	$1,700,000	$35,893,061	$34,193,061	21.1	This SAMA yields a large averted cost-risk for TMI-1. There is a large degree of uncertainty associated with flood risk that could impact the results of the cost benefit analysis, but the location of the plant suggests that enhancements to the extreme flood mitigation strategy should be in place for the site. This SAMA should be considered for implementation.
SAMA 19	Install Battery Backed Hydrogen Igniters or a Passive Hydrogen Ignition System	$760,000	$8,601,659	$7,841,659	11.3	The passive hydrogen ignition system is designed to prevent containment failures due to post-core-damage combustible gas burns in accident conditions and is intended to be operable even in long term SBO evolutions. The current PRA model considers combustible gas burns to be a credible containment failure mode, but the conservative assumptions related to the containment failure probabilities are considered to greatly overestimate the benefit of this SAMA. This SAMA is not recommended for implementation.
SAMA 12	Use the DHR System as an Alternate Suction Source for HPI	$50,000	$545,705	$495,705	10.9	This is an inexpensive change that would allow the operators to use HPI in the event that the normal BWST suction path fails. While the probability that the alternate suction alignment would be required during the life of the plant is low, this SAMA would proceduralize a means of addressing failures that could otherwise contribute to core damage. This SAMA should be considered for implementation.

TABLE E.8-1
SUMMAY OF COST BENEFICIAL SAMAS

SAMA ID	SAMA Title	SAMA Implementation Cost	Averted Cost-Risk	Net Value	DPD Ratio*	Comments
SAMA 11	Enhance Extreme External Flooding Mitigation Equipment to Address SBO and Loss of Seal Cooling Scenarios	$4,250,000	$44,243,903	$39,993,903	10.4	SAMA 11 is a complex plant modification that was designed to reduce internal events SBO risk by taking advantage of equipment that could also be used to mitigate the extreme flood scenarios. The intent of the SAMA was to determine if changes could be made to the extreme flooding equipment such that it would be beneficial in non-external flooding SBO cases. However, the differences in the external flooding SBO and a standard SBO require significantly different capabilities. The main issue is that the external flooding strategy uses the flood cues to predict the need for the mitigation equipment well before the loss of AC power. The implication is that seal cooling can be maintained such that there will not be a seal LOCA.
SAMA 11 (cont.)						If a seal LOCA did occur, the primary side makeup requirements increase and the injection inventory may be depleted over the long potential mission times for external flooding events. Consequently, seal LOCA prevention is considered to be a requirement for long term success. For standard SBO cases, seal LOCAs are assumed to be preventable only if seal cooling can be restored within 13 minutes of the initial loss of cooling (standard SBOs are generally not anticipated and the mitigation equipment could not be pre-initiated). Seal LOCA prevention would require an auto start/load of the 480V AC generator on an undervoltage signal to the HPI pump buses or high RCP cooling water temperature signal. Even without external flooding contributions, this SAMA would be cost beneficial based on the 95th percentile PRA results. However, SAMA 2 may be a more desirable means of addressing seal LOCAs given that its passive design would likely be more reliable than an active cooling system and because it yields a larger internal events risk reduction, which has benefits outside of the SAMA analysis.

TABLE E.8-1
SUMMAY OF COST BENEFICIAL SAMAS

SAMA ID	SAMA Title	SAMA Implementation Cost	Averted Cost-Risk	Net Value	DPD Ratio*	Comments
SAMA 33	Increase the Flood Protection Height	$2,700,000	$25,141,284	$22,441,284	9.3	This SAMA is a potential means of mitigating severe flood risk; however, this strategy is predicated on identifying and eliminating all flow paths into areas containing safety equipment. In addition, there is the implicit assumption that the flood gates and buildings will withstand the hydrodynamic forces of the flood waters. Because of the uncertainty associated with this SAMA, SAMA 32 is considered to be the better approach to addressing flood risk and SAMA 33 a less desirable alternative. If SAMA 32 is implemented, SAMA 33 would not be cost beneficial.
SAMA 27	Improve the 480V AC load center welds	$575,000	$3,593,752	$3,018,752	6.3	This modification was identified in the IPEEE as a change that could reduce seismic risk by about 50 percent. While this enhancement addressed a significant seismic concern, the modifications were not implemented because the load center failures only accounted for about 10 percent of the total TMI-1 CDF (internal + external events). If the LLNL seismic hazard curves are used in place of the EPRI seismic hazard curves that were used in the IPEEE base case, the seismic CDF increases from 3.21E-05/yr to 8.43E-05/yr. Given this condition, strengthening the 480 V AC load center welds would yield a CDF reduction of 4.22E-05/yr. While this appears to be a likely candidate for implementation, the seismic hazard curves represent a source of uncertainty in the seismic risk evaluation. Because TMI-1 is located in a seismically stable region, this SAMA may warrant further review, but it is not suggested for implementation at this time.

TABLE E.8-1
SUMMAY OF COST BENEFICIAL SAMAS

SAMA ID	SAMA Title	SAMA Implementation Cost	Averted Cost-Risk	Net Value	DPD Ratio*	Comments
SAMA 16	Automate HPI Injection on Low Pressurizer Level	$1,100,000	$4,379,735	$3,279,735	4.0	This SAMA suggests further automating an action on which the operators are well trained. While operator training is thorough and manual initiation failures are very unlikely even in cases where the current initiation logic would not actuate, failure to manually initiate HPI implies that a severe diagnosis error has occurred and that subsequent actions are also in jeopardy of failing. Even though the automatic HPI initiation could be inhibited/cancelled, such an action would require an active assessment of the RCS level and it would provide an opportunity for level recovery. However, the benefit of this SAMA is based on the PRA human error probability assessments, which are typically associated with a relatively high degree of uncertainty. In this case, a single joint human error probability is responsible for most of the PRA model-predicted risk and it is not appropriate to justify a large expenditure of resources to address a risk area with such a wide uncertainty. This SAMA should not be considered as a high priority item.
SAMA 21	Install Concrete Shields to Block Direct Pathways from the RPV to the Containment Wall and/or Direct Containment Flooding Early in External Flooding Scenarios	$1,200,000	$3,248,127	$2,048,127	2.7	This SAMA yields a relatively low benefit for internal events even for the 95th percentile results (about $560k), but when the benefits associated with the external flood contributions are added, the SAMA shows a much higher benefit. Implementation of SAMA 32 would reduce the benefit associated with this SAMA to the point where it would no longer be cost beneficial. If SAMA 32 is implemented, SAMA 21 should not be considered for implementation. Even without implementation of SAMA 32, discussions with Severe Accident Management personnel indicate that the path from the reactor vessel to the containment shell is obstructed and that the shell liner failure probability used in the PRA may be pessimistic.
SAMA 23	Develop Alarm Response Procedures to Direct Operation of RR-V-5 on Low RBEC Flow	$50,000	$84,230	$34,230	1.7	SAMA 23 is a low cost procedure change that would help the operators diagnose containment cooling problems. This SAMA should be considered for implementation.

