ATTACHMENT D. PUBLIC HEALTH AGENCY CORRESPONDENCE

NMC Committed to Nuclear Excellence

Xcel Energy

March 2, 2005

Ms. Patricia Bloomgren
Director, Division of Environmental Health
Minnesota Department of Health
85 E. Seventh Place, Suite 400
Saint Paul, MN 55164

Subject: Monticello Nuclear Generating Plant License Renewal Project

Dear Ms. Bloomgren:

Northern States Power Company d/b/a Xcel Energy (Xcel Energy) and Nuclear Management Company, LLC (NMC) are preparing an application to renew the operating license for the Monticello Nuclear Generating Plant (MNGP), which expires in 2010. As part of the license renewal process, NRC requires license applicants to assess potential impacts on public health from thermophilic microbiological organisms associated with continued operation of MNGP, in accordance with NRC regulations set forth in 10 CFR 51.53(c)(3)(iii)(G). This assessment will be included in the Environmental Report (ER), which is a required component of the license renewal application. Additionally, the NRC may request a consultation with your office as a component of their site-specific review.

NRC regulations specify that if discharges are made to a small river with an average annual flow rate of less than 3.15×10^{12} cubic feet per year, the applicant must assess the public health impacts of the proposed action regarding potential proliferation of thermophilic microbiological organisms in the affected waters. As a component of its operation, MNGP discharges cooling water into the Mississippi River. The Mississippi River has an average flow of 2.3×10^{11} cubic feet per year in the vicinity of MNGP, conforming to the NRC definition for consideration as a small river. This issue is therefore applicable to MNGP license renewal and will be addressed in the ER.

Based on considerations described below, NMC and Xcel Energy conclude that the Mississippi River near MNGP provides poor conditions for supporting prolific populations of pathogenic organisms and, therefore, continued operation of MNGP through the license renewal period would not impact public health from such organisms.

Ambient Mississippi River temperatures vary from 32°F in the winter to 83°F in the summer in the vicinity of MNGP. Based on MNGP discharge monitoring data collected from 1999 through 2001 for the months of June through September, the monthly average water temperature within the discharge canal ranged from 86.5°F to 90.82°F. As a condition of the plant's National Pollutant Discharge Elimination System (NPDES) permit, the maximum daily average temperature at the end of the discharge canal may not exceed 95°F (the temperature specified for April-October, the warmest months of the year). Populations of the pathogenic amoeba *Naegleria fowleri* can be enhanced in thermally-altered water bodies at temperatures ranging from 95°F to 106°F or higher, but the organism is rarely found to proliferate in water cooler than 95°F. From a public health

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perspective, MNGP's discharge canal temperature limit for the months of April through October (95°F), when ambient river temperatures are the highest, is cooler than that necessary for proliferation of pathogenic organisms of concern, particularly *Naegleria fowleri*.

After your review of this letter, we would appreciate your written input regarding our conclusions. Please detail any concerns regarding thermophilic microbiological organisms and confirm our conclusion that continued operation of MNGP would have no effect on public health in relation to these organisms. Your expeditious response will facilitate future NRC correspondence with your agency. NMC will include a copy of this letter and your response in the Environmental Report submitted to the NRC as part of the MNGP license renewal application.

NMC and Xcel Energy look forward to continued correspondence and cooperative efforts with the Minnesota Department of Health. If you have any questions, please contact:

James Holthaus
License Renewal Environmental Lead
2807 W. County Road 75
Monticello, MN 55362
James.Holthaus@nmcco.com
(763) 295-1309

Sincerely,

Thomas J. Palmisano
Monticello Site Vice President
Nuclear Management Company, LLC

Charles Bomberger
General Manager,
Nuclear Asset Management
Xcel Energy, Inc

Cc: Ms. Dianne Mandernach, Commissioner, Minnesota Department of Health
Jim Alders, Xcel Energy, Manager, Regulatory Administration
Terry Pickens, Nuclear Management Company, Director, Government Affairs

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ATTACHMENT E. CULTURAL RESOURCES CORRESPONDENCE

NMC Committed to Nuclear Excellence

Xcel Energy

February 10, 2005

Dennis A. Gimmestad
Government Programs and Compliance Officer
Minnesota Historical Society
State Historic Preservation Office
345 W. Kellogg Blvd
St. Paul, MN 55102-1906

RE: NMC/Xcel Energy; Monticello Nuclear Generating Plant Environmental Review
Monticello, Wright County
SHPO Number: 2004-2193

Dear Mr. Gimmestad:

Northern States Power Company d/b/a Xcel Energy (Xcel Energy) and Nuclear Management Company, LLC (NMC) would like to thank the Minnesota State Historic Preservation Office (SHPO) for providing comments on the April 28, 2004 letter regarding potential renewal of the Monticello Nuclear Generating Plant (MNGP) operating license. We appreciate the time your agency has taken to review the letter, as well as identify concerns pertaining to possible unreported archaeological properties present on, or within the vicinity of, the MNGP site. Additional information is provided below on the issue raised in your June 11, 2004 letter.

Xcel Energy, NMC, and the MNGP Environmental Review Team have concluded the operation of MNGP through the license renewal term of an additional twenty years will not have an adverse effect on any historic or cultural resources in the vicinity of the site. There are no plans to significantly alter current operations or engage in any substantive land disturbing activities as part of the license renewal process. In addition, any plans for site alteration will comply with permitting requirements administered by both the City of Monticello and the State of Minnesota. Therefore, NMC and Xcel Energy do not believe a survey of the project area is necessary. In addition, a finding has already been made by your agency that no historic sites, archeological or architectural, are known to exist on, or in the immediate vicinity of the MNGP site. A copy of the July 7, 1972 letter from the State Liaison Officer for the National Register to the Atomic Energy Commission (AEC) setting forth the above finding is enclosed.

Prior to the issuance of the original operating license DPR-22, Northern States Power Company (NSP) submitted the original Environmental Report (ER) to the U.S Atomic Energy Commission (AEC) on November 3, 1971. The AEC is the predecessor of the United States Nuclear Regulatory Commission (NRC). The original ER was prepared by

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NSP according to guidance set forth in *Draft Guidance to the Preparation of Environmental Reports for Nuclear Power Plants*, as well as regulations codified in 10 CFR 50 (36 F.R. 1807), both issued by the AEC in 1971. This guidance required NSP to evaluate areas of historical and archaeological significance as a component to overall environmental assessments contained in the original ER. Prior to submittal of the original ER, NSP consulted with Dr. Elden Johnson, Minnesota State Archaeologist. This consultation did not reveal any areas of historical or archaeological significance on the MNGP site.

Subsequently, the AEC conducted a site-specific analysis of MNGP in order to attain compliance with the National Environmental Policy Act of 1969 (42 U.S.C. 4321-4347). AEC findings were published in the November 1972, *Final Environmental Statement related to operation of Monticello Nuclear Generating Plant* (FES) (Docket No. 50-263). According to the FES, NSP has owned the property on which the plant is located since the early 1920's. In November 1972, the MNGP site consisted of approximately 1,325 acres, most of which had been leased by NSP to individuals for conventional farming. Prior to publication of the FES, the AEC consulted with the Minnesota Historical Society to determine if historic, archaeological or architectural sites were present on, or in the immediate vicinity of the site.

In a letter sent to the AEC from the Minnesota Historical Society on July 7, 1972, the State Liaison Officer for the National Register determined no areas of historical or archaeological value were present on the site. The letter maintained that while the area had a history of Native American and early French trader activity, no evidence of this activity was reported on the site. The letter also requested if any indication of previous habitation be discovered on the site that it be reported to the Minnesota Historical Society.

However, in order to ensure concerns raised by the Minnesota SHPO are addressed, existing site procedures will be reviewed and revised as necessary to incorporate guidance for the handling of items of potential historic, cultural and archaeological significance during soil disturbing activities on the site. The guidance currently envisioned includes a commitment to protect historic, archeological, and cultural resources during any land disturbing activity by requiring assessments or evaluations before starting any activity that could potentially impact a resource. Additionally, the envisioned procedure revisions will include appropriate identification and notification requirements and would necessitate work stoppage in the event employees should discover any potential items of importance or significance. Consultation with your office will commence if deemed appropriate, before any work involving resources of significance is to resume.

NMC and Xcel Energy would appreciate your review, and transmittal of written concurrence, or concerns relative to our conclusion that continued operation of MNGP for an additional twenty years would not adversely effect on any historical or archaeological resources in the vicinity of the site. Thank you again for your comments on the April 28, 2004 letter. NMC and Xcel Energy sincerely hope this letter provides an

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response to your agency's questions and concerns. NMC and Xcel Energy look forward to continued correspondence and cooperative efforts with your agency. Please direct any further questions, comments or concerns to:

James Holthaus
License Renewal Environmental Lead
2807 W County Road 75
Monticello, MN 55362
James.Holthaus@nmcco.com
(763) 295-1309

Sincerely,

Thomas J. Palmisano
Monticello Site Vice President
Nuclear Management Company, LLC

Charles Bomberger
General Manager,
Nuclear Asset Management
Xcel Energy, Inc

Enclosure: Letter from Minnesota State Historic Preservation Office to U.S. Atomic Energy Commission, July 7, 1972

CC: Jim Alders-Xcel Energy, Manager, Regulatory Administration
Terry Pickens-Nuclear Management Company, Director, Government Affairs

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C-51

July 7, 1972

Mr. Daniel R. Muller
Assistant Director for Environmental Projects
United States Atomic Energy Commission
Washington, D.C. 20545

RE: Monticello Nuclear Generating Plant, Unit No. 1
Northern States Power Company
Docket Number: 50-263

Dear Mr. Muller:

Environmental Impact documents regarding N.S.P. Monticello Nuclear Generating Plant, Unit No. 1 have been reviewed by the Historic Sites Department of the Minnesota Historical Society. It is the finding of this department that no historic sites, archaeological or architectural, are known to exist on or in the immediate vicinity of the plant site. The area is known in Minnesota's early Indian and fur trade history, but no sites of importance concerning these historic aspects have been located to date in the plant site.

It is requested, however, that should evidence of previous habitation be discovered during construction of the plant, notification of such be made to the Archaeology Department of the Minnesota Historical Society.

Respectfully,

Russell W. Fridley
Director, Minnesota Historical Society
State Liaison Officer for the
National Register

RWF/cim
cc: Robert R. Garvey, Jr., Executive Secretary
Advisory Council on Historic Preservation

ATTACHMENT F

SEVERE ACCIDENT MITIGATION ALTERNATIVES

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Acronyms Used in Attachment F

ABWR	Advanced Boiling Water Reactor
AC	alternating current
ASDS	Alternate Shut Down System
ATWS	anticipated transient without scram
BWR	Boiling Water Reactor
CCF	common cause failure
CDF	core damage frequency
CRD	Control Rod Drive
CS	Core Spray
CsI	Cesium Iodine
CST	Condensate Storage Tank
DC	direct current
DW	Drywell
EDG	Emergency Diesel Generator
EPZ	Emergency Planning Zone
ESW	Emergency Service Water
FPS	Fire Protection System
FSW	Fire Service Water
FW	Feedwater
HEP	human error probability
HPCI	High Pressure Coolant Injection
HPI	High Pressure Injection
HPSI	High Pressure Safety Injection
HPV	Hard Pipe Vent
HVAC	Heating Ventilation Air Conditioning
IPE	Individual Plant Examination
IPEEE	Individual Plant Examination – External Events
kV	kilovolt
LERF	large early release frequency
LOCA	Loss of Coolant Accident
LPCI	Low Pressure Coolant Injection
MAAP	Modular Accident Analysis Program
MACCS2	MELCOR Accident Consequences Code System, Version 2
MACR	maximum averted cost-risk
MCC	Motor Control Center
MNGP	Monticello Nuclear Generating Plant
NPSH	net positive suction head
NRC	U.S. Nuclear Regulatory Commission
OECR	off-site economic cost risk
PMF	probable maximum flood
PMP	probable maximum precipitation
PSA	Probabilistic Safety Assessment
RAW	risk achievement worth

Acronyms Used in Attachment F

RCIC	Reactor Core Isolation Cooling
RDR	real discount rate
RHR	residual heat removal
RHRSW	Residual Heat Removal Service Water
RPV	Reactor Pressure Vessel
RRW	risk reduction worth
RWCU	Reactor Water Cleanup
SAMA	severe accident mitigation alternative
SAMDA	severe accident mitigation design alternative
SBLC	Standby Liquid Control
SBO	station blackout
SDC	shutdown cooling
SRV	Safety Relief Valve
SW	Service Water
V	volt

Attachment F
Severe Accident Mitigation Alternatives

The severe accident mitigation alternatives (SAMA) analysis discussed in Section 4.17 of the Environmental Report is presented below.

F.1 METHODOLOGY

The methodology selected for this analysis involves identifying SAMA candidates that have potential for reducing plant risk 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 offsite 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:

- **Monticello Nuclear Generating Plant (MNGP) Probabilistic Safety Assessment (PSA) Model** – Use the MNGP internal events PSA model as the basis for the analysis (Section F.2). Incorporate external events contributions as described in Section F.5.1.7.

- **Level 3 PSA Analysis** – Use MNGP Level 1 and 2 internal events PSA output and site-specific meteorology, demographic, land use, and emergency response data as input in performing a Level 3 PSA using the MELCOR Accident Consequences Code System Version 2 (MACCS2) (Section F.3). Incorporate external events contributions as described in Section F.5.1.7.

- **Baseline Risk Monetization** – Use U.S. Nuclear Regulatory Commission (NRC) regulatory analysis techniques to calculate the monetary value of the unmitigated MNGP severe accident risk. This becomes the maximum averted cost-risk that is possible (Section F.4).

- **Phase I SAMA Analysis** – Identify potential SAMA candidates based on the MNGP PSA, Individual Plant Examination – External Events (IPEEE), and documentation from the industry and NRC. Screen out SAMA candidates that are not applicable to the MNGP design or are of low benefit in boiling water reactors (BWRs) such as MNGP; candidates that have already been implemented at MNGP or whose benefits have been achieved at MNGP using other means; and candidates whose estimated cost exceeds the maximum possible averted cost-risk (Section F.5).

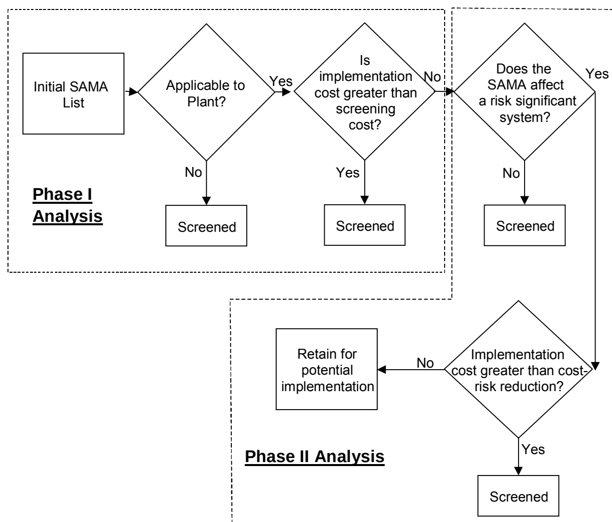
- **Phase II SAMA Analysis** – Calculate the risk reduction attributable to each remaining SAMA candidate and compare to a more detailed cost analysis to identify the net cost-benefit. PSA insights are also used to screen SAMA candidates in this phase (Section F.6).

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

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

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

SAMA Screening Process



F.2 MNGP PSA MODEL

A slightly modified version of the 2003 MNGP Level 1 and Level 2 internal events PSA model is used as the basis for the SAMA analysis. In this version of the PSA, the base CDF is 4.47E-05 events per year and the Large Early Release Frequency (LERF) is 4.20E-06 events per year. The slight modifications, which are conservative, are explained in Section F.2.2.

As a result of the MNGP PSA maintenance process, the model has evolved since the submittal of the Individual Plant Examination (IPE). For example, the current CDF is larger than the original IPE result reported to NRC in 1992 of 2.6E-05 events per year, and the Level 2 release categories have been redefined such that a comparison of the LERF is not readily available. This section provides an overview of the model changes since the IPE, the current risk profiles, and the model review history.

The external events models are not specifically discussed in this section; however Sections F.5.1.6 and F.5.1.7 provide a description of the process used to integrate the external events contributions into the MNGP SAMA process.

F.2.1 PSA MODEL CHANGES SINCE IPE SUBMITTAL

The internal events PSA used for the SAMA evaluation is based on a more current version of the PSA than the version used for the IPE. The IPE was submitted in 1992, and the PSA model was updated in 1995, 1999, and 2003.

The major differences in the PSA model between the original IPE and the 1995 model update include the following:

- Addition of a non-safety 480 kilovolt (kV) diesel generator that can backfeed through non-emergency bus 13 to supply battery charges
- Installation of a hard piped vent that provides an additional means for containment heat removal
- Improvements to safety relief valve pneumatics (including power supplies)
- Addition of a crosstie for alignment of the diesel fire pump as an additional source of low-pressure makeup water
- Replacement of an instrument air compressor with one that is not dependent on service water
- Establishment of more realistic success criteria for service water achieved by changing the success requirement from 2 of 3 pumps to 1 of 3 pumps

- Revision of internal floods initiating event frequency and effects

The 1999 PSA update was performed to incorporate the effects of power uprate conditions. The MNGP risk analysis model was again updated in 2003. This version incorporates the following changes:

- Updated failure rate data
- Changed the model from Set Equation Transformation System (SETS) to EPRI's Risk and Reliability Workstation software (CAFTA)
- Revised operator error fault tree structure to explicitly model dependencies
- Credited manual alignment of Core Spray and Low Pressure Coolant Injection (LPCI) when control power is unavailable
- Incorporated new findings related to two significant flood scenarios
- Modified recovery modeling for both offsite power and the emergency diesel generators (EDGs)
- Credited control rod drive (CRD) hydraulics as the sole injection source if specific operator actions are taken
- Corrected small errors and made small improvements to the event trees and system fault trees
- Incorporated fault tree model of the subyard

Minor changes have been made to the 2003 model since completion of the update. These changes are described in Section F.2.2. The following table provides a summary of the CDF associated with each model revision.

Model Revision	CDF
1992 (IPE)	2.60E-05 per year
1995 (plant mods)	1.37E-05 per year
1999 (power uprate)	1.44E-05 per year
2003 (internal flood corrections)[a]	4.37E-05 per year

a. No maintenance model quantified at a truncation limit of 1E-09 per year.

F.2.2 CURRENT LEVEL 1 MNGP PSA MODEL

The model used in the SAMA analysis, which will be referred to as the SAMA model, has been slightly modified since the 2003 PSA update. The results for the 2003 average maintenance model indicate that the CDF is 4.43E-05 per year; however, the SAMA model CDF is 4.47E-05 per year. This difference is due to the following:

- The truncation limit used to quantify the original 2003 model is 1E-09 with the exception of the loss of coolant accident (LOCA) with vapor suppression failures and LOCA outside containment. These sequences are quantified at 1E-11 and 1E-10, respectively. The SAMA model is quantified at a truncation limit of 1E-11.
- The database used for the SAMA model includes a small number of event failure probability changes based on updated tasks.
- In the 2003 model, 1.0 events were not set TRUE, which raises CDF relative to the SAMA model, where 1.0 events were set TRUE.

The remainder of this section provides a summary of the 2003 model results. While the CDF is slightly different than the SAMA model, the results are representative of the SAMA model and are used to provide an overview of the major model contributors.

F.2.2.1 2003 MODEL SUMMARY

The 2003 PSA model includes single event cutsets for a service water/fire protection system flood in the stator cooling room or a service water flood in the east corridor of the 931-foot elevation in the Turbine Building.

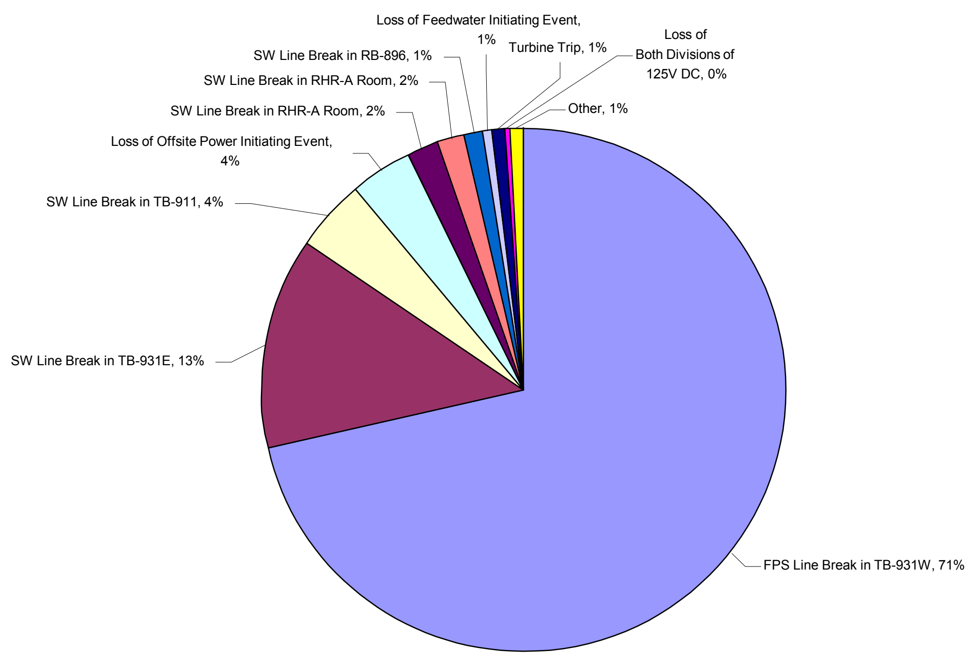
A pipe rupture on the service water / fire protection system in the stator cooling room (IEF_FS-TB931W) is the most dominant risk contributor (>71 percent of CDF in the average maintenance model). If a service water pipe ruptures in the stator cooling room, it is assumed to cause Division 2 alternating current (AC) power and direct current (DC) panel 211 failure due to flooding, in addition to service water failure due to flow diversion. Within a few minutes, the flood propagates to the 911-foot elevation where it floods Division 1 AC power and DC panel 111. The flood is also assumed to preclude long-term battery operation using Number 13 Diesel Generator to supply battery chargers, as well as prevent access to the service water to condenser hotwell crosstie manual valve. The supporting analysis is provided in the MNGP calculation for the flood events for the PSA Model.

A pipe rupture on the service water system in the east corridor on the 931-foot elevation of the Turbine Building (IEF_SW-TB931E) is another dominant risk contributor (>13 percent of CDF). If this service water pipe ruptures, it is assumed to cause service water failure due to flow diversion, and loss of Division 2 AC essential motor control center (MCC) power, compressor 14, and residual heat removal service water (RHRSW)/fire protection system crosstie to LPCI due to flooding. If the main access door to the Turbine Building opens (assumed), Division 1 and 2 125 volt (V) batteries and Division 1 250V battery flood. The supporting analysis is provided in the MNGP calculation for flood events for the PSA Model.

Other internal flooding scenarios also represent a significant portion of plant risk (>9 percent of CDF). These scenarios are dominated by service water pipe ruptures in RHR rooms and Turbine Building 911-foot elevation, but also include other flood sources and locations.

Core damage scenarios are grouped into accident classes consistent with previous analyses. Accident Class 6 (internal flooding) is included in the list, but it should be noted that it is not a unique category. Scenarios classified as Accident Class 6 are included in other accident classes, as appropriate. The accident classes and the contribution of each to CDF are summarized in Table F.2-1 for the average maintenance model. The 2003 CDF average maintenance model includes 31 initiating events (truncated at 1E-09 per year). The following figure summarizes this information.

Contribution to CDF by Initiator



Percent CDF is the Fussel-Vesely importance value for each initiator. All values are based on evaluation of Complete-T&M.caf, truncated at 1E-09 per year. Flag file (TRUEs.caf) is not included. Mutually exclusive file (MEX.cut) included.

The following table summarizes the ten most risk significant systems, based on the amount core damage frequency would be reduced if each system were perfect (i.e., never failed to perform its function).

System	Fussel Vesely Ranking
Turbine Building 931-foot elevation East doors	12.47
Emergency Diesel Generators	3.39
Diesel Generator-13	3.28
Safety Relief Valves and Depressurization	1.49
Uninterruptible AC	1.05
480V AC	1.01
Primary Containment	0.98
125V DC	0.97
Core Spray	0.90
Fire Protection	0.57

The measure of risk significance can be expressed as either the Fussel-Vesely importance factor (percent of CDF that includes failure of the system) or the risk reduction worth (RRW; ratio of nominal CDF value to CDF if the system were perfect). For example, if a system has a Fussel-Vesely value of 75 percent, cutsets with that system in it represent 75 percent of CDF. If that system were perfect, CDF would be reduced 75 percent. The risk reduction worth of that system would be 4 based on the following relationship between risk reduction and Fussel-Vesely (EPRI 1995):

$$RRW \approx 1 / (1 - FV)$$

Risk achievement worth (RAW) is the ratio of CDF with the system failed to the nominal CDF value. For example, if a system has a RAW value of 3, CDF increases by a factor of 3 when the system is unavailable. A summary of the ten most risk significant systems based on RAW values is shown below.

System	RAW Ranking
480V AC	83,602
4.16kV AC	83,602
Control Rods – Mechanical	2,861
125V DC	658
Uninterruptible AC	375
SRVs & Depressurization	137
ATWS – RPS	115
EDGs	67
EDG Emergency Service Water	65
RHR	12

F.2.3 CURRENT LEVEL 2 MNGP PSA MODEL

The Level 1 model provides a tool for estimating the likelihood or frequency of core damage. Because consequences of a core damage event can range from minimal (as in the case of the Three Mile Island event in 1979) to extreme (as in the case of the Chernobyl event in 1987), this is not enough information to assess risk. The PSA model (Level 2) is also designed to identify underlying causes of containment failure for severe accidents.

The MNGP radioactive release frequency event trees allow core damage scenarios defined in the Level 1 model to be further developed into consequence bins. Separating scenarios this way allows results of plant risk calculations to be presented in simple, meaningful terms. Consequence bins are based on the severity of the source term and the timing of the release relative to the time a General Emergency is declared. The characteristics of these bins are then used as input for the Level 3 model. The following subsections summarize the breakdown of the bins and the Level 2 results.

F.2.3.1 CONSEQUENCE BINS: SOURCE TERM SEVERITY

All core damage accident sequences are categorized into extreme, large, medium, small, and negligible release severity bins. The amount of radioactive material released to the environment (the source term) following a core damage event depends on whether or not it is scrubbed through the suppression pool or with drywell sprays, timeliness of providing debris cooling and overlying pool of water, and timing and size of containment failure relative to reactor pressure vessel (RPV) failure.

Accident sequences categorized as extreme releases are scenarios leading to more than 50 percent of the Cesium Iodine (CsI) inventory being released to the environment within 40 hours of accident initiation. Accident sequences categorized as a large release are scenarios that release between 10 percent and 50 percent of the CsI inventory to the environment within 40 hours of accident initiation. Accident sequences categorized as a medium release are scenarios that release between 1 percent and10 percent of the CsI inventory within 40 hours. Anything less, but greater than zero, is considered a small release. A negligible release is used for scenarios in which radioactive materials are assumed to remain within containment.

Modular Accident Analysis Program (MAAP) is used to estimate the source terms of various accident scenarios, and results are documented in a radioactive release severity calculation. Each accident sequence from the radioactive release event trees is characterized by a MAAP case from the radioactive release calculation.

F.2.3.2 CONSEQUENCE BINS: TIMING OF RELEASE

Each sequence that leads to a radioactive release from containment is classified as either early or late. This designation is intended to reflect mitigation of consequences by evacuating people from the area, as appropriate. It is assumed for the purpose of this analysis that 6 hours are required from the time a General Emergency is declared to the time radioactive material is released from containment to effectively reduce consequences by evacuation. Based on this assumption, radioactive releases within 6 hours of General Emergency declaration are considered early, and releases after 6 hours are categorized as late.

F.2.3.3 MNGP LEVEL 2 PSA RELEASE CATEGORIES

The frequency of radionuclide release is characterized by the quantification of the Level 2 PSA model. The Level 2 radioactive release frequency event tree end states are delineated by the magnitude and timing bins of the calculated radionuclide release, as described above. Therefore, the containment event tree end states are characterized using a two-term matrix (severity, time) as shown in Table F.2-2.

