APPENDIX F
MPS2 SEVERE ACCIDENT MITIGATION ALTERNATIVES ANALYSIS

Appendix F contains the following sections:

F.1 Melcor Accident Consequences Code System Modeling

F.1.1 Introduction

The following sections describe the assumptions made and the results of the Level 3 modeling performed to assess the offsite risks and consequences of severe accidents (U.S. Nuclear Regulatory Commission Class 9) at MPS2.

The severe accident consequence analysis was carried out with the Melcor Accident Consequence Code System (MACCS2) code (Ref. F.1-1). MACCS2 simulates the impact of severe accidents at nuclear power plants on the surrounding environment. The principal phenomena considered in MACCS2 are atmospheric transport, mitigating actions based on dose projection, dose accumulation by a number of pathways including food and water ingestion, early and latent health effects, and economic costs.

F.1.2 Input

The input data required by MACCS2 are outlined below. MACCS2 requires five separate input files or modules to simulate an accident scenario. These include EARLY, ATMOS, CHRONC, MET, and SITE modules. The Level 3 PRAs using the MACCS2 computer code were prepared by Dominion and reviewed by Dominion personnel.

The Level 3 model was constructed specifically for the license renewal SAMA analysis. The meteorological data have been collected and stored by the Dominion environmental personnel at Millstone Power Station. The population distribution and land use data for the region surrounding the site were determined based on software purchased from the federal government (SECPOP90). The source term data were generated using the MAAP3.0B computer code. The MACCS2 code was used to do the evaluation of the source term distribution.

F.1.2.1 Core Inventory

The core inventory is for MPS2 at a power level of 2700 megawatts-thermal. These values were obtained by adjusting the end-of-cycle values for a 3,412 megawatts-thermal pressurized water reactor (Table F.1-1) by a linear scaling factor of 0.791 in the MACCS2 input file (Ref. F.1-1). Potential core power uprate is accounted for by running a MACCS2 sensitivity with a 10 percent increase on the core scaling parameter. See Section F.3.4 below which discusses this sensitivity.

F.1.2.2 Source Terms

The source term input data to MACCS2 were generated using the MAAP 3.0B computer code for the dominant core damage sequences presented in the probabilistic risk assessment in the MPS2 IPE (Ref. F.1-2). The source term release fractions described in the MPS2 IPE were regenerated for 13 source term categories. There are 27 Plant Damage States (PDSs) in Ref. F.1-2, which were assigned to 13 source term categories. Table F.1-2 lists the conditional input release fractions for each MACCS2 nuclide group. The assignment of the adjusted radionuclides in Table F.1-1 to these nuclide groups is the same as that given in the standard MACCS2 input.

The amounts (becquerels) of each radionuclide released to the atmosphere for each accident sequence or release category are obtained by multiplying the (adjusted) core inventory at the time of the hypothetical accident (adjusted from Table F.1-1) by the release fractions (Table F.1-2) assigned to each of the nuclide groups.

The offsite consequences are summed for all the release modes weighted by the annual frequency to obtain the total annual accident risk, for the base case and for each of the SAMA concepts evaluated. (This summation calculation is performed outside of the MACCS2 code as part of the SAMA cost-benefit analyses.)

F.1.2.3 Meteorological Data

Yearly meteorological data has been generated for 1998 through 2000. The hourly data (wind direction, wind speed, and stability category) were collected on-site at Millstone Power Station. The wind direction and wind speed were recorded at the most probable release height (tower 142 foot elevation), as well as 33 feet, 374 feet, and 447 feet; the stability data were determined by a Delta T system measuring the temperature at the most probable release height, as well as at 374 feet and 447 feet. The data were collected and stored by the environmental personnel at Millstone Power Station. The data were provided to EES personnel at the Innsbrook Technical Center where the data were transferred to the corporate mainframe computer and any remaining unresolved data situations were resolved by professional meteorologists. Precipitation data were recorded at Green Airport near Providence, RI, the closest first order weather station to Millstone.

Morning and afternoon mixing height values for 1998 through 2000 were obtained from the National Climatic Data Center. Missing values were replaced where possible as prescribed in the USEPA document "Procedures for Substituting Values for Missing NWS Meteorological Data for Use in Regulatory Air Quality Models." All non-missing values greater than zero were considered valid.

A washout model which predicts how much radionuclide material is deposited on the ground by rainfall was used. Washout is a function of both rain duration and rain intensity. MACCS2 default washout coefficient values were assumed to be appropriate for this evaluation.

F.1.2.4 Population Distribution

The population distribution and land use information for the region surrounding the site are specified in the Site Data File. Contained in the Site Data file are the geometry data used for the site (spatial intervals and wind directions), population distribution, fraction of the area that is land, watershed data for the liquid pathways model, information on agricultural land use and growing seasons, and regional economic information. Some of the detailed data in this file supercedes certain data in the EARLY input file.

Much of the data were initially prepared by the computer program SECPOP90 (Ref. F.1-3). This code contains a database extracted from Bureau of the Census PL 94-171 (block level census) CD-ROMS (Ref. F.1-4), the 1992 Census of Agriculture CD ROM Series 1B, the 1994 US Census County and City Data Book CD-ROM, the 1993 and 1994 Statistical Abstract of the United States, and other minor sources. The reference contains details on how its database was created and checked. The output from SECPOP90 is a file in the MACCS2 site file format based on the data in its reference database for the specified site.

The Millstone Unit 2 plant is located in Waterford, Connecticut on the Long Island Sound. The 50 mile radius area around the plant was divided into sixteen directions that are equivalent to a standard navigational compass rosette. This rosette was further divided into 10 "inner" radial rings, each with sixteen azimuthal sections.

The SECPOP90-prepared Site data file was then modified and updated using the MPS2 50 mile population distribution for the year 2030 in place of the 1990 Census SECPOP90 data, based on 2000 census data, projected out to 2030. Pictures of the rosette for Millstone site 0-10 mile and 10-50 mile radii are shown in Figures F.1-1 and Figures F.1-2 respectively.

F.1.2.5 Emergency Response

The EARLY module of the MACCS code models the time period immediately following a radioactive release. This period is commonly referred to as the emergency phase. It may extend up to 1 week after the arrival of the first plume at any downwind spatial interval. The subsequent intermediate and long term periods are treated by CHRONC. In the EARLY module the user may specify emergency response scenarios that include evacuation, sheltering, and dose-dependent relocation. The EARLY module has the capability for combining results from up to three different emergency response scenarios. This is accomplished by appending change records to the EARLY input file. The first emergency-response scenario is defined in the main body of the EARLY input file. Up to two additional emergency-response scenarios can be defined through change record sets positioned at the end of the file.

The emergency evacuation model has been modeled as a single evacuation zone extending out 10 miles from the plant. The evacuation speed was estimated to be an average of 1.49 m/s (3.3mph) and a 7200 second delay time from the off-site alarm reference time point. Two sensitivity cases were made using evacuation speeds of 1.2 m/s and 1.8 m/s to bound fair and adverse weather conditions. The sensitivity results have shown that there is a small impact on population dose and practically no impact on the economic cost based on the evacuation speed change.

To demonstrate the possible significance of these assumptions, a sensitivity MACCS2 run was made with the delay time from the reference time point, parameter DLTSHL, increased by 0.5 hours (+1800 s) to 9000 seconds. The results demonstrate that the MACCS2 consequences are not significantly sensitive to the timings used.

F.1.2.6 **Economic Data**

Land use statistics including farmland values, farm product values, dairy production, and growing season information were provided on a countywide basis within 50 miles.

Much of the data is prepared by the computer program SECPOP90 (Ref. F.1-3). It contains a database extracted from Bureau of the Census PL 94-171 (block level census) CD-ROMS (Ref. F.1-4), the 1992 Census of Agriculture CD ROM Series 1B, the 1994 US Census County and City Data Book CD-ROM, the 1993 and 1994 Statistical Abstract of the United States, and other minor sources. The reference contains details on how the database was created and checked. The SECPOP90 regional economic values were updated to 2001 using cost of living and other data from the Bureau of the Census and the Department of Agriculture. Agricultural data is taken from data available in the 1997 Census of Agriculture (Ref. F.1-5). This was accomplished by replacing the SECPOP90 data for the counties within the fifty mile radius by the value from this census. That is, the

SECPOP90 county data base was modified so that the results produced by the code were correctly assigned to the various economic regions.

Offsite economic consequences were estimated using the MACCS code by summing the following costs:

- Costs of evacuation,
- Costs for temporary relocation (food, lodging, lost income),
- Costs of decontaminating land and buildings,
- Lost return-on-investments from properties that are temporarily interdicted to allow contamination to be decreased by decay of nuclides,
- Costs of repairing temporarily interdicted property,
- Value of crops destroyed or not grown because they were contaminated by direct deposition or would be contaminated by root uptake, and
- Value of farmland and of individual, public, and nonfarm commercial property that is condemned.

Onsite impacts (occupational exposure and facility clean-up costs) and replacement power costs are not calculated by MACCS2 but are instead derived from the methodology in NUREG/BR-0184, as described later in this appendix. In addition, the MACCS2 code does not assign a monetary cost to radiological exposure. An NRC-recommended conversion factor is subsequently applied for this purpose.

F.1.3 Results

Based on the preceding input data, MACCS2 was used to estimate the following:

- The downwind transport, dispersion, and deposition of the radioactive materials released to the atmosphere from the failed reactor containment.
- The short- and long-term radiation doses received by exposed populations via direct (cloudshine, plume inhalation, groundshine, and resuspension inhalation) and indirect (ingestion) pathways.
- The mitigation of those doses by protective actions (evacuation, sheltering, and post-accident relocation of people; disposal of milk, meat, and crops; and decontamination, temporary interdiction, or condemnation of land and buildings).
- The early fatalities and injuries projected to occur within 1 year of the hypothetical accident (early health effects) and the delayed (latent) cancer fatalities and injuries projected to occur over the lifetime of the exposed individuals.
- The offsite costs of short-term emergency response actions (evacuation, sheltering, and relocation), of crop and milk disposal, and of the decontamination, temporary interdiction, or condemnation of land and buildings.

The consequences calculated with the MACCS2 model in terms of the population dose and offsite economic costs for the SAMA base case and two sample sensitivity cases are shown in Table F.1-3.

Table F.1-1.
Generic 3412 MWt Core Inventory.[a]

Nuclide	Core inventory (becquerels)	Nuclide	Core inventory (becquerels)
Cobalt-58	3.22E+16	Tellurium-131M	4.68E+17
Cobalt-60	2.47E+16	Tellurium-132	4.66E+18
Krypton-85	2.48E+16	Iodine-131	3.21E+18
Krypton-85M	1.16E+18	Iodine-132	4.73E+18
Krypton-87	2.12E+18	Iodine-133	6.78E+18
Krypton-88	2.86E+18	Iodine-134	7.44E+18
Rubidium-86	1.89E+15	Iodine-135	6.39E+18
Strontium-89	3.59E+18	Xenon-133	6.78E+18
Strontium-90	1.94E+17	Xenon-135	1.27E+18
Strontium-91	4.62E+18	Cesium-134	4.32E+17
Strontium-92	4.80E+18	Cesium-136	1.32E+17
Yttrium-90	2.08E+17	Cesium-137	2.42E+17
Yttrium-91	4.37E+18	Barium-139	6.28E+18
Yttrium-92	4.82E+18	Barium-140	6.22E+18
Yttrium-93	5.45E+18	Lanthanum-140	6.35E+18
Zirconium-95	5.53E+18	Lanthanum-141	5.83E+18
Zirconium-97	5.76E+18	Lanthanum-142	5.62E+18
Niobium-95	5.22E+18	Cerium-141	5.65E+18
Molybdium-99	6.10E+18	Cerium-143	5.49E+18
Technetium-99M	5.26E+18	Cerium-144	3.41E+18
Ruthenium-103	4.54E+18	Praseodymium-143	5.40E+18
Ruthenium-105	2.95E+18	Neodymium-147	2.41E+18
Ruthenium-106	1.03E+18	Neptunium-239	6.46E+19
Rhodium-105	2.05E+18	Plutonium-238	3.66E+15
Antimony-127	2.79E+17	Plutonium-239	8.26E+14
Antimony-129	9.87E+17	Plutonium-240	1.04E+15
Tellurium-127	2.69E+17	Plutonium-241	1.76E+17
Tellurium-127M	3.56E+16	Americium-241	1.16E+14
Tellurium-129	9.27E+17	Curium-242	4.44E+16
Tellurium-129M	2.44E+17	Curium-244	2.60E+15

a. Ref. F.1-1.