TABLE E.8-1
SUMMAY OF COST BENEFICIAL SAMAS

SAMA ID	SAMA Title	SAMA Implementation Cost	Averted Cost-Risk	Net Value	DPD Ratio*	Comments
SAMA 2	Install Damage Resistant, High Temperature RCP Seals with a Portable 480V Generator for Extended EFW Operation	$7,300,000	$11,816,753	$4,516,753	1.6	SAMA 2 is a high cost change that impacts seal LOCAs and SBO scenarios. When the 95th percentile PRA results are considered, this SAMA is shown to be potentially cost beneficial. While the DPD ratio is smaller than what has been estimated for SAMA 11, SAMA 2 may be a more desirable means of addressing seal LOCAs given that its passive design would likely be more reliable than an active cooling system and because it yields a larger internal events risk reduction, which has benefits outside of the SAMA analysis.
SAMA 24	Install Damage Resistant, High Temperature RCP Seals with a Diesel Engine as an Alternate Drive for an EFW Pump and a Portable Generator for Level Control Instrumentation	$8,400,000	$12,144,553	$3,744,553	1.4	SAMA 24 is an enhancement of SAMA 2 that is designed to address turbine driven EFW failures. Given that the difference in benefit between SAMA 2 and SAMA 24 when considering the 95th percentile PRA results is only $327,800, it would not be beneficial to add the diesel driven motor option for the EFW pump when the cost of that portion of the SAMA is estimated to be $1.1 million. This SAMA is not recommended for implementation.
SAMA 7	Use Fire Service Water as an Alternate Cooling Source for the ICCW Heat Exchangers	$1,000,000	$1,235,449	$235,449	1.2	SAMA 7 provides an alternate means of cooling the ICCW heat exchangers when normal cooling flow to the heat exchangers fails. While this enhancement provides a non-negligible reduction in risk, the margin by which it is cost beneficial is low and it is not a likely candidate for implementation.
SAMA 15	Automate Swap to Recirculation Mode	$450,000	$547,520	$97,520	1.2	SAMA 15 is a SAMA that has been identified for many plants in the industry. For TMI-1, it is only considered to be cost effective using the 95th percentile PRA results and a generic implementation cost of $450,000, which may be low. This is not a high priority candidate for implementation based on the small margin by which it is cost effective and because a plant specific implementation cost estimate may provide a basis for excluding it from consideration.

TABLE E.8-1
SUMMAY OF COST BENEFICIAL SAMAS

SAMA ID	SAMA Title	SAMA Implementation Cost	Averted Cost-Risk	Net Value	DPD Ratio*	Comments
SAMA 26	Reroute Cables so that They Do Not Pass Over Ignition Sources in Fire Area CB-FA-2e (West Inverter Room) or Wrap them in Fire Proof Material	$900,000	$1,016,573	$116,573	1.1	The margin by which this SAMA is cost beneficial is small and the methods available to estimate the averted cost-risk were limited, as described in Section E.5.1.6.1. This SAMA may be considered cost beneficial, but a more detailed, up to date assessment of the fire risk would be required to better define the potential benefit of protecting the cables in Fire Area CB-FA-2E.

Table Notes:

* The DPD (dollar per dollar) Ratio is the Averted Cost-Risk divided by the SAMA cost.

** The absolute change in CDF (baseline CDF minus estimated CDF with the particular SAMA in place) is presented followed by the percent change (in parentheses).