Given this characterization strategy, the Level 2 quantification can be summarized in Table F.2-3. This table provides quantitative information that is useful in the interpretation of the current containment capability given the spectrum of core damage sequences calculated in the Level 1 PSA. Table F.2-3 provides a summary of the radioactive release frequency model results. The quantification provides a yardstick with which to measure the best estimate of containment performance given that severe accidents could progress beyond core damage.

A small fraction (less than 7 percent) of the core damage accidents transferred from Level 1 PSA are effectively mitigated such that releases are essentially contained within an intact containment (i.e., Negligible release bin). Approximately 92.5 percent of the postulated accidents do not have large releases occurring before protective action can be taken (i.e., approximately 92.5 percent of the accidents do not result in large early releases).

The following table summarizes the total core damage frequency (i.e., the results of the Level 1 PSA) with the frequencies for each of the release magnitude type. A substantial fraction of the core damage end states (approximately 84 percent) lead to small releases. While this release magnitude is associated with relatively low radionuclide releases, the high frequency yields a dose-risk that is about 11 percent of the total.

Summary of Consequence Bin Frequencies

Consequence Bin	Frequency	Percent of CDF[a]
Negligible	4.18E-06	9.3
Small	3.99E-05	89.4
Medium	1.18E-06	2.6
Large	1.14E-05	25.5
Extreme	2.64E-09	0.01

a. CDF is 4.47E-05. The sum of consequence bin frequencies is greater than CDF because of non-minimal scenarios. For example, a scenario that leads to a small release may also lead to a medium release with one additional failure. The medium release scenario is non-minimal and does not show up in the CDF scenarios.

F.2.3.4 MNGP LEVEL 2 PSA SOURCE TERMS

The input to the Level 3 MNGP model provided by the Level 2 model is a combination of radionuclide release fractions, the timing of the radionuclide releases and the declaration of a general emergency, and the frequencies at which the releases occur. This combination of information is used in conjunction with other MNGP site characteristics in the Level 3 model to evaluate the off-site consequences of a core damage event.

Source terms were developed for seven of the release categories identified in Table F.2-3. The negligible release category was excluded, as it was a negligible contributor. Table F.2-4 provides a summary of the Level 2 results that were used as Level 3 input for the MNGP SAMA analysis.

This table includes the following information:

- Frequency
- MNGP MAAP case identifier (for reference)
- Airborne release fraction at 40 hours for each of the fission product groups provided by 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)

The consequences corresponding to each of the release categories are developed in the MNGP Level 3 model, which is discussed in section F.3.

F.2.4 PSA MODEL REVIEW SUMMARY

This section summarizes the review activity for the MNGP PSA models.

F.2.4.1 NRC IPE REVIEW

The Staff Evaluation Report for the MNGP IPE was issued in May 1994 and concluded the following:

- The IPE is complete with respect to the information requested in Generic Letter 88-20 and associated Supplement 1;
- The IPE analytical approach is technically sound and capable of identifying plant-specific vulnerabilities;
- MNGP employed a viable means to verify that the IPE models reflect the current plant design and operation at the time of submittal to NRC;
- The IPE had been peer-reviewed;
- MNGP participated in the IPE process;
- The IPE specifically evaluated the MNGP decay heat removal functions for vulnerabilities; and
- MNGP had responded appropriately to the Containment Performance Improvement program recommendations.

In addition, there were no areas of improvement to the PSA model that were identified by NRC in their review of the plant's IPE submittal (NSP 1995).

F.2.4.2 BOILING WATER REACTOR OWNERS GROUP PEER REVIEW

In 1997, a Boiling Water Reactor Owners Group PSA Peer Certification Review was performed on the 1995 update PSA model. The overall conclusion was positive and said that the MNGP PSA can be effectively used to support applications involving relative risk significance. The "Facts and Observations" for MNGP have been evaluated and addressed by the MNGP PSA Program. As a result, all peer review comments or the evolution of those peer review comments are captured by the 2003 model. No outstanding model issues exist outside of the normal PSA maintenance program, and none of the maintenance tasks are known to have the potential to impact the SAMA conclusions (NSP 1997).

F.2.4.3 INDEPENDENT LEVEL 2 PSA MODEL REVIEW

In January 2004, an independent peer review of the MNGP Level 2 PSA model was performed. This review was performed specifically to prepare the Level 2 model to support the MNGP License Renewal application.

In general, it was determined that the Level 2 PSA was adequate to support the SAMA analysis subject to the disposition of three issues listed below that were resolved in the SAMA model.

- Updating the Drywell (DW) shell failure probability due to debris contact.
- Addressing items related to the Radionuclide Release States:
  - Shell failure timing
  - Methods of subsuming different accident phenomena
  - Application of DW spray for the prevention of shell failure
  - Matching order of events in accident sequences to procedural instructions
  - Accident scenario representation by MAAP
- Including established Net Positive Suction Head (NPSH) limits for LPCI/containment spray operation following vent in MAAP analyses

As with all PSA models, other items have been identified for update; however, the review results indicate that the resolution of these issues can be delayed until the next model update without adverse impact on the SAMA analysis (ERIN 2004).

F.3 LEVEL 3 PSA ANALYSIS

The MACCS2 code (NRC 1998a) was used to perform the Level 3 PSA for MNGP. The input parameters given with the MACCS2, Sample Problem A formed the basis for the analysis. These generic values were supplemented with parameters specific to MNGP and the surrounding area. Site-specific data included population distribution, economic parameters, and agricultural production. Plant-specific release data included the time-nuclide distribution of releases and release frequencies. The behavior of the population during a release (evacuation parameters) was based on plant and site-specific set points (i.e., declaration of a General Emergency) and the Emergency Planning Zone (EPZ) evacuation study (NMC 2003). These data were used in combination with site-specific meteorology to simulate the probability distribution of impact risks (exposure and economic) to the surrounding population (within 50 miles) from the seven MNGP release categories.

F.3.1 POPULATION

The population surrounding the MNGP site was estimated for the year 2030. Given that the license renewal term ends in 2030, this corresponds to the largest estimated population for the area surrounding the site. Applying the largest population exposure for the SAMA accidents, which could occur at any time during the 20 year license extension, is conservative.

Population projections within 50 miles of MNGP were determined using SECPOP2000 (NRC 2003), a Geographic Information System, U.S Census block-group level population data allocated to each sector based on the area fraction of the census block-groups in each sector, and population growth rate estimates. U.S. Census data from 1990 and 2000 were used to determine a regional annual average population growth estimate (1.4 percent per year). The annual population growth estimate was applied uniformly to all sectors to calculate the year 2030 population distribution, which is conservative compared with the population projections based on the county-specific growth rates. The distribution was given in terms of population at ten distances (one-mile intervals out to 5 miles, 10 miles, and 10-mile intervals out to 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 2030 population for the 160 sectors (10 distances × 16 directions) was estimated as 3,903,243. The 2030 population distribution is given in Table F.3-1 for the 10-mile radius and Table F.3-2 for the 50-mile radius.

F.3.2 ECONOMY

MACCS2 requires the spatial distribution of 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) in the same manner as the population. This was done by using the SECPOP2000 code for each of the counties surrounding the plant to a distance of 50 miles. SECPOP2000 utilizes economic data from the U.S. Department of Agriculture's 1997 Census of Agriculture (USDA 1998) and from other 1998 and 1999 data sources. Economic values for 97 economic zones were calculated and allocated to each of the 160 sectors.

In addition, generic economic data that are applied to the region as a whole were revised from the MACCS2 sample problem input when better information was 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 (NRC 2003).

F.3.3 AGRICULTURE

Agricultural production within 50 miles of the site was estimated based on those counties within this radius. Agricultural cropland includes food crops and pastures. The largest harvested food crops are comprised of grains, legumes, roots/tubers and stored forage (USDA 1998).

The lengths of the growing seasons for the primary crops of grains, stored forage and legumes were obtained from *Usual Planting and Harvesting Dates for U.S. Field Crops*. The duration of the growing season for the remaining crop categories (pasture, green leafy vegetables, roots/tubers and other food crops) were the same as those used in all five NUREG-1150 sites (NRC 1989). They were compared against the information that was available for Minnesota and judged to be reasonable (USDA 1997).

F.3.4 NUCLIDE RELEASE

The core inventory at the time of the accident was based on the input supplied in the MACCS User's Guide (NRC 1998a). The core inventory corresponds to the end-of-cycle values for a 3578-megawatt thermal BWR plant. A scaling factor of 0.496 (1775/3578=0.496) was used to provide a representative core inventory of 1775 megawatt thermal at MNGP. MAAP nuclide release categories were related to the MACCS categories as shown in Table F.3-3.

All releases were modeled as occurring at ground level. The thermal content of each of the releases was conservatively assumed to be the same as ambient (i.e., buoyant plume rise was not modeled).

F.3.5 EVACUATION

Reactor scram 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 25 minutes to 18 hours (Table F.2-4) for the release sequences evaluated.

Consistent with the MACCS2 User's Guide, input parameters of 95 percent of the population within 10 miles of the plant's EPZ evacuating and 5 percent not evacuating were employed. These values have been used in similar studies [e.g., Hatch (SNOC 2000), Calvert Cliffs, (BGE 1998)] and are conservative relative to the NUREG-1150 study, which assumed 99.5 percent evacuation of the population within the emergency planning zone (NRC 1989). The evacuees are assumed to begin evacuating 30 minutes after a General Emergency has been declared and are evacuated at an average radial speed of 2.5 miles per hour (1.12 meters per second). This speed is calculated from the maximum evacuation time of 270 minutes from the full 0-10 mile EPZ for summer, weekend, adverse weather conditions, an assumed 15 minute notification time, and 15 minutes for evacuation preparation (NMC 2003).

F.3.6 METEOROLOGY

Annual MNGP meteorology data from year 2000 were used in MACCS2. Data were utilized as follows:

- Wind speed and direction from the 10-meter sensor of the site tower were combined with precipitation (hourly cumulative). If the lower wind direction was unavailable, mid and/or upper directions were used to estimate the lower wind direction.
- If a brief period (i.e., few hours) of missing data existed for all tower sensors, interpolation was used between hours.
- For larger data voids (i.e., days), tower data from the previous or following week for the same time of day was utilized to fill data gaps.
- Atmospheric stability was calculated according to the vertical temperature gradient of the tower temperature data.
- Atmospheric mixing heights were specified for AM and PM hours. These values were based on information for St. Cloud, Minnesota (approximately 20 miles northwest from MNGP) (EPA 1972).

F.3.7 MACCS2 RESULTS

Table F.3-4 shows the mean off-site doses and economic impacts to the MNGP 50-mile region for each of seven release categories calculated using MACCS2. These impacts are multiplied by the annual frequency for each release category and then summed to obtain the risk-weighted mean doses and economic costs. The largest risks are from the large early (L-E) and large late (L-L) release categories. Both of these release categories have frequencies that are greater than 1E-06 per year and large consequential doses. Together, these two release categories account for 87 percent of the dose-risk and over 97 percent of the off-site economic cost-risk.

F.4 BASELINE RISK MONETIZATION

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

F.4.1 OFF-SITE EXPOSURE COST

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 1997):

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

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 (as fraction) = 0.07 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 37.95 person-rem. The calculated value for C using 20 years and a 7 percent discount rate is approximately 10.76. 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 (10.76). The calculated off-site exposure cost is $816,924.

F.4.2 OFF-SITE ECONOMIC COST RISK

The Level 3 analysis showed an annual off-site economic risk of $253,612. Calculated values for off-site economic costs caused by severe accidents 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 $2,729,601.

F.4.3 ON-SITE EXPOSURE COST RISK

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

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 (4.47E-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 = real discount rate (0.07 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:

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

$$= 2{,}000 * 4.47\text{E-}05 * 3{,}300 * \{[1 - \exp(-0.07 * 20)]/0.07\}$$

$$= \$3{,}175$$

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 long-term dose is:

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

= 2,000∗4.47E-05 ∗20,000∗{ [1 - exp(-0.07∗20)]/0.07} {[1 -exp(-0.07∗10)]/0.07∗10}

= $13,840

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

W_O = W_{IO} + W_{LTO} = ($3,175 + $13,840) = $17,015

F.4.4 ON-SITE CLEANUP AND DECONTAMINATION COST

The net present value that NRC provides for cleanup and decontamination for a single event is $1.1 billion, discounted over a 10-year cleanup period (NRC 1997). 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 (1.1E+09)

r = real discount rate (0.07)

t_f = 20 years (license renewal period)

The resulting net present value of cleanup integrated over the license renewal term, $1.18E+10, must be multiplied by the total CDF (4.47E-05) to determine the expected value of cleanup and decontamination costs. The resulting monetary equivalent is $529,212.

F.4.5 REPLACEMENT POWER COST

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

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

Where:

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

r = real discount rate (0.07)

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 MNGP's size relative to the "generic" reactor described in NUREG/BR-0184 (i.e., 587 megawatt electric/910 megawatt electric), the replacement power costs are determined to be 5.09E-09 ($-year). Multiplying this value by the CDF (4.47E-05) results in a replacement power cost of $227,509.

F.4.6 TOTAL COST RISK

The sum of the baseline costs is as follows:

Off-site exposure cost	=	$816,924
Off-site economic cost	=	$2,729,601
On-site exposure cost	=	$17,015
On-site cleanup cost	=	$529,212
Replacement Power cost	=	$227,509
Total cost	=	$4,320,261

This value is the single unit maximum averted cost-risk (MACR) based on on-line internal events contributions, which is rounded to next highest thousand ($4,321,000) for SAMA calculations for a single unit.

As described in section F.5.1.7, the internal events maximum averted cost-risk is doubled to account for external events contributions. The resulting modified MACR is $8,642,000 and was used in the Phase I screening process.

F.5 PHASE I SAMA ANALYSIS

The Phase I SAMA analysis, as discussed in Section F.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.

F.5.1 SAMA IDENTIFICATION

The initial list of SAMA candidates for MNGP was developed from a combination of resources including:

- MNGP PSA results
- Industry Phase II SAMAs
- MNGP Individual Plant Examination IPE (NSP 1992)
- MNGP IPEEE (NSP 1995)

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 MNGP.

In order to provide consistency with previous industry SAMA analyses and to provide a recognized source for potential SAMAs, a generic SAMA list was used to help identify potential enhancements for MNGP. This list is provided for reference purposes in Addendum 1. This list was compiled as part of the development of several industry SAMA analyses. It has been used in the MNGP SAMA analysis as a reference source to identify the types of plant changes that may be considered to improve selected functions of the plant.

F.5.1.1 LEVEL 1 MNGP IMPORTANCE LIST REVIEW

The MNGP PSA was used to generate a list of events sorted according to their RRW values. The top events in this list are those events that would provide the greatest reduction in the MNGP CDF if the failure probability were set to zero. The events were reviewed down to the 1.005 level, which corresponds to a 0.5 percent change in the CDF given 100 percent reliability of the event. If the dose-risk and offsite economic cost-risk were also assumed to be reduced by 0.5 percent, the corresponding averted cost-risk would be approximately $21,500. Applying a factor of 2 to estimate the potential impact of external events (refer to Section F.5.1.7), the result is about $43,000. This is considered to be the threshold for implementation costs for potential plant changes, especially given that this estimate is based on complete reliability of the proposed change. No further review of the importance listing was performed below the 1.005 level. Table F.5-1 documents the disposition of each event in the Level 1 MNGP RRW list.

F.5.1.2 LEVEL 2 MNGP IMPORTANCE LIST REVIEW

A similar review was performed on the importance listings from the Level 2 results. In this case, two importance files were used to identify potential SAMAs. The LERF-based importance file was used as it is the largest single release category contributor to dose-risk and offsite economic cost-risk. A composite file based on the top 97 percent of all dose-risk was used to check that the largest contributors were addressed by the LERF-based list. The composite file was composed of the following release category results: Extreme, Large-Early, Large-Late, and Small-Late. This method was chosen to prevent high frequency-low consequence events from dominating the importance listing. As the LERF-based importance list was more comprehensive than the composite list, it was used as the bases for Level 2 SAMA identification.

The Level 2 RRW values were reviewed down to the 1.005 level. As described for the Level 1 RRW list, events below the 1.005 threshold value are estimated to yield an averted cost-risk less than $43,000 and are not considered to be likely candidates for identifying cost effective SAMAs. As such, the events with RRW values below 1.005 were not reviewed. Table F.5-2 documents the disposition of each event in the Level 2 MNGP RRW list.

F.5.1.3 INDUSTRY SAMA ANALYSIS REVIEW

The SAMA identification process for MNGP is primarily based on the PSA importance listings, the IPE, and the IPEEE. In addition to these plant-specific sources, selected industry SAMA analyses were reviewed to identify any Phase II SAMAs that were determined potentially cost beneficial at other plants. These SAMAs were further analyzed and included in the MNGP SAMA list if they were considered potentially cost beneficial for MNGP.

While many of these SAMAs are not cost beneficial, some are close contenders and a small number have been shown to be cost beneficial at other plants. MNGP importance ranking is used to identify the types of changes that would most likely be cost beneficial for MNGP. In addition, review of selected industry Phase II SAMAs was needed to capture potentially important changes not identified for MNGP due to PSA modeling differences. Given this potential, it was considered prudent to include a review of selected industry Phase II SAMAs in the MNGP SAMA identification process.

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

- Calvert Cliffs (BGE 1998)

- H.B. Robinson (CPL 2002)
- Edwin I. Hatch (SNOC 2000)
- Peach Bottom (Exelon 2001)
- Dresden (Exelon 2003a)
- Quad Cities (Exelon 2003b)
- Brunswick (CPL 2004)

Two pressurized water reactor and five BWR sites were chosen from available documentation to serve as the Phase II SAMA sources. Not all of the Phase II SAMAs from these sources were included in the initial MNGP SAMA list (see Table F.5-3). Many of the industry Phase II SAMAs were already represented by other SAMAs in the MNGP list or were judged to have clearly little or no value for MNGP. These SAMAs were not considered further. SAMAs considered potentially cost beneficial were included in the initial MNGP SAMA lists based on engineering judgment. The following SAMAs were added as a result of review of the other industry analyses:

- Control Containment Venting Within a Narrow Band of Pressure (SAMA 33)
- Supplemental Air Supply for Containment Vent (SAMA 34)
- Enhance Procedural Guidance for Use of Cross-tied Service Water Pumps (SAMA 35)

F.5.1.4 MNGP IPE

The MNGP 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 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. While all of the enhancements proposed in the IPE are included in the SAMA list, there were only two that required additional analysis. These SAMAs include:

- Emergency Procedures for condensate storage tank (CST) Refill (SAMA 28)
- Enhanced, Test, and Train on Alternate Boron Injection (SAMA 13)

F.5.1.5 MNGP IPEEE

Similar to the IPE, there may be a number of proposed plant changes in the IPEEE that were not implemented or were previously rejected based on other criteria that should be re-examined using the SAMA methodology. In addition, there may be issues that are in the process of being resolved, which may be important to the disposition of some SAMAs. The IPEEE was used to identify these items.

An effort was also made to use the IPEEE to develop new SAMAs based on a review of the original results. However, the MNGP 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 PSA 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 mitigative 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 for the reasons described above.

F.5.1.6 USE OF EXTERNAL EVENTS IN THE MNGP SAMA ANALYSIS

IPEEE was used in the MNGP SAMA analysis primarily to identify the highest risk accident sequences and the potential means of reducing the risk posed by those sequences. Some of the events addressed in the IPEEE were not considered further based on inapplicability to the plant, low frequency of occurrence, or because the events or consequences of the events are already addressed by the PSA. These events include:

- Severe temperature transients (extreme heat, extreme cold)
- Severe storm (ice, hail, snow, dust, and sand storms)
- Lightning
- External Fires
- Extraterrestrial Activity (meteors, man-made objects entering earth’s atmosphere)

- Volcanic activity
- Earth movement (avalanche, landslide)

After the elimination of the preceding events, the events requiring further investigation at MNGP were limited to:

- Fires (F.5.1.6.1)
- Seismic (F.5.1.6.2)
- High Winds (F.5.1.6.3)
- External Flooding and Probable Maximum Precipitation (F.5.1.6.4)
- Transportation and Nearby Facility Accidents (F.5.1.6.5)

The type of information available for these events varied due to the manner in which they were addressed in the IPEEE. For instance, the fire analysis was performed using a combination of standard PSA modeling techniques and EPRI's Fire Induced Vulnerability Evaluation methodology, which produced results similar to those yielded by the internal events analysis. However, the seismic margins analysis does not produce a CDF and is predicated on the ability to evaluate the seismic durability of the equipment required to safely shut the plant down. The results of this kind of analysis do not directly lend themselves to the type of frequency-based analysis used in the SAMA evaluation. As a result, each of the external events 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 followed by a description of the method used to quantitatively incorporate external events contributions into the SAMA analysis (NSP 1995).

F.5.1.6.1 Fires

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

In general, fire PSAs are useful tools to identify design or procedural items that could be clear areas of focus for improving the safety of the plant. Fire PSAs use a structure and quantification technique similar to that used in the internal events PSA. Since less attention historically has been paid to fire PSAs, 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 PSA, 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 PSA topics involving technical inputs, data, and modeling that prevent the effective comparison of the calculated CDF between the internal events PSA and the fire PSA. These areas are identified as follows:

PSA 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 steps at plants.
System Response:	Fire protection 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. Cable routings are typically characterized conservatively because of the lack of data regarding the routing of cables or the lack of the analytic modeling to represent the different routings. This leads to limited credit for balance of plant systems that are extremely important in CDF mitigation.
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 PSAs. This has led to conservative characterization of crew actions in fire PSAs. Because the CDF is strongly correlated with crew actions, this conservatism has a profound effect on the calculated fire PSA results.
Level of Detail:	The fire PSAs 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 PSAs is not as developed as for internal events PSAs. For example, no industry standard, such as NEI 00-02, exists for the structured peer review of a fire PSA. This may lead to less assurance of the realism of the model.

Specifically, the MNGP IPEEE describes the major known conservatisms in the Fire modeling process, which are consistent with the general Fire model limitations. This text includes the following:

> The fire IPEEE accident sequence quantification includes a number of conservatisms. For example, fires were always assumed to completely engulf the area in which they started. Automatic or manual fire suppression was not credited except in the Motor Control Center (MCC)/Feedwater pump area, the main Control Room and the cable spreading room. Further, repair activities were only applied to accident

sequences in which a very long time was available to effect repairs, and then only to those components not damaged by the fire. When repair actions were credited, the recovery of only a single failed component was assumed even if there were multiple failures to which recovery could be applied. Systems were also assumed to fail in certain areas to limit the effect required to perform cable tracking. Therefore, the methodology, while yielding useful reliable results, gives core damage frequencies that are considered to be upper bounds. (NSP 1995)

In addition to modeling limitations, the fire PSA may be subject to more modeling uncertainty than the internal events PSA evaluations. While the fire PSA is generally self-consistent within its calculational framework, the fire PSA does not compare well with internal events PSAs because of the number of conservative assumptions that have been included in the fire PSA process. Therefore, the use of the fire PSA results as a reflection of CDF may be inappropriate. Any use of fire PSA results and insights should consider areas where the “state of the art” in fire PSAs is less evolved than other PSA 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 MNGP. Two types of information from the fire model have been used to identify SAMAs:

- Fire area results
- Accident class results

These are addressed separately below. The accident classes that are used in these results descriptions are defined in Table F.2-1.

Fire Area Results

Seven room/burn sequences contribute 83 percent of the fire risk with the largest contributor (18.6 percent) being Control Room fires. The room/burn areas are:

- Area VIII/9: Control Room (18.6 percent)
- Area XII/BS5: Turbine Building 931-foot elevation (16.3 percent)
- Area IX/BS4: Feedwater Pump Area (15.4 percent)
- Area VI/8: Cable Spreading Room (11.5 percent)
- Area II/BS2: Reactor Building 935/962-foot elevation West (7.1 percent)

- Area IX/12A: Lower 4kV Switchgear Room (6.4 percent)
- Area XXII/BS6: Division II Area of the Emergency Filtration Train Building (5.2 percent)

Detailed information about accident sequence progression for these fire compartments is not currently available. The CDF for the fire compartments are documented, but the relative importance of specific equipment is not typically contained in the available documentation. General descriptions of the fire compartments from the IPEEE are available, however, and these have been used to identify potential plant improvements.

Control Room/Cable Spreading Room (sub-areas VIII/9 & VI/8)

The Control and Cable Spreading Rooms contain controls, monitoring instrumentation, and cables for most of the equipment used to achieve safe shutdown of the plant. Loss of these areas due to a fire was assumed to disable all equipment that could not be controlled locally or from the Alternate Shut Down System (ASDS) panel.

Most Control and Cable Spreading Room fires start in electrical cabinets or panels. Fire damage or subsequent suppression induced damage were assumed to render all circuits within the cabinet inoperable. Fires within enclosed cabinets were assumed not to spread beyond the initiating cabinet; however, it was assumed that the smoke created from a fire that was not successfully suppressed forced the evacuation of the Control Room.

If the fire was suppressed, all equipment not controlled from that panel was assumed to be available for use and would fail only due to random causes. If the fire was not suppressed, evacuation of these rooms is assumed necessary and only equipment controlled from the ASDS panel was considered available.

General area fires (i.e., fires initiating outside of enclosed electrical cabinets) within the Control and Cable Spreading Rooms were assumed to engulf the entire room if not suppressed. Manual suppression was credited in the Control Room and automatic suppression was credited in the Cable Spreading Room. If suppression was successful, the cabling associated with at least one system (Feedwater) was assumed damaged. Suppression therefore limits the extent of fire damage to a single system.

Class 1A and Class 1D sequences (Table F.2-1 provides accident class descriptions) comprise the majority of the risk associated with a fire in both the Control Room and Cable Spreading Room. Class 1A sequences were dominated by operator inability to take control at the ASDS panel in time to provide adequate core cooling following failure to suppress the fire in these rooms. This procedure is detailed in MNGP Operations Manual Procedure C.4-C, “Shutdown Outside Control Room.” Core damage from Class 1D sequences required random failure of Core Spray Loop B following failures to suppress the fire. Efforts to repair and recover these components were not credited in these accident sequences given the short time from before core damage would occur.

Given that the Class 1A sequences are heavily influenced by the inability of the operators to take control of the reactor at the ASDS panel in time to prevent core damage, the following types of changes may reduce the risk for these scenarios:

- Permanently post an operator at the ASDS panel to allow immediate transfer of control in the event of a fire (SAMA 38).
- Improve fire suppression capabilities to prevent the need of evacuation.

Permanently posting an operator at the ASDS has been added to the SAMA list.

Fire suppression reliability is difficult to assess, especially attempting to quantify the improvement in manual suppression capabilities based on improved training or procedures. No measurable gain is judged to be attainable through these types of changes. Modification of the suppression equipment to include more effective automatic systems is limited. Due to the presence of humans in the Control Room, a halon system is not suggested. Other automatic systems are discouraged due to the potential damage that could be caused by spurious actuation. No SAMAs have been added for improved fire suppression.

Class 1D accidents are also driven by evacuation scenarios, but include failure to the “B” Loop of Core Spray. Potential methods of reducing the risk of these scenarios include those from Class 1A Control Room fire scenarios plus the following:

- Enhance the ASDS panel to include additional system controls (SAMA 39).

Turbine Building 931-foot Elevation (Sub-area XII/BS5)

This sub-area contains the Division II cable runs, the #14 air compressor and several MCCs.

Class 1A and 1D sequences dominate plant risk due to a fire in this area. Cables for Division II of Feedwater, CRD, Core Spray, and RHR are located in adjacent cable trays and would be susceptible to fire damage. In addition, High Pressure Coolant Injection (HPCI) cables are located in this area. Because most power cables from the Division II load centers (LC102/104) are located in this area, continued operation of the Division I essential load center is important to the safe shutdown of the plant. Concurrent random failures leading to loss of LC103 are, therefore, required before core damage would occur. Spurious opening of the breakers feeding LC103 (152-509/052-301), in conjunction with the failures caused by the fire, comprise the majority of the plant risk from fires in this area. Because several hours of Reactor Core Isolation Cooling (RCIC) injection may be available (until battery depletion), restoration of Division I power was credited.

The failure sequences described for this fire are adequately addressed by SAMAs identified based on the review of the MNGP internal events PSA results:

- Enhanced DC power availability (SAMA 2)
- Enhance alternate injection reliability (SAMA 11)
- Additional diesel fire pump for fire service water system (SAMA 12)

These SAMAs provide means of prolonging RPV injection beyond the station battery life of 4 hours provided that containment venting is available for heat removal. As battery power is available for 4 hours for RCIC injection, any access requirements in the Turbine Building are considered to be met in time to perform the injection alignment.