Table F.1-2.
MPS2 Release Fraction by Nuclide Group.

Source Term Category	Noble Gases	I	Cs	Te	Sr	Ru	La	Ce	Ba
M-1A	9.94E-01	5.52E-01	5.26E-01	1.73E-03	2.44E-04	3.14E-04	2.75E-06	3.31E-06	1.42E-03
*M-1A	1.0E+00	7.6E-01	7.8E-01	3.5E-01	1.2E-02	1.2E-01	2.6E-03	1.1E-02	4.3E-02
M-1B	1.00E+00	3.07E-02	3.21E-02	6.69E-03	9.56E-05	1.44E-04	1.62E-04	1.88E-04	1.29E-04
M-2	9.82E-01	2.08E-04	5.19E-04	1.61E-02	8.92E-06	7.37E-08	7.74E-07	5.35E-06	5.30E-06
M-3	9.81E-01	1.46E-02	1.39E-02	1.97E-02	5.49E-06	7.23E-05	1.35E-06	1.80E-06	2.98E-05
M-4	9.82E-01	2.08E-04	5.19E-04	1.61E-02	8.92E-06	7.37E-08	7.74E-07	5.35E-06	5.30E-06
M-5	9.82E-01	1.75E-03	2.71E-03	7.48E-02	5.06E-05	1.08E-06	5.11E-07	1.17E-05	2.87E-05
M-6	9.82E-01	1.75E-03	2.71E-03	7.48E-02	5.06E-05	1.08E-06	5.11E-07	1.17E-05	2.87E-05
M-7	9.82E-01	2.08E-04	5.19E-04	1.61E-02	8.92E-06	7.37E-08	7.74E-07	5.35E-06	5.30E-06
M-8	9.44E-01	1.80E-03	3.17E-03	8.82E-04	8.81E-07	1.61E-08	2.67E-08	2.43E-07	1.82E-05
M-9	5.45E-03	2.32E-08	2.43E-08	7.00E-07	3.19E-09	2.75E-11	1.73E-10	1.32E-09	1.58E-09
M-10	9.79E-01	2.27E-02	2.47E-02	7.95E-05	1.77E-06	1.51E-05	2.60E-07	2.87E-07	5.03E-05
M-11	6.56E-03	6.64E-08	7.00E-08	5.85E-07	3.68E-09	8.94E-13	1.15E-10	1.22E-09	2.63E-09
M-12	7.07E-03	1.17E-07	1.12E-07	5.95E-07	5.26E-09	1.00E-10	7.87E-10	3.77E-09	2.63E-09

* The MP3 sensitivity of the release fractions for the M1A source term category

Table F.1-3.
MPS2 Summary of Offsite Consequence Results and Sensitivities for Each Release Mode.

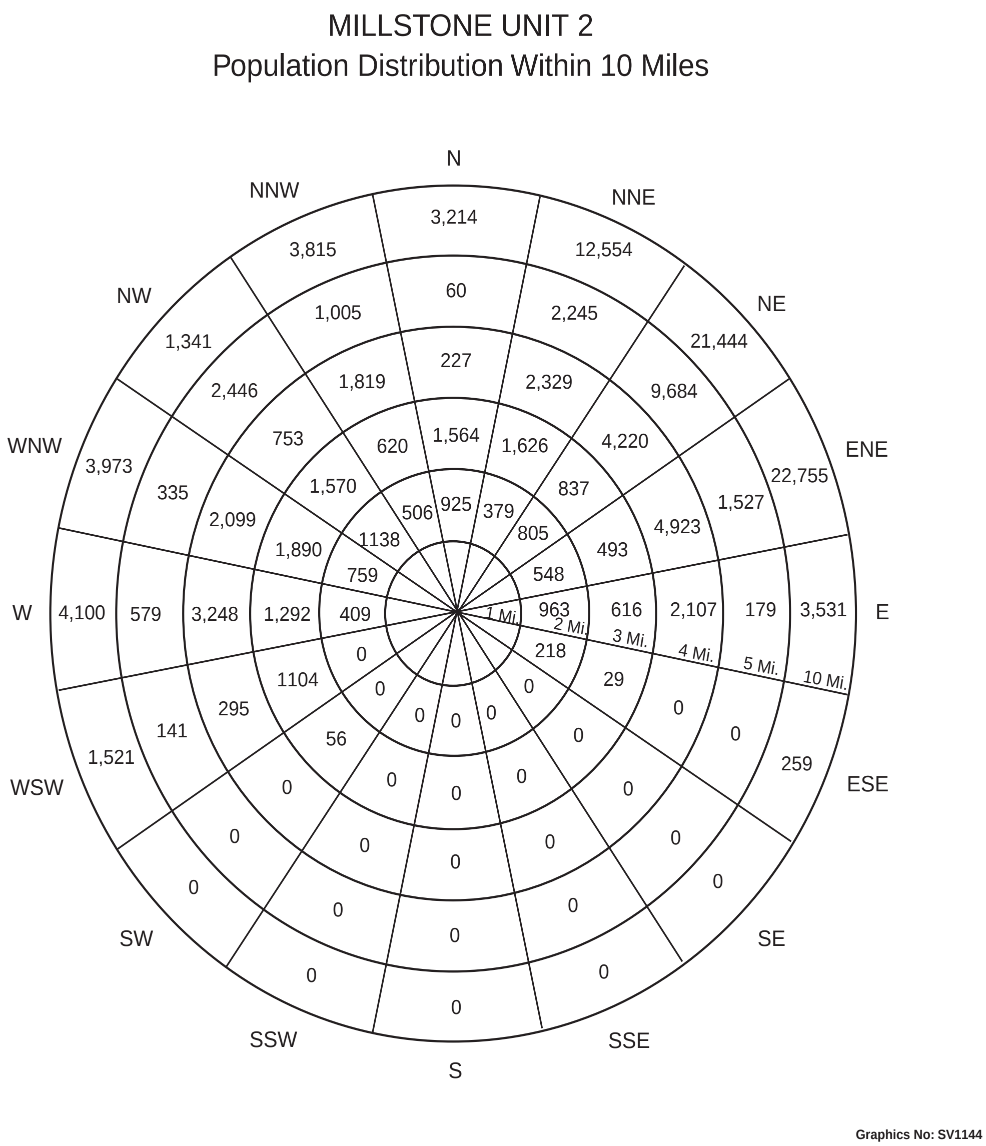
		Population Dose (Sieverts)			Offsite Economic Costs (Dollars)		
CET End Point (Release Mode)	Release Category Description	Basecase (100% Evac)	ESPEED = 1.8m/s	DLTSHL =9000	Basecase (100% Evac)	ESPEED = 1.8m/s	DLTSHL =9000
M-1A	Cont Bypass, V-Sequence	3.90E+04	3.89E+04	3.72E+04	9.56E+9	9.56E+9	9.56E+9
M-1B	Cont Bypass, SGTR	1.06E+04	1.06E+04	1.04E+04	1.69E+09	1.69E+09	1.69E+09
M-2	Early Cont Failure Early melt No Sprays	1.18E+03	1.14E+03	1.27E+03	4.80E+7	4.80E+7	4.80E+7
M-3	Early Cont Failure Late melt, No Sprays	7.04E+03	7.03E+03	6.84E+03	7.24E+8	7.24E+8	7.24E+8
M-4	Cont Iso Failure	1.32E+03	1.26E+03	1.45E+03	6.78E+7	6.78E+7	6.78E+7
M-5	Intermediate Cont Fail Late melt, No Sprays	4.47E+03	4.30E+03	4.75E+03	2.00E+8	2.00E+8	2.00E+8
M-6	Intermediate Fail Early melt, No Sprays	4.47E+03	4.31E+03	4.76E+03	2.00E+8	2.00E+8	2.00E+8
M-7	Late Fail No sprays	7.62E+02	7.62E+02	7.62E+02	2.57E+07	2.57E+07	2.57E+07
M-8	Intermediate Fail With Sprays	2.23E+03	2.23E+03	2.23E+03	2.23E+08	2.23E+08	2.23E+08
M-9	Late Fail With sprays	9.34E-02	9.34E-02	9.34E-02	3.93E+06	3.93E+06	3.93E+06
M-10	Basemat Failure No sprays	1.02E+04	1.02E+04	1.02E+04	1.23E+09	1.23E+09	1.23E+09
M-11	Basemat Failure With sprays	1.56E-01	1.56E-01	1.56E-01	8.27E+06	8.27E+06	8.27E+06

A fractional breakdown of the population dose (person-rem per year) by containment release mode is shown on Table F.1-4.

Table F.1-4.
MPS2 Summary of Offsite Consequence Results for Each Release Mode.

CET End Point (Release Mode)	Release Category Description	Basecase Frequency	Basecase Dose Person-Rem	Person-Rem /yr	%Person-Rem /yr
M-1A	Cont Bypass, V-Sequence	1.07E-07	3.90E+06	4.17E-01	2.40%
M-1B	Cont Bypass, SGTR	2.36E-06	1.06E+06	2.50E+00	14.36%
M-2	Early Cont Failure Early melt, No Sprays	0.00E+00	1.18E+05	0.00E+00	0.00%
M-3	Early Cont Failure Late melt, No Sprays	6.86E-07	7.04E+05	4.83E-01	2.77%
M-4	Cont Iso Failure	0.00E+00	1.32E+05	0.00E+00	0.00%
M-5	Intermediate Cont Fail Late melt, No Sprays	5.48E-06	4.47E+05	2.45E+00	14.06%
M-6	Intermediate Cont Fail Early melt, No Sprays	1.37E-05	4.47E+05	6.12E+00	35.16%
M-7	Late Cont Fail No sprays	2.14E-05	7.62E+04	1.63E+00	9.36%
M-8	Intermediate Cont Fail With Sprays	1.71E-05	2.23E+05	3.81E+00	21.89%
M-9	Late Cont Fail With sprays	0.00E+00	9.34E+00	0.00E+00	0.00%
M-10	Basemat Failure No sprays	0.00E+00	1.02E+06	0.00E+00	0.00%
M-11	Basemat Failure With sprays	0.00E+00	1.56E+01	0.00E+00	0.00%
		Total	8.13E+06	1.74E+01	100.00%

Figure F.1-1
Year 2030 Population Data

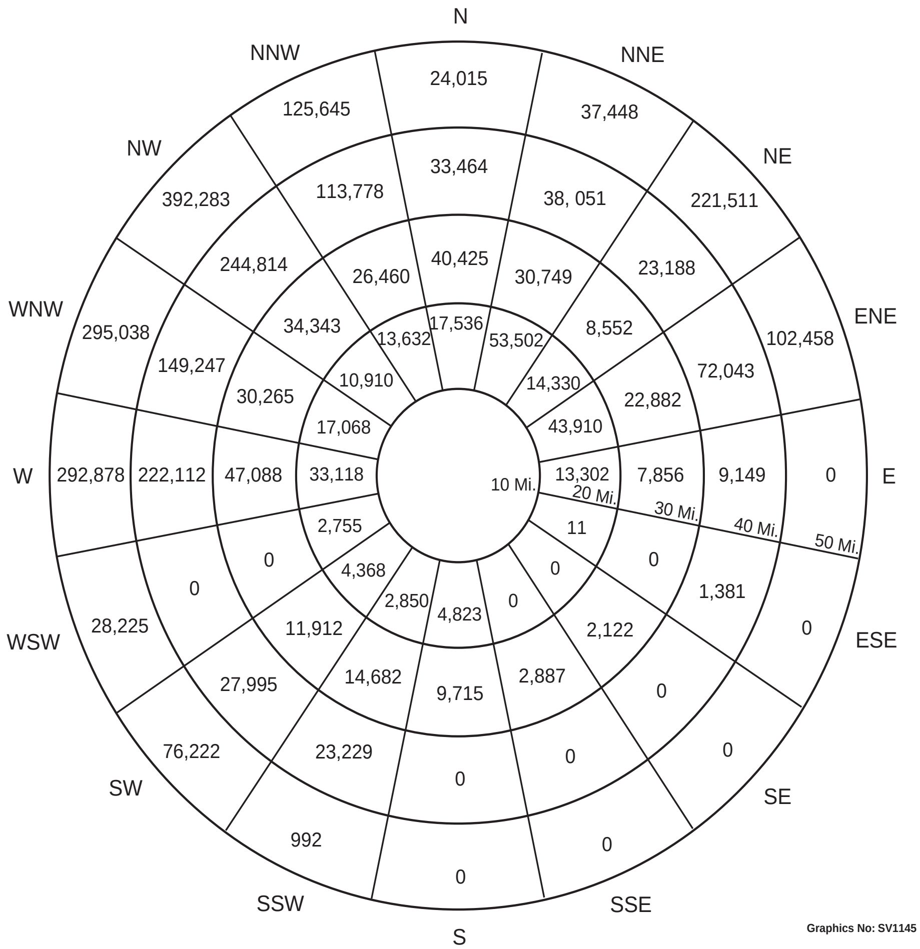


POPULATION BY ANNULUS

Annulus	0 To 2	2 To 3	3 To 4	4 To 5	5 To 10	**Total**
Population	6,650	11,697	22,020	18,201	78,507	**137,075**

Figure F.1-2
Year 2030 Population Data

MILLSTONE UNIT 2
Population Distribution Within 50 Miles



POPULATION BY ANNULUS

Annulus	0 To 10	10 To 20	20To 30	30 To 40	40 To 50	**Total**
Population	137,075	232,120	289,938	958,451	1,596,715	**3,214,299**

F.1.4 References

Ref. F.1-1 Code Manual for MACCS2: Volume 1, User's Guide, Chanin, D. I., et al, SAND07-054, March 1997. SEE ALSO: MACCS2 V.1.12, CCC-652 Code Package, ORNL (Oak Ridge National Laboratory RISCC Computer Code Collection), 1997; MELCOR Accident Consequence Code System (MACCS) Model Description, Jow, H. N, et al, NUREG/CR-4691, SAND86-1562, February 1990.