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ADDENDUM 1 TO ATTACHMENT E
SELECTED PREVIOUS INDUSTRY SAMAS

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
Improvements Related to RCP Seal LOCAs (Loss of CC or SW)		
1	Cap downstream piping of normally closed component cooling water drain and vent valves.	SAMA would reduce the frequency of a loss of component cooling event, a large portion of which was derived from catastrophic failure of one of the many single isolation valves.
2	Enhance loss of component cooling procedure to facilitate stopping reactor coolant pumps.	SAMA would reduce the potential for reactor coolant pump (RCP) seal damage due to pump bearing failure.
3	Enhance loss of component cooling procedure to present desirability of cooling down reactor coolant system (RCS) prior to seal LOCA.	SAMA would reduce the potential for RCP seal failure.
4	Provide additional training on the loss of component cooling.	SAMA would potentially improve the success rate of operator actions after a loss of component cooling (to restore RCP seal damage).
5	Provide hardware connections to allow another essential raw cooling water system to cool charging pump seals.	SAMA would reduce effect of loss of component cooling by providing a means to maintain the centrifugal charging pump seal injection after a loss of component cooling.
6	Procedure changes to allow cross connection of motor cooling for residual heat removal service water (RHRSW) pumps.	SAMA would allow continued operation of both RHRSW pumps on a failure of one train of PSW.
7	Proceduralize shedding component cooling water loads to extend component cooling heatup on loss of essential raw cooling water.	SAMA would increase time before the loss of component cooling (and reactor coolant pump seal failure) in the loss of essential raw cooling water sequences.
8	Increase charging pump lube oil capacity.	SAMA would lengthen the time before centrifugal charging pump failure due to lube oil overheating in loss of CC sequences.
9	Eliminate the RCP thermal barrier dependence on component cooling such that loss of component cooling does not result directly in core damage.	SAMA would prevent the loss of recirculation pump seal integrity after a loss of component cooling. Watts Bar Nuclear Plant IPE said that they could do this with essential raw cooling water connection to RCP seals.
10	Add redundant DC control power for PSW pumps C & D.	SAMA would increase reliability of PSW and decrease CDF due to a loss of SW.
11	Create an independent RCP seal injection system, with a dedicated diesel.	SAMA would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of component cooling or SW or from a SBO event.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
12	Use existing hydro-test pump for RCP seal injection.	SAMA would provide an independent seal injection source, without the cost of a new system.
13	Replace ECCS pump motor with air-cooled motors.	SAMA would eliminate ECCS dependency on component cooling system (but not on room cooling).
14	Install improved RCS pumps seals.	SAMA would reduce probability of RCP seal LOCA by installing RCP seal O-ring constructed of improved materials
15	Install additional component cooling water pump.	SAMA would reduce probability of loss of component cooling leading to RCP seal LOCA.
16	Prevent centrifugal charging pump flow diversion from the relief valves.	SAMA modification would reduce the frequency of the loss of RCP seal cooling if relief valve opening causes a flow diversion large enough to prevent RCP seal injection.
17	Change procedures to isolate RCP seal letdown flow on loss of component cooling, and guidance on loss of injection during seal LOCA.	SAMA would reduce CDF from loss of seal cooling.
18	Implement procedures to stagger high-pressure safety injection (HPSI) pump use after a loss of SW.	SAMA would allow HPSI to be extended after a loss of SW.
19	Use FPS pumps as a backup seal injection and high-pressure makeup.	SAMA would reduce the frequency of the RCP seal LOCA and the SBO CDF.
20	Enhance procedural guidance for use of cross-tied component cooling or SW pumps.	SAMA would reduce the frequency of the loss of component cooling water and SW.
21	Procedure enhancements and operator training in support system failure sequences, with emphasis on anticipating problems and coping.	SAMA would potentially improve the success rate of operator actions subsequent to support system failures.
22	Improved ability to cool the residual heat removal (RHR) heat exchangers.	SAMA would reduce the probability of a loss of decay heat removal by implementing procedure and hardware modifications to allow manual alignment of the FPS or by installing a component cooling water cross-tie.
23	Additional SW Pump	SAMA would conceivably reduce common cause dependencies from SW system and thus reduce plant risk through system reliability improvement.
24	Create an independent RCP seal injection system, without dedicated diesel	This SAMA would add redundancy to RCP seal cooling alternatives, reducing the CDF from loss of CC or SW, but not SBO.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
Improvements Related to Heating, Ventilation, and Air Conditioning		
25	Provide reliable power to control building fans.	SAMA would increase availability of CR ventilation on a loss of power.
26	Provide a redundant train of ventilation.	SAMA would increase the availability of components dependent on room cooling.
27	Procedures for actions on loss of HVAC.	SAMA would provide for improved credit to be taken for loss of HVAC sequences (improved affected electrical equipment reliability upon a loss of control building HVAC).
28	Add a diesel building switchgear room high temperature alarm.	SAMA would improve diagnosis of a loss of switchgear room HVAC. Option 1: Install high temp alarm. Option 2: Redundant louver and thermostat
29	Create ability to switch fan power supply to DC in an SBO event.	SAMA would allow continued operation in an SBO event. This SAMA was created for reactor core isolation cooling (RCIC) system room at Fitzpatrick Nuclear Power Plant.
30	Enhance procedure to instruct operators to trip unneeded RHR/CS pumps on loss of room ventilation.	SAMA increases availability of required RHR/CS pumps. Reduction in room heat load allows continued operation of required RHR/CS pumps, when room cooling is lost.
31	Stage backup fans in switchgear (SWGR) rooms	This SAMA would provide alternate ventilation in the event of a loss of SWGR Room ventilation
Improvements Related to Ex-Vessel Accident Mitigation/Containment Phenomena		
32	Delay containment spray actuation after large LOCA.	SAMA would lengthen time of refueling water storage tank (RWST) availability.
33	Install containment spray pump header automatic throttle valves.	SAMA would extend the time over which water remains in the RWST, when full CS flow is not needed
34	Install an independent method of suppression pool cooling.	SAMA would decrease the probability of loss of containment heat removal. For PWRs, a potential similar enhancement would be to install an independent cooling system for sump water.
35	Develop an enhanced drywell spray system.	SAMA would provide a redundant source of water to the containment to control containment pressure, when used in conjunction with containment heat removal.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
36	Provide dedicated existing drywell spray system.	SAMA would provide a source of water to the containment to control containment pressure, when used in conjunction with containment heat removal. This would use an existing spray loop instead of developing a new spray system.
37	Install an unfiltered hardened containment vent.	SAMA would provide an alternate decay heat removal method for non-ATWS events, with the released fission products not being scrubbed.
38	Install a filtered containment vent to remove decay heat.	SAMA would provide an alternate decay heat removal method for non-ATWS events, with the released fission products being scrubbed. Option 1: Gravel Bed Filter Option 2: Multiple Venturi Scrubber
39	Install a containment vent large enough to remove ATWS decay heat.	Assuming that injection is available, this SAMA would provide alternate decay heat removal in an ATWS event.
40	Create/enhance hydrogen recombiners with independent power supply.	SAMA would reduce hydrogen detonation at lower cost, Use either 1) a new independent power supply 2) a nonsafety-grade portable generator 3) existing station batteries 4) existing AC/DC independent power supplies.
41	Install hydrogen recombiners.	SAMA would provide a means to reduce the chance of hydrogen detonation.
42	Create a passive design hydrogen ignition system.	SAMA would reduce hydrogen denotation system without requiring electric power.
43	Create a large concrete crucible with heat removal potential under the basemat to contain molten core debris.	SAMA would ensure that molten core debris escaping from the vessel would be contained within the crucible. The water cooling mechanism would cool the molten core, preventing a melt-through of the basemat.
44	Create a water-cooled rubble bed on the pedestal.	SAMA would contain molten core debris dropping on to the pedestal and would allow the debris to be cooled.
45	Provide modification for flooding the drywell head.	SAMA would help mitigate accidents that result in the leakage through the drywell head seal.
46	Enhance FPS and/or standby gas treatment system hardware and procedures.	SAMA would improve fission product scrubbing in severe accidents.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
47	Create a reactor CFS.	SAMA would enhance debris coolability, reduce core concrete interaction, and provide fission product scrubbing.
48	Create other options for reactor cavity flooding.	SAMA would enhance debris coolability, reduce core concrete interaction, and provide fission product scrubbing.
49	Enhance air return fans (ice condenser plants).	SAMA would provide an independent power supply for the air return fans, reducing containment failure in SBO sequences.
50	Create a core melt source reduction system.	SAMA would provide cooling and containment of molten core debris. Refractory material would be placed underneath the reactor vessel such that a molten core falling on the material would melt and combine with the material. Subsequent spreading and heat removal form the vitrified compound would be facilitated, and concrete attack would not occur
51	Provide a containment inerting capability.	SAMA would prevent combustion of hydrogen and carbon monoxide gases.
52	Use the FPS as a backup source for the containment spray system.	SAMA would provide redundant containment spray function without the cost of installing a new system.
53	Install a secondary containment filtered vent.	SAMA would filter fission products released from primary containment.
54	Install a passive containment spray system.	SAMA would provide redundant containment spray method without high cost.
55	Strengthen primary/secondary containment.	SAMA would reduce the probability of containment overpressurization to failure.
56	Increase the depth of the concrete basemat or use an alternative concrete material to ensure melt-through does not occur.	SAMA would prevent basemat melt-through.
57	Provide a reactor vessel exterior cooling system.	SAMA would provide the potential to cool a molten core before it causes vessel failure, if the lower head could be submerged in water.
58	Construct a building to be connected to primary/secondary containment that is maintained at a vacuum.	SAMA would provide a method to depressurize containment and reduce fission product release.
59	Refill CST	SAMA would reduce the risk of core damage during events such as extended SBOs or LOCAs which render the suppression pool unavailable as an injection source due to heat up.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
60	Maintain ECCS suction on CST	SAMA would maintain suction on the CST as long as possible to avoid pump failure as a result of high suppression pool temperature
61	Modify containment flooding procedure to restrict flooding to below TAF	SAMA would avoid forcing containment venting
62	Enhance containment venting procedures with respect to timing, path selection and technique.	SAMA would improve likelihood of successful venting strategies.
63	Severe Accident EPGs/AMGs	SAMA would lead to improved arrest of core melt progress and prevention of containment failure
64	Simulator Training for Severe Accident	SAMA would lead to improved arrest of core melt progress and prevention of containment failure
65	Dedicated Suppression Pool Cooling	SAMA would decrease the probability of loss of containment heat removal. While PWRs do not have suppression pools, a similar modification may be applied to the sump. Installation of a dedicated sump cooling system would provide an alternate method of cooling injection water.
66	Larger Volume Containment	SAMA increases time before containment failure and increases time for recovery
67	Increased Containment Pressure Capability (sufficient pressure to withstand severe accidents)	SAMA minimizes likelihood of large releases
68	Improved Vacuum Breakers (redundant valves in each line)	SAMA reduces the probability of a stuck open vacuum breaker.
69	Increased Temperature Margin for Seals	This SAMA would reduce containment failure due to drywell head seal failure caused by elevated temperature and pressure.
70	Improved Leak Detection	This SAMA would help prevent LOCA events by identifying pipes which have begun to leak. These pipes can be replaced before they break.
71	Suppression Pool Scrubbing	Directing releases through the suppression pool will reduce the radionuclides allowed to escape to the environment.
72	Improved Bottom Penetration Design	SAMA reduces failure likelihood of RPV bottom head penetrations
73	Larger Volume Suppression Pool (double effective liquid volume)	SAMA would increase the size of the suppression pool so that heatup rate is reduced, allowing more time for recovery of a heat removal system