No additional SAMAs have been added based on the review of risk from this fire area.

Feedwater Pump Area (Sub-area IX/BS4)

This sub-area contains the Feedwater pumps, two service/instrument air compressors, and several MCCs. In addition, several large cable trays containing Division I power and control cables run the length of this area.

Class 1A and 1D sequences contribute the majority of the plant risk due to a fire in this area. Both Feedwater pumps are located in this space and could suffer damage if a fire were to occur. Cables for one train of Core Spray, RHR and CRD are located in adjacent cable trays and would be susceptible to fire damage. Because most power cables from the Division I load centers (LC101/103) are located in the feed water pump area as well, continued operation of the Division II essential load center is important to the safe shutdown of the plant. Concurrent random failures leading to loss of LC104 are, therefore, required before core damage would occur. Spurious opening of the breakers feeding LC104 (152-609/052-401), in conjunction with the failures caused by the fire, comprise the majority of the plant risk from fires in this area. Several hours of HPCI injection may be available (until battery depletion). Recovery factors to restore battery chargers or Division II power were applied.

The failure sequences identified for a fire in the Feedwater pump area are adequately addressed by SAMAs identified based on the review of the MNGP internal events PSA results:

- Enhanced DC power availability (SAMA 2)

- Enhance alternate injection reliability (SAMA 11)
- Additional diesel fire pump for fire service water system (SAMA 12)

These SAMAs provide a means of prolonging RPV injection beyond the station battery life of 4 hours provided that containment venting is available for heat removal. As battery power is available for 4 hours for HPCI injection in the event of random loss of the remaining power supply, any access requirements in the Turbine Building are considered available in time to perform the injections alignment.

No additional SAMAs have been added based on the review of risk from Feedwater pump fire area.

Reactor Building 935/962-foot Elevation West (Sub area II/BS2)

A fire in this area has the potential to disable several important systems. Division II of RHR, Suppression Pool Cooling and, CS as well as HPCI, Hard Pipe Vent (HPV) and Shutdown Cooling are failed by fires in this area. Both trains of Emergency Core Cooling System automatic start circuitry are also located in the Reactor Building west area. Because of the significant quantity of electrical and mechanical equipment located in this area, the ignition frequency is also large. Feedwater, RCIC, and Division I low pressure systems are available for injection following fires in this area.

Class 2 sequences (Table F.2-1) contribute the majority of the plant risk due to a fire in this area. Feedwater and RHR Division I are the only systems available to accommodate decay heat generation following a fire. Failures of the operator to control Feedwater and unavailability of RHR due to maintenance are significant contributors to core damage.

The failure sequences identified for a Reactor Building west fire are adequately addressed by SAMAs identified during the review of the MNGP internal events PSA results:

- Enhance alternate injection reliability (SAMA 11)
- Additional diesel fire pump for fire service water system (SAMA 12)

SAMAs 11 and 12 would allow for the use of the Fire Service Water (FSW) for injection and containment venting for heat removal.

No additional SAMAs have been added based on the review of risk from this fire area.

Lower 4kV Switchgear Room (Sub-area IX/12A)

A fire in this area will fail most Division I switchgear and consequently all Division I safety related equipment.

Class 1A and 1D sequences contribute the majority of the plant risk due to a fire in this area. Cables or the power supply for RCIC and one train of Feedwater, Core Spray, RHR, and CRD are located in this room and would be susceptible to fire damage. Because most power cables from the Division I load centers (LC101/103) are located in the switchgear room, fires in this area are almost identical to fires occurring in the Feedwater pump area (see explanation contained in description of Feedwater pump area fires).

Division II Area of the Emergency Filtration Train Building (Sub-area XXII/BS6)

This area contains cabling for the HPCI battery, HPV, MCC-144, and Division II low pressure systems. 125V DC panel #211 cabling is also located in this area and provides breaker control power for most Division II equipment. Systems available for injection include RCIC and one train each of Feedwater, LPCI and Core Spray (CRD was not credited). Many of the Division II cables are located in this area because of routing to the ASDS panel located in an adjoining room.

Class 2 sequences contribute the majority of the plant risk due to a fire in this area. Feedwater and RHR Division I are the only systems available to mitigate decay heat generation following this fire. Similar to burn sequence 2 (BS2), failures of Feedwater train A hardware, unavailability of RHR due to maintenance, and failure of the operators to recover RHR Service Water (RHRSW) are significant contributors to core damage.

As for many of the other important fire areas, SAMAs 2, 11 and 12 provide an alternate injection source that can be used with the remaining division's LPCI injection path and a means of containment heat removal. No additional SAMAs are suggested.

Accident Class Results

While the MNGP IPEEE documentation (NSP 1995) does not provide rankings of event importance on a fire area basis, some event importance ranking information is available for the contributing accident classes. As noted in the discussion above, the contributing accident classes include:

- Class 1A contributes 37.3 percent of the fire CDF
- Class 1D contributes 41.6 percent of the fire CDF
- Class 2 contributes 21.1 percent of the fire CDF

The event rankings within these classes are used to identify the largest contributors to fire risk at MNGP. SAMAs are suggested to prevent or mitigate the loss of the functions represented by the events.

Given the nature of the fire initiators, the following accident classes were not considered to be applicable to the fire analysis and are not included.

- Class 1B: Station Blackout (SBO) - No single fire area is likely to result in a loss of all AC power at MNGP.
- Class 3: Loss of Coolant Accident (LOCA)s - No fire initiator was identified that could credibly lead to a loss of coolant accident.
- Class 4: Anticipated Transient Without Scram (ATWS) - No fire initiator was identified that could credibly lead to a failure of the reactor protection system. The simultaneous, independent failure of the reactor protection system or for control rod insertion during a fire is insignificant.

The fire initiating events were reviewed and no obvious ignition sources were identified that could be eliminated. The fire ignition frequencies are based on plant equipment located in the fire areas. Excluding changing the design of the equipment, no means of reducing the ignition frequencies of the equipment has been identified. As a result, no SAMAs have been suggested specifically to reduce ignition frequencies. Fire suppression is treated separately.

<u>Class 1A</u>

The important operator actions for this accident class include:

- Failure to repair/re-close circuit breakers that randomly fail on the non-fire damaged train.
- Failure to depressurize the RPV.
- Failure to suppress Control Room fires.

The failure to repair a breaker or re-close a breaker that has spontaneously opened results in the loss of power to the non-fire damaged systems that would be used for core cooling. Given that SAMAs 2, 11, and 12 provide an alternate means of providing inventory makeup and containment heat removal, these SAMAs are considered to address the consequences of this failure event. No additional SAMAs suggested.

Failure to depressurize the RPV results in core damage given that no high pressure injection systems are available for makeup. Potential means to reduce high pressure core damage contributions include providing additional high pressure injection methods (SAMA 4) and improving the reliability of the depressurization action (SAMAs 5, 19). SAMAs for each of these items were identified based on the internal events PSA model results. No additional SAMAs have been suggested.

Failing to suppress Control Room fires results in evacuation of the main Control Room and the need to control the plant from the ASDS panel. The ASDS panel includes a limited set of Division II equipment and is less familiar to the operators than the main Control Room. For Class 1A sequences, however, the most important aspect associated with failure to control the plant from outside of the Control Room is the ability to take control of the plant at the ASDS panel in time to prevent core damage. This could potentially be averted by posting an operator at the ASDS panel full time. This SAMA was also identified based on the review of the Control Room/Cable Spreading Room fire area results (SAMA 38). As noted in Section B.2.13.3 of the IPEEE, MNGP's fire fighting procedures address all six components of NUREG/CR-5088's "Effective Fire Fighting Program". Given MNGP's apparent state of competence, no credible methods of measurably improving the fire suppression action for the Control Room have been identified.

Important hardware failures for the Class 1A sequences include:

- Division II feeder breakers from Bus 16 to LC 104 fail to remain closed.
- Division I feeder breakers from Bus 15 to LC 103 fail to remain closed.

These two events are components of the same sequences that include the operator failure to re-close or repair the feeder breakers, which is addressed above. No additional SAMAs are suggested.

<u>Class 1D</u>

The important operator actions for this accident class involve failure to suppress Control Room fires. Failing to suppress Control Room fires results in evacuation of the main Control Room and the need to control the plant from the ASDS panel. The ASDS panel includes a limited set of a Division II equipment and is less familiar to the operators than the main Control Room. For Class 1D sequences, the largest contributor to core damage (about 66 percent) is failure of the only injection system that is available for control from the ASDS panel (CS "B").

A potential means of reducing risk from this scenario is enhancing the ASDS panel to include control for additional core cooling systems (SAMA 39). This SAMA was also identified based on the review of the Control Room/Cable Spreading Room fire area results.

As noted in Section B.2.13.3 of the IPEEE, MNGP's fire fighting procedures address all six components of NUREG/CR-5088's "Effective Fire Fighting Program". Given MNGP's apparent state of competence, no credible methods of measurably improving the fire suppression action for the Control Room have been identified.

The important hardware failures for the Class 1D sequences are Loop "B" CS failures. The failure of the "B" Loop of CS is a component of the same sequences as the most important operator action for this accident class; therefore, the disposition of this failure is considered to be the same as for the operator action (described above).

Class 2

The important operator actions for this accident class include:

- Failure to manually align condensate to the main condenser.
- Failure to recover RHRSW from corrective maintenance.

For the cases in which Feedwater is the primary injection source with containment heat removal from suppression pool cooling, failure to provide a long-term suction source will result in core damage. SAMAs 2, 11, and 12 provide for an alternate injection method with containment venting for heat removal; however, human action dependence issues may limit the credit that may be taken. A potential means of reducing risk from this scenario would be to include an emergency automatic makeup control for the hotwell. This system would be supported by Emergency Diesel Generator (EDG) backed power and have an actuation setpoint well below the normal operational range to limit the potential for actuation in non-accident conditions. The makeup could be defaulted to the CST with a low CST level transfer to the service water (SW) system. This potential enhancement has been added to the MNGP SAMA list (SAMA 40).

The RHRSW system is a heat sink for the RHR heat exchangers. Only one train of the system remains available when a fire occurs in most of the significant fire areas. Loss of the remaining train results in failure of the RHR system to remove decay heat from the primary system or containment. Given the long period of time available prior to core damage, corrective maintenance is possible, but not guaranteed. While failure to repair a hardware system is a human action, the level of dependence between such a repair action and actuation of an alternate injection system is considered to be low. For this reason, the injection/heat removal methods in SAMAs 2, 11, and 12 are judged to address this issue by providing a long-term injection source and a means of containment heat removal. No additional SAMAs have been recommended.

Important hardware failures for the Class 2 sequences include:

- Feedwater system failures
- RHRSW system failure and failure of system repair

Feedwater system failures are addressed by SAMAs 2, 11, and 12 by providing an alternate injection path and a means of containment heat removal. No additional SAMAs are suggested.

The RHRSW system failure and subsequent failure to repair has already been addressed as part of the important Class 2 operator actions discussion above. No additional SAMAs suggested.

Fire SAMA Identification Summary

Based on the review of the MNGP fire area and Accident Class results, three SAMAs have been identified for inclusion on the SAMA list that was not identified through the review of other PSA results. These SAMAs are:

- Permanently post an operator at the ASDS panel (SAMA 38)
- Enhance the ASDS panel to include both divisions of controls for core injection/cooling systems (SAMA 39)
- Add an emergency level control system to the hotwell (SAMA 40)

F.5.1.6.2 Seismic

The EPRI seismic margins methodology (EPRI 1991) is used to identify the minimal set of equipment required to safely shut the reactor down and to determine if that equipment is capable of surviving the Review Level Earthquake. Equipment that is not capable of withstanding the Review Level Earthquake is identified and required to be addressed. While methods exist for using this information to develop a seismic induced core damage frequency, this was not performed as part of the MNGP IPEEE. In addition, the pedigree of information is not equivalent to what is used in the internal events models and it is not considered appropriate to combine the internal events and seismic core damage frequencies.

The nature of the seismic model limits its use in the SAMA analysis compared with the internal events model. However, it was possible to review the seismic analysis results and history in order to determine if there were any unresolved issues that could impact MNGP risk. The types of issues that were of interest included:

- Unfinished plant enhancements that were determined to be required to ensure the equipment on the Safe Shutdown List would be capable of withstanding the Review Level Earthquake

- Additional plant enhancements that were identified as means of reducing seismic risk, but were discarded due to cost considerations

At the time the IPEEE was completed, the Unresolved Safety Issue A-46 analysis was not completed and the findings that were to be addressed under the Seismic Qualification Utilities Group program were identified as open items. After the submittal of the MNGP IPEEE, these findings were addressed to the satisfaction of NRC and closed out as documented in NRC safety evaluation (NRC 1998b).

Based on review of the IPEEE seismic results and subsequent interactions with NRC, no outstanding issues were found to exist that could impact the SAMA results.

F.5.1.6.3 High Winds

The approach taken to analyze the high wind risk at MNGP was a two-stage process. The first was to show that MNGP was designed to withstand the high wind events defined by NRC Regulatory Guide 1.76 (NRC 1974) and that those events would not challenge the design criteria. The second stage involved a probabilistic analysis to demonstrate that for those components of the design basis that did not meet the regulatory criteria, the risk was below the 1E-06 screening cutoff value and could be eliminated from consideration.

For MNGP, the high wind threats were analyzed and it was determined that tornadoes were the bounding event type for the plant. Given this, MNGP also examined the high-sustained wind threat to the plant stack considering the potential for gusting. No vulnerabilities were found.

Tornadoes were examined and two components of Regulatory Guide 1.76 were found to exceed the design criteria of the plant: 1) the pressure drop associated with the wind event, and 2) the weight and velocity of the utility pole missile. The CDF contributions associated with the larger pressure drop and utility pole missiles were estimated and determined to be below the 1E-06 screening cutoff used in the IPEEE and were screened from further consideration. No high wind vulnerabilities were found for MNGP.

Given the low potential for identifying cost beneficial SAMAs to mitigate risk posed by high winds, no further efforts were made in the SAMA analysis to develop high wind related SAMAs.

F.5.1.6.4 External Flooding and Probable Maximum Precipitation

The MNGP external flooding analysis assessed the potential for flood damage to the plant. The assessment included both a river flooding event and high water effects from precipitation. It was determined that neither posed an undue hazard to the plant. The MNGP Probable Maximum Flood (PMF), which was used as the basis for external flooding protection, was compared against the predicted effects of the 1000-year flood at the site. The PMF results in flood levels greater than the 1000-year flood and has “a probability of occurrence, in any particular year, approaching zero” (NSP 1995).

Procedures have been developed to respond to the PMF, which are building specific and address the particular flooding concerns of each building separately. While procedural improvements may be possible, quantifying the impacts of such changes is difficult and they are not assumed to result in a measurable improvement to the plant’s mitigating capabilities.

Flood safe systems could be added to the plant or changes could be made to the plant buildings to improve the flooding resistance of critical buildings; however, these types of changes are not likely to be cost beneficial. Assuming that 85 percent of the external events contribution is attributable to fires, the remaining 15 percent of the risk is assumed divided between seismic and flooding events (other event types are considered to be negligible contributors for this estimate). Given a total modified MACR of $8,642,000, the maximum averted cost-risk for external flooding events is $324,075. A cost of a new flood safe system is judged to greatly exceed this cost-risk and is not considered further. If changes to the buildings could be assumed to reduce the existing flood risk by 50 percent, the averted cost-risk would be only about $162,000. This allows for a limited set of hardware improvements once design, engineering, and labor are considered. No further efforts were made in the SAMA analysis to develop flood-related SAMAs.

The impact of the flooding effects of the Probable Maximum Precipitation (PMP) event is bounded by the PMF. In fact, the PMP is considered to occur as part of the PMF event. The PMP flooding event is, therefore, screened from further review.

While the PMP event was bounded by the PMF with respect to flooding effects, structural failures of building roofs at MNGP were considered. However, it was shown that the buildings’ yield strengths were in excess of the forces that would result from the water ponding that would occur during a PMP event. Roof failure from excess water collection was not a credible failure mode for MNGP. Therefore, SAMAs were not considered to address this failure mode.

F.5.1.6.5 Transportation and Nearby Facility Accidents

Transportation and nearby facility accidents were included in the MNGP 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 identified for analysis included:

- Transportation Accidents due to Aircraft Activity
- Transportation Accidents due to Marine Activity
- Transportation Accidents due to Pipeline Activity
- Transportation Accidents due to Railroad Activity
- Transportation Accidents due to Truck Activity
- Nearby Industrial Facilities
- Nearby Military Facilities
- Hazardous Material Releases from Onsite Storage
- Other Onsite Hazards

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 less than 1E-06 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, aircraft impact events are considered to be out of the scope of the SAMA analysis.

The transportation and nearby facility related events listed above were reviewed, and it was determined that they do not pose a credible threat to the plant. No effort was expended to identify SAMAs related to these events due to the fact that even if the events were likely to occur, they would not impact the operation of the plant systems.

F.5.1.7 QUANTITATIVE STRATEGY FOR EXTERNAL EVENTS

The quantitative methods available to evaluate external events risk at MNGP are limited, as discussed above. In order to account for the external events contributions in the SAMA analysis, a two stage process has been implemented to provide gross estimates of the averted cost-risk based on external events accidents. The first stage is used in the Phase I analysis and is based on the assumption that the risk posed by external and internal events is approximately equivalent. This is reasonable for MNGP given that the total external events CDF contribution is only 1.7E-5 per year (excluding Seismic Events and any aircraft related transportation accidents). The following table summarizes the MNGP external event contributors and their corresponding CDF estimates (NSP 1995).

External Event Contributor	CDF (per year)	Comments
Internal Fires	7.8E-06	This CDF, or any external event CDF, is not necessarily compatible with the internal events CDF, as described in Section F.5.1.6.1.
High Winds	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
External Flooding	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
Transportation Accidents: Aircraft Activity	--	Not addressed as part of the SAMA Analysis
Transportation Accidents: Marine Activity	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
Transportation Accidents: Pipeline Activity	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
Transportation Accidents: Railroad Activity	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
Transportation Accidents: Truck Activity	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
Accidents due to Activity at Nearby Industrial Facilities	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
Accidents due to Activity at Nearby Military Facilities	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
Accidents due to Releases of Hazardous Material Stored On-Site	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
Accidents Related to Other On-Site Hazards	<1E-06	CDF assessed as either below 1E-06 per year or not a threat to plant operations.
Seismic Events	--	Seismic margins analysis performed; no CDF available.
Total	1.7E-05	

The estimates included in the table above are based on the following assumptions:

- The external events contributors that were found to be applicable to MNGP all contribute at least 1E-06 per year to the CDF even if they were found to pose no threat to plant operations or were found to contribute less than 1E-06 per year to the CDF.
- Aircraft related accidents are not included as they are deemed to be beyond the scope of the SAMA evaluation.
- External events CDFs can be compared to the internal events CDF, which is not considered to be appropriate, as discussed in Section F.5.1.6.1 for Fire events.

The Seismic CDF is not included in the external events CDF estimate of 1.75E-05 per year due to the fact that no means of estimating the Seismic CDF were provided in the IPEEE. While this is true, it is possible to determine the maximum allowable Seismic CDF for maintaining the assumption that the external events contributions are approximately equivalent to the internal events contributions. In this case, the Seismic CDF could be as high as 2.7E-05 per year without causing the total external events contributions to exceed the internal events contributions of 4.47E-05 per year. A Seismic CDF of 2.7E-05 per year is about 3.5 times greater than the highest quantified external events contributor for MNGP (Fire). Given that the IPEEE found that no Seismic vulnerabilities existed at MNGP, a Seismic CDF of this magnitude is not considered to be likely.

Continuing with the assumption that the risk is assumed to be equal, the MACR calculated for the internal events model has been doubled to account for external events contributions. This total is referred to as the modified MACR. The modified MACR is used in the Phase I screening process to represent the maximum achievable benefit if all risk related to power operations was eliminated. Therefore, those SAMAs with costs of implementation that are greater than the modified MACR were eliminated from further review.

The second stage of the strategy also uses the Phase II analysis. Any averted cost-risk calculated was multiplied by two for each SAMA to account for the corresponding reduction in external events risk.

F.5.2 PHASE I SCREENING PROCESS

The initial list of SAMA candidates is presented in Table F.5-3. The process used to develop the initial list is described in Section F.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 MNGP design, it is screened from further analysis.
- Implementation Cost Greater than Screening Cost: If the estimated cost of implementation is greater than the modified MACR, the SAMA cannot be cost beneficial and is screened from further analysis.

Table F.5-3 provides a description of how each SAMA was dispositioned in Phase I. Those SAMAs that required a more detailed cost-benefit analysis are evaluated in Section F.6.

F.6 PHASE II SAMA ANALYSIS

Phase II involves additional screening and detailed cost-benefit analysis. Some of the remaining SAMA candidates were screened from further analysis based on plant-specific insights regarding the risk significance of the systems that would be affected by the proposed SAMA. The SAMAs related to non-risk significant systems were screened from a detailed cost-benefit analysis as any change in the reliability of these systems is known to have a negligible impact on the PSA evaluation. In addition, those SAMAs that can be shown to have a small averted cost-risk based on relevant importance rankings are excluded from further review. The disposition of these SAMAs is provided in Tables F.5-4 and F.5-5.

For each of the remaining SAMA candidates, a more detailed conceptual design was prepared along with a more detailed estimated cost. This information was then used to evaluate the effect of the candidates' changes upon the plant safety model.

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

Net Value = (baseline cost-risk of site operation (modified MACR) – cost-risk of site operation with SAMA implemented) – cost of implementation

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 cost-risk of plant operation was derived using the methodology presented in Section F.4. The cost-risk of plant operation with the SAMA implemented is determined in the same manner with the exception that the revised PSA results reflect implementation of the SAMA.

Sections F.6.1 – F.6.16 describe the detailed cost-benefit analysis that was used for each of the remaining candidates. It should be noted that the release category results provided for each SAMA do not include contributions from the negligible release category.

F.6.1 SAMA NUMBER 2: ENHANCED DC POWER AVAILABILITY

DC power availability is important for several reasons at MNGP, including 1) maintaining high pressure injection, 2) maintaining low pressure injection [Safety Relief Valves (SRVs), as well as control power], and 3) supporting containment venting. Several accident scenarios include these functions. Improving DC availability could reduce the risk for each of them. Several options are available to improve DC availability, including:

a) Provide an independent battery for SRVs and HPV

b) Provide a portable generator to support SRVs and HPV

c) Proceduralize use of car batteries for SRVs and bypass HPV DC dependency with manual vent control

d) Practice and test DG-13 backfeed to the battery chargers

e) Provide a direct connection from DG-13, the security diesel, or another source to the 250V battery chargers or other required loads

While each of these permutations has the potential to reduce risk at MNGP, option "e" takes advantage of an existing system and would require minimal hardware additions as part of its implementation. This modification would also be effective in mitigating the largest contributors to accident scenarios where injection and venting failures have occurred due to loss of DC support. For MNGP, certain internal flooding initiators result in the loss of the DC batteries and/or supporting equipment; however, those floods do not impact DG-13 or preclude the potential to provide direct feeds to required loads.

Additional cable, procedural updates, and training would be required to implement option “e”; however, the costs would be comparable to or lower than the other proposed options, and the benefit would be approximately the same as installing an independent DC source. Options "a", "b", and "c" require the same types of changes as option “e”, but, they also require the purchase of a new DC source or rely on equipment that is not maintained by the plant. Option "d" relies on existing equipment, but it may be unavailable in a flood event, which is the primary area of concern for this SAMA. As a result, option "e" is considered to be the best candidate for MNGP and has been chosen as the representative case for this SAMA.

While it may be possible to power multiple loads with DG-13, this SAMA assumes that only the battery chargers are supplied with power. In order to estimate the benefit of this SAMA, a failure probability of 1E-02 has been assigned to the alignment and operation of the direct feed line. In order to represent this SAMA, the model was modified by replacing MCC-144 power unavailability with a gate that additionally credits an alternate power supply provided by DG-13.

The cost of implementation for this SAMA was estimated to be $75,000 based on engineering judgment. This is assumed to include equipment procurement, training, and procedure updates.

Results

The results from this case indicate a 0.7 percent reduction in CDF (CDF_{new}=4.44E-05 per year), a 1.0 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=37.6 person-rem per year), and a 1.0 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $251,159 per year). Results by release category are provided below.

SAMA Number 2 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.64E-09	4.17E-06	7.10E-06	8.99E-08	9.66E-07	1.81E-07	3.97E-05	5.22E-05
$Dose\text{-}Risk_{NEW}$	0.0	17.2	15.6	0.3	0.4	0.0	4.1	37.6
$OECR_{NEW}$	$61	$130,064	$115,535	$1,790	$410	$59	$3,240	$251,159

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 2 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$8,562,810	$79,191	$75,000	$4,191

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

F.6.2 SAMA NUMBER 4: ADDITIONAL HIGH PRESSURE INJECTION SYSTEM

An additional High Pressure Injection (HPI) system would increase the diversity of the function and reduce the probability of requiring RPV depressurization early in an accident. An additional HPI system would also impact the contribution of liner melt-through sequences in the Level 2 evaluation by reducing the frequency of high pressure core melt accident class. The benefit of this SAMA would be increased if the pump was 1) diesel powered, 2) could provide power to operate its own injection valves, and 3) be located in a flood safe zone.

In order to estimate the potential benefit of such a modification, the failure probability of the alignment and operation of this system was assumed to be 1E-02. The system was included with no dependencies on other plant support equipment and was not failed by any flood initiators. In order to represent this SAMA, all HPI failure gates were replaced with gates that can additionally credit the new, independent cooling system.

The cost of implementation for this SAMA was estimated based on a previous industry SAMA analysis. CPL, Brunswick, estimated the cost of installing a direct drive diesel injection pump at $2,000,000 (CPL 2004). As the injection system proposed for Brunswick is considered to be similar in scope and nature to the changes considered for MNGP, the cost estimate has been adopted for this analysis.

Results

The results from this case indicate a 97.9 percent reduction in CDF (CDF_{new}=9.59E-07 per year), a 97.9 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=0.8 person-rem per year), and a 97.9 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $5,411 per year). Results by release category are provided below.

SAMA Number 4 Results By Release Category

Release Category	E	L-E	L-L	M-E	5M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.26E-09	7.91E-08	1.05E-07	5.60E-08	2.74E-08	7.57E-08	3.91E-07	7.36E-07
$Dose\text{-}Risk_{NEW}$	0.0	0.3	0.2	0.2	0.0	0.0	0.0	0.8
$OECR_{NEW}$	$52	$2,467	$1,709	$1,115	$12	$24	$32	$5,411

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 4 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$184,869	$8,457,131	$2,000,000	$6,457,131

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

F.6.3 SAMA NUMBER 6: ADDITIONAL FAN AND LOUVER PAIR FOR EDG HVAC

Failure of EDG Building Heating, Ventilation, and Air Conditioning (HVAC) results in loss of the EDGs. Room heat-up after loss of HVAC results in actuation of the fire system sprinklers, which in turn fails the EDGs due to the effects of water spray.

Due to the short time that is estimated to be available after loss of room cooling and before fire system actuation, operator actions to set up portable fans or to open doors are not credited. An additional fan and louver pair could be installed with logic to auto start on high temperature. This would provide cooling in a timely manner and mitigate failures of the existing HVAC system. In order to estimate the potential benefit of such a modification, the failure probability of system actuation and operation was assumed to be 1E-02. This SAMA is modeled by replacing both divisions of “EDG room cooling failure” gates with gates that can additionally credit a new, independent cooling system.

SNOC estimated the cost of installing an additional thermostat and louver pair at Hatch to be $100,000 (SNOC 2000). Given that this SAMA requires installation of a fan in addition to the thermostat and louver considered by SNOC, $100,000 is adopted as the lower bound cost estimate for this plant improvement at MNGP.

Results

The results from this case indicate a 2.0 percent reduction in CDF (CDF_{new}=4.38E-05 per year), a 1.0 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=37.5 person-rem per year), and a 1.0 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $251,098 per year). Results by release category are provided below.