Ref. F.1-2 Millstone Power Station Unit 2, Individual Plant Examination for Severe Accident Vulnerabilities (IPE), Northeast Utilities, December 1993.

Ref. F.1-3 RF-Report, S. L. Humphreys, et al., "SECPOP90: Sector Population, Land Fraction, and Economic Estimation Program, " NUREG/CR-6525, September, 1997.

Ref. F.1-4 RF-Report, Bureau of the Census, "Census of Population and Housing, 1990: Public Law (P. L.) 94-171, Data Technical Documentation", CD - ROM set, 1991.

Ref. F.1-5 RF-Report, U.S. Dept. of Agriculture, "1997 Census of Agriculture," National Agricultural Statistics Service.

F.2 Probabilistic Risk Assessment Model

This section describes the Millstone Unit 2 Probabilistic Risk Assessment (PRA) model used for the quantification of the reduction in CDF due to the SAMA changes to the model. The resulting source term category frequencies were calculated using this model for all the SAMAs that were screened in.

F.2.1 Introduction

The quantitative analysis of the SAMAs was performed using the Millstone Unit 2 Probabilistic Risk Assessment (PRA) model. The PRA model used for the SAMA analysis consists of the usual three elements: The Level 1 model looks at accident scenarios from initiation to the point of a plant damage state (core damage with containment heat removal status). The Level 2 model assesses the likelihood that the plant damage state (PDS) will result in each of the release categories. The Level 3 model considers the distribution of the released radionuclides to the environment which is discussed in Section F.1 above. A discussion of the external events model and how it was accounted for in the SAMA benefit calculation is shown below.

F.2.2 Level 1 Model

The Level 1 model was originally developed in response to the request for information contained in Generic Letter 88-20. The fault tree linking approach was used and all event trees and fault trees were developed based on plant drawings and procedures. The model includes detailed fault tree models of all front line (accident mitigating) systems and their support systems (HVAC, Electrical, Air). The model also included detailed event trees which delineate accident sequences based primarily on the temporal response of the systems needed to mitigate the initiating event. The MP2 PRA model chronology is shown in Table F.2-1.

Table F.2-1.
MPS2 PRA Model Chronology.

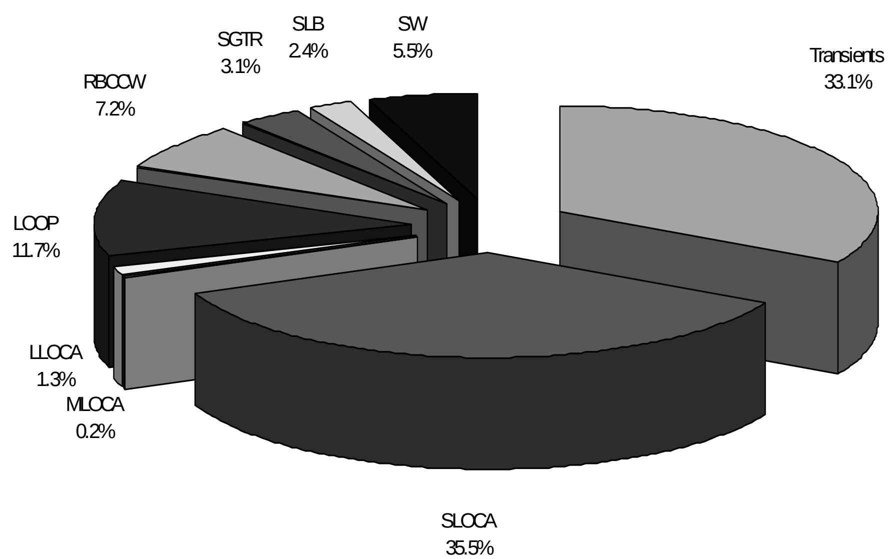
Date	Description
12/90	Millstone 2 Level 1 model completed
6/93	Millstone 2 internal flooding analysis completed
8/93	Millstone 2 Level 1 model updated to reflect the as-designed, as-operated plant
12/93	Millstone 2 IPE submitted
5/94	Supplement regarding a potential vulnerability identified in the IPE submittal • Updated the model to include the possibility of a RCP thermal barrier tube failure leading to possible overpressurization of RBCCW and a small intersystem LOCA
9/95	Responses to the RAIs on the IPE submittal
12/95	Millstone 2 IPEEE submitted
5/96	Millstone 2 IPE approved, NRC SER issued
1/00	PRA updated (Rev. 0) plant-specific data incorporated
6/00	PRA updated (Rev. 1) incorporated changes to address significant peer review comments and corrected modeling errors which include: • Modified support system initiating event trees to ensure effects on mitigating systems are captured. • Correct inconsistencies in Feed and Bleed initiation timing • Performed more detailed evaluation of several human actions basic events
1/01	Millstone 2 IPEEE approved, NRC SER issued
4/01	PRA update (Rev. 2) incorporated the Unit 1/Unit 2 electrical separation and the connection to Unit 3

The information used in the Level 1 model was verified using plant walkdowns. An independent peer review was conducted of the Level 1 and Level 2 models prior to submittal to NRC.

A peer review was performed on the current PRA model used for the SAMA analysis during January 2000.

A breakdown of the CDF by initiating event (specifically, SBLOCA, Transients, SW, SLB, LOOP, RBCCW, SGTR, LLOCA and MLOCA) are shown on Figure F.2-1. It is seen that Transients and SBLOCA contribute over two thirds to the total CDF for MP2.

Figure F.2-1
MPS2 Breakdown of CDF by Initiating Event



A list of the top 30 cutsets is shown in Table F.2-2 below.

Table F.2-2.
MPS2 Summary of Top 30 Cutsets.

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
1	%GPT	General plant transient		2.43	2.43E+00	1.75E-06
	MTC	Probability of an adverse MTC with turbine trip		0.05	5.00E-02	
	RTELEC	Reactor trip failure (signal, coils, breaker)		1.44E-05	1.44E-05	
2	%RBP4RP11CFN	RBCCW Pump P-11C fails to run (initiator)	3.31E-05	8760.00	2.90E-01	1.52E-06
	ACSWING24C	BUS 24C aligned to power swing BUS 24E		0.64	6.40E-01	
	CS1MVCS16ANN	Motor operated valve 2-CS-16.1A fails to open on demand	1.11E-02	1.00	1.11E-02	
	RB2P11CX18C	P-11C and X-18C in operation		0.88	8.80E-01	
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	
3	%RBP4RP11CFN	RBCCW pump P-11C fails to run (initiator)	3.31E-05	8760.00	2.90E-01	1.40E-06
	ACSWING24C	BUS 24C aligned to power swing BUS 24E		0.64	6.40E-01	
	RB2P11CX18C	P-11C and X-18C in operation		0.88	8.80E-01	
	SW1AVSW32BFF	Air operated valve 2-SW-3.2B fails to close on demand	1.02E-02	1.00	1.02E-02	
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	
4	%RBP4RP11AFN	RBCCW pump P-11A fails to run (initiator)	3.31E-05	8760.00	2.90E-01	8.56E-07
	ACSWING24D	AC BUS 24E aligned to BUS 24D		0.36	3.60E-01	
	CS2MVCS16BNN	Motor operated valve 2-CS-16.1B fails to open on demand	1.11E-02	1.00	1.11E-02	
	RB1P11AX18A	P-11A and HX X-18A in operation		0.88	8.80E-01	
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	
5	%RBP4RP11AFN	RBCCW pump P-11A fails to run (initiator)	3.31E-05	8760.00	2.90E-01	7.87E-07
	ACSWING24D	AC BUS 24E aligned to BUS 24D		0.36	3.60E-01	

Table F.2-2.
MPS2 Summary of Top 30 Cutsets. (Cont.)

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
	RB1P11AX18A	P-11A and HX X-18A in operation		0.88	8.80E-01	
	SW2AVSW32AFF	Air operated valve 2-SW-3.2A fails to close on demand	1.02E-02	1.00	1.02E-02	
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	
6	%SWP3SWP5CFN	service water pump P-5C fails to run (initiator)	1.72E-05	8760.00	1.51E-01	6.92E-07
	ACSWING24C	BUS 24C aligned to power swing BUS 24E		0.64	6.40E-01	
	CS1MVCS16ANN	Motor operated valve 2-CS-16.1A fails to open on demand	1.11E-02	1.00	1.11E-02	
	SWP5AC	Service water pumps A and C operating		0.77	7.70E-01	
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	
7	%SWP3SWP5CFN	Service water pump P-5C fails to run (initiator)	1.72E-05	8760.00	1.51E-01	6.36E-07
	ACSWING24C	BUS 24C aligned to power swing BUS 24E		0.64	6.40E-01	
	SW1AVSW32BFF	Air operated valve 2-SW-3.2B fails to close on demand	1.02E-02	1.00	1.02E-02	
	SWP5AC	Service water pumps A and C operating		0.77	7.70E-01	
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	
8	%SWSTSWABCNF	CCF of strainers L-1A, B, and C to operate (initiator)	1.05E-04	717.40	7.53E-02	6.33E-07
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	
	OASWSTRAIN	Operator fails to recover strainer		1.00E-02	1.00E-02	
9	%LNPW	Loss of normal power - weather related		5.20E-03	5.20E-03	5.91E-07
	AC1DGDGH7AFN	Diesel generator 'A' (15G-12U) fails to run	4.64E-03	24.00	1.11E-01	
	AC2DGDGH7BFN	Diesel generator 'B' (15G-13U) fails to run	4.64E-03	24.00	1.11E-01	
	ACXBGSBODGFN	SBO diesel fails to run	2.00E-03	24.00	4.80E-02	
	SITE750W	Failure to recover offsite power in 12.5 hours - weather related		0.19	1.91E-01	
	EDGS750	DG mission time given SBO and TDAFWP operates successfully			1.00E+00	

Table F.2-2.
MPS2 Summary of Top 30 Cutsets. (Cont.)