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
74	Unfiltered Vent	SAMA would provide an alternate decay heat removal method with the released fission products not being scrubbed.
75	Filtered Vent	SAMA would provide an alternate decay heat removal method with the released fission products being scrubbed.
76	Post Accident Inerting System	SAMA would reduce likelihood of gas combustion inside containment
77	Hydrogen Control by Venting	Prevents hydrogen detonation by venting the containment before combustible levels are reached.
78	Pre-inerting	SAMA would reduce likelihood of gas combustion inside containment
79	Ignition Systems	Burning combustible gases before they reach a level which could cause a harmful detonation is a method of preventing containment failure.
80	Fire Suppression System Inerting	Use of the FPS as a back up containment inerting system would reduce the probability of combustible gas accumulation. This would reduce the containment failure probability for small containments (e.g. BWR MKI).
81	Drywell Head Flooding	SAMA would provide intentional flooding of the upper drywell head such that if high drywell temperatures occurred, the drywell head seal would not fail.
82	Containment Spray Augmentation	This SAMA would provide additional means of providing flow to the containment spray system.
83	Integral Basemat	This SAMA would improve containment and system survivability for seismic events.
84	Reactor Building Sprays	This SAMA provides the capability to use firewater sprays in the reactor building to mitigate release of fission products into the Rx Bldg following an accident.
85	Flooded Rubble Bed	SAMA would contain molten core debris dropping on to the pedestal and would allow the debris to be cooled.
86	Reactor Cavity Flooder	SAMA would enhance debris coolability, reduce core concrete interaction, and provide fission product scrubbing.
87	Basaltic Cements	SAMA minimizes carbon dioxide production during core concrete interaction.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
88	Provide a core debris control system	(Intended for ice condenser plants): This SAMA would prevent the direct core debris attack of the primary containment steel shell by erecting a barrier between the seal table and the containment shell.
89	Add ribbing to the containment shell	This SAMA would reduce the risk of buckling of containment under reverse pressure loading.
Improvements Related to Enhanced AC/DC Reliability/Availability		
90	Proceduralize alignment of spare diesel to shutdown board after LOOP and failure of the diesel normally supplying it.	SAMA would reduce the SBO frequency.
91	Provide an additional DG.	SAMA would increase the reliability and availability of onsite emergency AC power sources.
92	Provide additional DC battery capacity.	SAMA would ensure longer battery capability during an SBO, reducing the frequency of long-term SBO sequences.
93	Use fuel cells instead of lead-acid batteries.	SAMA would extend DC power availability in an SBO.
94	Procedure to cross-tie high-pressure core spray diesel.	SAMA would improve core injection availability by providing a more reliable power supply for the high-pressure core spray pumps.
95	Improve 4.16-kV bus cross-tie ability.	SAMA would improve AC power reliability.
96	Incorporate an alternate battery charging capability.	SAMA would improve DC power reliability by either cross-tying the AC busses, or installing a portable diesel-driven battery charger.
97	Increase/improve DC bus load shedding.	SAMA would extend battery life in an SBO event.
98	Replace existing batteries with more reliable ones.	SAMA would improve DC power reliability and thus increase available SBO recovery time.
99	Mod for DC Bus A reliability.	SAMA would increase the reliability of AC power and injection capability. Loss of DC Bus A causes a loss of main condenser, prevents transfer from the main transformer to OSP, and defeats one half of the low vessel pressure permissive for low pressure coolant injection (LPCI)/CS injection valves.
100	Create AC power cross-tie capability with other unit.	SAMA would improve AC power reliability.
101	Create a cross-tie for diesel fuel oil.	SAMA would increase diesel fuel oil supply and thus DG, reliability.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
102	Develop procedures to repair or replace failed 4-kV breakers.	SAMA would offer a recovery path from a failure of the breakers that perform transfer of 4.16-kV non-emergency busses from unit station service transformers, leading to loss of emergency AC power.
103	Emphasize steps in recovery of OSP after an SBO.	SAMA would reduce HEP during OSP recovery.
104	Develop a severe weather conditions procedure.	For plants that do not already have one, this SAMA would reduce the CDF for external weather-related events.
105	Develop procedures for replenishing diesel fuel oil.	SAMA would allow for long-term diesel operation.
106	Install gas turbine generator.	SAMA would improve onsite AC power reliability by providing a redundant and diverse emergency power system.
107	Create a backup source for diesel cooling. (Not from existing system)	This SAMA would provide a redundant and diverse source of cooling for the DGs, which would contribute to enhanced diesel reliability.
108	Use FPS as a backup source for diesel cooling.	This SAMA would provide a redundant and diverse source of cooling for the DGs, which would contribute to enhanced diesel reliability.
109	Provide a connection to an alternate source of OSP.	SAMA would reduce the probability of a LOOP event.
110	Bury OSP lines.	SAMA could improve OSP reliability, particularly during severe weather.
111	Replace anchor bolts on DG oil cooler.	Millstone Nuclear Power Station found a high seismic SBO risk due to failure of the diesel oil cooler anchor bolts. For plants with a similar problem, this would reduce seismic risk. Note that these were Fairbanks Morse DGs.
112	Change undervoltage (UV), AFW actuation signal (AFAS) block and high pressurizer pressure actuation signals to 3-out-of-4, instead of 2-out-of-4 logic.	SAMA would reduce risk of 2/4 inverter failure.
113	Provide DC power to the 120/240-V vital AC system from the Class 1E station service battery system instead of its own battery.	SAMA would increase the reliability of the 120-VAC Bus.
114	Bypass DG Trips	SAMA would allow D/Gs to operate for longer.
115	2.i. 16 hour SBO Injection	SAMA includes improved capability to cope with longer SBO scenarios.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
116	Steam Driven Turbine Generator	This SAMA would provide a steam driven turbine generator which uses reactor steam and exhausts to the suppression pool. If large enough, it could provide power to additional equipment.
117	Alternate Pump Power Source	This SAMA would provide a small dedicated power source such as a dedicated diesel or gas turbine for the feedwater or condensate pumps, so that they do not rely on OSP.
118	Additional DG	SAMA would reduce the SBO frequency.
119	Increased Electrical Divisions	SAMA would provide increased reliability of AC power system to reduce core damage and release frequencies.
120	Improved Uninterruptible Power Supplies	SAMA would provide increased reliability of power supplies supporting front-line equipment, thus reducing core damage and release frequencies.
121	AC Bus Cross-Ties	SAMA would provide increased reliability of AC power system to reduce core damage and release frequencies.
122	Gas Turbine	SAMA would improve onsite AC power reliability by providing a redundant and diverse emergency power system.
123	Dedicated RHR (bunkered) Power Supply	SAMA would provide RHR with more reliable AC power.
124	Dedicated DC Power Supply	This SAMA addresses the use of a diverse DC power system such as an additional battery or fuel cell for the purpose of providing motive power to certain components (e.g., RCIC).
125	Additional Batteries/Divisions	This SAMA addresses the use of a diverse DC power system such as an additional battery or fuel cell for the purpose of providing motive power to certain components (e.g., RCIC).
126	Fuel Cells	SAMA would extend DC power availability in an SBO.
127	DC Cross-ties	This SAMA would improve DC power reliability.
128	Extended SBO Provisions	SAMA would provide reduction in SBO sequence frequencies.
129	Add an automatic bus transfer feature to allow the automatic transfer of the 120V vital AC bus from the on-line unit to the standby unit	Plants are typically sensitive to the loss of one or more 120V vital AC buses. Manual transfers to alternate power supplies could be enhanced to transfer automatically.
Improvements in Identifying and Mitigating Containment Bypass		