SAMA Number 6 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.64E-09	4.17E-06	7.10E-06	8.75E-08	1.05E-06	1.81E-07	3.91E-05	5.17E-05
$Dose\text{-}Risk_{NEW}$	0.0	17.2	15.6	0.3	0.4	0.0	4.1	37.5
$OECR_{NEW}$	$61	$130,064	$115,535	$1,742	$446	$59	$3,191	$251,098

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 6 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$8,539,210	$102,790	$100,000	$2,790

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

F.6.4 SAMA NUMBER 8: IMPROVED EDG-ESW PUMPING CAPABILITY

Common cause failure of the EDG-Emergency Service Water (ESW) pumps is a large contributor to the system failure, which results in the loss of the EDGs. Installing a diverse, engine driven EDG-ESW pump would address common cause failure (CCF) issues. Alternatively, a cross-tie to the SW system or FSW system could be implemented to back-up EDG-ESW. Given the relatively rapid heatup of the EDGs' cooling water without an active heat sink, the existing connection to SW is not credited. The SW pumps are shed on loss of power, and the EDGs would fail before the pumps could be re-started and aligned to the EDGs through the cross-tie. A potential means of crediting the SW cross-tie would be to install a high-temperature trip on the EDGs to prevent damage while the SW system was re-started and aligned. This would result in a temporary loss of AC power, which is undesirable. Finally, the FSW system could be modified to backup the cooling function. No load shed problems would exist, but new piping would have to be installed. Locating cross-tie controls in the main Control Room would allow for rapid alignment. This is the option that is explored in this SAMA.

In order to estimate the potential benefit of such a modification, the failure probability of system actuation and operation was assumed to be 1E-02. This SAMA is modeled by replacing both divisions of “EDG-ESW failure” gates with gates that can additionally credit a new, independent EDG-ESW pump.

The cost of implementation for this SAMA was estimated based on a previous industry SAMA analysis. BGE estimated the cost of using the FSW system as a back-up for EDG cooling at Calvert Cliffs to be $500,000 per diesel (BGE 1998). Given that there are two diesels at MNGP, the cost was doubled so that both EDGs would have alternate cooling available. In order to respond to this loss of EDG cooling in the short available time frame, it was assumed that it should be possible to align FSW to the EDGs from the main Control Room. To account for the addition of motor operated valve, wiring, and main Control Room updates, the cost was doubled to $2,000,000.

Results

The results from this case indicate a 1.8 percent reduction in CDF (CDF_{new}=4.39E-05 per year), a 2.4 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=37.0 person-rem per year), and a 2.6 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $246,921 per year). Results by release category are provided below.

SAMA Number 8 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.64E-09	4.18E-06	6.82E-06	8.79E-08	1.19E-06	1.81E-07	3.91E-05	5.16E-05
$Dose\text{-}Risk_{NEW}$	0.0	17.2	15.0	0.3	0.5	0.0	4.1	37.0
$OECR_{NEW}$	$61	$130,376	$110,979	$1,750	$505	$59	$3,191	$246,921

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 8 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$8,430,542	$211,458	$2,000,000	-$1,788,542

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

F.6.5 SAMA NUMBER 10: DRYWELL IGNITERS OR PASSIVE HYDROGEN IGNITION SYSTEM

For periods when the containment is de-inerted, there is a risk of hydrogen detonation during an accident. The resulting overpressure can lead to catastrophic containment failure. A potential means of preventing a hydrogen detonation is to install igniters that would burn the combustible gases as they are produced rather than allow them to collect to a level that could yield a containment-challenging explosion.

In order to estimate the potential benefit of such a modification, the failure probability of the system was assumed to be 1E-02. Model changes that were made to the PSA to represent the implementation of this SAMA include replacing the “hydrogen deflagration” gate with a gate that additionally credits mitigation by independent hydrogen igniters.

The cost of implementation for this SAMA was estimated based on a previous industry SAMA analysis. BGE estimated the cost of a passive hydrogen ignition system at Calvert Cliffs to be $760,000 (BGE 1998). As the Calvert Cliffs enhancement is considered to be similar in scope and nature to the changes considered for MNGP, the cost estimate has been adopted for this SAMA.

Results

The results from this case indicate no reduction in CDF (CDF_{new}=4.47E-05 per year), a 3.5 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=36.6 person-rem per year), and a 3.9 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $243,631 per year). Results by release category are provided below.

SAMA Number 10 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.64E-09	3.88E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.21E-05
$Dose\text{-}Risk_{NEW}$	0.0	16.0	15.8	0.3	0.4	0.0	4.1	36.6
$OECR_{NEW}$	$61	$121,019	$117,000	$1,790	$463	$59	$3,240	$243,631

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 10 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$8,370,406	$271,594	$760,000	-$488,406

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

F.6.6 SAMA NUMBER 11: ENHANCE ALTERNATE INJECTION RELIABILITY

The capability exists at MNGP to provide flow from the RHRSW and FSW systems to the RHR system; however, the reliability of the cross-tie could potentially be improved by including the cross-tie valves in the maintenance program so that the operability of the valves is monitored and tested.

Currently, the alternate injection alignments are proceduralized and operators receive training on them, and, therefore, the human error probability (HEP) for the alignment action is reasonably low. No measurable reductions in the HEP are assumed to be justified through increased training.

In order to estimate the potential benefit of testing the alternate injection valves, testing was assumed to occur every 5 years, which reduces the failure probability of the valves from 2 percent each to 0.2 percent each.

The cost of implementation for this SAMA was estimated to be $50,000 based on engineering judgment. It is assumed to include the labor required for the increased testing, update of the governing documentation, and training.

Results

The results from this case indicate a 0.2 percent reduction in CDF (CDF_{new}=4.46E-05 per year), an 8.9 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=34.6 person-rem per year), and a 9.9 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $228,577 per year). Results by release category are provided below.

SAMA Number 11 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	1.44E-09	3.91E-06	6.21E-06	8.93E-08	1.08E-06	1.81E-07	3.97E-05	5.12E-05
$Dose\text{-}Risk_{NEW}$	0.0	16.1	13.6	0.3	0.4	0.0	4.1	34.6
$OECR_{NEW}$	$33	$121,955	$101,053	$1,778	$459	$59	$3,240	$228,577

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 11 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$7,954,956	$687,044	$50,000	$637,044

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

F.6.7 SAMA NUMBER 12: ADDITIONAL DIESEL FIRE PUMP FOR FIRE SERVICE WATER SYSTEM

The FWS system is available as a source of alternate injection and containment spray; however, the reliability of the diesel-driven pumps is not estimated to be as high as for other types of pumps. As a result, pump failure is a large contributor to system reliability.

While an additional diesel fire pump would provide another source of water for RPV injection and containment spray, this could be achieved in long-term scenarios through the implementation of a procedure to direct the pressurization of the FSW system using a fire truck. This is considered to be a more cost-effective means of improving alternate injection than the installation of an additional fire pump.

In order to estimate the potential benefit of this change, it was assumed that the failure probability of pressurizing the FSW system with a fire truck was 1E-02 and that the failure probability of the diesel fire pump was 1.2E-02 instead of 1.2E-01. This SAMA was modeled by replacing the “Fire Protection System (FPS) pump failure” event with a gate that additionally credits a fire pumper truck and an improved diesel fire pump.

The cost of implementation for this SAMA was assumed to be $50,000 based on engineering judgment. This estimate is assumed to include procedure changes and training to govern the use of the fire truck to pressurize the FPS in an accident scenario requiring alternate injection from the fire header. MNGP currently has an agreement with the local fire department to assist with fire fighting efforts, including bringing a fire pumper truck on site and drawing water from the Mississippi River.

Results

The results from this case indicate a 0.4 percent reduction in CDF (CDF_{new}=4.45E-05 per year), a 33.7 percent reduction in dose-risk (Dose-Risk_{new}=25.1 person-rem per year), and a 37.6 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $158,204 per year). Results by release category are provided below.

SAMA Number 12 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.64E-09	3.08E-06	3.48E-06	8.60E-08	1.03E-06	1.81E-07	3.97E-05	4.76E-05
Dose-Risk_{NEW}	0.0	12.7	7.6	0.2	0.4	0.0	4.1	25.1
$OECR_{NEW}$	$61	$96,067	$56,629	$1,712	$438	$59	$3,240	$158,204

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 12 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$6,030,218	$2,611,782	$50,000	$2,561,782

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

F.6.8 SAMA NUMBER 13: ENHANCE, TEST AND TRAIN ON ALTERNATE BORON INJECTION

MNGP has the capability to use the Reactor Water Cleanup (RWCU) and CRD systems to inject boron into the RPV; however, these alignments are not practiced. The RWCU alignment is not credited in the PSA model due to the length of time required for alignment. Changes to make these connections permanent and capable of being aligned from the main Control Room would improve their reliability.

Additional training and practice of boron injection with CRD in the simulator and with mock-up test rigs could potentially improve reliability of the alternate boron injection action. However, the improvements in the human error probability would be small, and the common dependence of this injection alignment on the initial failure to scram due to CRD failure would also limit the benefit. This SAMA assumes that the RWCU system is upgraded so that it can be aligned from the Control Room rapidly enough to effectively respond to a Standby Liquid Control (SBLC) failure during an ATWS. The alignment action is assumed to be completely dependent on the action to inject with SBLC.

In order to estimate the potential benefit of this change, it was assumed that the failure probability of boron injection through RWCU was 1E-03. Model changes to represent the implementation of this SAMA consist of replacing the “SBLC boron injection failure” gate with a gate that additionally credits RWCU boron injection. Operator dependence between SBLC and RWCU boron injection is already included in the model.

The cost of implementation for this SAMA was estimated to be $50,000 based on engineering judgment. This estimate includes only procedure and training upgrades for alternate boron injection as a surrogate to a total enhancement package that would include hardware changes for RWCU boron injection. This surrogate cost estimate is used because the complexity of developing a detailed cost estimate for enhancing RWCU boron injection would require significant resources, and the averted cost risk is small enough that this SAMA is not cost beneficial even when the cost of implementation only considers procedure and training changes.

Results

The results from this case indicate a 0.2 percent reduction in CDF (CDF_{new}=4.46E-05 per year), no reduction in dose-risk ($Dose\text{-}Risk_{new}$=38.0 person-rem per year), and less than a 0.01 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $253,611 per year). Results by release category are provided below.

SAMA Number 13 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.76E-07	3.97E-05	5.24E-05
$Dose\text{-}Risk_{NEW}$	0.0	17.3	15.8	0.3	0.4	0.0	4.1	38.0
$OECR_{NEW}$	$61	$131,000	$117,000	$1,790	$463	$57	$3,240	$253,611

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 13 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$8,638,495	$3,505	$50,000	-$46,495

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

F.6.9 SAMA NUMBER 16: PASSIVE OVERPRESSURE RELIEF

This SAMA would prevent catastrophic failure of the containment. The current Torus Hard Pipe Vent includes a rupture disk beyond an isolation valve; however, an alternate path to the Torus Hard Pipe Vent could be made in the wetwell using a rupture disk that would fail at about 60 psid. Alternatively, the containment vent valves could be changed so that they "fail open" on loss of support. Given this change, the vent path would be open after a failure of the support systems with the exception of the rupture disk. To prevent premature opening of the vent path during scenarios with loss of vent valve support, the strength of the rupture disk could be increased so that it is closer to the Emergency Operating Procedure vent pressure. Of the two potential changes suggested, the latter is more likely to be a cost beneficial change and is considered here.

In order to estimate the potential benefit of this change, all of the gates crediting hard pipe vent failure (operator action, hardware, and system dependencies) were replaced with a gate representing rupture disk failure at 1E-03.

The cost of implementation for this SAMA was estimated to be $200,000 based on engineering judgment. This is assumed to include changing the valve hardware to “fail open” operation and increasing rupture disk strength.

Results

The results from this case indicate a 2.5 percent reduction in CDF (CDF_{new}=4.36E-05 per year), a 3.5 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=36.6 person-rem per year), and a 3.4 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $245,059 per year). Results by release category are provided below.

SAMA Number 16 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.64E-09	4.10E-06	6.87E-06	8.99E-08	5.35E-07	1.81E-07	3.98E-05	5.16E-05
$Dose\text{-}Risk_{NEW}$	0.0	16.9	15.1	0.3	0.2	0.0	4.1	36.6
$OECR_{NEW}$	$61	$127,881	$111,793	$1,790	$227	$59	$3,248	$245,059

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 16 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$8,362,520	$279,480	$200,000	$79,480

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

F.6.10 SAMA NUMBER 28: REFILL CST

While MNGP has procedures to refill the CST under normal operating conditions, no procedures exist to direct this operation during emergency conditions. Development of such a procedure and ensuring the viability of refilling the CST with FSW would provide a means to allow for long-term availability of the CST as an injection suction source. Availability of the CST is important as it provides a cool suction source in LOCA or extended Station Blackout (SBO) conditions when the suppression pool becomes saturated, or for Interfacing System LOCA, it provides additional inventory.

The benefit of this SAMA is likely limited due to the fact that the 200,000 gallon CST volume is adequate during SBO for approximately 3 days and the Interfacing System LOCA importance is relatively low.

In order to estimate the potential benefit of this change, it was assumed that the failure probability of refilling the CST during an accident in the required timeframe was 1E-02. In order to model this SAMA, the gate representing insufficient CST volume was changed to include credit for the refill actions.

The cost of implementation for this SAMA was estimated based on a previous industry SAMA analysis. CPL estimated the cost of procedure changes at Brunswick to be between \$50,000 and \$100,000. A cost estimate of \$50,000 is used in the analysis and covers modifications to existing emergency procedures. Costs associated with the procurement of materials to support this SAMA have been conservatively ignored.

Results

The results from this case indicate no reduction in CDF (CDF_{new}=4.47E-05 per year), less than a 0.03 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=37.9 person-rem per year), and less than a 0.02 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = \$253,570 per year). Results by release category are provided below.

SAMA Number 28 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	7.90E-10	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
$Dose\text{-}Risk_{NEW}$	0.0	17.3	15.8	0.3	0.4	0.0	4.1	37.9
$OECR_{NEW}$	\$18	\$131,000	\$117,000	\$1,790	\$463	\$59	\$3,240	\$253,570

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 28 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$8,640,668	$1,332	$50,000	-$48,668

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

F.6.11 SAMA NUMBER 36: DIVERT WATER FROM TURBINE BUILDING 931-FOOT ELEVATION EAST

Given a flood in the Turbine Building 931-foot elevation east area, water level will rise and flood rooms critical to DC and AC power distribution. Floor failure is also possible from the weight of accumulating water in the flooded rooms, which would consequently cause equipment failure in areas other than the initial flood area. Installation of an interlock to open the door to the Hot Machine Shop on high water level will prevent these flooding consequences by diverting water to a "safe" area. In addition, changing the swing direction of the door to the Plant Administration Building would help protect the batteries by reducing the likelihood of opening the flood path to the battery rooms.

In order to estimate the potential benefit of this change, it was assumed that the failure probability of the flood door actuating and diverting water to the “safe zone” was 1E-03. As this SAMA is already under investigation by the PSA team, the model already includes logic that models this flood mitigating change. An existing model flag was set to “False” to allow the logic to propagate through the model.

The cost of implementation for this SAMA was estimated to be $100,000 based on engineering judgment. The cost is assumed to include changing the relevant door’s swing direction and the hardware required to allow the Hot Machine Shop door to open on high water level.

Results

The results from this case indicate a 13 percent reduction in CDF (CDF_{new}=3.89E-05 per year), a 22.9 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=29.3 person-rem per year), and a 24.3 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $192,083 per year). Results by release category are provided below.

SAMA Number 36 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.64E-09	2.41E-06	6.87E-06	8.99E-08	1.05E-06	1.81E-07	3.39E-05	4.45E-05
Dose-Risk$_{NEW}$	0.0	9.9	15.1	0.3	0.4	0.0	3.5	29.3
OECR$_{NEW}$	$61	$75,169	$111,793	$1,790	$446	$59	$2,767	$192,083

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 36 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$6,742,385	$1,899,615	$100,000	$1,799,615

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

F.6.12 SAMA NUMBER 37: MANUAL RCIC OPERATION

The important flooding scenarios at MNGP result in loss of DC and, in some cases, also AC power. This fails motor-driven injection and eventually safety relief valve (SRV) operation. While RCIC is capable of injecting to the RPV when it is at high pressure (given loss of SRVs), it is currently dependent on DC power. If guidance could be provided so that the system could be operated with local, manual control, injection could be maintained for a longer period of time. Engineering analysis will also be required to confirm the viability of this strategy.

In order to estimate the potential benefit of this change, it was assumed that the failure probability of operating RCIC was 1E-02. Model changes that were made to the PSA to represent the implementation of this SAMA consist of changing gate LATE-1 to include RCIC. This credits RCIC injection after containment heat removal failure with subsequent containment vent success. In addition, the gate representing long-term RCIC injection was modified to remove dependencies on electric power when operators are successful at manually operating the system.

The cost of implementation for this SAMA was estimated to be $100,000 based on engineering judgment. This estimate is assumed to include hardware and procedure changes to allow RCIC operation without electric support.

Results

The results from this case indicate a 16.3 percent reduction in CDF (CDF_{new}=3.74E-05 per year), an 81.7 percent increase in dose-risk ($Dose\text{-}Risk_{new}$=68.9 person-rem per year), and an 82.4 percent increase in Offsite Economic Cost-Risk ($OECR_{new}$ = $462,661 per year). Results by release category are provided below.

SAMA Number 37 Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	6S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	2.64E-09	5.99E-06	1.64E-05	2.07E-08	1.95E-05	7.43E-08	2.20E-06	4.42E-05
$Dose\text{-}Risk_{NEW}$	0.0	24.7	36.0	0.1	7.9	0.0	0.2	68.9
$OECR_{NEW}$	$61	$186,831	$266,871	$412	$8,283	$24	$180	$462,661

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 37 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$14,223,445	-$5,581,445	$100,000	-$5,681,445

The implementation of this SAMA alone results in a negative averted cost-risk and an increase in “risk”. The increase is due to the fact that operation of RCIC after loss of electric support changes the timing of core damage. All of the core damage sequences that previously occurred prior to containment failure occur after or at the time of containment failure with implementation of this SAMA. Given that the averted cost-risk is negative, this SAMA is not cost beneficial based on the SAMA methodology.

F.6.13 SAMA NUMBER 38: POST AN OPERATOR AT THE ASDS PANEL FULL TIME

In the event that a fire in the main Control Room requires evacuation to the ASDS panel, having a full time operator at the panel would allow for a more rapid transition to alternate reactor control. This is important for loss of injection cases where there is currently not enough time for the operators to evacuate the main Control Room and assume control at the ASDS panel (Class 1A).

This SAMA assumes that if an operator were to be permanently posted at the ASDS panel, it would be possible to transition plant control to the ASDS panel in time to prevent core damage during a Control Room evacuation scenario.

The existing fire model assumes that none of the Class 1A accidents can be mitigated by the ASDS panel. For the purposes of this analysis, it is assumed that all risk from Class 1A accidents can be eliminated by implementing this SAMA.

The impact of this change is 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 MNGP CDF and release consequences related to Control Room evacuation 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 percentage of the overall modified MACR attributable to external events
- Determine the percentage of the external events modified MACR contribution attributable to fire events
- Determine the percentage of the fire component of the modified MACR attributable to Control Room and Cable Spreading Room fires (these require Control Room evacuation)
- Determine the percentage of the Control Room/Cable Spreading Room fire component of the modified MACR attributable to Class 1A scenarios
- Calculate the reduction in the Class 1A fire risk initiated by Control Room/Cable Spreading Room fires that would occur if an operator were permanently posted at the ASDS panel

The baseline assumption for external events contributions in the MNGP SAMA is that they are approximately equal to the internal events contributions. Given that the internal events contribution to the modified MACR is $4,321,000, 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 seismic analysis was a margins analysis and did not produce a CDF. For the purposes of this calculation, it is assumed that the fire events comprise 85 percent of the external events risk. This corresponds to a cost-risk of $3,672,850.

Based on the MNGP IPEEE, Control Room and Cable Spreading Room fires require main Control Room evacuation, which comprise 30 percent of the fire risk. This corresponds to a cost-risk of $1,101,855. The IPEEE indicates further that 30 percent of the Control Room/Cable Spreading Room fire CDF is comprised of Class 1A sequences. This corresponds to a cost-risk of $330,557. Given that it was assumed that implementation of this SAMA could eliminate all of this risk, the averted cost-risk for this SAMA is also $330,557.

The cost of implementation for this SAMA is based on an estimated base salary and the cost of benefits for 5 additional licensed operators. Five operators are justified considering that personnel are required to cover all shifts, 7 days a week and that 20 percent of operator time is spent in training. Assuming that an operator's salary and benefits cost $100,000 per year and that the panel will be manned for the 20 year license renewal period, the cost of implementation would be $10 million, not including raises.

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 38 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$8,311,443	$330,557	$10,000,000	-$9,669,443

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

F.6.14 SAMA NUMBER 39: ENHANCE THE ASDS PANEL TO INCLUDE ADDITIONAL SYSTEM CONTROLS

Fire scenarios that result in Control Room evacuation require reactor control from the ASDS panel. Given that only one division of controls is available at the panel, a single additional system failure would result in the loss of a safety function and core damage would ensue. If controls for the opposite division were added, single division failures would be eliminated as a failure mode. This is important for loss of injection cases in which the operators have time to initially take control of the plant from the ASDS panel and depressurize the RPV (Class 1D).

This SAMA assumes that addition of the opposite division's controls will allow the operators to start the remaining equipment and effectively eliminate all risk associated with Class 1D fires during Control Room evacuations.

The impact of this change is 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 MNGP CDF and release consequences related to Control Room evacuation 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 percentage of the overall modified MACR attributable to external events
- Determine the percentage of the external events modified MACR contribution attributable to fire events
- Determine the percentage of the fire component of the modified MACR attributable to Control Room and Cable Spreading Room fires (these require Control Room evacuation)
- Determine the percentage of the Control Room/Cable Spreading Room fire component of the modified MACR attributable to Class 1D scenarios
- Calculate the reduction in the Class 1D fire risk initiated by Control Room/Cable Spreading Room fires that would occur if the ASDS panel were expanded to include control for both divisions of equipment

The baseline assumption for external events contributions in the MNGP SAMA is that they are approximately equal to the internal events contributions. Given that the internal events contribution to the modified MACR is $4,321,000, 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 seismic analysis was a margins analysis and did not produce a CDF. For the purposes of this calculation, it is assumed that the fire events comprise 85 percent of the external events risk. This corresponds to a cost-risk of $3,672,850.

Based on the MNGP IPEEE, Control Room and Cable Spreading Room fires require main Control Room evacuation, which comprise 30 percent of the fire risk. This corresponds to a cost-risk of $1,101,855. The IPEEE indicates further that 68.3 percent of the Control Room/Cable Spreading Room fire CDF is comprised of Class 1D sequences. This corresponds to a cost-risk of $752,567. Given that it was assumed that implementation of this SAMA could eliminate all of this risk, the averted cost-risk for this SAMA is also $752,567.

The Advanced Boiling Water Reactor (ABWR) Severe Accident Mitigation Design Alternative (SAMDA) analysis (GE 1994) estimated the cost of installing enhanced computer aided instrumentation to be about $600,000 in 1994. Upgrading the ASDS panel to contain an additional division of controls is judged to require at least an equal investment of resources. Assuming an inflation rate of 2.75 percent per year between 1994 and 2004, the cost in 2004 dollars is $786,991.

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 39 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$7,855,009	$752,567	$786,991	-$34,424

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

F.6.15 SAMA NUMBER 40: ADD AN EMERGENCY LEVEL CONTROL SYSTEM TO THE HOTWELL

This system would actuate on low level in the main condenser (well outside of the normal operating range) and automatically provide makeup so that the Feedwater (FW)/Condensate system would have a long-term suction source. This would relegate the operator action that is currently required to align the CST or Service Water to the main condenser to a backup action and improve the reliability of main condenser makeup. This is important for Class 2 accident sequences in which FW/Condensate is initially established but fails in the long term due to lack of hotwell inventory.

This SAMA assumes that the addition of the hotwell level control system removes all risk associated with Class 2 accidents that contain the failure of the operator to align the CST or SW to the hotwell. Based on the IPEEE, Class 2 accidents comprise 21 percent of the fire CDF. Twenty-three percent of the Class 2 accidents include the operator error to align makeup to the hotwell.

The impact of this change is 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 MNGP CDF and release consequences related to Control Room evacuation 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 percentage of the overall modified MACR attributable to external events

- Determine the percentage of the external events modified MACR contribution attributable to fire events
- Determine the percentage of the fire component of the modified MACR attributable to accident Class 2 sequences
- Determine the percentage of the Class 2 fire sequences attributable to operator based hotwell makeup failure
- Calculate the reduction in the Class 2 fire risk with hotwell make-up failures that would occur if the automatic hotwell makeup system was installed at MNGP

The baseline assumption for external events contributions in the MNGP SAMA is that they are approximately equal to the internal events contributions. Given that the internal events contribution to the modified MACR is $4,321,000, 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 seismic analysis was a margins analysis and did not produce a CDF. For the purposes of this calculation, it is assumed that the fire events comprise 85 percent of the external events risk. This corresponds to a cost-risk of $3,672,850.

Based on the MNGP IPEEE, accident Class 2 sequences comprise 21.1 percent of the fire risk. This corresponds to a cost-risk of $774,971. The IPEEE indicates further that 23 percent of the accident Class 2 sequences include operator based hotwell makeup failures. This corresponds to a cost-risk of $178,243. Given that it was assumed that implementation of this SAMA could eliminate all of this risk, the averted cost-risk for this SAMA is also $178,243.

The addition of a level sensor and a control valve is similar to the automatic refill system for the elevated water storage tank at the Oconee Nuclear Station, which Duke Power estimated to cost $230,000 (NRC 1999).

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table.

SAMA Number 40 Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$8,463,757	$178,243	$230,000	-$51,757

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

F.6.16 COMBINED IMPACT OF RECOMMENDED SAMAs

While it is important to examine the impact of implementation for each individual SAMA, some combinations of SAMAs may act synergistically to yield a combined risk reduction greater than the individual modifications. For example, providing an alternate DC source would improve DC reliability and adding a diesel powered low-pressure injection pump would increase injection diversity, but together, these SAMAs could provide a low-pressure injection source for long-term SBO cases that neither individual SAMA would necessarily provide on its own.

NMC recognizes the value of considering a combination of SAMAs in the analysis. This sub-section documents two distinct insights: 1) the impact of implementing a specific “recommended” combination of SAMAs, and 2) the potential benefits of the remaining Phase 2 SAMAs if the recommended SAMAs were implemented. The second insight is important for MNGP because the implementation of a combination of low cost SAMAs alters the conclusions about the remaining Phase 2 SAMAs.

The “recommended” SAMAs for MNGP consist of the following:

SAMA 2: Enhanced DC Power Availability (provide cables from DG-13, the security diesel, or another source to directly power division II 250V battery chargers or other required loads)

SAMA 11: Enhance Alternate Injection Reliability (include the RHRSW and FSW valves in the maintenance testing program)

SAMA 12: Additional Diesel Fire Pump for FSW system (proceduralize the use of a fire truck to pressurize and provide flow to the fire main for RPV injection)

SAMA 28: Refill CST (develop emergency procedures and ensure viability of refilling the CSTs with FSW)

SAMA 36: Divert Water from Turbine Building 931-foot elevation

SAMA 37: Manual RCIC Operation

The model changes that were made to the PSA to represent the implementation of the individual SAMAs at MNGP, including the reliability estimates, were also used for the combined application. The combined implementation cost is assumed to be the sum of the individual implementation costs; no savings are assumed to occur related to the timing or manner in which the SAMAs are implemented together. The total cost of implementation is $425,000.

F.6.16.1 PSA MODEL RESULTS FOR THE RECOMMENDED SAMAs

The results from this case indicate an 86.4 percent reduction in CDF (CDF_{new}=6.10E-06 per year), a 79.6 percent reduction in dose-risk ($Dose\text{-}Risk_{new}$=7.7 person-rem per year), and a 79.7 percent reduction in Offsite Economic Cost-Risk ($OECR_{new}$ = $51,477 per year). Results by release category are provided below.