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
10	%LNPW	Loss of normal power - weather related		5.20E-03	5.20E-03	4.74E-07
	AC1DGDGH7AFN	Diesel generator 'a' (15g-12u) fails to run	4.64E-03	24.00	1.11E-01	
	AC2DGDGH7BFN	Diesel generator 'B' (15g-13u) fails to run	4.64E-03	24.00	1.11E-01	
	SITE750W	Failure to recover offsite power in 12.5 hours - weather related		0.19	1.91E-01	
	EDGS750	DG mission time given SBO and TDAFWP operates successfully			1.00E+00	
	OAM3SBODG	Operators fail to align SBO diesel to unit 2		0.04	3.85E-02	
11	%RBP4RP11CFN	RBCCW pump P-11C fails to run (initiator)	3.31E-05	8760.00	2.90E-01	4.61E-07
	ACSWING24C	BUS 24C aligned to power swing BUS 24E		0.64	6.40E-01	
	HP1P2P41AXNN	HPSI pump P-41A fails to start	3.36E-03	1.00	3.36E-03	
	RB2P11CX18C	P-11C and X-18C in operation		0.88	8.80E-01	
	OAP41B	Operator fails to align HPSI B swing pump (P-41B)		1.00	1.00E+00	
	OAPRCPTRIP	Operators fail to trip RCPS given loss of thermal barrier cooling		8.40E-04	8.40E-04	
12	%SGTR	Steam generator tube rupture		3.86E-03	3.86E-03	4.60E-07
	HPCP2P4133NN	CCF of 3/3 HPSI pumps P-41 A/B/C to start	3.36E-03	0.04	1.19E-04	
13	%GPT	General plant transient		2.43	2.43E+00	4.55E-07
	RTELEC	Reactor trip failure (signal, coils, breaker)		1.44E-05	1.44E-05	
	OAEMBOR	Operator fails to initiate emergency boration		0.01	1.30E-02	
14	%SWP3SWP5AFN	Service water pump p-5a fails to run (initiat0r)	1.72E-05	8760.00	1.51E-01	3.89E-07
	ACSWING24D	AC BUS 24E aligned to BUS 24D		0.36	3.60E-01	
	CS2MVCS16BNN	Motor operated valve 2-CS-16.1B fails to open on demand	1.11E-02	1.00	1.11E-02	
	SWP5AC	Service water pumps A and C operating		0.77	7.70E-01	
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	

Table F.2-2.
MPS2 Summary of Top 30 Cutsets. (Cont.)

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
15	%SGTR	Steam generator tube rupture		3.86E-03	3.86E-03	3.86E-07
	CSXCVCS26XNN	Check valve 2-CS-26 fails to open on demand	1.00E-04	1.00	1.00E-04	
16	%SLOCA1A	Small loca initiator in loop 1A		5.06E-04	5.06E-04	3.82E-07
	CSCMVCS161NN	CCF of 2/2 CS motor operated valves 2-CS-16.1A&B to open on demand	1.11E-02	0.07	7.55E-04	
17	%SLOCA1B	Small LOCA initiator in loop 1B		5.06E-04	5.06E-04	3.82E-07
	CSCMVCS161NN	CCF of 2/2 CS motor operated valveS 2-CS-16.1A&B to open on demand	1.11E-02	0.07	7.55E-04	
18	%SLOCA2A	Small LOCA initiator in loop 2A		5.06E-04	5.06E-04	3.82E-07
	CSCMVCS161NN	CCF of 2/2 CS motor operated valves 2-CS-16.1A&B to open on demand	1.11E-02	0.07	7.55E-04	
19	%SLOCA2B	Small LOCA initiator in loop 2B		5.06E-04	5.06E-04	3.82E-07
	CSCMVCS161NN	CCF of 2/2 CS motor operated valves 2-CS-16.1A&B to open on demand	1.11E-02	0.07	7.55E-04	
20	%SLOCA1A	Small LOCA initiator in loop 1A		5.06E-04	5.06E-04	3.79E-07
	SWCAV81BCONN	CCF of 2/3 service wateR AOVS SW-8.1A/B/C to open	7.80E-03	0.10	7.49E-04	
21	%SLOCA1B	Small LOCA initiator in loop 1B		5.06E-04	5.06E-04	3.79E-07
	SWCAV81BCONN	CCF of 2/3 service water AOVS SW-8.1A/B/C to open	7.80E-03	0.10	7.49E-04	
22	%SLOCA2A	Small LOCA initiator in loop 2A		5.06E-04	5.06E-04	3.79E-07
	SWCAV81BCONN	CCF of 2/3 service wateR AOVS SW-8.1A/B/C to open	7.80E-03	0.10	7.49E-04	
23	%SLOCA2B	Small LOCA initiator in loop 2B		5.06E-04	5.06E-04	3.79E-07
	SWCAV81BCONN	CCF of 2/3 service wateR AOVS SW-8.1A/B/C to open	7.80E-03	0.10	7.49E-04	
24	%RBP4RP11CFN	RBCCW pump P-11C fails to run (initiator)	3.31E-05	8760.00	2.90E-01	3.61E-07
	ACSWING24C	BUS 24C aligned to power swing BUS 24E		0.64	6.40E-01	
	HP1P2TRAINXQ	HPSI train a OOS for maintenance	2.63E-03	1.00	2.63E-03	
	RB2P11CX18C	P-11C and X-18C in operation		0.88	8.80E-01	

Table F.2-2.
MPS2 Summary of Top 30 Cutsets. (Cont.)

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	
25	%SWP3SWP5AFN	Service water pump P-5A fails to run (initiat0r)	1.72E-05	8760.00	1.51E-01	3.58E-07
	ACSWING24D	AC BUS 24E aligned to bus 24D		0.36	3.60E-01	
	SW2AVSW32AFF	Air operated valve 2-SW-3.2A fails to close on demand	1.02E-02	1.00	1.02E-02	
	SWP5AC	Service water pumps A and C operating		0.77	7.70E-01	
	OAPRCPTRIP	Operators fail to trip RCPs given loss of thermal barrier cooling		8.40E-04	8.40E-04	
26	%SLOCA1A	Small LOCA initiator in loop 1A		5.06E-04	5.06E-04	3.51E-07
	SWCAVV32ABFF	CCF of air operated valves 2-SW-3.2A and B to close on demand	1.02E-02	0.07	6.94E-04	
27	%SLOCA1B	Small LOCA initiator in loop 1B		5.06E-04	5.06E-04	3.51E-07
	SWCAVV32ABFF	CCF of air operated valves 2-SW-3.2A and B to close on demand	1.02E-02	0.07	6.94E-04	
28	%SLOCA2A	Small LOCA initiator in loop 2A		5.06E-04	5.06E-04	3.51E-07
	SWCAVV32ABFF	CCF Of air operated valves 2-SW-3.2A and B to close on demand	1.02E-02	0.07	6.94E-04	
29	%SLOCA2B	Small LOCA initiator in loop 2B		5.06E-04	5.06E-04	3.51E-07
	SWCAVV32ABFF	CCF of air operated valves 2-SW-3.2A and B to close on demand	1.02E-02	0.07	6.94E-04	
30	%GPT	General plant transient		2.43	2.43E+00	3.11E-07
	CH1MVCH501FF	MOV CH-501 fails to close on demand	8.89E-03	1.00	8.89E-03	
	RTELEC	Reactor trip failure (signal, coils, breaker)		1.44E-05	1.44E-05	

F.2.3 **Level 2 Model**

A full Level 2 model was developed for the IPE and completed at the same time as the Level 1 model. The Level 2 model consists of a containment event tree with nodes that represent phenomenological events. The nodes were quantified using subordinate trees and logic rules. The original Level 2 model was updated slightly for the SAMA analysis. Recent experimental results have shown that certain outcomes on the containment event tree are much less likely than previously thought. These changes were incorporated into the Level 2 model. A list of the plant damage states (PDS) and descriptions, used for the Level 2 analysis is shown on Table F.2-3 below.

Table F.2-3.
Notation and Definitions for MPS2 Plant Damage States.

PDS	Description
AEC	Large or medium LOCA, early core damage, no containment heat removal
AEF	Large or medium LOCA, early core damage, CAR fans available
AEH	Large or medium LOCA, early core damage, high RCS pressure
AEL	Large or medium LOCA, early core damage, low RCS pressure
AL	Large or medium LOCA, late core damage, containment spray available
ALC	Large or medium LOCA, late core damage, no containment heat removal
ALFH	Large or medium LOCA, late core damage, CAR fans available, high RCS pressure
ALFL	Large or medium LOCA, late core damage, CAR fans available, low RCS pressure
SECH	Small or small small LOCA, early core damage, no containment heat removal, high RCS pressure
SECL	Small or small small LOCA, early core damage, no containment heat removal, low RCS pressure
SEF	Small or small small LOCA, early core damage, CAR fans available
SEGH	Small or small small LOCA, early core damage, containment spray available after AC recovery high RCS pressure
SEH	Small or small small LOCA, early core damage, high RCS pressure
SEL	Small or small small LOCA, early core damage, low RCS pressure
SLCH	Small or small small LOCA, late core damage, no containment heat removal, high RCS pressure
SLCL	Small or small small LOCA, late core damage, no containment heat removal, low RCS pressure
SLFH	Small or small small LOCA, late core damage, CAR fans available, high RCS pressure
SLFL	Small or small small LOCA, late core damage, CAR fans available, low RCS pressure
SLH	Small or small small LOCA, late core damage, high RCS pressure
SLL	Small or small small LOCA, late core damage, low RCS pressure
TECH	Transient, early core damage, no containment heat removal, high RCS pressure
TEFH	Transient, early core damage, CAR fans available, high RCS pressure
TEGH	Transient, early core damage, containment spray available after AC recovery, high RCS pressure
TEH	Transient, early core damage, high RCS pressure
TL	Transient, late core damage
V	Interfacing System LOCA
V2	Steam Generator Tube Rupture bypassing containment

Table F.2-4 is an expression of the MPS2 Level 2 IPE in a form consistent with current MPS2 PRA practice. This table shows the transformation matrix used to convert the PDS frequencies to the STC frequencies. The correlation between the IPE PDSs and the current PDSs are given on the two left hand columns of Table F.2-4. The first column in the table shows the old PDS nomenclature used for the MP2 IPE which was modified to the current nomenclature shown in the second column. The conversion of the MPS2 Level 2 PDS nomenclature is a multi-step process. These steps include:

- New RCs are first given descriptions in terms of the IPE RC criteria

- New RCs are given the attributes of Early or Late depending on whether releases start within about 2 hours or later
- Timing data for core uncovery and release start time is assigned to each RC
- Volatiles using CsI release fractions are classified as High, Medium or Low according to IPE criteria
- Non-volatiles are classified similarly using Te release fractions
- These attributes are consolidated in IPE form, using MP2 IPE nomenclature which forms the basis for correlating the two sets of RCs
- The IPE RCs are correlated to the current RCs based on similarity of the release time, release level, and failure mode
- The (conditional IPE RCs as a function of IPE PDS) Table 4.9-5 in the MP2 IPE report was then converted to current Table F.2-4 using the previous step results as a directory

Also, since the original IPE submittal, a new set of release categories has been developed, as shown in Table F.2-5. New release category frequencies have been calculated which were used for this SAMA analysis. The new baseline release category frequencies are shown on Table F.F.2-6 below.

The current version of the PRA model was used for the SAMA analysis. The quantification of the CDF change due to the SAMA changes was made using the CAFTA computer code at a truncation value of 1.0E-11.

Table F.2-4.
Transformation of MPS2 IPE PDS and SAMA PDS Freq. into Containment Release Category Frequency.