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
130	Install a redundant spray system to depressurize the primary system during a steam generator tube rupture (SGTR).	SAMA would enhance depressurization during a SGTR.
131	Improve SGTR coping abilities.	SAMA would improve instrumentation to detect SGTR, or additional system to scrub fission product releases.
132	Add other SGTR coping abilities.	SAMA would decrease the consequences of an SGTR.
133	Increase secondary side pressure capacity such that an SGTR would not cause the relief valves to lift.	SAMA would eliminate direct release pathway for SGTR sequences.
134	Replace steam generators (SG) with a new design.	SAMA would lower the frequency of an SGTR.
135	Revise emergency operating procedures to direct that a faulted SG be isolated.	SAMA would reduce the consequences of an SGTR.
136	Direct SG flooding after a SGTR, prior to core damage.	SAMA would provide for improved scrubbing of SGTR releases.
137	Implement a maintenance practice that inspects 100% of the tubes in a SG.	SAMA would reduce the potential for an SGTR.
138	Locate RHR inside of containment.	SAMA would prevent intersystem LOCA (ISLOCA) out the RHR pathway.
139	Install additional instrumentation for ISLOCAs.	SAMA would decrease ISLOCA frequency by installing pressure of leak monitoring instruments in between the first two pressure isolation valves on low-pressure inject lines, RHR suction lines, and HPSI lines.
140	Increase frequency for valve leak testing.	SAMA could reduce ISLOCA frequency.
141	Improve operator training on ISLOCA coping.	SAMA would decrease ISLOCA effects.
142	Install relief valves in the CC System.	SAMA would relieve pressure buildup from an RCP thermal barrier tube rupture, preventing an ISLOCA.
143	Provide leak testing of valves in ISLOCA paths.	SAMA would help reduce ISLOCA frequency. At Kewaunee Nuclear Power Plant, four MOVs isolating RHR from the RCS were not leak tested.
144	Revise EOPs to improve ISLOCA identification.	SAMA would ensure LOCA outside containment could be identified as such. Salem Nuclear Power Plant had a scenario where an RHR ISLOCA could direct initial leakage back to the pressurizer relief tank, giving indication that the LOCA was inside containment.
145	Ensure all ISLOCA releases are scrubbed.	SAMA would scrub all ISLOCA releases. One example is to plug drains in the break area so that the break point would be covered with water.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
146	Add redundant and diverse limit switches to each containment isolation valve.	SAMA could reduce the frequency of containment isolation failure and ISLOCAs through enhanced isolation valve position indication.
147	Early detection and mitigation of ISLOCA	SAMA would limit the effects of ISLOCA accidents by early detection and isolation
148	Improved MSIV Design	This SAMA would improve isolation reliability and reduce spurious actuations that could be initiating events.
149	Proceduralize use of pressurizer vent valves during steam generator tube rupture (SGTR) sequences	Some plants may have procedures to direct the use of pressurizer sprays to reduce RCS pressure after an SGTR. Use of the vent valves would provide a back-up method.
150	Implement a maintenance practice that inspects 100% of the tubes in an SG	This SAMA would reduce the potential for a tube rupture.
151	Locate RHR inside of containment	This SAMA would prevent ISLOCA out the RHR pathway.
152	Install self-actuating containment isolation valves	For plants that do not have this, it would reduce the frequency of isolation failure.
Improvements in Reducing Internal Flooding Frequency		
153	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	SAMA would prevent flood propagation, for a plant where internal flooding from turbine building to safeguards areas is a concern.
154	Improve inspection of rubber expansion joints on main condenser.	SAMA would reduce the frequency of internal flooding, for a plant where internal flooding due to a failure of circulating water system expansion joints is a concern.
155	Implement internal flood prevention and mitigation enhancements.	This SAMA would reduce the consequences of internal flooding.
156	Implement internal flooding improvements such as those implemented at Fort Calhoun.	This SAMA would reduce flooding risk by preventing or mitigating rupture in the RCP seal cooler of the component cooling system an ISLOCA in a shutdown cooling line, an AFW flood involving the need to remove a watertight door.
157	Shield electrical equipment from potential water spray	SAMA would decrease risk associated with seismically induced internal flooding
158	Reduction in Reactor Building Flooding	This SAMA reduces the Reactor Building Flood Scenarios contribution to core damage and release.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
Improvements Related to Feedwater/Feed and Bleed Reliability/Availability		
159	Install a digital feedwater upgrade.	This SAMA would reduce the chance of a loss of main feedwater following a plant trip.
160	Perform surveillances on manual valves used for backup AFW pump suction.	This SAMA would improve success probability for providing alternative water supply to the AFW pumps.
161	Install manual isolation valves around AFW turbine-driven steam admission valves.	This SAMA would reduce the dual turbine-driven AFW pump maintenance unavailability.
162	Install accumulators for turbine-driven AFW pump flow control valves (CVs).	This SAMA would provide control air accumulators for the turbine-driven AFW flow CVs, the motor-driven AFW pressure CVs and SG power-operated relief valves (PORVs). This would eliminate the need for local manual action to align nitrogen bottles for control air during a LOOP.
163	Install separate accumulators for the AFW cross-connect and block valves	This SAMA would enhance the operator's ability to operate the AFW cross-connect and block valves following loss of air support.
164	Install a new CST	Either replace the existing tank with a larger one, or install a back-up tank.
165	Provide cooling of the steam-driven AFW pump in an SBO event	This SAMA would improve success probability in an SBO by: (1) using the FP system to cool the pump, or (2) making the pump self cooled.
166	Proceduralize local manual operation of AFW when control power is lost.	This SAMA would lengthen AFW availability in an SBO. Also provides a success path should AFW control power be lost in non-SBO sequences.
167	Provide portable generators to be hooked into the turbine driven AFW, after battery depletion.	This SAMA would extend AFW availability in an SBO (assuming the turbine driven AFW requires DC power)
168	Add a motor train of AFW to the Steam trains	For PWRs that do not have any motor trains of AFW, this would increase reliability in non-SBO sequences.
169	Create ability for emergency connections of existing or alternate water sources to feedwater/condensate	This SAMA would be a back-up water supply for the feedwater/condensate systems.
170	Use FP system as a back-up for SG inventory	This SAMA would create a back-up to main and AFW for SG water supply.
171	Procure a portable diesel pump for isolation condenser make-up	This SAMA would provide a back-up to the city water supply and diesel FP system pump for isolation condenser make-up.
172	Install an independent DG for the CST make-up pumps	This SAMA would allow continued inventory make-up to the CST during an SBO.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
173	Change failure position of condenser make-up valve	This SAMA would allow greater inventory for the AFW pumps by preventing CST flow diversion to the condenser if the condenser make-up valve fails open on loss of air or power.
174	Create passive secondary side coolers.	This SAMA would reduce CDF from the loss of Feedwater by providing a passive heat removal loop with a condenser and heat sink.
175	Replace current PORVs with larger ones such that only one is required for successful feed and bleed.	This SAMA would reduce the dependencies required for successful feed and bleed.
176	Install motor-driven feedwater pump.	SAMA would increase the availability of injection subsequent to MSIV closure.
177	Use Main feedwater pumps for a Loss of Heat Sink Event	This SAMA involves a procedural change that would allow for a faster response to loss of the secondary heat sink. Use of only the feedwater booster pumps for injection to the SGs requires depressurization to about 350 psig; before the time this pressure is reached, conditions would be met for initiating feed and bleed. Using the available turbine driven feedwater pumps to inject water into the SGs at a high pressure rather than using the feedwater booster alone allows injection without the time consuming depressurization.
Improvements in Core Cooling Systems		
178	Provide the capability for diesel driven, low pressure vessel make-up	This SAMA would provide an extra water source in sequences in which the reactor is depressurized and all other injection is unavailable (e.g., FP system)
179	Provide an additional HPSI pump with an independent diesel	This SAMA would reduce the frequency of core melt from small LOCA and SBO sequences
180	Install an independent AC HPSI system	This SAMA would allow make-up and feed and bleed capabilities during an SBO.
181	Create the ability to manually align ECCS recirculation	This SAMA would provide a back-up should automatic or remote operation fail.
182	Implement an RWT make-up procedure	This SAMA would decrease CDF from ISLOCA scenarios, some smaller break LOCA scenarios, and SGTR.
183	Stop LPSI pumps earlier in medium or large LOCAs.	This SAMA would provide more time to perform recirculation swap over.
184	Emphasize timely swap over in operator training.	This SAMA would reduce HEP of recirculation failure.