Recommended SAMAs Results By Release Category

Release Category	E	L-E	L-L	M-E	M-L	S-E	S-L	Total
Baseline Freq.	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05	5.25E-05
SAMA Freq.	7.90E-10	6.48E-07	1.81E-06	4.00E-08	1.86E-06	1.36E-07	2.02E-06	6.51E-06
$Dose\text{-}Risk_{NEW}$	0.0	2.7	4.0	0.1	0.8	0.0	0.2	7.7
$OECR_{NEW}$	$18	$20,211	$29,453	$796	$790	$44	$165	$51,477

This information was used as input to the cost-benefit calculation. The results of this calculation are provided in the following table:

Recommended SAMAs Net Value

Base Case Cost-Risk	Revised Cost-Risk	Averted Cost-Risk	Cost of Implementation	Net Value
$8,642,000	$1,653,834	$6,988,166	$425,000	$6,563,166

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

F.6.16.2 PHASE II SAMA COST-BENEFIT GIVEN IMPLEMENTATION OF THE RECOMMENDED SAMAs

Implementation of the recommended SAMAs changes the MNGP risk profile. If it is assumed that the recommended SAMAs are implemented, the cost-benefit analysis changes for the remaining Phase 2 SAMAs. For MNGP, it reduces the potential averted cost-risk for some of those plant changes and increases it for others. The following table identifies the net values for the remaining SAMAs with and without implementation of the recommended SAMAs.

SAMA Number	Net Value Without Recommended SAMAs	Net Value With Recommended SAMAs	Change in Cost Effectiveness
4	$6,457,131	-$466,421	Yes
6	$2,790	-$81,604	Yes
8	-$1,788,542	-$1,984,385	No
10	-$488,406	-$744,723	No
13	-$46,495	-$49,522	No
16	$79,480	$1,037,012	No
38	-$9,669,443	-$9,936,735[a]	No
39	-$34,424	-$642,957[a]	No
40	-$51,757	-$195,886[a]	No

a. This estimate is derived by preserving the assumption that external risk is comparable to the internal events risk. Thus if the internal events risk is reduced, the external events risk is reduced as well.

As demonstrated in this table, the impact of implementing the recommended SAMAs changes the conclusions of the base-case analysis with regard to the remaining Phase II SAMAs. SAMA 4, which analyzes the benefit of installing an independent high pressure injection system, changed from being cost beneficial by over $6 million to being not cost beneficial by over $460,000. The averted cost-risk for SAMA 6 was likewise reduced to the point where it would not be considered cost beneficial. The margin by which SAMAs 8 and 10 were not cost beneficial increased as a result of implementing the recommended SAMAs. SAMA 16, which proposes reconfiguring the vent valves to “fail open”, actually becomes more cost beneficial if the recommended SAMAs are implemented. This is because the recommended SAMAs shifted the risk to categories influenced by containment venting, which SAMA 16 could mitigate.

The external events based calculations (SAMAs 38, 39, and 40) have greatly reduced averted cost-risk after implementation of the recommended SAMAs using the assumptions adopted in this analysis; however, an accurate assessment is difficult to perform with the information that is available.

F.7 UNCERTAINTY ANALYSIS

Sensitivity cases were run for the following three conditions to assess the impact on the overall SAMA evaluation:

- Use of a 3 percent discount rate, instead of 7 percent used in the base case analysis.
- Use of the 95^{th} percentile PSA results in place of the mean PSA results used in the base case analysis.
- Use of the PSA model with credit taken for operator depressurization at the ASDS panel.

F.7.1 REAL DISCOUNT RATE

A sensitivity case has been performed in order to identify how the conclusions of the SAMA analysis might change based on the value assigned to the real discount rate (RDR). The original RDR of 7 percent has been changed to 3 percent, and the modified maximum averted cost-risk was re-calculated using the methodology outlined in Section F.4. The Phase I screening against the modified MACR was re-examined using the revised modified MACR to identify any SAMA candidates that could no longer be screened based on the premise that their costs of implementation exceeded all possible benefit. In addition, the Phase II analysis was re-performed using the 3 percent RDR.

Implementation of the 3 percent RDR increased the modified MACR by 36.1 percent. This relates to an increase in the modified MACR from $8,642,000 to $11,766,000. The Phase I SAMA list was reviewed to determine if such an increase in the modified MACR would impact the disposition of any SAMAs. Of the three SAMAs screened on high cost, only SAMA 9 would be retained for Phase II analysis.

The Phase II SAMAs are initially dispositioned based on PSA insights or detailed analysis. Use of the 3 percent discount rate did not affect the PSA insights used to screen the SAMAs. Therefore, the SAMA candidates screened based on these insights are not investigated further.

The remaining Phase II SAMAs were dispositioned based on the results of a SAMA-specific cost-benefit analysis. This step has been re-performed using the 3 percent RDR to calculate the net values for the SAMAs.

As shown below, the determination of cost effectiveness changed for two Phase II SAMAs when the 3 percent RDR was used. Implementation of these SAMAs may be considered, but as mentioned in Section F.6.16.2, the benefit of these SAMAs, which involves external events-based calculations, is difficult to accurately assess with the available information and should be considered separately.

Results Summary for the 3 Percent Discount Rate

SAMA ID	Cost of Implementation	Averted Cost- Risk (7 percent RDR)	Net Value (7 percent RDR)	Averted Cost- Risk (3 percent RDR)	Net Value (3 percent RDR)	Change in Cost Effectiveness
2	$75,000	$79,191	$4,191	$108,581	$33,581	No
4	$2,000,000	$8,457,131	$6,457,131	$11,514,874	$9,514,874	No
6	$100,000	$102,790	$2,790	$137,405	$37,405	No
8	$2,000,000	$211,458	-$1,788,542	$289,946	-$1,710,054	No
10	$760,000	$271,594	-$488,406	$379,514	-$380,486	No
11	$50,000	$687,044	$637,044	$959,354	$909,354	No
12	$50,000	$2,611,782	$2,561,782	$3,648,207	$3,598,207	No
13	$50,000	$3,505	-$46,495	$4,206	-$45,794	No
16	$200,000	$279,480	$79,480	$382,919	$182,919	No
28	$50,000	$1,332	-$48,668	$1,861	-$48,139	No
36	$100,000	$1,899,615	$1,799,615	$2,614,295	$2,514,295	No
37	$100,000	-$5,581,445	-$5,681,445	-$7,849,797	-$7,949,797	No
38	$10,000,000	$330,557	-$9,669,443	$450,050	-$9,549,950	No
39	$786,991	$752,567	-$34,424	$1,024,613	$237,622	Yes
40	$230,000	$178,243	-$51,757	242,677	$12,677	Yes
Recommended	$425,000	$6,988,166	$6,563,166	$9,497,789	$9,072,789	No

F.7.2 95TH PERCENTILE PSA RESULTS

The results of the SAMA analysis can be impacted by implementing conservative values from the PSA's uncertainty distribution. If the best estimate failure probability values were consistently lower than the "actual" failure probabilities, the PSA 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 PSA model.

Given that it would require major model modifications to obtain an uncertainty distribution from the MNGP model, the information required to perform this sensitivity is not readily available for the SAMA analysis. As a result, the 95th percentile PSA results have been estimated for MNGP.

It is assumed that the factor by which the 95^{th} percentile PSA results exceed the point estimate CDF is similar for many industry PSA models. While the degree of incorporation of plant-specific data varies from plant to plant, the use of similar generic base data and the methods used to incorporate plant-specific data are becoming more standardized. As a result, the characteristics of data uncertainties should be trending toward conformity.

The following is a summary of the point estimate CDF and 95^{th} percentile CDFs for three SAMA submittals:

Plant	Point Estimate CDF (per year)	95^{th} Percentile CDF (per year)	Factor by which the 95^{th} Percentile Results are Greater than the Point Estimates
V.C. Summer	5.59E-05	1.32E-04	2.36
Robinson	4.32 E-05	1.06E-04	2.45
Brunswick	4.19 E-05	9.84E-05	2.35

For the plants identified above, the 95^{th} percentile CDF is between 2.35 and 2.45 times greater than the point estimate CDF. While it is possible that the MNGP 95^{th} percentile CDF may be greater than a factor of 2.5 over the point estimate CDF, a factor of 2.5 is greater than the other industry examples and is assumed to be acceptable for identifying the impact of data uncertainty in the model.

F.7.2.1 PHASE I IMPACT

For Phase I screening, use of the 95^{th} percentile PSA results will increase the modified MACR and may prevent the screening of some of the higher cost modifications. However, the impact on the overall SAMA results due to the retention of the higher cost SAMAs for Phase II analysis is small. 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.

The impact of uncertainty in the PSA results on the Phase I SAMA analysis has been examined. The modified MACR is the primary Phase I criteria affected by PSA uncertainty. Thus, this portion of this sensitivity is focused on recalculating the modified MACR using the 95^{th} percentile PSA results and re-performing the Phase I screening process.

As discussed above, the 95^{th} PSA results are assumed to be a factor of 2.5 greater than point estimate CDF. For MNGP, this corresponds to a revised CDF of 1.12E-04 per year.

The uncertainty analyses that are currently available for some industry Level 1 models are not available for Level 2 and 3 PSA models. The dose risk and offsite economic cost risk were increased by a factor of 2.5 to simulate the increase in the CDF resulting from the use of the 95th percentile CDF. The 95th percentile dose-risk and offsite economic cost-risk are 94.9 person-rem per year and $634,030 per year, respectively. The corresponding modified MACR is about $21.6 million.

The initial SAMA list has been re-examined using the revised modified MACR to identify SAMAs that would be retained for the Phase II analysis. Those SAMAs that were previously screened due to costs of implementation that exceeded $8.64 million are now retained if the costs of implementation are less than $21.6 million. The only additional SAMA candidates that would be retained for Phase II analysis are SAMAs 1, 9, and 14. Given that the SAMA 1 (additional EDG) cost of implementation is 92 percent of the revised modified MACR, this SAMA is not considered further. The impact of installing an additional EDG is judged to be limited due to common cause failure. In addition, the current model results indicate that the diesel generators contribute to less than 4 percent of the CDF; thus, the EDG could not be cost beneficial even if the system was 100 percent reliable. Therefore, SAMA 1 is not considered further.

SAMA 9 (additional low pressure injection system) may be cost beneficial if the 95th PSA results are used; however, implementation of the recommended SAMAs provides a more cost-effective means of improving low pressure injection reliability. If the recommended SAMAs are implemented, the importance of an additional low pressure injection would be reduced due to alternate treatment and would yield a limited reduction in risk. As a result, SAMA 9 is not considered further.

The cost estimate provided for SAMA 14 (strengthening containment) is based on the ABWR SAMDA analysis, which focused on implementing a strengthened containment during the design and construction phase. The cost of retrofitting an existing containment is judged to exceed this cost and that $12 million is actually a lower bound cost. In addition, this cost was provided in 1994 dollars. In 2004 dollars, the cost of implementation would be $15.74 million assuming an inflation rate of 2.75 percent. If SAMA 14 is assumed to eliminate all dose-risk and offsite economic cost-risk, which would be the result of perfect containment, the associated averted cost-risk would be about $16 million. Given the containment is not expected to perform perfectly, this SAMA is not expected to be cost effective, even if the 95th PSA percentile results were used, and is not considered further.

F.7.2.2 PHASE II IMPACT

As mentioned above, it was necessary to make an assumption about the 95th percentile PSA results for the Level 2 and 3 analyses. The assumption has been made is that

95th percentile results have been represented by increasing the base dose-risk and offsite economic cost-risk in proportion to the Level 1 results. The factor of 2.5 is also assumed to propagate through the results for the model runs performed for Phase II detailed calculations. This means the averted cost-risks for each case will be increased by the same factor.

The following table provides a summary of the impact of using the 95th percentile PSA results in the detailed cost-benefit calculations performed.

Results Summary for the 95th Percentile PSA Results

SAMA ID	Cost of Implementation	Averted Cost- Risk (Base)	Net Value (Base)	Averted Cost- Risk (95th Percentile)	Net Value (95th Percentile)	Change in Cost Effectiveness
2	$75,000	$79,191	$4,191	$197,978	$122,978	No
4	$2,000,000	$8,457,131	$6,457,131	$21,142,828	$19,142,828	No
6	$100,000	$102,790	$2,790	$256,975	$156,975	No
8	$2,000,000	$211,458	-$1,788,542	$528,645	-$1,471,355	No
10	$760,000	$271,594	-$488,406	$678,985	-$81,015	No
11	$50,000	$687,044	$637,044	$1,717,610	$1,667,610	No
12	$50,000	$2,611,782	$2,561,782	$6,529,455	$6,479,455	No
13	$50,000	$3,505	-$46,495	$8,763	-$41,237	No
16	$200,000	$279,480	$79,480	$698,700	$498,700	No
28	$50,000	$1,332	-$48,668	$3,330	-$46,670	No
36	$100,000	$1,899,615	$1,799,615	$4,749,038	$4,649,038	No
37	$100,000	-$5,581,445	-$5,681,445	-$13,953,613	-$14,053,613	No
38	$10,000,000	$330,557	-$9,669,443	$826,393	-$9,173,607	No
39	$786,991	$752,567	-$34,424	$1,881,418	$1,094,427	Yes
40	$230,000	$178,243	-$51,757	$445,608	$215,608	Yes
Recommended	$425,000	$6,988,166	$6,563,166	$17,470,415	$17,045,415	No

When the 95th percentile PSA results are used, only two of the SAMAs that were previously classified as not cost effective are determined to be cost effective. Implementation of these SAMAs may be considered, but as mentioned in Section F.6.16.2, the benefit of these SAMAs, which includes external events based calculations, is difficult to accurately assess with the available information and should be considered separately.

F.7.3 CREDIT FOR ASDS PANEL DEPRESSURIZATION

A sensitivity case has been performed in order to assess the impact on the SAMA analysis if the PSA model were updated to credit ASDS panel depressurization. The latest approved PSA model was developed before procedural changes were made to allow use of the ASDS panel for depressurization on loss of 125V DC and Division I 250V DC. Given that these conditions could exist during important flood initiators, the impact of updating the model to credit current procedures was examined.

The SAMA model was updated to include credit for the ASDS panel depressurization, and the modified MACR was re-calculated using the methodology outlined in Section F.4. The Phase I screening against the modified MACR was re-examined using the revised modified MACR. In addition, the Phase II analysis was re-performed using the revised model.

Allowing credit for depressurization at the ASDS panel decreased the modified MACR by 18.8 percent compared with the base case. This relates to a decrease in the modified MACR from $8,642,000 to $7,016,000. The Phase I SAMA list was reviewed to determine if such a decrease in the modified MACR would impact the disposition of any SAMAs. No additional SAMAs were identified that could be screened on high cost in the Phase I analysis.

The Phase II SAMAs are initially dispositioned based on PSA insights or detailed analysis. Use of the revised model did not affect the PSA insights used to screen the SAMAs. Therefore, the incorporation of credit for ASDS panel depressurization was not found to impact this screening process.

The remaining Phase II SAMAs were dispositioned based on the results of a SAMA-specific cost-benefit analysis. This step has been re-performed using the revised model to calculate the net values for the SAMAs. As shown below, the determination of cost effectiveness did not change for any Phase II SAMAs when depressurization at the ASDS panel is credited.

Results Summary Considering Credit for ASDS Depressurization

SAMA ID	Cost of Implementation	Averted Cost- Risk (Base)	Net Value (Base)	Averted Cost- Risk (ASDS Dep)	Net Value (ASDS Dep)	Change in Cost Effectiveness
2	$75,000	$79,191	$4,191	$1,712,214	$1,637,214	No
4	$2,000,000	$8,457,131	$6,457,131	$6,850,640	$4,850,640	No
6	$100,000	$102,790	$2,790	$103,468	$3,468	No
8	$2,000,000	$211,458	-$1,788,542	$209,991	-$1,790,009	No
10	$760,000	$271,594	-$488,406	$243,005	-$516,995	No
11	$50,000	$687,044	$637,044	$691,493	$641,493	No
12	$50,000	$2,611,782	$2,561,782	$2,621,256	$2,571,256	No
13	$50,000	$3,505	-$46,495	$43	-$49,957	No
16	$200,000	$279,480	$79,480	$322,427	$122,427	No
28	$50,000	$1,332	-$48,668	$1,332	-$48,668	No
36	$100,000	$1,899,615	$1,799,615	$288,927	$188,927	No
37	$100,000	-$5,581,445	-$5,681,445	-$7,110,816	-$7,210,816	No
38	$10,000,000	$330,557	-$9,669,443	$268,362	-$9,731,638	No
39	$786,991	$752,567	-$34,424	$610,971	-$176,020	No
40	$230,000	$178,243	-$51,757	$144,707	-$85,293	No
Recommended	$425,000	$6,988,166	$6,563,166	$5,727,403	$5,302,403	No

While the modified MACR decreased as a result of crediting ASDS panel depressurization, some of the averted cost-risk estimates actually increased, which made the net values more positive. This is due to the fact that the ability to depressurize the RPV allows for the corresponding SAMAs to be more effective than they were when no credit was available for depressurization. In other cases, the averted cost risks decreased. For those cases, crediting ASDS panel depressurization reduces risk in the same manner as the relevant SAMAs. Thus, some of the risk that would have been reduced by the SAMA is already reduced by ASDS credit. This results in making the net values for the SAMAs more negative, which corresponds to being less cost beneficial.

A more useful consideration is reviewing the results assuming implementation of the recommended SAMAs. For instance, if a SAMA was shown to be cost beneficial even after the recommended SAMAs were implemented, crediting depressurization on the ASDS panel may change the net value such that it is no longer cost beneficial. Given that ASDS panel depressurization is already proceduralized at MNGP, this result would be considered to better reflect actual operating conditions. The results of this comparison are provided below.

SAMA Number	Net Value Cost-Risk With Recommended SAMAs (Base)	Net Value With Recommended SAMAs (ASDS Depressurization)	Change in Cost Effectiveness
4	-$466,421	-$778,884	No
6	-$81,604	-$105,889	No
8	-$1,984,385	-$2,006,236	No
10	-$744,723	-$766,236	No
13	-$49,522	-$49,615	No
16	$1,037,012	$859,465	No
38	-$9,936,735[a]	-$9,950,719[a]	No
39	-$642,957[a]	-$674,794[a]	No
40	-$195,886[a]	-$203,426[a]	No

a. This estimate is derived by preserving the assumption that external risk is comparable to the internal events risk. Thus if the internal events risk is reduced, the external events risk is reduced as well.

In this case, crediting ASDS panel depressurization pushes the net value in a negative direction on all of the remaining SAMAs. Based on the results above, only SAMA 16 warrants further consideration as it remains potentially cost beneficial with the recommended SAMAs implemented.

The external events based calculations (SAMAs 38, 39, and 40) have greatly reduced averted cost-risk after implementation of the recommended SAMAs using the assumptions adopted in this analysis; however, an accurate assessment is difficult to perform with the information that is available and these SAMAs should be evaluated deterministically by MNGP.

F.8 CONCLUSIONS

The benefits of revising the operational strategies in place at MNGP and/or implementing hardware modifications can be evaluated without the insight from a risk-based analysis. Use of the PSA 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 a much larger future population. The results of this study indicate that of the identified potential improvements that can be made at MNGP, several are cost beneficial based on the methodology applied in this analysis and warrant further review for potential implementation.

The most effective means of reducing risk at MNGP appears to include the implementation of a combination of SAMAs that allow for a synergistic effect. For instance, while improving low pressure injection reliability can reduce plant risk, such an improvement in conjunction with the ability to maintain the RPV at low pressure for long term cases greatly improves the effectiveness of the SAMA. The “recommended” combination of SAMAs includes:

SAMA 2: Enhanced DC Power Availability (provide cables from DG-13, the security diesel, or another source to directly power division II 250V battery chargers or other required loads)

SAMA 11: Enhance Alternate Injection Reliability (include the RHRSW and FSW valves in the maintenance testing program)

SAMA 12: Additional Diesel Fire Pump for FSW system (proceduralize the use of a fire truck to pressurize and provide flow to the fire main for RPV injection)

SAMA 28: Refill CST (develop emergency procedures and ensure viability of refilling the CSTs with FSW)

SAMA 36: Divert Water from Turbine Building 931-foot elevation East

SAMA 37: Manual RCIC Operation

Based on the results presented in Section F.7.3, which are considered to best represent the current plant configuration; implementation of this combination of SAMAs reduces the cost-risk of operating the plant by about 82 percent for a relatively low cost of implementation. With the recommended combination of SAMAs implemented, SAMA 16 (Passive Overpressure Relief) also appears to be cost beneficial. The benefits of changing the vent path valves to “fail open” on loss of support should be considered further.

NMC notes that this analysis should not necessarily be considered dispositive because other engineering reviews are necessary to determine ultimate implementation. NMC continues consideration and implementation of the 7 SAMAs (2, 11, 12, 16, 28, 36, and 37) identified in this analysis through MNGP’s corrective action process.

The conclusions related to the external events based calculations (SAMAs 38, 39, and 40) are highly subject to assumptions made in the analysis and the determination of whether or not to pursue the changes suggested in the SAMAs should be based on other engineering reviews and deterministic analysis.

TABLE F.2-1
ACCIDENT CLASS DISTRIBUTION TABLE (2003 MODEL)[a]

Class	Description	Frequency[b] (per year)	Percent of Total
1A	Transient leading to core damage with reactor at high pressure	4.00E-05	90.0
1B	SBO leading to core damage[c]	1.52E-06	3.4
1C	ATWS leading to core damage in an intact containment	1.05E-08	0.0
1D	Transient leading to core damage with reactor at low pressure	2.72E-07	0.6
2	Loss of containment heat removal leading to core damage	1.65E-06	3.7
3A	RPV rupture leading to core damage at low pressure	5.51E-07	1.2
3B	LOCA leading to core damage with the reactor at high pressure	3.16E-08	0.1
3C	LOCA leading to core damage with the reactor at low pressure	3.14E-07	0.7
3D	LOCA with vapor suppression failure	6.63E-10	0.0
4	ATWS leading to core damage and containment overpressure failure	7.19E-08	0.2
5	LOCA bypassing containment leading to core damage	8.97E-10	0.0
6	Internal flood leading to core damage	4.15E-05	93.5
	Total[d]	4.44E-05	

a. The model is based on the Complete-T&M.caf fault tree. New gates are created to eliminate SBO sequences for each accident class (A-and-not-B gate of each accident class gate and SBO gate). SBO is evaluated by creating fault tree gate CDF-SBO, which is an AND gate of fault tree gate CDF (core damage) and fault tree gate SBO (station blackout sequence).

b. The frequency of each accident class is quantified with a truncation of 1E-09 per year, except LOCA with vapor suppression failure (Class 3D), which is truncated at 1E-11 per year and LOCA outside containment (Class 5), which is truncated at 1E-10 per year because all associated cutsets are less than 1E-09 per year.

c. SBO leading to core damage (Class 1B) scenarios may lead to accident classes 1A, 1D, or 2, but for the purpose of this table are instead counted as Class 1B. No SBO scenarios are included in any other accident category.

d. The sum of accident class frequencies (4.44E-05) does not match the value of CDF calculated separately (4.43E-05) because quantification of accident classes results in nonminimal cutsets, relative to CDF cutsets. The number of nonminimal cutsets is reduced by setting events with a probability of 1 to TRUE (eliminated from cutsets). This is done with flag file TRUEs.caf.

ATWS = Anticipated Transient without Scram
LOCA = Loss of Coolant Accident
RPV = Reactor Pressure Vessel
SBO = Station Blackout

TABLE F.2-2
RELEASE SEVERITY AND TIMING CLASSIFICATION SCHEME

Source Term Release Fraction by Release Severity		Release Timing	
Classification Category	**Percent Cs in Release**	**Classification Category**	**Time of Release[(a)]**
Extreme (E) [(b)]	greater than 50	Late (L)	greater than 6 hours
Large (L)	10 to 50	Early (E)	less than 6 hours
Medium(M)	1 to 10		
Small (S)	less than 1		

a. Relative to the declaration of a General Emergency.
b. Extreme includes all releases up to 40 hours after accident initiation.

TABLE F.2-3
SUMMARY OF CONTAINMENT EVALUATION (2003 MODEL)

Release Bin[a]	Release Frequency (per year)
Negligible	3.75E-06
Extreme (E)	2.64E-09
Large-Early (L-E)	4.20E-06
Large-Late (L-L)	7.19E-06
Medium-Early (M-E)	8.99E-08
Medium-Late (M-L)	1.09E-06
Small-Early (S-E)	1.81E-07
Small-Late (S-L)	3.97E-05

a. See Table F.2-2 for nomenclature on the release bins.

TABLE F.2-4
MNGP SOURCE TERM SUMMARY

	Release Categories[a,b]						
	E	**L-E**	**L-L**	**M-E**	**M-L**	**S-E**	**S-L**
Bin Frequency	2.64E-09	4.20E-06	7.19E-06	8.99E-08	1.09E-06	1.81E-07	3.97E-05
MAAP Run	fw-loca-early	loca-vap-sup	no-inj-highp	none-lowp-dw-early	chr-ww	atws-fw-loca-ww	none-lpcipb-ww56
Time after Scram when General Emergency is Declared (hr)	25[c]	30[c]	2	2	18	1	2
Fission Product Group:							
1) Noble							
Total Release Fraction at 40 Hours	9.9E-01	7.4E-01	8.5E-01	6.2E-01	1.0E+00	1.0E+00	1.0E+00
Start of Release (hr)	0.25	0.80	9.00	4.40	34.00	1.00	16.00
End of Release (hr)	2.00	4.00	10.00	6.00	36.00	4.00	18.00
2) CsI							
Total Release Fraction at 40 Hours	8.3E-01	4.6E-01	2.8E-01	8.9E-02	2.7E-02	5.0E-03	2.7E-03
Start of Release (hr)	0.25	0.80	9.00	4.40	36.00	1.00	16.00
End of Release (hr)	2.00	40.00	40.00	14.00	40.00	6.00	18.00
3) TeO2							
Total Release Fraction at 40 Hours	6.8E-01	2.4E-01	9.9E-02	1.2E-01	7.5E-03	2.4E-03	9.6E-04
Start of Release (hr)	0.25	0.80	9.00	4.40	34.00	1.00	16.00
End of Release (hr)	2.00	12.00	22.00	8.00	40.00	4.00	40.00
4) SrO							
Total Release Fraction at 40 Hours	1.5E-02	4.7E-03	2.0E-05	2.3E-02	7.4E-06	1.5E-04	5.2E-06
Start of Release (hr)	0.25	0.80	9.00	4.40	34.00	2.00	16.00
End of Release (hr)	6.00	6.00	9.00	6.00	40.00	6.00	26.00
5) MoO2							
Total Release Fraction at 40 Hours	2.4E-02	3.7E-03	4.1E-07	4.4E-06	6.1E-06	2.7E-04	8.4E-08
Start of Release (hr)	0.25	0.80	9.00	4.40	34.00	1.00	16.00
End of Release (hr)	2.00	2.00	16.00	6.00	34.00	4.00	16.00
6) CsOH							
Total Release Fraction at 40 Hours	6.9E-01	3.1E-01	1.9E-01	1.4E-01	5.7E-03	3.4E-03	8.7E-04
Start of Release (hr)	0.25	0.80	9.00	4.40	34.00	1.00	16.00
End of Release (hr)	2.00	30.00	18.00	8.00	40.00	6.00	18.00
7) BaO							
Total Release Fraction at 40 Hours	2.8E-02	6.1E-03	1.6E-05	1.0E-02	6.4E-06	3.7E-04	2.8E-06
Start of Release (hr)	0.25	0.80	9.00	4.40	34.00	1.00	16.00
End of Release (hr)	2.00	6.00	9.00	6.00	40.00	4.00	16.00

TABLE F.2-4 (CONTINUED)
MNGP SOURCE TERM SUMMARY

	Release Categories[a,b]						
	E	**L-E**	**L-L**	**M-E**	**M-L**	**S-E**	**S-L**
8) La2O3							
Total Release Fraction at 40 Hours	6.5E-04	4.8E-04	5.6E-07	1.7E-03	1.3E-07	9.7E-06	8.9E-08
Start of Release (hr)	0.25	0.80	9.00	4.40	34.00	1.00	16.00
End of Release (hr)	6.00	6.00	9.00	6.00	36.00	8.00	16.00
9) CeO2							
Total Release Fraction at 40 Hours	4.6E-03	2.0E-03	8.8E-06	1.5E-02	3.8E-07	5.9E-05	9.4E-07
Start of Release (hr)	4.00	3.00	9.00	4.40	34.00	4.00	16.00
End of Release (hr)	6.00	6.00	9.00	6.00	36.00	6.00	24.00
10) Sb							
Total Release Fraction at 40 Hours	5.9E-01	3.8E-01	1.6E-01	4.4E-01	2.0E-04	3.2E-02	3.4E-03
Start of Release (hr)	0.25	0.80	9.00	4.40	34.00	1.00	16.00
End of Release (hr)	2.00	40.00	40.00	40.00	36.00	14.00	40.00
11) Te2							
Total Release Fraction at 40 Hours	2.3E-03	2.4E-02	1.2E-02	2.4E-02	7.8E-06	3.3E-04	1.2E-03
Start of Release (hr)	4.00	3.00	9.00	4.40	36.00	5.00	16.00
End of Release (hr)	6.00	40.00	20.00	40.00	40.00	8.00	40.00
12) UO2							
Total Release Fraction at 40 Hours	2.0E-05	1.1E-05	1.8E-07	7.7E-05	1.3E-10	3.2E-07	8.0E-09
Start of Release (hr)	4.00	3.00	9.00	4.40	36.00	5.00	16.00
End of Release (hr)	6.00	6.00	20.00	6.00	40.00	8.00	40.00

a. Puff releases are denoted in the table by those entries with equivalent start and end times.

b. All cases run for 40 hrs.