MP2 IPE PDS	SAMA PDS	M1A	M1B	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	Total
AECL	AEC	0.00E+00	0.00E+00	0.00E+00	1.12E-02	0.00E+00	2.04E-07	0.00E+00	0.00E+00	9.88E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
AEFL	AEF	0.00E+00	0.00E+00	0.00E+00	2.01E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.80E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
AEH	AEH	0.00E+00	0.00E+00	0.00E+00	1.91E-02	0.00E+00	1.00E-03	0.00E+00	9.70E-01	9.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
AEL	AEL	0.00E+00	0.00E+00	0.00E+00	1.91E-02	0.00E+00	1.00E-03	0.00E+00	9.70E-01	9.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
ALH	AL	0.00E+00	0.00E+00	0.00E+00	1.91E-02	0.00E+00	1.00E-03	0.00E+00	9.73E-01	9.81E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
ALCH	ALC	0.00E+00	0.00E+00	0.00E+00	1.12E-02	0.00E+00	2.04E-07	0.00E+00	0.00E+00	9.88E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
ALFH	ALFH	0.00E+00	0.00E+00	0.00E+00	2.01E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.80E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
ALFH	ALFL	0.00E+00	0.00E+00	0.00E+00	2.01E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.80E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
SECL	SECH	0.00E+00	0.00E+00	0.00E+00	6.15E-03	0.00E+00	1.38E-03	4.14E-03	9.33E-05	8.77E-01	0.00E+00	0.00E+00	0.00E+00	1.11E-01	1.00E+00
SECL	SECL	0.00E+00	0.00E+00	0.00E+00	6.15E-03	0.00E+00	1.38E-03	4.14E-03	9.33E-05	8.77E-01	0.00E+00	0.00E+00	0.00E+00	1.11E-01	1.00E+00
SEFL	SEF	0.00E+00	0.00E+00	0.00E+00	2.01E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.81E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
SECL	SEGH	0.00E+00	0.00E+00	0.00E+00	6.15E-03	0.00E+00	1.38E-03	4.14E-03	9.33E-05	8.77E-01	0.00E+00	0.00E+00	0.00E+00	1.11E-01	1.00E+00
SEH	SEH	0.00E+00	1.37E-03	0.00E+00	6.49E-03	0.00E+00	6.84E-02	2.50E-02	1.06E-01	3.14E-03	0.00E+00	0.00E+00	0.00E+00	7.87E-01	1.00E+00
SEL	SEL	0.00E+00	0.00E+00	0.00E+00	1.91E-02	0.00E+00	1.00E-03	0.00E+00	9.71E-01	9.78E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
SLCH	SLCH	0.00E+00	2.75E-03	0.00E+00	9.50E-03	0.00E+00	6.39E-02	9.20E-02	6.69E-01	7.47E-03	0.00E+00	0.00E+00	0.00E+00	1.55E-01	1.00E+00
SLCH	SLCL	0.00E+00	2.75E-03	0.00E+00	9.50E-03	0.00E+00	6.39E-02	9.20E-02	6.69E-01	7.47E-03	0.00E+00	0.00E+00	0.00E+00	1.55E-01	1.00E+00
SLFH	SLFH	0.00E+00	0.00E+00	0.00E+00	2.01E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
SLFH	SLFL	0.00E+00	0.00E+00	0.00E+00	2.01E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
SLH	SLH	0.00E+00	0.00E+00	0.00E+00	1.92E-02	0.00E+00	1.00E-03	0.00E+00	9.71E-01	9.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
SLH	SLL	0.00E+00	0.00E+00	0.00E+00	1.92E-02	0.00E+00	1.00E-03	0.00E+00	9.71E-01	9.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
TECH	TECH	0.00E+00	2.75E-03	0.00E+00	5.57E-03	0.00E+00	8.45E-02	2.54E-01	0.00E+00	6.13E-01	0.00E+00	0.00E+00	0.00E+00	4.05E-02	1.00E+00
TEFH	TEFH	0.00E+00	2.75E-03	0.00E+00	1.00E-02	0.00E+00	6.11E-02	1.83E-01	0.00E+00	6.79E-01	0.00E+00	0.00E+00	0.00E+00	6.39E-02	1.00E+00
TEGH	TEGH	0.00E+00	2.74E-03	0.00E+00	9.50E-03	0.00E+00	1.40E-01	2.04E-01	5.68E-01	6.03E-03	0.00E+00	0.00E+00	0.00E+00	7.06E-02	1.00E+00
TEHD	TEH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.89E-02	7.02E-02	4.76E-01	6.62E-03	0.00E+00	0.00E+00	0.00E+00	3.98E-01	1.00E+00
TLCH	TL	0.00E+00	5.41E-03	0.00E+00	1.09E-02	0.00E+00	2.46E-01	7.38E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.75E-05	1.00E+00
ISLOCA	V	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
SGTR	V2	0.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00

Table F.2-5.
Notation and Definitions for MPS2 Containment Release Categories.

Release Category	Description
M1A	Containment Bypass, V-Sequence
M1B	Containment Bypass, SGTR
M2	Early Failure/Early Melt, No Sprays
M3	Early Failure/Late Melt, No Sprays
M4	Containment Isolation Failure
M5	Intermediate Failure/Late Melt, No Sprays
M6	Intermediate Failure/Early Melt, No Sprays
M7	Late Failure, No Sprays
M8	Intermediate Failure With Sprays
M9	Late Failure With Sprays
M10	Basemat Failure, No Sprays
M11	Basemat Failure With Sprays
M12	No Containment Failure

Table F.2-6.
MPS2 Baseline STC Frequencies.

STC:	Base Frequency
M1A	1.07E-07
M1B	2.36E-06
M2	0.00E+00
M3	6.86E-07
M4	0.00E+00
M5	5.48E-06
M6	1.37E-05
M7	2.14E-05
M8	1.71E-05
M9	0.00E+00
M10	0.00E+00
M11	0.00E+00
M12	1.08E-05
Sum	7.17E-05

F.2.4 PRA IPEEE Model

The PRA results used in this analysis are calculated using internal event results only, because MPS2 does not currently have a complete external events model. Only a qualitative screening analysis using a combination of the Fire Induced Vulnerability Evaluation (FIVE) methodology and Fire PRA was used (Ref. F.2-2). To account for the potential impact of external events on the results of these SAMA evaluations, the benefits of each SAMA were multiplied by a factor for purposes of comparing with its cost.

The following summarizes the IPEEE at Millstone Unit 2:

The seismic, high winds and external flooding analyses resulted in the finding that the plant is adequately designed to protect against the effects of these natural events. These events were screened out using the NUREG-1407 and EPRI NP-6041-SL methodology. In summary, none of these external events was significant enough to warrant a rigorous CDF calculation.

The external events contribution to the CDF consists mostly of fire events but other events were considered. The plant fire CDF contribution is 6.3E-6/year. The fire analysis found that five fire areas required detailed analysis: the auxiliary building (47 percent), the turbine building (25 percent), the intake structure (14 percent), the control room (10 percent), and the cable vault (4 percent). Additional events considered include: the plant internal flood CDF contribution of 0.2E-6/year and seismic contribution of 9.1E-6/year. Although the seismic contribution could be screened out it was included here for the purpose of a bounding evaluation. The total external events contribution is 1.56E-5/year.

F.2.5 **References**

Ref. F.2-1 Millstone Power Station Unit 2, Individual Plant Examination for Severe Accident Vulnerabilities (IPE), Northeast Utilities, December 1993.

Ref. F.2-2 Millstone Power Station Unit 2, Response to Generic Letter 88-20, Supplements 4 and 5, Individual Plant Examination for External Events (IPEEE) - Summary Report, Docket No. 50-336 B15481, Northeast Utilities, December 29, 1995.

F.3 Evaluation Of Candidate SAMAs

This section describes the generation of the initial list of potential SAMAs for MPS2, screening methods and the analysis of the remaining SAMAs.

F.3.1 SAMA List Compilation

Dominion generated a list of candidate SAMAs by reviewing industry documents and considering plant-specific enhancements not considered in published industry documents. Industry documents reviewed include the following:

- The MPS2 IPE submittal (only items not already evaluated and/or implemented during the IPE) (Ref. F.3-1)
- The Watts Bar Nuclear Plant Unit 1 PRA/IPE submittal (Ref. F.3-2)
- The Limerick SAMDA cost estimate report (Ref. F.3-3)
- NUREG-1437 description of Limerick SAMDA (Ref. F.3-4)
- NUREG-1437 description of Comanche Peak SAMDA (Ref. F.3-5)
- Watts Bar SAMDA submittal (Ref. F.3-6)
- TVA response to NRC's RAI on the Watts Bar SAMDA submittal (Ref. F.3-7)
- Westinghouse AP600 SAMDA (Ref. F.3-8)
- Safety Assessment Consulting (SAC) presentation by Wolfgang Werner at the NUREG 1560 conference (Ref. F.3-9)
- NRC IPE Workshop - NUREG 1560 NRC Presentation (Ref. F.3-10)
- NUREG 0498, supplement 1, section 7 (Ref. F.3-11)
- NUREG/CR-5567, PWR Dry Containment Issue Characterization (Ref. F.3-12)
- NUREG-1560, Volume 2, NRC Perspectives on the IPE Program (Ref. F.3-13)
- NUREG/CR-5630, PWR Dry Containment Parametric Studies (Ref. F.3-14)
- NUREG/CR-5575, Quantitative Analysis of Potential Performance Improvements for the Dry PWR Containment (Ref. F.3-15)
- CE System 80+ Submittal (Ref. F.3-16)
- NUREG 1462, NRC Review of ABB/CE System 80+ Submittal (Ref. F.3-17)
- An ICONE paper by C. W. Forsberg, et. al, on a core melt source reduction system (Ref. F.3-18)
- NRC Submittal Letter, MPS2 Response to Generic Letter 88-20, Supplements 4 and 5, IPEEE summary report (only items not already evaluated and/or implemented during the IPEEE), December 29, 1995 (Ref. F.3-19)

- Additional items from the Millstone PRA staff from the review of the most significant Basic Events which were sorted by the Fussell-Vesely parameter
- The Calvert Cliffs Nuclear Power Plant Application for License Renewal (Ref. F.3-21)
- The North Anna and Surry Nuclear Power Plant Applications for License Renewal (Ref. F.3-22)

Although MPS2 is a Combustion Engineering design, each of the above documents were reviewed for potential SAMAs, even if they were not necessarily applicable to a Combustion Engineering plant. SAMAs not applicable to MPS2 were subsequently screened from this list. The document reviews did not include sections pertaining to containment performance improvement programs for boiling water reactors and ice condenser plants. Conceptual enhancement for which no specific details were available (e.g., "improve diesel reliability" or "improve procedures for loss of support systems") were not adopted as potential SAMAs, unless they were considered as vulnerabilities in the MPS2 IPE or updated PRA analyses.

The review of the most significant Basic Events which were sorted by the Fussell-Vesely parameter also yielded a significant amount of SAMAs which were used for this evaluation. A partial list of these sorted Basic Events is shown on Table F.3-4.

F.3.2 Qualitative Screening of SAMAs

Table F.3-1 lists the 196 potential SAMAs that were identified for consideration. SAMA items 159-196 of this list were obtained by the review of the most significant Basic Events which were sorted by the Fussell-Vesely parameter or the corresponding risk reduction worth (RRW) parameter. Those Basic Events were considered whose Fussell-Vesely parameter was greater than 0.005 or whose RRW parameter was greater than 1.005. Table F.3-1 also presents a qualitative screening of these SAMAs. Items were eliminated from further evaluation based on one of the following criteria:

- (Criterion A): The SAMA is not applicable at MPS2, either because the enhancement is only for boiling water reactors, the Westinghouse AP600 design or PWR ice condenser containment, or it is a plant-specific enhancement that does not apply at MPS2.
- (Criterion B): The SAMA has already been implemented at MPS2 (or the MPS2 design meets the intent of the SAMA).

- (Criterion C): The SAMA is related to a Reactor Coolant pump (RCP) seal vulnerability at many PWRs stemming from charging pump dependency on Component Cooling Water (CCW). MPS2 does not have this vulnerability because the charging pumps are not used for RCP seal injection. MP2 is a CE design that uses the RBCCW pump to provide RCP seal cooling. However, other RCP seal LOCA improvements will still be considered.

Based on the preliminary screening of the 196 SAMAs, 152 were eliminated, leaving 44 subject to the cost/benefit process. The 44 SAMAs left after the initial screening are listed in Table F.3-2.

The final screening process involved identifying and eliminating those items whose cost exceeded their benefit. Table F.3-2 provides a description of the evaluation of each and provides the basis for their elimination or describes their final resolution. In general, the conclusion of most quantitative analyses resulted in a cost that exceeded the benefit by at least a factor of two. The presentation of the factor of two in Table F.3-2 provided confidence that even when uncertainties are considered, the cost would still exceed the benefit.

One SAMA was considered to be within the cost estimate range, which is SAMA #3, whose improvement includes enhancing the loss of RBCCW procedure to consider RCS cooldown and depressurization prior to a seal LOCA. The RBCCW provides seal, thermal barrier, upper and lower bearing cooling for the RCPs. Dominion is addressing this issue as part of a comprehensive industry initiative, in response to NRC Generic Issue 23 (GI-23), "Reactor Coolant Pump Seal Failure." The Combustion Engineering Owners Group (CEOG) is addressing this in CEOG Task 1136, "Model for Failure of RCP Seals Given Loss of Seal Cooling."

F.3.3 Analysis of Potential SAMAs

The methodology used for this evaluation was based upon the NRC's guidance for the performance of cost-benefit analyses (Ref. F.3-20). This guidance involves determining the net value for each SAMA according to the following formula:

Net Value = (APE + AOC + AOE + AOSC) – COE

where:

APE = present value ($) of averted public exposure from the results of the MACCS2 model,

AOC = present value ($) of averted offsite property damage costs from the results of the MACCS2 model,

AOE = present value ($) of averted occupational exposure from the guidance provided in Ref. F.3-20,

AOSC = present value ($) of averted onsite costs including cleanup/ decontamination costs, repair/refurbishment costs, replacement power costs,

COE = cost of enhancement ($).