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SAMA ID number	SAMA title	Result of potential enhancement
185	Upgrade Chemical and Volume Control System to mitigate small LOCAs.	For a plant like the AP600 where the Chemical and Volume Control System cannot mitigate a Small LOCA, an upgrade would decrease the Small LOCA CDF contribution.
186	Install an active HPSI system.	For a plant like the AP600 where an active HPSI system does not exist, this SAMA would add redundancy in HPSI.
187	Change "in-containment" RWT suction from 4 check valves to 2 check and 2 air operated valves.	This SAMA would remove common mode failure of all four injection paths.
188	Replace 2 of the 4 safety injection (SI) pumps with diesel-powered pumps.	This SAMA would reduce the SI system CCF probability. This SAMA was intended for the System 80+, which has four trains of SI.
189	Align low pressure core injection or core spray to the CST on loss of suppression pool cooling.	This SAMA would help to ensure low pressure ECCS can be maintained in loss of suppression pool cooling scenarios.
190	Raise high pressure core injection/RCIC backpressure trip setpoints	This SAMA would ensure high pressure core injection/RCIC availability when high suppression pool temperatures exist.
191	Improve the reliability of the ADS.	This SAMA would reduce the frequency of high pressure core damage sequences.
192	Disallow automatic vessel depressurization in non-ATWS scenarios	This SAMA would improve operator control of the plant.
193	Create automatic swap over to recirculation on RWT depletion	This SAMA would reduce the human error contribution from recirculation failure.
194	Proceduralize intermittent operation of high pressure coolant injection (HPCI).	SAMA would allow for extended duration of HPCI availability.
195	Increase available NPSH for injection pumps.	SAMA increases the probability that these pumps will be available to inject coolant into the vessel by increasing the available NPSH for the injection pumps.
196	Modify Reactor Water Cleanup (RWCU) for use as a decay heat removal system and proceduralize use.	SAMA would provide an additional source of decay heat removal.
197	Control Rod Drive (CRD) Injection	SAMA would supply an additional method of level restoration by using a non-safety system.
198	Condensate Pumps for Injection	SAMA to provide an additional option for coolant injection when other systems are unavailable or inadequate