TABLE F.3-1
ESTIMATED POPULATION DISTRIBUTION WITHIN A 10-MILE RADIUS OF MNGP, YEAR 2030

Sector	Distance from MNGP (miles)						
	0-1	1-2	2-3	3-4	4-5	5-10	Total
N	0	0	0	232	567	953	1,752
NNE	0	3	4	132	296	1,594	2,029
NE	0	3	14	131	256	1,953	2,357
ENE	0	98	3	2,194	1,799	3,703	7,797
E	0	0	490	46	2,105	5,795	8,436
ESE	78	38	264	397	1,040	4,426	6,243
SE	0	939	1,862	2,343	1,947	2,885	9,976
SSE	0	581	149	1,181	711	492	3,114
S	3	0	0	0	64	5,065	5,132
SSW	53	0	342	75	81	1,444	1,995
SW	0	244	27	378	236	1,547	2,432
WSW	0	0	129	128	0	1,115	1,372
W	0	295	35	215	47	1,287	1,879
WNW	0	112	3	125	153	1,278	1,671
NW	0	0	0	27	40	672	739
NNW	0	0	0	377	1,348	2,885	4,610
Total	134	2,313	3,322	7,981	10,690	37,094	61,534

TABLE F.3-2
ESTIMATED POPULATION DISTRIBUTION WITHIN A 50-MILE RADIUS OF MNGP, YEAR 2030

Sector	Distance from MNGP (miles)					
	0-10	10-20	20-30	30-40	40-50	Total
N	1,752	3,211	6,617	3,250	1,666	16,496
NNE	2,029	1,530	5,073	9,080	3,560	21,272
NE	2,357	10,080	12,428	4,616	15,346	44,827
ENE	7,797	9,726	9,548	23,262	23,199	73,532
E	8,436	25,584	36,954	30,706	50,569	152,249
ESE	6,243	22,217	224,818	322,317	372,411	948,006
SE	9,976	26,461	188,697	788,711	785,680	1,799,525
SSE	3,114	12,878	45,896	179,943	150,702	392,533
S	5,132	17,275	17,036	24,134	12,217	75,794
SSW	1,995	6,219	9,689	8,202	13,624	39,729
SW	2,432	5,053	9,951	11,975	16,255	45,666
WSW	1,372	8,140	3,616	13,662	6,280	33,070
W	1,879	4,061	5,821	6,432	8,220	26,413
WNW	1,671	6,540	14,434	15,309	7,830	45,784
NW	739	10,546	130,402	9,655	6,890	158,232
NNW	4,610	4,129	4,398	6,235	10,743	30,115
Total	61,534	173,650	725,378	1,457,489	1,485,192	3,903,243

TABLE F.3-3
MACCS RELEASE CATEGORIES VERSUS MAAP RELEASE CATGEGORIES

MACCS Release Categories	MAAP Release Categories
Xe/Kr	Group 1 – noble gases
I	Group 2 – CsI
Sr	Group 4 – SrO
Ru	Group 5 – MoO_2 (Mo is in Ru MACCS category)
Cs	Group 6 – CsOH
Ba	Group 7 – BaO
La	Group 8 – La_2O_3
Ce	Group 9 – CeO_2 (included UO_2 in this category)
Te	Group 10 - Sb (TeO_2 & Te_2 fractions are smaller)

TABLE F.3-4
MACCS RESULTS[a]

Release Category	MAAP Case	Dose (Sv)	Costs($)	Frequency	Weighted Dose (p-rem)	Weighted Cost ($)
E	FW-LOCA-EARLY	5.25E+04	2.29E+10	2.64E-09	1.39E-02	6.05E+01
L-E	LOCA-VAP-SUP	4.11E+04	3.13E+10	4.20E-06	1.73E+01	1.31E+05
L-L	NO-INJ-HIGHP	2.20E+04	1.63E+10	7.19E-06	1.58E+01	1.17E+05
M-E	NONE-LOWP-DW-EARLY	2.86E+04	1.99E+10	8.99E-08	2.57E-01	1.79E+03
M-L	CHR-WW	4.06E+03	4.25E+08	1.09E-06	4.43E-01	4.63E+02
S-E	ATWS-FW-LOCA-WW	3.87E+03	3.23E+08	1.81E-07	7.00E-02	5.85E+01
S-L	NONE-LPCIPB-WW56	1.04E+03	8.17E+07	3.97E-05	4.13E+00	3.24E+03
Frequency Weighted Totals				5.245E-05	3.80E+01	2.54E+05

a. Refer to Table F.2-2 for release category definitions.

TABLE F.5-1
LEVEL 1 IMPORTANCE LIST REVIEW

Event Name	Probability	RRW	Description	Potential SAMAs
IEF_FS-TB931W	3.16E-05	3.413	FPS line break in Turbine Building 931-foot elevation West	In general, the enhancements proposed to reduce the risk of flooding events are mitigative and address any scenario. The proposed changes include: 1) Proceduralize RCIC operation with no electrical support (SAMA 37); 2) Modify the alignment capabilities of the 480V AC generator so that it can be directly aligned to key loads, such as the battery charger (bypass flooded buses) (SAMA 2); 3) Provide an independent DC source to allow long-term operation of the SRVs and the containment vent (SAMA 2); and 4) Divert water from Turbine Building 931-foot elevation West (SAMA 36).
IEF_SW-TB931E	5.80E-06	1.149	SW line break in Turbine Building 931-foot elevation East	See IE_FS-TB931W.
IEF_SW-TB911	4.10E-03	1.05	SW line break in Turbine Building 911-foot elevation	See IEF_FS-TB931W.
REC-OSP-30	6.80E-01	1.045 (1.000a)	Fail to recover offsite power (OSP) within 30 minutes	The actual RRW value of 1.000 is below the 1.005 cutoff value for SAMA event development. Not used.
REC-OSP-50/30	8.50E-01	1.045 (1.001a)	Fail to recover OSP within 50 minutes, given failure to recover within 30 minutes	The actual RRW value of 1.001 is below the 1.005 cutoff value for SAMA event development. Not used.
REC-OSP-3/50	4.30E-01	1.044 (1.000a)	Fail to recover OSP within 3 hours, given failure to recover within 50 minutes	The actual RRW value of 1.000 is below the 1.005 cutoff value for SAMA event development. Not used.
REC-OSP-6/3	6.00E-01	1.044 (1.006a)	Fail to recover OSP within 6 hours, given failure to recover within 3 hours	This longer period may suggest battery depletion such that in addition to an EDG (SAMA 1) or diesel injection pump (SAMA 4), testing and training to use the 480V AC generator for long-term DC power could be beneficial (SAMA 2).

TABLE F.5-1 (CONTINUED)
LEVEL 1 IMPORTANCE LIST REVIEW

Event Name	Probability	RRW	Description	Potential SAMAs
IE_LOOP	3.10E-02	1.044	Loss of offsite power (LOOP) initiating event	Contingencies for switchyard work are provided (SAMA 3). Otherwise, MNGP has diverse power supplies and no suggestions for reducing the LOOP frequency are suggested. Mitigating SAMAs are provided elsewhere (e.g. SAMA 1, SAMA 2, SAMA 4, etc.).
A-DG13-EQP	5.00E-01	1.038	DG-13 Crosstie (proceduralized but untested process)	Test and practice the DG-13 cross-tie or provide direct feed from DG-13 to equipment of interest (SAMA 2).
REC-OSP-11/6	7.50E-01	1.038 (1.033[a])	Fail to recover OSP within 11 hours, given failure to recover within 6 hours	This longer period may suggest battery depletion such that in addition to an EDG (SAMA 1) or diesel injection pump (SAMA 4), testing and training to use the 480V AC generator for long term DC power could be beneficial (SAMA 2).
DEP-HOUR-Y	1.60E-04	1.031	Fail to identify need for depressurization; more than an hour available	Additional HP systems (SAMA 4), enhance EOPs, change CR alarms for depressurization to be more unique, enhance instrumentation (SAMA 5).
DEP-50MN-Y	1.80E-04	1.024	Fail to identify need for depressurization within 50 minutes	Additional HP systems (SAMA 4), enhance EOPs, change CR alarms for depressurization to be more unique, enhance instrumentation (SAMA 5).
IEF_SW-RHR1	2.20E-03	1.021	SW line break in RHR-A room	See IEF_FS-TB931W.
EOP-DWWLL	4.00E-01	1.019	DW water level limit reached prior to containment failure	This event was based on procedural limitations that existed in a previous version of the EOPs related to terminating injection from sources outside of primary containment to preserve integrity. The current EOPs allow for continued injection from outside sources when it is required for core cooling. No further evaluation required.
IEF_SW-RHR2	2.00E-03	1.017	SW line break in RHR-B room	See IEF_FS-TB931W.
REC-EDG-3/50	6.90E-01	1.014 (1.000[a])	Fail to recover EDG within 3 hours, given failure to recover within 50 minutes	The actual RRW value of 1.000 is below the 1.005 cutoff value for SAMA event development. Not used.

TABLE F.5-1 (CONTINUED)
LEVEL 1 IMPORTANCE LIST REVIEW

REC-EDG-30	8.50E-01	1.014 (1.000[a])	Fail to recover EDG within 30 minutes	The actual RRW value of 1.000 is below the 1.005 cutoff value for SAMA event development. Not used.
REC-EDG-50/30	9.10E-01	1.014 (1.000[a])	Fail to recover EDG within 50 minutes, given failure to recover within 30 minutes	The actual RRW value of 1.000 is below the 1.005 cutoff value for SAMA event development. Not used.
REC-EDG-6/3	5.10E-01	1.014 (1.003[a])	Fail to recover EDG within 6 hours, given failure to recover within 3 hours	The actual RRW value of 1.000 is below the 1.005 cutoff value for SAMA event development. Not used.
AFNEDGSCCS 22	1.99E-04	1.011	Fans V-SF-9 And V-SF-10 Common Cause Failure to Start	Provide alternate train of HVAC (SAMA 6) or determine if there are alternate room cooling methods for the EDGs that can be credited.
REC-EDG-11/6	7.30E-01	1.011 (1.010[a])	Fail to recover EDG within 11 hours, given failure to recover within 6 hours	This longer period may suggest battery depletion such that in addition to an EDG (SAMA 1) or diesel injection pump (SAMA 4), testing and training to use the 480V AC generator for long-term DC power could be beneficial (SAMA 2).
IEF_SW-RB896	1.40E-03	1.011	SW line break in RB 896-foot elevation	See IEF_FS-TB931W.
MVR4543XXN	1.03E-02	1.008	Hard pipe vent rupture disk PSD-4543 fails to open	Install a bypass line around the rupture disk or change the vent valves to “fail open”. If the bypass were manually operated, it would address scenarios driven by uncontrolled containment pressurization (SAMAs 7, 16).
LEVEL-45-Y	1.00E-05	1.007	Fail to detect need for injection within 45 minutes of compelling signal	Include a unique, timed annunciator for low-level indication to provide operators with an additional injection cue (SAMA 5).
SPEESWDCCS 22	1.20E-04	1.007	ESW Pumps P-111A AND P-111B Common Cause failure to start	Add an additional EDG-ESW pump to provide cooling to each EDG (SAMA 8).
WLOOP2XXCM	6.85E-03	1.006	LOOP 2 out for corrective maintenance	Implementation of the Maintenance Rule is considered to address maintenance related issues.
ASMY83XXXL	5.52E-05	1.005	Manual bypass switch Y83 fails to remain closed	No suggestions.

TABLE F.5-1 (CONTINUED)
LEVEL 1 IMPORTANCE LIST REVIEW

ASMY85XXXL	5.52E-05	1.005	Disconnect switch Y85 fails to remain closed	No suggestions.
REC-OSP-12/11	9.20E-01	1.005 (1.000[a])	Fail to recover OSP within 12 hours, given failure to recover within 11 hours	The actual RRW value of 1.000 is below the 1.005 cutoff value for SAMA event development. Not used.
REC-OSP-22/12	5.00E-01	1.005 (1.005[a])	Fail to recover OSP within 22 hours, given failure to recover within 12 hours	This longer period may suggest battery depletion such that in addition to an EDG (SAMA 1) or diesel injection pump (SAMA 4), testing and training to use the 480V AC generator for long-term DC power could be beneficial (SAMA 2).

a. The RRW values for conditional events are not properly calculated by the software code due to the nature of the events. The actual value has been calculated and provided.

AC = alternating current
CR = Control Room
DC = direct current
DG = diesel generator
DW = drywell
EDG = Emergency Operation Procedure
EOP = Emergency Operation Procedure
FPS = Fire Protection System
HP = high pressure
HVAC = Heating Ventilation Air Conditioning
LOOP = loss of offsite power
MNGP = Monticello Nuclear Generating Plant
OSP = offsite power
RCIC = Reactor Core Isolation Cooling
RHR = residual heat removal
RRW = risk reduction worth
SAMA = severe accident mitigation alternative
SRV = Safety Relief Valve
SW = Service Water
V = volt

TABLE F.5-2
LEVEL 2 IMPORTANCE LIST REVIEW (BASED ON LERF)

Event Name	Probability	RRW	Description	Potential SAMAs
LINER-MELT	3.00E-01	9.362	Probability of sufficient corium leaving vessel to melt containment liner	Increased injection systems (SAMA 4), dedicated drywell spray system (SAMA 9).
IEF_FS-TB931W	3.16E-05	1.812	FPS line break in Turbine Building 931-foot elevation West	Addressed in the Level 1 RRW list.
IEF_SW-TB931E	5.80E-06	1.681	SW line break in Turbine Building 931-foot elevation East	Addressed in the Level 1 RRW list.
YPDP105XXR	1.13E-01	1.353	DFP P-105 fails to run	The DFP is in the model for both RPV injection and for containment flooding. Add an additional, low-pressure diesel injection pump for RPV or containment injection (SAMA 12). Alternatively, a dedicated low-pressure injection/containment spray system could be added (SAMA 9).
WW-BREACH	5.50E-01	1.088	Containment failure is in the wetwell airspace (scrubbed release)	While it is desirable to prevent this event from occurring, a wetwell airspace break is preferred over a drywell break due to the scrubbing potential in a wetwell airspace release. No additional insights are gained by reviewing this event.
UNINERTED	8.00E-03	1.081	Containment uninerted at time of core damage	Install igniters (SAMA 10).
IEF_SW-TB911	4.10E-03	1.065	SW line break in Turbine Building 911-foot elevation	Addressed in the Level 1 RRW list.

TABLE F.5-2 (CONTINUED)
LEVEL 2 IMPORTANCE LIST REVIEW (BASED ON LERF)

Event Name	Probability	RRW	Description	Potential SAMAs
RVHRHSW14N	1.73E-02	1.042	RHR Manual Valve RHRSW-14 fails to open	This event represents the failure to supply FPS to RHRSW to RHR for injection or containment flooding. Install an alternate injection system or path (SAMA 9 and SAMA 11).
RVHRHSW46N	1.73E-02	1.041	RHRSW Manual Valve RHRSW-46 fails to open	See RVRHRSW14N.
DEP-HOUR-Y	1.60E-04	1.036	Fail to identify need for depressurization more than an hour available	Addressed in the Level 1 RRW list.
EOP-DWWLL	4.00E-01	1.032	DW water level limit reached prior to containment failure	Addressed in the Level 1 RRW list.
IE_LOOP	3.10E-02	1.027	LOOP initiating event	Addressed in the Level 1 RRW list.
REC-OSP-6/3	6.00E-01	1.027 (1.002[a])	Fail to recover OSP within 6 hours, given failure to recover within 3 hours	Addressed in the Level 1 RRW list.
REC-OSP-50/30	8.50E-01	1.027 (1.000[a])	Fail to recover OSP within 50 minutes, given failure to recover within 30 minutes	Addressed in the Level 1 RRW list.
REC-OSP-30	6.80E-01	1.027 (1.000[a])	Fail to recover OSP within 30 minutes	Addressed in the Level 1 RRW list.

TABLE F.5-2 (CONTINUED)
LEVEL 2 IMPORTANCE LIST REVIEW (BASED ON LERF)

Event Name	Probability	RRW	Description	Potential SAMAs
REC-OSP-3/50	4.30E-01	1.027 (1.000[a])	Fail to recover OSP within 3 hours, given failure to recover within 50 minutes	Addressed in the Level 1 RRW list.
REC-OSP-11/6	7.50E-01	1.025 (1.015[a])	Fail to recover OSP within 11 hours, given failure to recover within 6 hours	Addressed in the Level 1 RRW list.
YSRBS1939F	1.07E-02	1.025	Fire water strainer BS-1939 plugged	Add alternate, dedicated, low-pressure diesel injection pump or a more reliable or redundant path for RPV or containment injection (SAMA 9).
YPDP105XXS	1.00E-02	1.023	DFP P-105 fails to start	See YPDP105XXR.
A-DG13-EQP	5.00E-01	1.023	DG-13 Crosstie (proceduralized but untested process)	Addressed in the Level 1 RRW list.
DEP-PD-Y	3.00E-01	1.02	Fail to depressurize reactor after core damage, but before vessel penetration	Addressed in the Level 1 RRW list or subsumed by a similar event (DEP-HOUR-Y, etc.).
LASCRAMMEC	2.10E-06	1.014	Failure to SCRAM (mechanical)	1) Test and train the ability to inject borated water using the CRD and RWST systems (SAMA 13). 2) Add permanent connections to the systems to allow for improved alignment reliability and speed.
IEF_SW-RHR1	2.20E-03	1.014	SW line break in RHR-A room	Addressed in the Level 1 RRW list.

TABLE F.5-2 (CONTINUED)
LEVEL 2 IMPORTANCE LIST REVIEW (BASED ON LERF)

Event Name	Probability	RRW	Description	Potential SAMAs
MVR4543XXN	1.03E-02	1.013	Hard pipe vent rupture disk PSD-4543 fails to open	Addressed in the Level 1 RRW list.
UNCOOL-ATWS	9.00E-01	1.012	Corium penetrates reactor vessel, despite injection after core damage - ATWS	See LASCRAMMEC.
REC-OSP-16/12	8.00E-01	1.012 (1.002[a])	Fail to recover OSP within 16 hours, given failure to recover within 12 hours	Addressed in the Level 1 RRW list or subsumed by a similar event (REC-OSP-*).
IE_FW	5.60E-01	1.012	Loss of Feedwater initiating event	Digital Feedwater controls and instrumentation are already installed. No suggestions.
DW-BREACH	4.50E-01	1.01	Containment failure is in the drywell (unscrubbed release)	This event simply addresses the difference between containment failure in the drywell instead of the wetwell. Its review provides no additional insights regarding risk reduction strategies.
REC-OSP-22/12	5.00E-01	1.01	Fail to recover OSP within 22 hours, given failure to recover within 12 hours	Addressed in the Level 1 RRW list.
REC-OSP-12/11	9.20E-01	1.01 (1.000 [a])	Fail to recover OSP within 12 hours, given failure to recover within 11 hours	Addressed in the Level 1 RRW list.
WLOOP2XXCM	6.85E-03	1.009	LOOP 2 out for corrective maintenance	Addressed in the Level 1 RRW list.

TABLE F.5-2 (CONTINUED)
LEVEL 2 IMPORTANCE LIST REVIEW (BASED ON LERF)

Event Name	Probability	RRW	Description	Potential SAMAs
IEF_SW-RHR2	2.00E-03	1.009	SW line break in RHR-B room	Addressed in the Level 1 RRW list.
EXV-STM-EX	1.00E-03	1.009	Steam explosion in containment fails containment	Strengthen the drywell, add a diverse injection system, such as a diesel injection pump (SAMA 14).
ASMY85XXXL	5.52E-05	1.009	Disconnect switch Y85 fails to remain closed	Addressed in the Level 1 RRW list.
ASMY83XXXL	5.52E-05	1.009	Manual bypass switch Y83 fails to remain closed	Addressed in the Level 1 RRW list.
ALT-INJ-MY	4.00E-03	1.009	Fail to align FPS, RHRSW, Condensate Service Water, or SW - hour available	Enhance alignment methods for alternate injection systems and train on their alignments. These improvements could include adding control capability from the main Control Room (SAMA 11).
AFNEDGSCCS22	1.99E-04	1.008	Fans V-SF-9 and V-SF-10 common cause failure to start	Addressed in the Level 1 RRW list.
XPP-SRV--L	8.76E-05	1.006	SRV tailpipe rupture in the wetwell airspace	This event results in at least two important phenomena: 1) containment overpressurization, and 2) creating an additional pathway for an unscrubbed release. Containment overpressure may be mitigated by proceduralizing closing SRVs that have failed tailpipes. Initiation of suppression pool spray may provide some scrubbing in the event of a wetwell airspace break coincident with a tailpipe failure during a core damage event (SAMA 15).

TABLE F.5-2 (CONTINUED)
LEVEL 2 IMPORTANCE LIST REVIEW (BASED ON LERF)

Event Name	Probability	RRW	Description	Potential SAMAs
REC-EDG-50/30	9.10E-01	1.006 (1.000[a])	Fail to recover EDG within 50 minutes, given failure to recover within 30 minutes	Addressed in the Level 1 RRW list.
REC-EDG-30	8.50E-01	1.006 (1.000[a])	Fail to recover EDG within 30 minutes	Addressed in the Level 1 RRW list.
REC-EDG-3/50	6.90E-01	1.006 (1.000[a])	Fail to recover EDG within 3 hours, given failure to recover within 50 minutes	Addressed in the Level 1 RRW list.
IEF_SW-RB896	1.40E-03	1.006	SW line break in Reactor Building 896-foot elevation	Addressed in the Level 1 RRW list.
DEP-12MN-Y	5.20E-03	1.006	Fail to identify need for depressurization within 12 minutes	Addressed in the Level 1 RRW list or subsumed by a similar event (DEP-HOUR-Y).
SPEESWDCCS22	1.20E-04	1.005	ESW Pumps P-111A and P-111B Common cause failure to start	Addressed in the Level 1 RRW list.
REC-EDG-6/3	5.10E-01	1.006 (1.000*)	Fail to recover EDG within 6 hours, given failure to recover within 3 hours	Addressed in the Level 1 RRW list.
REC-EDG-11/6	7.30E-01	1.006 (1.005*)	Fail to recover EDG within 11 hours, given failure to recover within 6 hours	Addressed in the Level 1 RRW list.

TABLE F.5-2 (CONTINUED)
LEVEL 2 IMPORTANCE LIST REVIEW (BASED ON LERF)

Event Name	Probability	RRW	Description	Potential SAMAs
IE_TURB-TRIP	5.00E-01	1.005	Turbine trip	The application of the Maintenance Rule is considered to have improved plant operations through focused maintenance plans. PSA applications have also helped to identify areas for improvement in plant practices, equipment availability, and operation. No credible, potentially cost effective means of further reducing the turbine trip frequency have been identified. The equipment and operator actions important to mitigating turbine trip initiators is judged to be addressed by the other components in this list.

a. The RRW values for conditional events are not properly calculated by the software code due to the nature of the events. The actual value has been calculated and provided.

ATWS = anticipated transient without scram
CRD = Control Rod Drive
DFP = Diesel Fire Pump
DG = diesel generator
DW = drywell
EDG = Emergency Diesel Generator
ESW = Emergency Service Water
FPS = Fire Protection System
LOOP = loss of offsite power
OSP = offsite power
PSA = Probabilistic Safety Assessment
RB = Reactor Building
RHR = residual heat removal
RGRSW = Residual Heat Removal Service Water
RPV = Reactor Pressure Vessel
RRW = risk reduction worth
Refueling Water Storage Tank
SAMA = severe accident mitigation alternative
SCRAM =
SRV = Safety Relief Valve
SW = Service Water