If the net value of a SAMA is negative, the cost of implementing the SAMA is larger than the benefit associated with the SAMA and is not considered beneficial. The derivation of each of these costs is described below.

The following specific values were used for various terms in the analyses:

Present Worth

The present worth was determined by:

$$PW = \frac{1 - e^{-rt}}{r}$$

where:

r is the discount rate = 7 percent (as prescribed by NUREG/BR-0184 {Ref. F.3-20])

r is the duration of the license renewal = 20 years

PW is the present worth of a string of annual payments = 10.76

Dollars per REM

The conversion factor used for assigning a monetary value to on-site and off-site exposures was $2,000/person-rem averted. This is consistent with the NRC's regulatory analysis guidelines presented in and used throughout NUREG/BR-0184, Ref. F.3-20.

On-site Person REM per Accident

The occupational exposure associated with severe accidents was assumed to be 23,300 person-rem/accident. This value includes a short-term component of 3,300 person-rem/accident and a long-term component of 20,000 person-rem/accident. These values are the "best estimate" values provided in Section 5.7.3 of Ref. F.3-20. In the cost-benefit analyses, the accident-related on-site exposures were calculated using the best estimate exposure components applied over the on-site cleanup period.

On-site Cleanup Period

In the cost-benefit analyses, the accident-related on-site exposures were calculated over a 10-year cleanup period.

Present Worth On-site Cleanup Cost per Accident

The estimated cleanup cost for severe accidents was assumed to be \$1.5E+09/accident (undiscounted). This value was derived by the NRC in Ref. F.3-20, Section 5.7.6.1, Cleanup and Decontamination. This cost is the sum of equal annual costs over a 10-year cleanup period. At a 7 percent discount rate, the present value of this stream of costs is \$1.1E+09.

Methods for Calculating Averted Costs Associated with Onsite Accident Dose and Property Loss Costs

a) **Immediate Doses** (at time of accident and for immediate management of emergency)

For the case where the plant is in operation, the equations in Ref. F.3-20 can be expressed as:

$$W_{IO} = \left(F_S D_{IO_S} - F_A D_{IO_A}\right) R \frac{1 - e^{-rt_f}}{r} \quad (1)$$

where:

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

R = monetary equivalent of unit dose, (\$/person-rem)

F = accident frequency (events/yr)

D_{IO} = immediate occupational dose (person-rems/event)

S = status quo (current conditions)

A = after implementation of proposed action

r = real discount rate

t_f = years remaining until end of facility life.

The values used are:

R = \$2000/person rem

r = .07

D_{IO} = 3,300 person-rems /accident (best estimate)

The license renewal time of 20 years is used for t_f.

For the base discount rate, assuming F_A is zero, the <u>best estimate</u> of the limiting saving is

$$W_{IO} = \left(F_S D_{IO_S}\right) R \frac{1-e^{-rt_f}}{r}$$

$$= 3300 * F * \$2000 * \frac{1-e^{-.07*20}}{.07}$$

$$= F * \$6{,}600{,}000 * 10.763$$

$$= F * \$0.71E+8, (\dot{\$}).$$

b) **<u>Long-Term Doses</u>** (process of cleanup and refurbishment or decontamination)

For the case where the plant is in operation, the equations in Ref. F.3-20 can be expressed as:

$$W_{LTO} = \left(F_S D_{LTO} - F_A D_{LTO_A}\right) R * \frac{1-e^{-rt_f}}{r} * \frac{1-e^{-rm}}{rm} \qquad (2)$$

where:

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

m = years over which long-term doses accrue.

The values used are:

R = \$2000/person rem

r = .07

D_{LTO} = 20,000 person-rem /accident (best estimate)

m = “as long as 10 years”

The license renewal period of 20 years is used for t_f.

For the discount rate of 7 percent assuming F_A is zero, the <u>best estimate</u> of the limiting saving is

$$W_{LTO} = \left(F_S D_{LTO_S}\right) R * \frac{1 - e^{-rt_f}}{r} * \frac{1 - e^{-rm}}{rm}$$

$$= (F_S\ 20{,}000)\ \$2000 * \frac{1 - e^{-.07*20}}{.07} * \frac{1 - e^{-.07*10}}{.07 * 10}$$

$$= F_S * \$40{,}000{,}000 * 10.763 * 0.719$$

$$= F_S * \$3.095E + 8, (\$)$$

c) **<u>Total Accident-Related Occupational (On-site) Exposures</u>**

Combining equations (1) and (2) above, using delta (Δ) to signify the difference in accident frequency resulting from the proposed actions, and using the above numerical values, the long term accident related on-site (occupational) exposure avoided (AOE) is:

<u>Best Estimate:</u>

$$AOE = DW_{IO} + DW_{LTO} \Delta F * \$(0.71 + 3.1)E + 8 = DF * \$3.81E + 8(\$)$$

<u>Methods for Calculation of Averted Costs Associated with Accident-Related On-Site Property Damage</u>

a) **<u>Cleanup/Decontamination</u>**

Ref. F.3-20 assumes a total cleanup/decontamination cost of \$1.5E+9 as a reasonable estimate and this same value was adopted for these analyses. Considering a 10-year cleanup period, the present value of this cost is:

$$PV_{CD} = \left(\frac{C_{CD}}{m}\right)\left(\frac{1 - e^{-rm}}{r}\right)$$

where:

PV_{CD}	=	Present value of the cost of cleanup/decontamination.
C_{CD}	=	Total cost of the cleanup/decontamination effort.
m	=	Cleanup period.
r	=	Discount rate.

Based upon the values previously assumed:

$$PV_{CD} = \left(\frac{\$1.5E + 9}{10}\right)\left(\frac{1 - e^{-.07*10}}{.07}\right)$$

$$PV_{CD} = \$1.079E + 9$$

This cost is integrated over the term of the proposed license renewal as follows

$$U_{CD} = PV_{CD}\frac{1 - e^{-rt_f}}{r}$$

Based upon the values previously assumed:

U_{CD} = $1.079E+9 [10.763]

U_{CD} = $1.161E+10

b) **Replacement Power Costs**

Replacement power costs, U_{RP}, are an additional contributor to onsite costs. These are calculated in accordance with NUREG/BR-0184, Section 5.6.7.2.[1] Since replacement power will be needed for that time period following a severe accident, for the remainder of the expected generating plant life, long-term power replacement calculations have been used. For a ‘generic’ plant of 910 MWe, the present value of replacement power is calculated as follows:

$$PV_{RP} = \left(\frac{\$1.2E + 8}{r}\right)\left(1 - e^{-rt_f}\right)^2$$

1. The section number for Section 5.6.7.2 apparently contains a typographical error. This section is a subsection of 5.7.6 and follows 5.7.6.1. However, the section number as it appears in the NUREG will be used in this document.

where:

PV_{RP} = Present value of the cost of replacement power for a single event.

t_f = years remaining until end of facility life.

r = Discount rate.

The $1.2E+8 value has no intrinsic meaning but is a substitute for a string of non-constant replacement power costs that occur over the lifetime of a "generic" reactor after an event (from Ref. F.3-20). This equation was developed per NUREG/BR-0184 for discount rates between 5 percent and 10 percent only.

For discount rates between 1 percent and 5 percent, Ref. F.3-20 indicates that a linear interpolation is appropriate between present values of $1.2E+9 at 5 percent and $1.6E+9 at 1 percent. So for discount rates in this range the following equation was used to perform this linear interpolation.

$$PV_{RP} = (\$1.6E + 9) - \left(\frac{[(\$1.6E+9) - (\$1.2E + 9)]}{[5\% - 1\%]} * [r_s - 1\%]\right)$$

where:

r_s = Discount rate (small), between 1 percent and 5 percent.

To account for the entire lifetime of the facility, U_{RP} was then calculated from PV_{RP}, as follows:

$$U_{RP} = \frac{PV_{RP}}{r}\left(1 - e^{-rt_f}\right)^2$$

where:

U_{RP} = Present value of the cost of replacement power over the life of the facility.

Again, this equation is only applicable in the range of discount rates from 5 percent to 10 percent. NUREG/BR-0184 states that for lower discount rates, linear interpolations for U_{RP} are recommended between $1.9E+10 at 1 percent and $1.2E+10 at 5 percent. The following equation was used to perform this linear interpolation:

$$U_{RP} = (\$1.9E + 10) - \left(\frac{[(\$1.9E+10) - (\$1.2E + 10)]}{[5\% - 1\%]} * [r_s - 1\%]\right)$$

where:

r_s = Discount rate (small), between 1 percent and 5 percent.

MPS2 has a design electrical rating (DER) of 870 MWe. The DER of 870 MWe will be used in this calculation, yielding a scaling factor of 0.96 (870/910) to be applied to these formulae.

c) **Repair and Refurbishment**

It is assumed that the plant would not be repaired.

d) **Total Onsite Property Damage Costs**

The total averted onsite damage costs is, therefore:

$$AOSC = F^*(U_{CD} + U_{RP})$$

Where F = Annual frequency of the event.

Accident-Related Off-Site Dose Costs

Offsite doses were determined using the MACCS2 model developed for MPS2. Costs associated with these doses were calculated using the following equation:

$$APE = \left(F_S D_{P_S} - F_A D_{P_A}\right) R \frac{1 - e^{-rt_f}}{r} \qquad (1)$$

where:

APE = monetary value of accident risk avoided due to population doses, after discounting

R = monetary equivalent of unit dose, ($/person-rem)

F = accident frequency (events/yr)

D_P = population dose factor (person-rems/event)

S = status quo (current conditions)

A = after implementation of proposed action

r = real discount rate

t_f = years remaining until end of facility life.

Using the values for r, t_f, and R given above:

$$W_P = (\$2.15E + 4)\left(F_S D_{P_S} - F_A D_{P_A}\right)$$

Accident-Related Off-Site Property Damage Costs

$$AOC = \left(F_S P_{D_S} - F_A P_{D_A}\right)\frac{1 - e^{-rt_f}}{r}$$

AOC = monetary value of accident risk avoided due to offsite property damage, after discounting

P_D = offsite property loss factor (dollars/event)

The evaluation process described in Ref. F.3-20 calculates the value of averted risk on an annual basis. Therefore, a method of "discounting" is used to calculate the "present value" or "present worth of averted risk" based on a specified period of time. For this analysis, a discount rate of 7 percent as prescribed in Ref. F.3-20 was used to determine the present worth of averted risk over the 20 year license renewal period for MPS2.

The PSA results used in this analysis are calculated using internal event results only, because MPS2 does not currently have a complete external events model. To account for the potential impact of external events on the results of these SAMA evaluations, the benefits of each SAMA were multiplied by a factor of 1.3 for purposes of comparing with its cost. Further description of how the 1.3 multiplier was calculated is described below. However, for some SAMAs that relate only to specific internal events initiators (e.g., some SGTR and ISLOCA SAMAs), the benefits will not necessarily be multiplied. In addition, to account for uncertainties, the benefit of each SAMA list in Table F.3-2 is doubled for purposes of the comparison with its cost, except for SGTR and ISLOCA SAMAs.

The 1.3 multiplier and doubling of the benefit bounds any contribution that would be expected from the external events effects. The following summarizes the IPEEE at Millstone Unit 2:

The external events contribution of 1.56E-5/year (from Section F.2.4) compares to a base CDF of 7.2E-5/year from the internal events model used to calculate SAMA benefit. The ratio of the internal events plus the external events, over the internal events yields a value of 1.22, (rounded up to 1.3) was used as an external events multiplier, on all the SAMA benefits except for the SGTR and ISLOCA events. In addition, as an extra measure of conservatism to account for parameter uncertainties, these SAMA benefits were doubled when compared to the cost values.

The maximum theoretical benefit (also called Maximum Attainable Benefit, or MAB) is based upon the elimination of all plant risk (CDF=0.0) and equates to the previously calculated base case risk. The monetary value of the risk associated with those SAMAs that involve major plant modifications may simply be compared with this benefit as a means of eliminating them from further consideration (e.g., a SAMA that would require construction of a large structure might be compared with the MAB).

The SAMA cost estimates do not always require rigorous effort, since the benefit from many of the SAMAs is found to be much less than even an order of magnitude estimate of the cost. Detailed cost estimating is only applied in those situations in which the benefit is significant and application of judgement would be questioned.