TABLE A-1
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SAMA ID number	SAMA title	Result of potential enhancement
199	Align EDG to CRD for Injection	SAMA to provide power to an additional injection source during loss of power events
200	Re-open MSIVs	SAMA to regain the main condenser as a heat sink by re-opening the MSIVs.
201	Bypass RCIC Turbine Exhaust Pressure Trip	SAMA would allow RCIC to operate longer.
202	Passive High Pressure System	SAMA will improve prevention of core melt sequences by providing additional high pressure capability to remove decay heat through an isolation condenser type system
203	Suppression Pool Jockey Pump	SAMA will improve prevention of core melt sequences by providing a small makeup pump to provide low pressure decay heat removal from the RPV using the suppression pool as a source of water.
204	Improved High Pressure Systems	SAMA will improve prevention of core melt sequences by improving reliability of high pressure capability to remove decay heat.
205	Additional Active High Pressure System	SAMA will improve reliability of high pressure decay heat removal by adding an additional system.
206	Improved Low Pressure System (Firepump)	SAMA would provide FPS pump(s) for use in low pressure scenarios.
207	CUW Decay Heat Removal	This SAMA provides a means for Alternate Decay Heat Removal.
208	High Flow Suppression Pool Cooling	SAMA would improve suppression pool cooling.
209	Diverse Injection System	SAMA will improve prevention of core melt sequences by providing additional injection capabilities.
210	Alternate Charging Pump Cooling	This SAMA will improve the high pressure core flooding capabilities by providing the SI pumps with alternate gear and oil cooling sources. Given a total loss of Chilled Water, abnormal operating procedures would direct alignment of preferred Demineralized Water or the Fire System to the Chilled Water System to provide cooling to the SI pumps' gear and oil box (and the other normal loads).
Instrument Air/Gas Improvements		
211	Modify EOPs for ability to align diesel power to more air compressors.	For plants that do not have diesel power to all normal and back-up air compressors, this change would increase the reliability of IA after a LOOP.