TABLE F.5-3
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
1	Additional EDG	This SAMA would help mitigate LOOP events and would reduce the risk of on-line EDG maintenance. Benefit would be increased if the additional diesel generator could 1) be substituted for any current diesel generator that is in maintenance, and 2) if the diesel generator was of a diverse design such that common cause failure dependence was minimized.	MNGP Level 1 Importance List	The cost of installing an additional EDG has been estimated to be greater than $20 million in the Calvert Cliffs Application for License Renewal (BGE 1998). As this is greater than the MNGP modified MACR, it has been screened from further analysis.	No
2	Enhanced DC Power Availability	DC power availability is important for several reasons at MNGP, including 1) maintaining high pressure injection, 2) maintaining low pressure injection (SRVs as well as control power), and 3) supporting containment venting. These functions are important for several accident scenarios, and improving DC availability could reduce the risk for each of them. Several options are available to improve DC availability, including: a) Provide an independent battery for SRVs and HPV; b) Provide a portable generator to support SRVs and HPV; c) Proceduralize use of car batteries for SRVs and bypass HPV DC dependency with manual vent control; d) Practice and test DG-13 backfeed to the battery chargers; or e) Provide a direct connection from DG-13, the security diesel, or another source to the 250V battery chargers or other required loads.	MNGP Level 1 and 2 Importance Lists, Internal Flooding Scenario, Brunswick Application for License Renewal (CPL 2004)	While each of these permutations has the potential to reduce risk at MNGP, option "e" takes advantage of an existing system that would be operable in the scenarios for which alternate DC power would be required. Additional cable, procedural updates, and training would be required to implement this option; however, the cost would be low. Options "a", "b", and "c" also require these types of changes, but in addition, they require the purchase of a new DC source or rely on equipment that is not maintained by the plant. Option "d" relies on existing equipment, but it may be unavailable in the flood events, which are the largest contributors to plant risk. Option "e" is considered to be the best candidate for MNGP and has been chosen as the representative case for this SAMA. As the cost of implementation is judged to cost less than the MNGP modified MACR, it has been retained for Phase II analysis.	Yes
3	Contingency Plans During Switchyard Work	Assessing likely failures of the off-site AC power supply due to switchyard work and providing plans for power restoration in the event that such a loss occurs could reduce the time required to recover off-site power.	MNGP Level 1 Importance List	Already implemented. Planned plant switchyard work is assessed and contingency plans are developed on an as needed basis.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
4	Additional HP Injection System	An additional high-pressure injection system would increase high-pressure injection diversity and reduce the probability of requiring RPV depressurization early in an accident. An additional HP injection system would also impact the contribution of liner melt-through sequences in the Level 2 evaluation by reducing the frequency of high-pressure core melt accident class. The benefit of this SAMA would increase if the pump was 1) diesel powered, 2) could provide power to operate its own injection valves, and 3) be located in a flood safe zone.	MNGP Level 1 and 2 Importance Lists	The cost of installing a direct drive diesel injection pump was estimated to be $2 million in the Brunswick Application for License Renewal (CPL 2004). This is less than the MNGP modified MACR.	Yes
5	Enhance Depressurization and Injection Cues	RPV depressurization, while a reliable action, is an important contributor to plant risk. The cognitive portion of this action is specifically identified as an important contributor for MNGP. Potential means of improving the probability of identifying the need for depressurization include adding a unique audible alarm and/or a highly visible alarm light to denote the need for depressurization. Installation of a large, graphical core display for water level is an additional enhancement.	MNGP Level 1 Importance List	The estimated cost of implementation for this modification is about $700,000. This is the result of combining the costs of performing the training/procedural changes and the required hardware changes. Procedural changes are generally on the order of $50,000 to $100,000 (CPL 2004), and the hardware costs are estimated based on the $600,000 cost of installing computer aided instrumentation in the main Control Room (GE 1994).	Yes
6	Additional Fan and Louver pair for EDG HVAC	Providing an additional HVAC train for the EDG Building would improve cooling reliability. Low cost, alternate means of cooling that require local operator actions, such as the use of portable fans, have been excluded as the sprinkler system would start and damage the EDGs before the actions could be completed.	MNGP Level 1 Importance List, Brunswick Application for License Renewal (CPL 2004)	The cost of this SAMA has been estimated to be $100,000 (SNOC 2000). As this is less than the modified MACR, it has been retained for Phase II analysis.	Yes
7	Rupture Disk Bypass Line	In the event that the rupture disk fails to open for containment venting, a bypass line around the disk would provide an alternate means of opening the vent path.	MNGP Level 1 and Level 2 Importance Lists	This SAMA is considered to be subsumed by SAMA 16. The intent and implementation are similar, but the method proposed in SAMA 16 is considered to be more cost effective.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
8	Improved EDG-ESW Pumping Capability	Common cause failure of the EDG-ESW pumps is a large contributor to the system failure, which results in the loss of the EDGs. Installing a diverse, engine driven EDG-ESW pump would address CCF issues. Alternatively, a cross-tie to the SW system or Fire Service Water system could be implemented to back-up EDG-ESW. Given the relatively rapid heatup of the EDGs' cooling water without an active heat sink, the existing connection to SW is not credited. The SW pumps are shed on loss of power, and the EDGs would fail before the pumps could be re-started and aligned to the EDGs through the cross-tie. A potential means of crediting the SW cross-tie would be to install a high temperature trip on the EDGs to prevent damage while the SW system was re-started and aligned. This would result in a temporary loss of AC power, which is undesirable. Finally, the fire service water system could be modified to backup the cooling function. No load shed problems would exist, but new piping would have to be installed. Locating cross-tie controls in the main Control Room would allow for rapid alignment.	MNGP Level 1 Importance List	The cost of using Fire Service Water as a backup cooling supply for EDGs is estimated to be $500,000 per EDG in the Calvert Cliffs Application for License Renewal (BGE 1998). Given that there are two EDGs, the cost of this enhancement for the plant would be $1 million. To account for the addition of controls in the main Control Room, this estimate is doubled to $2 million. As this is less than the MNGP modified MACR, it has been retained for further analysis.	Yes
9	Additional, Dedicated Alternate Low-Pressure Injection/Drywell Spray System	This SAMA would provide a source of water to the containment to ensure water is on the drywell floor prior to, or at the time of RPV breach. Maintaining water on the drywell floor is a potential means of reducing the probability of drywell liner melt-through, which is an important contributor to MNGP LERF. A dedicated drywell spray system will also provide another means of containment pressure control, when used in conjunction with containment heat removal. An alternate RPV injection method would further improve low pressure injection reliability.	MNGP Level 2 Importance List	Based on engineering judgment, the cost of this SAMA would exceed the modified MACR for MNGP. The Calvert Cliffs application for license renewal (BGE 1998) estimates the cost of installing a reactor cavity flood system to be about $8.8 million. The scope of that SAMA is considered to be similar to the installation of a new Low-Pressure Injection /CS system; both are low-pressure and require piping changes in similar areas. The reactor cavity flooder system, however, does not require penetration of the primary RCS.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
10	Drywell Igniters or Passive Hydrogen Ignition System	This SAMA would provide a means to reduce the chance of hydrogen detonation.	MNGP Level 2 Importance List	The Calvert Cliffs application for license renewal (BGE 1998) estimates the cost of a passive hydrogen ignition system to be $760,000, which is less than the MNGP modified MACR.	Yes
11	Enhance Alternate Injection Reliability	The capability exists at MNGP to provide flow from the RHRSW and FSW systems to the RHR system; however, the reliability of the cross-tie could potentially be improved by including the cross-tie valves in the maintenance program so that the operability of the valves is monitored and tested.	MNGP Level 2 Importance List	The cost of this SAMA has been estimated to be $50,000 based on engineering judgment. As this is less than the modified MACR, it has been retained for Phase II analysis.	Yes
12	Additional Diesel Fire Pump for Fire Service Water System	An additional DFP would provide another source of water for RPV injection and containment spray. This could be achieved through the implementation of a procedure to direct the pressurization of the FSW system using a fire truck.	MNGP Level 2 Importance List	The cost of this enhancement is judged to be less than the MNGP modified MACR.	Yes
13	Enhance, Test and Train on Alternate Boron Injection	MNGP has the capability to use the RWCU and CRD systems to inject boron into the RPV; however, these alignments are not practiced. The RWCU alignment is not credited in the PSA model due to the length of time required for alignment. Changes to make these connections permanent and capable of being aligned from the MCR would improve their reliability. Additional training and practice of the alignments in the simulator and with mock-up test rigs would also improve alternate boron injection reliability.	MNGP Level 2 Importance List, MNGP IPE	While failure of the alternate boron injection method has previously been shown by MNGP staff to have a limited impact on CDF, the importance list suggests that ATWS does contribute to LERF. Procedural changes are generally on the order of $50,000 to $100,000 (CPL 2004). $50,000 is used for this SAMA, and the required hardware enhancements are conservatively ignored. As this is less than the modified MACR, it ahs been retained for Phase II analysis.	Yes
14	Strengthen the Containment	Strengthening the containment may improve the likelihood that the containment will remain intact after an ex-vessel steam explosion.	MNGP Level 2 Importance List	The cost of this enhancement was estimated in the ABWR SAMDA analysis (GE 1994) to be $12 million. The cost to properly retrofit an existing containment is judged to exceed this estimate.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
15	SRV Isolation with Suppression Pool Spray Given Tailpipe Rupture	Proceduralize SRV isolation and initiation of suppression pool spray for scenarios involving a tailpipe break. Closing the SRV with the broken tailpipe will prevent continued flow of steam to the containment while suppression pool spray will help condense the steam in the SP and help remove airborne fission products.	MNGP Level 2 Importance List	Isolation of an SRV with a tailpipe rupture is already credited in the PSA.	No.
16	Passive Overpressure Relief	This SAMA would reduce the risk of catastrophic failure of the containment. The current Torus Hard Pipe Vent includes a rupture disk beyond an isolation valve; however, an alternate path to the Torus Hard Pipe Vent could be made in the wetwell using a rupture disk that would fail at about 60 psid. Alternatively, the containment vent valves could be changed so that they "fail open" on loss of support. Given this change, the vent path would be open on loss of support with the exception of the rupture disk. To prevent premature opening of the vent path during scenarios with loss of vent valve support, the strength of the rupture disk could be increased so that it is closer to the EOP vent pressure.	MNGP Level 2 Importance List	The cost of this SAMA has been estimated to be $200,000 based on engineering judgment. As this is less than the modified MACR, it has been retained for Phase II analysis.	Yes
17	Improved Feedwater Recovery	Recovery of Feedwater is a potential means of mitigating high-pressure core melt scenarios. By familiarizing operators with the importance of the action and the steps that may be taken to recover Feedwater as a high-pressure injection source, plant risk may be reduced.	MNGP IPE	This change has been competed. Operator training is routinely performed in the simulator on Feedwater recovery and the importance of high-pressure injection.	No
18	Use DC Backed Panels for SRV Solenoid Valves	Perform modification to provide power to solenoid valves for bottled nitrogen (used to operate the SRVs to depressurize) from an instrument panel that can be powered by a battery based supply. Without a battery backed supply, the SRV's cannot function even if a pneumatic source is available.	MNGP IPE	This change has been competed. Modifications have been made to the solenoid power supplies such that they are supported by batteries.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
19	Increased Training on ADS Inhibit and Depressurization	Emphasize importance of ADS inhibit and depressurization in training.	MNGP IPE	The current EOPs are clear in the use of the ADS inhibit feature and in the timing and use of the SRVs to reduce reactor pressure for water level restoration, if necessary. Training on the use of ADS inhibit and subsequent RPV blowdown is routinely performed in the simulator.	No
20	Training on SBO Load Shed	The training program could be enhanced to familiarize the operators with the importance of preserving DC battery life and its impact on plant operations. Successful DC load shed can extend high pressure coolant injection (HPCI) or RCIC operation during an SBO and increase the probability that power will be recovered prior to loss of injection.	MNGP IPE	The abnormal procedure for a SBO has been updated to maximize the use of the remaining available plant equipment and to emphasize restoration of AC power sources in a timely manor. Specific direction is given to operation of the HPCI and RCIC systems in a way that will maximize battery duration. Other steps in the procedure, such as avoiding unnecessary breaker operation and shedding the main generator excitation load, are directed to prolong battery operation. Implementation of a procedure that establishes an alternate AC power supply to the essential battery chargers is also directed by the SBO procedure. Operations personnel are routinely trained on SBO procedures both in the classroom and on the simulator. The current PSA model reflects the current state of SBO procedures, including the potential for the alternate power supply to the battery chargers, with consideration given to the level of training devoted to SBO events.	No
21	Improve Battery Load Shed Procedures	The plant procedures could be enhanced to provide better written guidelines for prolonging DC battery life, which could improve the reliability of the load shed action. Successful DC load shed can extend HPCI or RCIC operation during an SBO and increase the probability that power will be recovered prior to loss of injection.	MNGP IPE	Refer to the disposition for SAMA 20.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
22	Modify Plant 480V AC Generator for Battery Charger Supply	The existing plant 480V AC generator could be modified to provide power to the station battery chargers. This would provide a source of power to the DC buses during an SBO and extend the available HPCI or RCIC injection beyond the battery life. Another possible benefit would be the ability to supply the SRV solenoids for a longer period of time and maintain the vessel depressurized for injection with the DFP. This is addressed in SAMA 2.	MNGP IPE	A process has been developed and procedures have been generated to support use of a non-essential diesel generator to provide an alternate source of AC power to various critical loads including the essential station battery chargers. Successful completion of these procedures will allow continued use of the systems dependant on DC power including HPCI, RCIC, SRV, and Containment Venting. This alternate AC source to the battery chargers is reflected in the updated PSA model.	No
23	Diesel Fire Pump Injection Through RHR	Modification of the plant to allow the Fire Water System to be crosstied to the RHR system would provide an additional means of injection to the RPV. The DFP would allow for injection through this crosstie during SBO scenarios given that the RPV is depressurized.	MNGP IPE	The fire header has been modified to allow low-pressure injection through LPCI, and procedures have been written to govern the action.	No
24	Proceduralize Alternate Injection	Develop procedures for the use of low-pressure backup injection methods including: RHRSW through LPCI, condensate service water, and service water to the hotwell. Providing written guidance for the use of these alternate injection methods will improve the reliability of aligning the systems when they are needed.	MNGP IPE	Methods of various alternate low-pressure injection to the reactor vessel have been developed and procedures have been incorporated into the EOPs to allow RHRSW injection via the LPCI system, Condensate Service Water injection via the LPCI and/or Core Spray systems, and Service Water makeup water to the condenser hotwell to supplement the water source available to the Condensate/Feedwater System.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
25	Enhance Training on ECCS Injection Pumps	Plant conditions can impact the operability of emergency core cooling system (ECCS) injection pumps. Providing additional training on the conditions impacting pump use may help prevent pump damage in certain scenarios and increase the availability of injection methods. Operators could be trained on the use of pumps in regimes outside the EOP pump curves.	MNGP IPE	Detailed consideration has been given to NPSH and vortex limit issues for the Core Spray, RHR, HPCI, and RCIC systems under various torus water temperature/level and containment pressure conditions. The EOPs recommend appropriate pump usage based on the existing plant parameters that can effect pump operation. Emergency procedures make intentional provision for the operators to exceed NPSH and/or vortex limits when appropriate to prevent potentially avoidable consequences. Operators are routinely trained on the limitations imposed on the various pumps taking suction from the torus.	No
26	Operator Training on Failed Main Condenser	Include operator training on recovery of failed decay heat removal through the Main Condenser. The ability to perform some relatively simple ex-Control Room actions would restore the main heat sink for the plant.	MNGP IPE	Significant modifications have been made to the Off-gas removal and recombiner system that enhance its reliability in the maintenance of condenser vacuum. EOP C.5-1200 (Primary Containment Control) has been upgraded to provide specific guidance on maintaining level, temperature, and pressure parameters within the primary containment.	No
27	Remove Locks on Air Receiver Tank Discharge Valves	Eliminate the locked open condition for discharge valves for air receiver tanks to allow isolation to prevent loss of air given a system leak.	MNGP IPE	The discharge valves from the air receiver tanks are no longer locked in the open position. Isolation of a failed open relief valve on any of the three air receivers can be accomplished by simply closing the appropriate manual isolation valve.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
28	Refill CST	Develop a procedure for the replenishment of the water in the CSTs (in emergency conditions) and confirm the viability of using FSW for this task. This would provide a cool suction source in LOCA or extended SBO conditions when the suppression pool becomes saturated, or for ISLOCAs, additional inventory. The benefit of this SAMA is likely limited due to the fact that 1) for SBO, the 200,000 gallon CST volume is adequate for about 3 days of boiloff makeup flow, and 2) for a LOCA, the containment level limits would be surpassed early in an accident if volume were added from outside containment.	MNGP IPE	No emergency procedures exist for refill of the CST. While the CST may be adequate for boiloff makeup, ISLOCAs could drain the suppression pool and CST inventories. Given that procedural changes are generally on the order of $50,000 to $100,000 (CPL 2004) and are less than the MNGP modified MACR, this SAMA has been retained for further evaluation.	Yes
29	Torus Hard Pipe Vent	A Torus Hard Pipe Vent would allow venting of the containment at or near the Primary Containment Pressure Limit without rupturing the duct work in the Reactor Building. Without the Hard Pipe Vent, the venting action would result in a hazardous Reactor Building Environment, which may lead to equipment failures.	MNGP IPE	This change has been completed.	No
30	ATWS Training	Include operator training on the significant insights for ATWS. Providing the operators with information about the significant contributors to ATWS and scenario development may improve operator response during an accident.	MNGP IPE	Revisions to the EOPs have been made to give specific guidance to reactor level, pressure, and power control in an ATWS scenario (C.5-2007 Failure to SCRAM). Methods of controlling reactor power following an ATWS event including alternate control rod insertion, boron injection, water level control, and recirculation flow control are contained in various simulator and classroom operator initial and re-qualification training lessons.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
31	Move Control Room Binding Recovery Steps to a Contingency Procedure	Move the operator actions for mechanically bound control rods to a contingency procedure to allow operators to focus on reactor shutdown with SBLC or SBLC? Troubleshooting control rod movement problems is likely more time consuming than initiating SBLC. Given that shutting the reactor down as soon as possible is a high priority in an ATWS, the focus on timely SBLC operation is considered to be of greater benefit than attempting to free jammed control rods.	MNGP IPE	Operator actions for inserting mechanically bound control rods that were once contained directly in the EOP flowcharts (C5-1103), have been moved to a contingency procedure (C.5-3101 Alternate Rod Insertion).	No
32	Demonstrate RCIC Operability Following Depressurization	This SAMA would increase the operators' options for injection with the vessel at low pressure. Given MNGP's ability to power the battery chargers with the 480V AC generator, the limiting factor for RCIC injection appears to be depressurization at the Heat Capacity Temperature Limit. If it could be shown that a limited depressurization to about 100 psid could be performed and allow continued injection with RCIC, injection could be maintained for a longer period during an SBO.	Quad Cities Application for License Renewal (Exelon 2003b)	RCIC operation after SRVs are demanded open is already credited at MNGP.	No
33	Control Containment Venting Within a Narrow Band of Pressure	This SAMA would establish a narrow pressure control band that would thereby prevent rapid containment depressurization when venting is implemented. Venting in this manner would avoid adverse impacts on the low-pressure ECCS injection systems taking suction from the torus.	Quad Cities Application for License Renewal (Exelon 2003b)	The MNGP EOPs already include guidance on controlled venting.	No
34	Supplemental Air Supply for Containment Vent	The containment vent function is among the last resort methods currently specified in BWRs to remove heat from containment and control containment pressure under extremely adverse circumstances. Many plants require a long-term source of air or nitrogen and a DC power source to allow venting in an SBO.	Dresden Application for License Renewal (Exelon 2003a)	MNGP has an adequate nitrogen supply that can be used to vent even in long term SBO scenarios. The venting issue for MNGP is that the solenoid valves used to control the nitrogen flow are dependent on DC power from the station batteries. This issue is addressed in SAMA 2.	No

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
35	Enhance Procedural Guidance for Use of Cross-tied Service Water Pumps	For MNGP, this SAMA could be interpreted to mean the enhancement of procedures directing the use of the Service Water system as a back up for 1) ESW and 2) EDG ESW. Updated procedures and training on their use may improve the reliability of the cross-ties.	PBAPS Application for License Renewal (Exelon 2001)	EDG-ESW backup is addressed in SAMA 8. The ESW system is not used in the PSA model and implementing the SW backup would not yield a measurable benefit.	No
36	Divert Water from TB931 East	Given a flood in the TB 931-foot elevation area, water level will rise and flood rooms critical to DC and AC power distribution. Floor failure is also possible from ponding effects. Installation of an interlock to open the door to the Hot Machine Shop on high water level will prevent these flooding consequences by diverting water to a "safe" area. Changing the swing direction of the door to the Plant Administration Building will also reduce the probability of opening a flood path to the battery rooms.	MNGP Level 1 Importance List (Internal Flooding Scenario)	The cost of this SAMA is judged to be less than the MNGP modified MACR and it has been retained for Phase II analysis.	Yes
37	Manual RCIC Operation	The important flooding scenarios at MNGP result in loss of DC and, in some cases, also AC power. This fails motor driven injection and eventually SRV operation. While RCIC is capable of injecting to the RPV when it is at high pressure (given loss of SRVs), it is currently dependent on DC power. If procedures were developed so that the system could be operated with local, manual control, injection could be maintained for a longer period of time.	MNGP Level 1 Importance List (Internal Flooding Scenario)	The cost of this SAMA is judged to be less than the MNGP modified MACR and it has been retained for Phase II analysis.	Yes

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?
38	Post an Operator at the ASDS Panel Full Time	In the event that a fire in the main Control Room requires evacuation to the ASDS panel, having a full time operator at the panel would allow for a more rapid transition to alternate reactor control. This is important for loss of injection cases where there is currently not enough time for the operators to evacuate the main Control Room and assume control at the ASDS panel (Class 1A).	IPEEE (Fire)	The cost of implementation for this SAMA is based on an estimated base salary and the cost of benefits for 5 additional licensed operators. Five operators are justified considering that personnel are required to cover all shifts, 7 days a week and that 20 percent of operator time is spent in training. Assuming that an operator's salary and benefits cost $100,000 per year and that the panel will be manned for the 20 year license renewal period, the cost of implementation would be $10 million, not including raises. As this is less than the MNGP modified MACR, it has been retained for Phase II analysis.	Yes
39	Enhance the ASDS Panel to Include Additional System Controls	Fire scenarios that result in Control Room evacuation require reactor control from the ASDS panel. Given that only one division of controls is available at the panel, a single additional system failure would result in the loss of a safety function and core damage would ensue. If controls for the opposite division were added, single division failures would be eliminated as a failure mode. This is important for loss of injection cases in which the operators have time to initially take control of the plant from the ASDS panel and depressurize the RPV (Class 1D).	IPEEE (Fire)	The ABWR SAMDA analysis (GE 1994) estimated the cost of installing enhanced computer aided instrumentation to be about $600,000 in 1994. Upgrading the ASDS panel to contain an additional division of controls is judged to require at least an equal investment of resources. Assuming an inflation rate of 2.75% per year between 1994 and 2004, the cost in 2004 dollars is $786,991. As this is less than the MNGP modified MACR, it has been retained for Phase II analysis.	Yes
40	Add an Emergency Level Control System to the Hotwell	This system would actuate on low level in the main condenser (well outside of the normal operating range) and automatically provide makeup so that the FW/Condensate system will have a long-term suction source. This would relegate the operator action that is currently required to align the CST or Service Water to the main condenser to a backup action and improve the reliability of main condenser makeup. This is important for Accident Class II cases in which the FW/Condensate is initially established but fails in the long term due to lack of hotwell inventory.	IPEEE (Fire)	The addition of a level sensor and a control valve is similar to the automatic refill system for the elevated water storage tank at the Oconee Nuclear Station, which was estimated to cost $230,000 (NRC 1999). Given that the cost of implementation for this system has been estimated to be less than the MNGP modified MACR, this SAMA has been retained for Phase II analysis.	Yes

TABLE F.5-3 (CONTINUED)
PHASE I SAMA

SAMA ID NO.	SAMA TITLE	SAMA DESCRIPTION	SOURCE	PHASE 1 DISPOSITION	RETAINED FOR PHASE II ANALYSIS?

ABWR = Advanced Boiling Water Reactor
AC = alternating current
ADS = Automatic Depressurization System
ASDS = Alternate Shut Down System
ATWS = anticipated transient without scram
BWR = Boiling Water Reactor
CCF = common cause failure
CDF = core damage frequency
CRD = Control Rod Drive
CS = Core Spray
CST = Condensate Storage Tank
DC = direct current
DFP = Diesel Fire Pump
DG = diesel generator
ECCS = Emergency Core Cooling System
EDG = Emergency Diesel Generator
EOPs = Emergency Operating Procedures
ESW = Emergency Service Water
FSW = Fire Service Water
FW = Feedwater
HP = high pressure
HPCI = High Pressure Coolant Injection
HPV = Hard Pipe Vent
HVAC = Heating Ventilation Air Conditioning
IPE = Individual Plant Examination
IPEEE = Individual Plant Examination – External Events
ISLOCA = interfacing system loss of coolant accident
LERF = large early release frequency
LOCA = loss of coolant accident
LOOP = loss of offsite power
LPCI = Low Pressure Coolant Injection
MACR = Maximum Averted Cost-Risk
MNGP = Monticello Nuclear Generating Plant
NPSH = net positive suction head
NRC = U.S. Nuclear Regulatory Commission
PSA = Probabilistic Safety Assessment
RCIC = Reactor Core Isolation Cooling
RHR = residual heat removal
RHRSW = Residual Heat Removal Service Water
RPV = Reactor Pressure Vessel
RWCU = Reactor Water Cleanup
RWST = Refueling Water Storage Tank
SAMDA = severe accident mitigation design alternative
SBLC = Standby Liquid Control
SBO = station blackout
SP = Suppression Pool
SRV = Safety Relief Valve
SW = Service Water
V = volt

TABLE F.5-4
PHASE II SAMA

SAMA ID NUMBER	SAMA TITLE	SAMA DESCRIPTION	ESTIMATED COST	COMMENT	PHASE II DISPOSITION
2	Enhanced DC Power Availability	DC power availability is important for several reasons at MNGP, including 1) maintaining high pressure injection, 2) maintaining low pressure injection (SRVs as well as control power), and 3) supporting containment venting. These functions are important for several accident scenarios, and improving DC availability could reduce the risk for each of them. Several options are available to improve DC availability, including: a) Provide an independent battery for SRVs and HPV; b) Provide a portable generator to support SRVs and HPV; c) Proceduralize use of car batteries for SRVs and bypass HPV DC dependency with manual vent control; d) Practice and test DG-13 backfeed to the battery chargers; or e) Provide a direct connection from DG-13, the security diesel, or another source to the 250v battery chargers or other required loads	The cost of this SAMA has been estimated to be $75,000 based on engineering judgment.	The averted cost risk associated with this SAMA is $79,191, which is greater than the $75,000 cost of implementation. While this SAMA is cost beneficial alone, it provides additional benefit when combined with other SAMAs and is included in the group of recommended SAMAs. Refer to sections F.6.1 and F.6.16 for additional details.	Included in the recommended SAMAs. Consider for implementation.
4	Additional HP Injection System	An additional high-pressure injection system would increase high-pressure injection diversity and reduce the probability of requiring RPV depressurization early in an accident. An additional HP injection system would also impact the contribution of liner melt-through sequences in the Level 2 evaluation by reducing the frequency of high-pressure core melt accident class. The benefit of this SAMA would increase if the pump was 1) diesel powered, 2) could provide power top operate its own injection valves, and 3) be located in a flood safe zone.	The cost of installing a direct drive diesel injection pump was estimated to be $2 million in the Brunswick Application for License Renewal (CPL 2004).	The averted cost-risk for this SAMA is $8,457,131, which is greater than the cost of implementation. However, other more cost beneficial alternatives are available to reduce risk and this SAMA is not recommended for implementation. Refer to sections F.6.2 and F.6.16.	Screened from further consideration.

TABLE F.5-4 (CONTINUED)
PHASE II SAMA

SAMA ID NUMBER	SAMA TITLE	SAMA DESCRIPTION	ESTIMATED COST	COMMENT	PHASE II DISPOSITION
5	Enhance Depressurization and Injection Cues	RPV depressurization, while a reliable action, is an important contributor to plant risk. The cognitive portion of this action is specifically identified as an important contributor for MNGP. Potential means of improving the probability of identifying the need for depressurization include adding a unique audible alarm and/or a highly visible alarm light to denote the need for depressurization. Installation of a large, graphical core display for water level is an additional enhancement.	The estimated cost of implementation for this modification is about $700,000. This is the result of combining the costs of performing the training/procedural changes and the required hardware changes. Procedural changes are generally on the order of $50,000 to $100,000 [Brunswick SAMA] and the hardware costs are estimated based on the $600,000 cost of installing computer aided instrumentation in the main Control Room (GE 1994).	RPV depressurization is already a reliable action for which the operators are thoroughly trained. Addition of another instrument or annunciator would not be considered to yield a measurable change in the MNGP failure probability based on current PSA. As a result, the averted cost-risk for this SAMA would be approximately zero. In addition, high-pressure core melt is a large contributor to the MNGP risk profile due to internal flooding events, which are judged to be better addressed by other MNGP SAMAs. This SAMA has been screened from further consideration.	Screened from further consideration.
6	Additional Fan and Louver pair for EDG HVAC	Providing an additional HVAC train for the EDG Building would improve cooling reliability. Low cost, alternate means of cooling that require local operator actions, such as the use of portable fans, have been excluded as the sprinkler system would start and damage the EDGs before the actions could be completed.	The cost of this SAMA has been estimated to be $100,000 (SNOC 2000).	This SAMA is cost beneficial when considered prior to implementation of the recommended SAMAs; however, it is not cost beneficial once those SAMAs are credited. Refer to sections F.6.3 and F.6.16 for additional details.	Screened from further consideration.

TABLE F.5-4 (CONTINUED)
PHASE II SAMA

SAMA ID NUMBER	SAMA TITLE	SAMA DESCRIPTION	ESTIMATED COST	COMMENT	PHASE II DISPOSITION
8	Improved EDG-ESW Pumping Capability	Common cause failure of the EDG-ESW pumps is a large contributor to the system failure, which results in the loss of the EDGs. Installing a diverse, engine driven EDG-ESW pump would address CCF issues. Alternatively, a cross-tie to the SW system or FSW system could be implemented to back-up EDG-ESW. Given the relatively rapid heatup of the EDGs' cooling water without an active heat sink, the existing connection to SW is not credited. The SW pumps are shed on loss of power, and the EDGs would fail before the pumps could be re-started and aligned to the EDGs through the cross-tie. A potential means of crediting the SW cross-tie would be to install a high temperature trip on the EDGs to prevent damage while the SW system was re-started and aligned. This would result in a temporary loss of AC power, which is undesirable. Finally, the FSW system could be modified to backup the cooling function. No load shed problems would exist, but new piping would have to be installed. Locating cross-tie controls in the main Control Room would allow for rapid alignment.	The cost of using FSW as a backup cooling supply for EDGs is estimated to be $500,000 per EDG in the Calvert Cliffs Application for License Renewal (BGE 1998). Given that there are two EDGs, the cost of this enhancement for the plant would be $1 million. To account for the addition of controls in the main Control Room, this estimate is doubled to $2 million.	The averted cost risk associated with this SAMA is $211,458, which is less than the $2,000,000 cost of implementation. This SAMA is not cost beneficial. Refer to section F.6.4 for additional details.	Screened from further consideration.
10	Drywell Igniters or Passive Hydrogen Ignition System	This SAMA would provide a means to reduce the chance of hydrogen detonation.	The cost of implementation for this SAMA is $760,000 based on an estimate for a passive hydrogen ignition system at Calvert Cliffs (BGE 1998).	The averted cost risk associated with this SAMA is only $271,594, which is less than the $760,000 cost of implementation. This SAMA is not cost beneficial. Refer to section F.6.5 for additional details.	Screened from further consideration.
11	Enhance Alternate Injection Reliability	The capability exists at MNGP to provide flow from the RHRSW and FSW systems to the RHR system; however, the reliability of the cross-tie could potentially be improved by including the cross-tie valves in the maintenance program so that the operability of the valves is monitored and tested.	The cost of implementation for this SAMA is estimated to be $50,000 based on engineering judgment.	The averted cost risk associated with this SAMA is $687,044, which is greater than the $50,000 cost of implementation. While this SAMA is cost beneficial alone, it provides additional benefit when combined with other SAMAs and is included in the group of recommended SAMAs. Refer to sections F.6.6 and F.6.16 for additional details.	Included in the recommended SAMAs. Consider for implementation.
12	Additional Diesel Fire Pump for Fire Service Water System	An additional DFP would provide another source of water for RPV injection and containment spray. This could be achieved through the implementation of a procedure to direct the pressurization of the FSW system using a fire truck.	The cost of implementation for this SAMA is estimated to be $50,000 based on engineering judgment.	The averted cost risk associated with this SAMA is $2,611,782, which is greater than the $50,000 cost of implementation. While this SAMA is cost beneficial alone, it provides additional benefit when combined with other SAMAs and is included in the group of recommended SAMAs. Refer to sections F.6.7 and F.6.16 for additional details.	Included in the recommended SAMAs. Consider for implementation.