F.3.4 Sensitivity Analyses

The PRA calculations of SAMA benefit are recognized to have some uncertainty around the mean frequencies used in the analyses. The uncertainty is related to both quantifiable uncertainty distributions of the data and unquantifiable uncertainty in the PRA assumptions. To account for the possible uncertainty, rather than perform a quantitative uncertainty analysis, the following sensitivity analyses were performed to bound the analysis.

NUREG/BR-0184 recommends using a 7 percent real (i.e., inflation-adjusted) discount rate for value-impact analysis and notes that a 3 percent discount rate (Case 1) should be used for sensitivity analysis to indicate the sensitivity of the results to the choice of discount rate. This reduced discount rate takes into account the additional uncertainties (i.e., interest rate fluctuations) in predicting costs for activities that would take place several years in the future. Analyses presented in Section F.3.3 used the 7 percent discount rate (Baseline Case) in calculating benefits of all the unscreened SAMAs. Dominion also performed a sensitivity analysis by substituting the lower discount rate and recalculating the benefit of the candidate SAMAs. In addition, a sensitivity case was run using a 15 percent discount rate (Case 2), which is judged to be more realistic for Dominion.

A total of fifteen sensitivity cases were analyzed, each varying an aspect of the MACCS2 input deck. These MACCS2 runs included 1 Baseline case plus 15 sensitivity cases. The Baseline case used the best estimate values with year 2030 population projections, an evacuation speed of 1.49m/s and year 2000 meteorological data. The Baseline case assumed that 100 percent of the population within the 10 mile radius of the plant will evacuate. A sensitivity run (Case 3) on evacuation modeling was carried out by assuming an evacuation scenario wherein 95 percent of the population are evacuated normally and 5 percent are not evacuated at all (within the 10 mile emergency zone). Two sensitivity runs were made to evaluate the evacuation speed (ESPEED) and another to evaluate the delay time to take shelter from the reference time point parameter (DLTSHL). Case 4 and Case 11 evaluated an evacuation speed of 1.8 m/s and 1.2 m/s respectively. Case 5 evaluated a delay time to take shelter from the reference time point of 9000 seconds. Another sensitivity run (Case 6) was made to determine the impact of a 10 percent increase in the core power (CORSCA) on the resulting population dose. Two sensitivity runs (Case 7 and Case 8) were made using 1999 and 1998 meteorological data respectively. A sensitivity run (Case 9) was made to determine the impact of doubling the plume release height (PLHITE) on the resulting population dose. Sensitivity Case 10 was made by doubling the duration of source term release time, MACCS parameter (PLDUR), to determine the impact on the resulting population dose. Sensitivity Case 12 determined the impact of a 10 percent decrease on the plume heat parameter PLHEAT. Sensitivity Case 13 was made to determine if the dollar cost for release categories M9 and M11 relative to the Baseline case, is sensitive to the source term data. Sensitivity Case 13 was made by using the release category M10 source term data in place of the M9 and M11 data. It was determined that use of the higher M10 source term data in place of the M9 and M11 data resulted in higher dollar cost to the environment relative to the Baseline case. Sensitivity Case 14 was added to include the source term category M12 which is a "No Containment failure with design leakage SBO". Sensitivity Case 15 was included to determine the sensitivity of using the MP3 modeled V-sequence source term release fractions instead of the MP2 surrogate SGTR values used in the Baseline Case.

A summary of the sensitivity cases is as follows:

- Baseline Case - Year 2000 Met Data, 100 percent Evacuation
- Case 1 - 3 percent Discount Rate
- Case 2 - 15 percent Discount Rate
- Case 3 - Sensitivity Case: WTFRAC = 0.95
- Case 4 - Sensitivity Case: ESPEED = 1.8 m/s
- Case 5 - Sensitivity Case: DLTSHL = 9000 s
- Case 6 - Sensitivity Case: CORSCA = x 1.1
- Case 7 - Sensitivity Case: 1999 Met Data
- Case 8 - Sensitivity Case: 1998 Met Data
- Case 9 - Sensitivity Case: PLHITE = 2(x)
- Case 10 - Sensitivity Case: PLDUR = 2(x)
- Case 11 - Sensitivity Case: ESPEED=1.2 m/s
- Case 12 - Sensitivity Case: PLHEAT-10 percent
- Case 13 - Sensitivity Case: Same as CASE3 except set Source Term for M9 and M11 = M10

- Case 14 - Sensitivity Case: Same as Baseline Case except add source term category M12
- Case 15 - Sensitivity Case: Same as CASE14 except use MP3 source term for M1A

The benefits calculated for each of these sensitivities are presented in Table F.3-3. As seen in the table, all of the sensitivity cases result in less than a factor of 2 increase in the benefit calculation. Table F.3-2 showed that all of the SAMAs except for SAMA #3 screened with costs at least twice the benefit, so it is concluded that the cost-benefit results hold true even when the many uncertainties are considered.

F.3.5 References

Ref. F.3-1 Millstone Power Station Unit 2, Individual Plant Examination for Severe Accident Vulnerabilities (IPE), Northeast Utilities, December 1993.

Ref. F.3-2 Letter from Mr. M. O. Medford (TVA) to NRC Document Control Desk, dated September 1, 1992. "Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Generic Letter (GL) 88-20 - Individual Plant Examination (IPE) for Severe Accident Vulnerabilities - Response - (TAC M74488)."

Ref. F.3-3 "Cost Estimate for Severe Accident Mitigation Design Alternatives. Limerick Generating Station for Philadelphia Electric Company," Bechtel Power Corporation, June 22, 1989.

Ref. F.3-4 NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," Volume 1, Table 5.35, Listing of SAMDAs considered for the Limerick Generating Station, NRC, May 1996.

Ref. F.3-5 NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," Volume 1, Table 5.36, Listing of SAMDAs considered for the Comanche Peak Steam Electric Station, NRC, May 1996.

Ref. F.3-6 Letter from Mr. W. J. Museler (TVA) to NRC Document Control Desk, dated June 5, 1993. "Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Severe Accident Mitigation Design Alternatives (SAMDA) - (TAC Nos. M77222 and M77223)."

Ref. F.3-7 Letter from Mr. D. E. Nunn (TVA) to NRC Document Control Desk, dated October 7, 1994. "Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Severe Accident Mitigation Design Alternatives (SAMDA) - Response to Request for Additional Information (RAI) - (TAC Nos. M77222 and M77223)."

Ref. F.3-8 Letter from N. J. Liparulo (Westinghouse Electric Corporation) to NRC Document Control Desk, dated December 15, 1992, "Submittal of Material Pertinent to the AP600 Design Certification Review."

Ref. F.3-9 Brookhaven National Laboratory, Department of Advanced Technology, Technical Report FIN W-6449, "NRC - IPE Workshop Summary/ Held in Austin Texas; April 7-9 1997," dated July 17, 1997/Appendix F - Industry Presentation Material, Contribution by Swedish Nuclear Power Inspectorate (SKI) and Safety Assessment Consulting (SAC): "Insights from PSAs for European Nuclear Power Plants," presented by Wolfgang Werner, SAC.

Ref. F.3-10 Brookhaven National Laboratory, Department of Advanced Technology, Technical Report FIN W-6449, "NRC - IPE Workshop Summary/ Held in Austin Texas; April 7-9 1997," dated July 17, 1997/Appendix D - NRC Presentation Material on Draft NUREG-1560.

Ref. F.3-11 NUREG 0498, "Final Environmental Statement related to the operation of Watts Bar Nuclear Plant, Units 1 and 2," Supplement No. 1, NRC, April 1995.

Ref. F.3-12 NUREG/CR-5567, "PWR Dry Containment Issue Characterization," NRC, August 1990.

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Ref. F.3-14 NUREG/CR-5630, "PWR Dry Containment Parametric Studies," NRC, April 1991.

Ref. F.3-15 NUREG/CR-5575, "Quantitative Analysis of Potential Performance Improvements for the Dry PWR Containment," NRC, August 1990.

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Ref. F.3-17 NUREG 1462, "Final Safety Evaluation Report Related to the Certification of the System 80+ Design," NRC, August 1994.

Ref. F.3-18 Forsberg, C. W., E. C., Beahm, and G. W. Parker, "Core-Melt Source Reduction System (COMSORS) to Terminate LWR Core-Melt Accidents," Second International Conference on Nuclear Engineering (ICONE-2) San Francisco, California, March 21-24, 1993.

Ref. F.3-19 Letter From D. B. Miller to USNRC, "Millstone Power Station, Unit 2, Response to Generic Letter 88-20, Supplements 4 and 5, Individual Plant Examination for External Events-Summary Report, December 29, 1995.

Ref. F.3-20 NUREG/BR 0184, "Regulatory Analysis Technical Evaluation Handbook", January 1997.

Ref. F.3-21 BGE Letter to NRC, Calvert Cliffs Nuclear Power Plant Unit Nos. 1 &2; Docket Nos. 50-317& 50-318, Application for License Renewal, April 8, 1998.

Ref. F.3-22 Dominion License Renewal Applications, North Anna Units 1 and 2, Surry Units 1 and 2, May 2001.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis.