TABLE A-1
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SAMA ID number	SAMA title	Result of potential enhancement
212	Replace old air compressors with more reliable ones	This SAMA would improve reliability and increase availability of the IA compressors.
213	Install nitrogen bottles as a back-up gas supply for SRVs.	This SAMA would extend operation of SRVs during an SBO and loss of air events (BWRs).
214	Allow cross connection of uninterruptible compressed air supply to opposite unit.	SAMA would increase the ability to vent containment using the hardened vent.
ATWS Mitigation		
215	Install MG set trip breakers in CR	This SAMA would provide trip breakers for the MG sets in the CR. In some plants, MG set breaker trip requires action to be taken outside of the CR. Adding control capability to the CR would reduce the trip failure probability in sequences where immediate action is required (e.g., ATWS).
216	Add capability to remove power from the bus powering the control rods	This SAMA would decrease the time to insert the control rods if the reactor trip breakers fail (during a loss of feedwater ATWS which has a rapid pressure excursion)
217	Create cross-connect ability for standby liquid control trains	This SAMA would improve reliability for boron injection during an ATWS event.
218	Create an alternate boron injection capability (back-up to standby liquid control)	This SAMA would improve reliability for boron injection during an ATWS event.
219	Remove or allow override of low pressure core injection during an ATWS	On failure on high pressure core injection and condensate, some plants direct reactor depressurization followed by 5 minutes of low pressure core injection. This SAMA would allow control of low pressure core injection immediately.
220	Install a system of relief valves that prevents any equipment damage from a pressure spike during an ATWS	This SAMA would improve equipment availability after an ATWS.
221	Create a boron injection system to back up the mechanical control rods.	This SAMA would provide a redundant means to shut down the reactor.
222	Provide an additional instrument system for ATWS mitigation (e.g., ATWS mitigation scram actuation circuitry).	This SAMA would improve instrument and control redundancy and reduce the ATWS frequency.
223	Increase the SRV reseat reliability.	SAMA addresses the risk associated with dilution of boron caused by the failure of the SRVs to reseat after standby liquid control (SLC) injection.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
224	Use CRD for alternate boron injection.	SAMA provides an additional system to address ATWS with SLC failure or unavailability.
225	Bypass MSIV isolation in Turbine Trip ATWS scenarios	SAMA will afford operators more time to perform actions. The discharge of a substantial fraction of steam to the main condenser (i.e., as opposed to into the primary containment) affords the operator more time to perform actions (e.g., SLC injection, lower water level, depressurize RPV) than if the main condenser was unavailable, resulting in lower human error probabilities
226	Enhance operator actions during ATWS	SAMA will reduce human error probabilities during ATWS
227	Guard against SLC dilution	SAMA to control vessel injection to prevent boron loss or dilution following SLC injection.
228	ATWS Sized Vent	This SAMA would provide the ability to remove reactor heat from ATWS events.
229	Improved ATWS Capability	This SAMA includes items which reduce the contribution of ATWS to core damage and release frequencies.
Other Improvements		
230	Provide capability for remote operation of secondary side relief valves in an SBO	Manual operation of these valves is required in an SBO scenario. High area temperatures may be encountered in this case (no ventilation to main steam areas), and remote operation could improve success probability.
231	Create/enhance RCS depressurization ability	With either a new depressurization system, or with existing PORVs, head vents, and secondary side valve, RCS depressurization would allow earlier low pressure ECCS injection. Even if core damage occurs, low RCS pressure would alleviate some concerns about HPME.
232	Make procedural changes only for the RCS depressurization option	This SAMA would reduce RCS pressure without the cost of a new system
233	Defeat 100% load rejection capability.	This SAMA would eliminate the possibility of a stuck open PORV after a LOOP, since PORV opening would not be needed.
234	Change CRD flow CV failure position	Change failure position to the "fail-safest" position.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
235	Install secondary side guard pipes up to the MSIVs	This SAMA would prevent secondary side depressurization should a steam line break occur upstream of the MSIVs. This SAMA would also guard against or prevent consequential multiple SGTR following a Main Steam Line Break event.
236	Install digital large break LOCA protection	Upgrade plant instrumentation and logic to improve the capability to identify symptoms/precursors of a large break LOCA (leak before break).
237	Increase seismic capacity of the plant to a high confidence, low pressure failure of twice the Safe Shutdown Earthquake.	This SAMA would reduce seismically -induced CDF.
238	Enhance the reliability of the demineralized water (DW) make-up system through the addition of diesel-backed power to one or both of the DW make-up pumps.	Inventory loss due to normal leakage can result in the failure of the CC and the SRW systems. Loss of CC could challenge the RCP seals. Loss of SRW results in the loss of three EDGs and the containment air coolers (CACs).
239	Increase the reliability of SRVs by adding signals to open them automatically.	SAMA reduces the probability of a certain type of medium break LOCA. Hatch evaluated medium LOCA initiated by an MSIV closure transient with a failure of SRVs to open. Reducing the likelihood of the failure for SRVs to open, subsequently reduces the occurrence of this medium LOCA.
240	Reduce DC dependency between high-pressure injection system and ADS.	SAMA would ensure containment depressurization and high-pressure injection upon a DC failure.
241	Increase seismic ruggedness of plant components.	SAMA would increase the availability of necessary plant equipment during and after seismic events.
242	Enhance RPV depressurization capability	SAMA would decrease the likelihood of core damage in loss of HPCI scenarios
243	Enhance RPV depressurization procedures	SAMA would decrease the likelihood of core damage in loss of HPCI scenarios
244	Replace mercury switches on FPSs	SAMA would decrease probability of spurious fire suppression system actuation given a seismic event+D114
245	Provide additional restraints for CO_2 tanks	SAMA would increase availability of FP given a seismic event.
246	Enhance control of transient combustibles	SAMA would minimize risk associated with important fire areas.
247	Enhance fire brigade awareness	SAMA would minimize risk associated with important fire areas.
248	Upgrade fire compartment barriers	SAMA would minimize risk associated with important fire areas.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
249	Enhance procedures to allow specific operator actions	SAMA would minimize risk associated with important fire areas.
250	Develop procedures for transportation and nearby facility accidents	SAMA would minimize risk associated with transportation and nearby facility accidents.
251	Enhance procedures to mitigate Large LOCA	SAMA would minimize risk associated with Large LOCA
252	Computer Aided Instrumentation	SAMA will improve prevention of core melt sequences by making operator actions more reliable.
253	Improved Maintenance Procedures/Manuals	SAMA will improve prevention of core melt sequences by increasing reliability of important equipment
254	Improved Accident Management Instrumentation	SAMA will improve prevention of core melt sequences by making operator actions more reliable.
255	Remote Shutdown Station	This SAMA would provide the capability to control the reactor in the event that evacuation of the MCR is required.
256	Security System	Improvements in the site's security system would decrease the potential for successful sabotage.
257	Improved Depressurization	SAMA will improve depressurization system to allow more reliable access to low pressure systems.
258	Safety Related CST	SAMA will improve availability of CST following a Seismic event
259	Passive Overpressure Relief	This SAMA would prevent vessel overpressurization.
260	Improved Operating Response	Improved operator reliability would improve accident mitigation and prevention.
261	Operation Experience Feedback	This SAMA would identify areas requiring increased attention in plant operation through review of equipment performance.
262	Improved SRV Design	This SAMA would improve SRV reliability, thus increasing the likelihood that sequences could be mitigated using low pressure heat removal.
263	Increased Seismic Margins	This SAMA would reduce the risk of core damage and release during seismic events.
264	System Simplification	This SAMA is intended to address system simplification by the elimination of unnecessary interlocks, automatic initiation of manual actions or redundancy as a means to reduce overall plant risk.

TABLE A-1
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID number	SAMA title	Result of potential enhancement
265	Train operations crew for response to inadvertent actuation signals	This SAMA would improve chances of a successful response to the loss of two 120V AC buses, which may cause inadvertent signal generation.
266	Install tornado protection on gas turbine generators	This SAMA would improve onsite AC power reliability.