TABLE F.5-4 (CONTINUED)
PHASE II SAMA

SAMA ID NUMBER	SAMA TITLE	SAMA DESCRIPTION	ESTIMATED COST	COMMENT	PHASE II DISPOSITION
13	Enhance, Test and Train on Alternate Boron Injection	MNGP has the capability to use the RWCU and CRD systems to inject boron into the RPV; however, these alignments are not practiced. The RWCU alignment is not credited in the PSA model due to the length of time required for alignment. Changes to make these connections permanent and capable of being aligned from the main Control Room would improve their reliability. Additional training and practice of the alignments in the simulator and with mock-up test rigs would also improve alternate boron injection reliability.	The cost of implementation for this SAMA is estimated to be $50,000 based on engineering judgment. The required hardware enhancements are conservatively ignored.	The averted cost-risk associated with this SAMA is $3,505, which is less than the cost of implementation. Refer to Section F.6.8 for additional details.	Screened from further consideration.
16	Passive Overpressure Relief	This SAMA would reduce the risk of catastrophic failure of the containment. The current Torus Hard Pipe Vent includes a rupture disk beyond an isolation valve; however, an alternate path to the Torus Hard Pipe Vent could be made in the wetwell using a rupture disk that would fail at about 60 psid. Alternatively, the containment vent valves could be changed so that they "fail open" on loss of support. Given this change, the vent path would be open on loss of support with the exception of the rupture disk. To prevent premature opening of the vent path during scenarios with loss of vent valve support, the strength of the rupture disk could be increased so that it is closer to the EOP vent pressure.	The cost of implementation for this SAMA is estimated to be $200,000 based on engineering judgment.	The averted cost risk associated with this SAMA is $279,480, which is greater than the $200,000 cost of implementation. While this SAMA is cost beneficial alone, it provides additional benefit when combined with other SAMAs. While this SAMA is not included in the list of recommended SAMAs, it is highly cost beneficial if the recommended SAMAs are implemented. Refer to sections F.6.9 and F.6.16 for additional details.	Consider for implementation.
28	Refill CST	Develop a procedure for the replenishment of the water in the CSTs (in emergency conditions) and confirm the viability of using FSW for this task. This would provide a cool suction source in LOCA or extended SBO conditions when the suppression pool becomes saturated, or for ISLOCAs, additional inventory. The benefit of this SAMA is likely limited due to the fact that 1) for SBO, the 200,000 gallon CST volume is adequate for about 3 days of boiloff makeup flow, and 2) for a LOCA, the containment level limits would be surpassed early in an accident if volume were added from outside containment.	Procedural changes are generally on the order of $50,000 to $100,000 (CPL 2004). $50,000 is used in the analysis for modifying existing emergency procedures only. Procurement of materials to support this SAMA have been conservatively ignored.	The averted cost risk associated with this SAMA is only $1,332, which is less than the $50,000 cost of implementation. While this SAMA is not cost beneficial alone, it provides benefit when combined with other SAMAs and is included in the group of recommended SAMAs. Refer to sections F.6.10 and F.6.16 for additional details.	Included in the group of recommended SAMAs. Consider for implementation

TABLE F.5-4 (CONTINUED)
PHASE II SAMA

SAMA ID NUMBER	SAMA TITLE	SAMA DESCRIPTION	ESTIMATED COST	COMMENT	PHASE II DISPOSITION
36	Divert Water from TB931 East	Given a flood in the TB 931-foot elevation area, water level will rise and flood rooms critical to DC and AC power distribution. Floor failure is also possible from ponding effects. Installation of an interlock to open the door to the Hot Machine Shop on high water level will prevent these flooding consequences by diverting water to a "safe" area. Changing the swing direction of the door to the Plant Administrative Building will also reduce the probability of opening a flood path to the battery rooms.	The cost of implementation for this SAMA is estimated to be $100,000 based on engineering judgment.	The averted cost risk associated with this SAMA is $1,899,615, which is greater than the $100,000 cost of implementation. While this SAMA is cost beneficial alone, it provides additional benefit when combined with other SAMAs and is included in the group of recommended SAMAs. Refer to sections F.6.11 and F.6.16 for additional details.	Included in the group of recommended SAMAs. Consider for implementation.
37	Manual RCIC Operation	The important flooding scenarios at MNGP result in loss of DC and, in some cases, also AC power. This fails motor driven injection and eventually SRV operation. While RCIC is capable of injecting to the RPV when it is at high pressure (given loss of SRVs), it is currently dependent on DC power. If procedures were developed so that the system could be operated with local, manual control, injection could be maintained for a longer period of time.	The cost of implementation for this SAMA is estimated to be $100,000 based on engineering judgment.	The averted cost risk associated with this SAMA is -$5,581,445, which represents a risk increase. However, when this SAMA is combined with the SAMAs to enable containment venting in SBO scenarios, the plant risk would decrease. This SAMA is included in the list of recommended SAMAs. Refer to sections F.6.12 and F.6.16 for additional details.	Included in the group of recommended SAMAs. Consider for implementation.
38	Post an Operator at the ASDS Panel Full Time	In the event that a fire in the main Control Room requires evacuation to the ASDS panel, having a full time operator at the panel would allow for a more rapid transition to alternate reactor control. This is important for loss of injection cases where there is currently not enough time for the operators to evacuate the main Control Room and assume control at the ASDS panel (Class 1A).	The cost of implementation for this SAMA is based on an estimated base salary and the cost of benefits for 5 additional licensed operators. Five operators are justified considering that personnel are required to cover all shifts, 7 days a week and that 20 percent of operator time is spent in training. Assuming that an operator's salary and benefits cost $100,000 per year and that the panel will be manned for the 20 year license renewal period, the cost of implementation would be $10 million, not including raises.	The estimated averted cost-risk for this SAMA is $330,557 assuming all risk from Class 1A accidents stemming from Control Room evacuation situations could be eliminated. As the cost of implementation is estimated to be $10 million, this SAMA would not be considered cost beneficial. However, due to the variability in the cost-benefit assessment, this SAMA should be evaluated deterministically to better define the potential benefits of implementation. Refer to Section F.6.13 for additional details.	Deterministic analysis required.

TABLE F.5-4 (CONTINUED)
PHASE II SAMA

SAMA ID NUMBER	SAMA TITLE	SAMA DESCRIPTION	ESTIMATED COST	COMMENT	PHASE II DISPOSITION
39	Enhance the ASDS Panel to Include Additional System Controls	Fire scenarios that result in Control Room evacuation require reactor control from the ASDS panel. Given that only one division of controls is available at the panel, a single additional system failure would result in the loss of a safety function and core damage would ensue. If controls for the opposite division were added, single division failures would be eliminated as a failure mode. This is important for loss of injection cases in which the operators have time to initially take control of the plant from the ASDS panel and depressurize the RPV (Class 1D).	The ABWR SAMDA analysis (GE 1994) estimated the cost of installing enhanced computer aided instrumentation to be about $600,000 in 1994. Upgrading the ASDS panel to contain an additional division of controls is judged to require at least an equal investment of resources. Assuming an inflation rate of 2.75 percent per year between 1994 and 2004, the cost in 2004 dollars is $786,991.	The estimated averted cost-risk for this SAMA is $752,567 assuming all risk from Class 1D accidents stemming from Control Room evacuation situations could be eliminated. As the cost of implementation is estimated to be $786,991, this SAMA would not be considered cost beneficial. However, due to the variability in the cost-benefit assessment, this SAMA should be evaluated deterministically to better define the potential benefits of implementation. Refer to Section F.6.14 for additional details.	Deterministic analysis required.
40	A	This system would actuate on low level in the main condenser (well outside of the normal operating range) and automatically provide makeup so that the FW/Condensate system will have a long-term suction source. This would relegate the operator action that is currently required to align the CST or Service Water to the main condenser to a backup action and improve the reliability of main condenser makeup. This is important for Accident Class II cases in which the FW/Condensate is initially established but fails in the long term due to lack of hotwell inventory.	The addition of a level sensor and a control valve is similar to the automatic refill system for the elevated water storage tank at the Oconee Nuclear Station, which was estimated to cost $230,000 (NRC 1999).	The estimated averted cost-risk for this SAMA is $178,243 assuming all risk from Class II accidents stemming from failure to align condensate to the condenser could be eliminated. As the cost of implementation is estimated to be $230,000, this SAMA would not be considered cost beneficial. However, due to the variability in the cost-benefit assessment, this SAMA should be evaluated deterministically to better define the potential benefits of implementation. Refer to Section F.6.15 for additional details.	Deterministic analysis required.

TABLE F.5-4 (CONTINUED)
PHASE II SAMA

SAMA ID NUMBER	SAMA TITLE	SAMA DESCRIPTION	ESTIMATED COST	COMMENT	PHASE II DISPOSITION

ABWR = Advanced Boiling Water Reactor
AC = alternating current
ASDS = Alternate Shut Down System
CCF = common cause failure
CRD = Control Rod Drive
CST = Condensate Storage Tank
DC = direct current
DFP = Diesel Fire Pump
DG = diesel generator
EDG = Emergency Diesel Generator
EOP = Emergency Operating Procedure
ESW = Emergency Service Water
FSW = Fire Service Water
FW = Feedwater
HP = high pressure
HPV = Hard Pipe Vent
HVAC = Heating Ventilation Air Conditioning
ISLOCA = interfacing system loss of coolant accident
LOCA = loss of coolant accident
MNGP = Monticello Nuclear Generating Plant
NRC = U.S. Nuclear Regulatory Commission
PSA = Probabilistic Safety Assessment
RCIC = Reactor Core Isolation Cooling
RHR = residual heat removal
RHRSW = Residual Heat Removal Service Water
RPV = Reactor Pressure Vessel
RWCU = Reactor Water Cleanup
SAMA = severe accident mitigation alternative
SAMDA = severe accident mitigation design alternative
SBO = station blackout
SRV = Safety Relief Valve
SW = Service Water
TB = Turbine Building
V = volt

TABLE F.5-5
SUMMARY OF DETAILED PHASE II SAMA ANALYSIS

Phase II SAMA ID	Averted Cost- Risk	Cost of Implementation	Net Value	Cost Beneficial?
2	$79,191	$75,000	$4,191	Yes
4	$8,457,131	$2,000,000	$6,457,131	Yes
6	$102,790	$100,000	$2,790	Yes
8	$211,458	$2,000,000	-$1,788,542	No
10	$271,594	$760,000	-$488,406	No
11	$687,044	$50,000	$637,044	Yes
12	$2,611,782	$50,000	$2,561,782	Yes
13	$3,505	$50,000	-$46,495	No
16	$279,480	$200,000	$79,480	Yes
28	$1,332	$50,000	-$48,668	No
36	$1,899,615	$100,000	$1,799,615	Yes
37	-$5,581,445	$100,000	-$5,681,445	No
38	$330,557	$10,000,000	-$9,669,443	No
39	$752,567	$786,991	-$34,424	No
40	$178,243	$230,000	-$51,757	No
Recommended	$6,988,166	$425,000	$6,563,166	Yes

F.9 REFERENCES

Note to reader: This list of references identifies web pages and associated URLs where reference data was obtained. Some of these web pages may likely no longer be available or their URL addresses may have changed. NMC has maintained hard copies of the information and data obtained from the referenced web pages.

BGE (Baltimore Gas and Electric). 1998. *Calvert Cliffs Application for License Renewal*, Attachment 2 of Appendix F - Severe Accident Mitigation Alternatives Analysis. April.

CPL (Carolina Power and Light). 2002. *Applicant's Environmental Report; Operating License Renewal Stage; H. B. Robinson Steam Electric Plant Unit No. 2*. Appendix F Severe Accident Mitigation Alternatives, Letter, J. W. Moyer (CP&L) to U.S. Nuclear Regulatory Commission. "Application for Renewal of Operating License." June 14. Available on U.S. Nuclear Regulatory Commission website at http://www.nrc.gov/reactors/operating/licensing/renewal/applications/robinson.html.

CPL (Carolina Power and Light). 2004. *Applicant's Environmental Report; Operating License Renewal Stage; Brunswick Steam Electric Plant*. Appendix F Severe Accident Mitigation Alternatives. October. Available on U.S. Nuclear Regulatory Commission website at http://www.nrc.gov/reactors/operating/licensing/renewal/applications/brunswick.html.

EPA (U.S. Environmental Protection Agency). 1972. *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States*. AP-101. Holzworth. George. C. January.

EPRI (Electric Power Research Institute). 1991. *A Methodology for Assessment of Nuclear Power Plant Seismic Margin*. EPRI NP-6041 Revision 1, August.

EPRI (Electric Power Research institute). 1995. *PSA Applications Guide*. EPRI TR-105396, Final Report. D.E. True. August.

ERIN (ERIN Engineering and Research, Inc.). 2004. *Level 2 PRA Review in Preparation for SAMA*. February.

EXELON (Exelon Corporation). 2001. *Peach Bottom Application for License Renewal*, PBAPS (Peach Bottom Atomic Power Station). Appendix E - Environmental Report and Appendix G - Severe Accident Mitigation Alternatives.

EXELON (Exelon Corporation). 2003a. *Applicant's Environmental Report; Operating License Renewal Stage; Dresden Nuclear Power Station Units 2 and 3*. Section 4.20 Severe Accident Mitigation Alternatives (SAMA) and Appendix F SAMA Analysis, Letter, Benjamin, Exelon, to U.S. Nuclear Regulatory Commission. Application for Renewed Operating Licenses. January 3. Available on U.S. Nuclear Regulatory Commission website at http://www.nrc.gov/reactors/operating/licensing/renewal/applications/dresden-quad.html.

EXELON (Exelon Corporation). 2003b. *Applicant's Environmental Report; Operating License Renewal Stage; Quad Cities Nuclear Power Station Units 1 and 2*. Section 4.20 Severe Accident Mitigation Alternatives (SAMA) and Appendix F SAMA Analysis, Letter, Benjamin, Exelon, to U.S. Nuclear Regulatory Commission. Application for Renewed Operating Licenses. January 3. Available on U.S. Nuclear Regulatory Commission website at http://www.nrc.gov/reactors/operating/licensing/renewal/applications/dresden-quad.html.

GE (GE Nuclear Energy). 1994. *Technical Support Document for the ABWR.* 25A5680 Rev. 1. November.

NMC (Nuclear Management Company, LLC.). 2003. *Evacuation Time Estimate Study for the Monticello Nuclear Generating Plant Emergency Planning Zone*. Revision 1, November.

NRC (U.S. Nuclear Regulatory Commission). 1974. *Design Basis Tornado for Nuclear Power Plants*. Regulatory Guide 1.76. Washington, D.C., April.

NRC (U.S. Nuclear Regulatory Commission). 1989. *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants*. NUREG-1150. Washington, D.C., June.

NRC (U.S. Nuclear Regulatory Commission). 1997. *Regulatory Analysis Technical Evaluation Handbook*. NUREG/BR-0184.

NRC (U.S. Nuclear Regulatory Commission). 1998a. *Code Manual for MACCS2: User's-Guide*. NUREG/CR-6613, Volume 1, SAND 97-0594. Chanin, D. and Young, M. May.

NRC (U.S. Nuclear Regulatory Commission). 1998b. *Plant-Specific Safety Evaluation for USIA-46 Program Implementation at Monticello Nuclear Plant.* TAC No. 69460. Washington, D.C. November.

NRC (U.S. Nuclear Regulatory Commission). 1999. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Oconee Nuclear Station*. NUREG-1437, Supplement 2, Washington, D.C., December.

NRC (U.S. Nuclear Regulatory Commission). 2003. *Sector Population, Land Fraction, and Economic Estimation Program.* SECPOP2000: NUREG/CR-6525, Washington, D.C., Rev. 1, August.

NSP (Northern States Power Company). 1992. *MNGP Individual Plant Examination Submittal*. February.

NSP (Northern States Power Company). 1995. *MNGP Individual Plant Examination for External Events Submittal*. November.

NSP (Northern States Power Company). 1997. *Monticello PSA Peer Review Certification Report*. Boiling Water Reactor Owner's Group. October.

SNOC (Southern Nuclear Operating Company). 2000. *Edwin I. Hatch Nuclear Plant Application for License Renewal, Environmental Report.* Appendix D, Attachment F. February.

USDA (U.S. Department of Agriculture). 1997. *Usual Planting and Harvesting Dates for U.S. Field Crops.* National Agricultural Statistics Service. December. http://usda.mannlib.cornell.edu/reports/nassr/field/planting/uph97.pdf.

USDA (U.S. Department of Agriculture). 1998. *1997 Census of Agriculture.* National Agricultural Statistics Service. http://www.nass.usda.gov/census/census97/volume1/vol1pubs.htm.

ADDENDUM 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 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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
10	Add redundant DC control power for PSW pumps C & D.	SAMA would increase reliability of PSW and decrease core damage frequency 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 service water or from a station blackout event.
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 service water.	SAMA would allow HPSI to be extended after a loss of service water.
19	Use fire protection system 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 service water pumps.	SAMA would reduce the frequency of the loss of component cooling water and service water.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
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 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 fire protection system or by installing a component cooling water cross-tie.
23	8.a. Additional Service Water 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.
	Improvements Related to Heating, Ventilation, and Air Conditioning	
25	Provide reliable power to Control Building fans.	SAMA would increase availability of Control Room 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 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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
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 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 Containment Spray 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.
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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
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 fire protection system and/or standby gas treatment system hardware and procedures.	SAMA would improve fission product scrubbing in severe accidents.
47	Create a reactor cavity flooding system.	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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
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 fire protection system 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 station blackouts or LOCAs which render the suppression pool unavailable as an injection source due to heat up.
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 Top of Active Fuel	SAMA would avoid forcing containment venting

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
62	Enhance containment venting procedures with respect to timing, path selection and technique.	SAMA would improve likelihood of successful venting strategies.
63	1.a. Severe Accident EPGs/Accident Management Guidelines	SAMA would lead to improved arrest of core melt progress and prevention of containment failure
64	1.h. Simulator Training for Severe Accident	SAMA would lead to improved arrest of core melt progress and prevention of containment failure
65	2.g. 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	3.a. Larger Volume Containment	SAMA increases time before containment failure and increases time for recovery
67	3.b. Increased Containment Pressure Capability (sufficient pressure to withstand severe accidents)	SAMA minimizes likelihood of large releases
68	3.c. Improved Vacuum Breakers (redundant valves in each line)	SAMA reduces the probability of a stuck open vacuum breaker.
69	3.d. Increased Temperature Margin for Seals	This SAMA would reduce containment failure due to drywell head seal failure caused by elevated temperature and pressure.
70	3.e. 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	3.f. Suppression Pool Scrubbing	Directing releases through the suppression pool will reduce the radionuclides allowed to escape to the environment.
72	3.g. Improved Bottom Penetration Design	SAMA reduces failure likelihood of RPV bottom head penetrations
73	4.a. 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

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
74	5.a/d. Unfiltered Vent	SAMA would provide an alternate decay heat removal method with the released fission products not being scrubbed.
75	5.b/c. Filtered Vent	SAMA would provide an alternate decay heat removal method with the released fission products being scrubbed.
76	6.a. Post Accident Inerting System	SAMA would reduce likelihood of gas combustion inside containment
77	6.b. Hydrogen Control by Venting	Prevents hydrogen detonation by venting the contaiment before combustible levels are reached.
78	6.c. Pre-inerting	SAMA would reduce likelihood of gas combustion inside containment
79	6.d. Ignition Systems	Burning combustible gases before they reach a level which could cause a harmful detonation is a method of preventing containment failure.
80	6.e. Fire Suppression System Inerting	Use of the fire protection system 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	7.a. 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	7.b. Containment Spray Augmentation	This SAMA would provide additional means of providing flow to the containment spray system.
83	12.b. Integral Basemat	This SAMA would improve containment and system survivability for seismic events.
84	13.a. Reactor Building Sprays	This SAMA provides the capability to use firewater sprays in the Reactor Building to mitigate release of fission products into the Reactor Building following an accident.
85	14.a. Flooded Rubble Bed	SAMA would contain molten core debris dropping on to the pedestal and would allow the debris to be cooled.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
86	14.b. Reactor Cavity Flooder	SAMA would enhance debris coolability, reduce core concrete interaction, and provide fission product scrubbing.
87	14.c. Basaltic Cements	SAMA minimizes carbon dioxide production during core concrete interaction.
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 loss of offsite power and failure of the diesel normally supplying it.	SAMA would reduce the SBO frequency.
91	Provide an additional diesel generator.	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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
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 offsite power, and defeats one half of the low vessel pressure permissive for 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 diesel generator, reliability.
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 offsite power after an SBO.	SAMA would reduce human error probability during offsite power 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 diesel generators, which would contribute to enhanced diesel reliability.
108	Use fire protection system as a backup source for diesel cooling.	This SAMA would provide a redundant and diverse source of cooling for the diesel generators, which would contribute to enhanced diesel reliability.
109	Provide a connection to an alternate source of offsite power.	SAMA would reduce the probability of a loss of offsite power event.
110	Bury offsite power lines.	SAMA could improve offsite power reliability, particularly during severe weather.
111	Replace anchor bolts on diesel generator 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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
112	Change undervoltage (UV), auxiliary Feedwater 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 Diesel Generator Trips	SAMA would allow D/Gs to operate for longer.
115	2.i. 16 hour Station Blackout Injection	SAMA includes improved capability to cope with longer station blackout scenarios.
116	9.a. 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	9.b. 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 offsite power.
118	9.d. Additional Diesel Generator	SAMA would reduce the SBO frequency.
119	9.e. Increased Electrical Divisions	SAMA would provide increased reliability of AC power system to reduce core damage and release frequencies.
120	9.f. Improved Uninterruptable Power Supplies	SAMA would provide increased reliability of power supplies supporting front-line equipment, thus reducing core damage and release frequencies.
121	9.g. AC Bus Cross-Ties	SAMA would provide increased reliability of AC power system to reduce core damage and release frequencies.
122	9.h. Gas Turbine	SAMA would improve onsite AC power reliability by providing a redundant and diverse emergency power system.
123	9.i. Dedicated RHR (bunkered) Power Supply	SAMA would provide RHR with more reliable AC power.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
124	10.a. 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	10.b. 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	10.c. Fuel Cells	SAMA would extend DC power availability in an SBO.
127	10.d. DC Cross-ties	This SAMA would improve DC power reliability.
128	10.e. Extended Station Blackout 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	
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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
137	Implement a maintenance practice that inspects 100% of the tubes in a SG.	SAMA would reduce the potential for an SGTR.
138	Locate residual heat removal (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.
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	8.e. 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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
150	Implement a maintenance practice that inspects 100 percent 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 systeman ISLOCA in a shutdown cooling line, an auxiliary Feedwater (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	13.c. Reduction in Reactor Building Flooding	This SAMA reduces the Reactor Building Flood Scenarios contribution to core damage and release.
	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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
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 condensate storage tank (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 diesel generator for the CST make-up pumps	This SAMA would allow continued inventory make-up to the CST during an SBO.
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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
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 FW pump.	SAMA would increase the availability of injection subsequent to MSIV closure.
177	Use Main FW 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 FW 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 FW pumps to inject water into the SGs at a high pressure rather than using the FW 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 low pressure safety injection 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 human error probability of recirculation failure.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

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 common cause failure 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/reactor core isolation cooling backpressure trip setpoints	This SAMA would ensure high pressure core injection/reactor core isolation cooling availability when high suppression pool temperatures exist.
191	Improve the reliability of the automatic depressurization system.	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 HPCI.	SAMA would allow for extended duration of HPCI availability.
195	Increase available net positive suction head (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	CRD Injection	SAMA would supply an additional method of level restoration by using a non-safety system.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
198	Condensate Pumps for Injection	SAMA to provide an additional option for coolant injection when other systems are unavailable or inadequate
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	2.a. 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	2.c. 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	2.d. Improved High Pressure Systems	SAMA will improve prevention of core melt sequences by improving reliability of high pressure capability to remove decay heat.
205	2.e. Additional Active High Pressure System	SAMA will improve reliability of high pressure decay heat removal by adding an additional system.
206	2.f. Improved Low Pressure System (Firepump)	SAMA would provide fire protection system pump(s) for use in low pressure scenarios.
207	4.b. Clean Up Water Decay Heat Removal	This SAMA provides a means for Alternate Decay Heat Removal.
208	4.c. High Flow Suppression Pool Cooling	SAMA would improve suppression pool cooling.
209	8.c. Diverse Injection System	SAMA will improve prevention of core melt sequences by providing additional injection capabilities.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
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.
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 safety relief valves.	This SAMA would extend operation of safety relief valves during an SBO and loss of air events (BWRs).
214	Allow cross connection of uninterruptable 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 Control Room	This SAMA would provide trip breakers for the MG sets in the Control Room. In some plants, MG set breaker trip requires action to be taken outside of the Control Room. Adding control capability to the Control Room 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 FW 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.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
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 safety relief valve (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 (SBLC) injection.
224	Use control rod drive (CRD) for alternate boron injection.	SAMA provides an additional system to address ATWS with SBLC 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., SBLC 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 SBLC dilution	SAMA to control vessel injection to prevent boron loss or dilution following SBLC injection.
228	11.a. ATWS Sized Vent	This SAMA would be provide the ability to remove reactor heat from ATWS events.
229	11.b. Improved ATWS Capability	This SAMA includes items which reduce the contribution of ATWS to core damage and release frequencies.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
	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 high pressure melt ejection.
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 control rod drive flow control valve failure position	Change failure position to the "fail-safest" position.
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 main steam isolation valves. 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).

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
239	Increase the reliability of safety relief valves 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 high pressure coolant injection scenarios
243	Enhance RPV depressurization procedures	SAMA would decrease the likelihood of core damage in loss of high pressure coolant injection scenarios
244	Replace mercury switches on fire protection systems	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 fire protection 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.
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	1.b. Computer Aided Instrumentation	SAMA will improve prevention of core melt sequences by making operator actions more reliable.

ADDENDUM 1 (CONTINUED)
SELECTED PREVIOUS INDUSTRY SAMAs

SAMA ID Number	SAMA Title	Result of Potential Enhancement
253	1.c/d. Improved Maintenance Procedures/Manuals	SAMA will improve prevention of core melt sequences by increasing reliability of important equipment
254	1.e. Improved Accident Management Instrumentation	SAMA will improve prevention of core melt sequences by making operator actions more reliable.
255	1.f. Remote Shutdown Station	This SAMA would provide the capability to control the reactor in the event that evacuation of the main Control Room is required.
256	1.g. Security System	Improvements in the site's security system would decrease the potential for successful sabotage.
257	2.b. Improved Depressurization	SAMA will improve depressurization system to allow more reliable access to low pressure systems.
258	2.h. Safety Related Condensate Storage Tank	SAMA will improve availability of CST following a Seismic event
259	4.d. Passive Overpressure Relief	This SAMA would prevent vessel overpressurization.
260	8.b. Improved Operating Response	Improved operator reliability would improve accident mitigation and prevention.
261	8.d. Operation Experience Feedback	This SAMA would identify areas requiring increased attention in plant operation through review of equipment performance.
262	8.e. Improved SRV Design	This SAMA would improve SRV reliability, thus increasing the likelihood that sequences could be mitigated using low pressure heat removal.
263	12.a. Increased Seismic Margins	This SAMA would reduce the risk of core damage and release during seismic events.
264	13.b. 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.
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.