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
1	Cap downstream piping of normally closed RBCCW drain and vent valves	Reduces the frequency of loss of RBCCW initiating event, a large portion of which was derived from catastrophic failure of one of the many single isolation valves.	(13)	B	Screened out. RBCCW drain and vent valves account for less than a 10% flow diversion.
2	Enhance Loss of RBCCW procedure to facilitate stopping RCPs	Reduces potential for RCP seal damage due to pump bearing failure	(2), (10), (13)	B	Screened out. Procedure AOP-2564 already exists that covers loss of RBCCW and stopping RCP's.
3	Enhance Loss of RBCCW procedure to ensure cool down of RCS prior to seal LOCA	Potential reduction in the probability of RCP seal failure.	(2)		Not initially screened. Considered further in the cost benefit analysis.
4	Additional training on the Loss of RBCCW	Potential improvement in success rate of operator actions after a loss of RBCCW.	(2)	B	Screened out. Training on the loss of RBCCW is already taught to operators in Lesson Plan A64-01-S, Loss of RBCCW and requalification training is provided in Lesson Plan C01304, Loss of RBCCW/Service Water, Review. It is also taught on the Simulator Lesson Plan A64-01-S, Loss of RBCCW.
5	Provide hardware connections to allow another SW to cool charging pump seals	Reduce effect of loss of RBCCW by providing a means to maintain the charging pump seal injection after a loss of RBCCW. Note, in Watts Bar, this capability was already there for one charging pump at one unit, and the potential enhancement identified was to make it possible for all the charging pumps.	(2), (6), (11), (13)	C	Screened out. MPS2 Charging pump motor is air cooled.
6	On loss of SW, proceduralize shedding RBCCW loads to extend the RBCCW heatup time	Increase time before the loss of RBCCW (and RCP seal failure) in the loss of ERCW sequences.	(2)	B	Screened out. Procedure AOP-2565 already exists for shedding RBCCW loads to extend the RBCCW heatup time.
7	Increase charging pump lube oil capacity	Would lengthen time before charging pump failure due to lube oil overheating in loss of CCW sequences	(2)	C	Screened out. Charging pump not used for RCP seal injection.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
8	Eliminate RCP thermal barrier dependence on CCW, such that loss of CCW does not result directly in core damage.	Would prevent loss of RCP seal integrity after a loss of CCW. Watts Bar IPE said this could be done with SW connection to charging pump seals.	(2), (13)		Not initially screened. Considered further in the cost benefit analysis.
9	Provide additional diverse SW pump that can be connected to either SW header	Providing another pump would decrease core damage frequency due to a loss of SW.	(5)	B	Screened out. A third installed spare SW pump may be lined up to either train.
10	Create an independent RCP seal cooling system, with dedicated diesel	Would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of seal cooling or SBO. There is no seal injection at MP2, only seal cooling.	(6), (11), (13)		Not initially screened. Considered further in the cost benefit analysis.
11	Create an independent RCP seal injection system, without dedicated diesel	Would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of seal cooling, but not SBO.	(11)		Not initially screened. Considered further in the cost benefit analysis.
12	Use existing hydro test pump for RCP seal injection	Independent seal injection source, without cost of a new system.	(7)	C	Screened out. MP2 does not utilize RCP seal injection.
13	Replace ECCS pump motors with air cooled motors	Remove dependency on RBCCW.	(10), (13)	B	Screened out. ECCS motors are air cooled.
14	Install improved RCP seals	RCP seal O-rings constructed of improved materials would reduce chances of RCP seal LOCA.	(11), (13)	B	Screened out. CE design requires a complete seal package (N9000) that is cooled by RBCCW.
15	Add a third RBCCW pump	Reduce chance of loss of RBCCW.	(13)	B	Screened out. The MPS2 design is that it already has 3 RBCCW pumps. This design provides sufficient redundancy.
16	Prevent charging pump flow diversion from the relief valves	If relief valve opening causes a flow diversion large enough to prevent RCP seal injection, then modification can reduce frequency of loss of RCP seal cooling.	(13)	C	Screened out. MP2 does not utilize RCP seal injection.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
17	Change procedures to isolate RCP seal letdown flow on loss of RBCCW, and guidance on loss of injection during seal LOCA.	Reduce CDF from loss of seal cooling.	(13)	B	Screened out. Emergency Procedure EOP-2532LOCA already exists to isolate RCP seal letdown flow on loss of RBCCW.
18	Procedures to stagger charging pump use after a loss of SW	Allow high pressure injection to be extended after a loss of SW.	(13)	C	Screened out. Charging pumps are not cooled by SW.
19	Use firewater pumps as a backup seal injection and high pressure makeup	Reduce RCP seal LOCA frequency and SBO core damage frequency.	(13)	A	Screened out. This SAMA is considered not feasible since the fire pumps cannot deliver sufficient head to provide high pressure makeup.
20	Procedural guidance for use of cross-tied RBCCW or SW pumps	Can reduce the frequency of the loss of either of these.	(13)	B	Screened out. Procedures OP-2330A for RBCCW and OP-2326D for service water exist for use of cross-tied RBCCW or SW pumps.
21	Procedure & operator training enhancements in support system failure sequences, with emphasis on anticipating problems and coping.	Potential improvement in success rate of operator actions after support system failures. Such as loss of RBCCW or SW procedural enhancements.	(2), (13)	B	Screened out. Procedures AOP-2564 for RBCCW and AOP-2565 for SW exist for loss of RBCCW and SW conditions.
22	Improve ability to cool RHR heat exchangers	Reduced chance of loss of RHR by 1)Performing procedure and hardware modification to allow manual alignment of fire protection system to the RBCCW system, or 2)Installing a RBCCW header cross-tie.	(12), (13)		Not initially screened. Considered further in the cost benefit analysis.
23	Improve SW pump alignments when a header is out for maintenance	An optimal alignment would improve SW availability during these periods.		B	Screened out. Have two SW pumps (one on each train) with a third installed spare pump that could be aligned to either train.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
24	Stage backup fans in Switchgear rooms	Provides alternate ventilation in the event of a loss of switchgear ventilation.	(13)	B	Screened out. This item is screened out on the basis that current ventilation system is reliable.
25	Provide redundant train of ventilation to 480V board room.	Would improve reliability of 480V HVAC. At Watts Bar, only one train of HVAC cools the 480V board room that contains the unit vital inverters, and recovery actions are heavily relied on. Watts Bar IPE said their corrective action program is dealing with this.	(2), (13)	B	Screened out. For a loss of switchgear HVAC there are proceduralized compensatory cooling measures in place to open doors and use fans for cross ventilation.
26	Procedures for temporary HVAC	Provides for improved credit to be taken for loss of HVAC sequences.	(11), (13)	B	Screened out. Procedure OP-2315D already exists for temporary HVAC.
27	Add a switchgear room high temp alarm	Improve diagnosis of a loss of switchgear HVAC.	(13)	B	Screened out. A high temp alarm exists at MPS2 and procedures tell operators what to do.
28	Create ability to switch fan power supply to DC in SBO	(was created for a BWR RCIC room, Fitzpatrick; possible for turbine AFW if has its own fan) Allow continued operation in SBO.	(13)	A	Screened out. MPS2 turbine AFW pump can operate during an SBO.
29	Delay containment spray actuation after large LOCA	When ice remains in the ice condenser at such plants, containment sprays have little impact on containment performance, yet rapidly drain down the RWST. This improvement would lengthen time of RWST availability.	(2), (6)	A	Screened out. MPS2 has a large liquid inventory in their RWST. RWST makeup is possible.
30	Install containment spray throttle valves	Can extend the time over which water remains in the RWST, when full containment spray flow is not needed.	(11), (12), (13)	B	Screened out. RWST makeup is possible.
31	Install an independent method of suppression pool cooling	Would decrease frequency of loss of containment heat removal.	(3), (4)	A	Screened out. Does not apply to PWR.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
32	Develop an enhanced containment spray system	Would provide a redundant source of water to the containment to control containment pressure, when used in conjunction with containment heat removal.	(3), (4), (16), (17)	B	Screened out. MP2 has 2 trains of containment spray and 4 CAR fan coolers. The containment spray system importance is low due to the heat removal capability of the CAR fan coolers. Additional trains of containment spray would not be risk significant.
33	Provide a dedicated existing containment spray system	Identical to the previous concept, except that one of the existing spray loops would be used instead of developing a new spray system.	(3), (4) (similar PWR containment spray option in (5), (6), (11))	B	Screened out. See SAMA #32.
34	Install a containment vent large enough to remove ATWS decay heat	Assuming injection is available, would provide alternative decay heat removal in an ATWS.	(3), (4)		Not initially screened. Considered further in the cost benefit analysis.
35	Install a filtered containment vent to remove decay heat	Assuming injection is available (non-ATWS sequences), would provide alternate decay heat removal with the released fission products being scrubbed.	(3), (4) (similar options in (5), (6), (8), (11), (12), (16), (17)		Not initially screened. Considered further in the cost benefit analysis.
36	Install an unfiltered hardened containment vent	Provides an alternate decay heat removal method (non-ATWS), which is not filtered.	(3), (4), (9), (14)		Not initially screened. Considered further in the cost benefit analysis.
37	Create/enhance hydrogen ignitors with independent power supply.	Use either a new, independent power supply, a non-safety grade portable generator, existing station batteries, or existing AC/DC independent power supplies such as the security system diesel. Would reduce hydrogen detonation at lower cost.	(3), (5), (6), (7), (9), (12), (13), (14), (15), (16), (17)	A	Screened out. Hydrogen burn is not a challenge for MP2 containment.
38	Create a passive hydrogen ignition system	Reduce hydrogen detonation potential without requiring electric power.	(7), (11), (16), (17)	A	Screened out. See SAMA #37.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
39	Create a giant concrete crucible with heat removal potential under the basemat to contain molten debris	A molten core escaping from the vessel would be contained within the crucible. The water cooling mechanism would cool the molten core, preventing a meltthrough.	(3), (4), (16), (17)	A	Screened out. Impractical to add heat removal system under an existing basemat.
40	Create a water cooled rubble bed on the pedestal	This rubble bed would contain a molten core dropping onto the pedestal, and would allow the debris to be cooled.	(3), (4), (8), (16), (17)	A	Screened out. MP2 has a basaltic concrete basemat. Due to the chemical nature of this basemat type less concrete ablation by molten corium / concrete interaction (MCCI) would be expected compared to a limestone concrete type. Also, for core melt sequences where the vessel would breach at low RCS pressure, it is most likely that some concrete ablation may occur but most of the ex-vessel molten material will freeze in the cavity below the vessel.
41	Provide modification for flooding of the drywell head	Would help mitigate accidents that result in leakage through the drywell head seal.	(4), (9)	A	Screened out. Enhancement is only for BWRs
42	Enhance fire protection system and/or standby gas treatment system hardware and procedures	Improve fission product scrubbing in severe accidents.	(4)	A	Screened out. MP2 does not have a standby gas treatment system. See SAMA #49 for fire protection system analysis.
43	Create a reactor cavity flooding system	Would enhance debris coolability, reduce core concrete interaction and provide fission product scrubbing.	(5), (6), (9), (11), (12), (13), (15), (16), (17)		Not initially screened. Considered further in the cost benefit analysis.
44	Creating other options for reactor cavity flooding	(a) Use water from dead-ended volumes, the condensed blowdown of the RCS, or secondary system by drilling pathways in the reactor vessel support structure to allow drainage from the steam generator compartments, refueling canal, sumps, etc., to the reactor cavity. Also (for ice condensers), allow drainage of water from melted ice into the reactor cavity. (b)Flood cavity via systems such as diesel driven fire pumps.	(7), (9), (13)	(a) - the ice condenser portion of this alternative is not applicable to MPS2	Not initially screened. Considered further in the cost benefit analysis.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
45	Enhance air return fans (ice condenser containment)	Provide an independent power supply for the air return fans, reducing containment failure in SBO sequences.	(6), (11)	A	Screened out. Enhancement not applicable at MPS2.
46	Provide a core debris control system	Would prevent the direct core debris attack of the primary containment steel shell by erecting a barrier between the seal table and containment shell.	(6), (11)	A	Screened out. Primary containment steel liner attacked by ejected molten debris is not a dominant failure mode for MP2.
47	Create a core melt source reduction system (COMSORS)	Place enough glass underneath the reactor vessel such that a molten core falling on the glass would melt and combine with the material. Subsequent spreading and heat removal from the vitrified compound would be facilitated, and concrete attack would not occur (such benefits are theorized in the reference).	(19)	A	Screened out. MP2 concrete basemat is of basaltic type. This concrete type has a high SiO2 concentration.
48	Provide containment inerting capability	Would prevent combustion of hydrogen and carbon monoxide gases.	(6), (9), (11), (14)	A	Screened out. Not practical because steam generated during a severe accident is sufficient to inert containment.
49	Use fire water spray pump for containment spray	Redundant containment spray method without high cost.	(7), (9), (10), (12)	A	Screened out. Fire water pump does not provide sufficient head to reach spray rings and provide adequate spray flow.
50	Install a passive containment spray system	Containment spray benefits at a very high reliability, and without support systems.	(8)	B	Screened out. Bounded by SAMA #32 and #33.
51	Secondary containment filtered ventilation	For plants with a secondary containment, would filter fission products released from the primary containment.	(8)	B	Screened out. The secondary containment gas space is filtered during an accident using charcoal filter banks.
52	Increase containment design pressure	Reduce chance of containment overpressure.	(8)	A	Screened out. This improvement is intended for a new design, not an existing one. MP2 containment design pressure is 54 psig.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
53	Increase the depth of the concrete basemat, or use an alternative concrete material to ensure melt through does not occur	Prevent basemat melt through.	(16), (17)	A	Screened out. This improvement is intended for a new design, not an existing one.
54	Provide a reactor vessel exterior cooling system.	Potential to cool a molten core before it causes vessel failure, if the lower head can be submerged in water.	(16), (17)	A	Screened out. Not practical given the containment lower compartment's configuration.
55	Create another building, maintained at a vacuum to be connected to containment	In an accident, connecting the new building to containment would depressurize containment and reduce any fission product release.	(17)	B	Screened out. Secondary containment has a purge and exhaust system that directs gas to a filter bank that is safety related. MPS2 has a large dry containment that is normally operated at atmospheric pressure.
56	Add ribbing to the containment shell	Would reduce the chance of buckling of containment under reverse pressure loading.	(17)	A	Screened out. This improvement is intended for a new design, not an existing one.
57	Train operations crew for response to inadvertent actuation signals	Improves chances of a successful response to the loss of two 120V AC buses, which causes inadvertent signals.	(13)	B	Screened out. Operations is already trained for inadvertent actuation signals.
58	Proceduralize alignment of spare diesel to shutdown board after LOP and failure of the diesel normally supplying it	Reduced SBO frequency.	(2)	B	Screened out. Procedures are already in place for this.
59	Provide an additional diesel generator	Would increase on-site emergency AC power reliability and availability (decrease SBO).	(5), (6), (10), (13) (16), (17)	B	Screened out. Have cross-tie to MP3, SBO DG, NSST, and RSST.
60	Provide additional DC battery capability	Would ensure longer battery capability during a SBO, reducing frequency of long term SBO sequences.	(5), (6), (13), (16), (17)	B	Screened out. Modification in progress to create a swing battery charger between 201A and 201B.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
61	Use fuel cells instead of lead-acid batteries	Extend DC power availability in a SBO.	(16), (17)	B	Screened out. Bounded by SAMA #60.
62	Procedure to cross tie HPCS diesel	(BWR 5/6).	(10)	A	Screened out. Enhancement is only for BWRs.
63	Improved bus cross tie ability	Improved AC power reliability.	(10), (13)	B	Screened out. Already have a swing bus (24E) as well as a cross-tie to MP3.
64	Alternate battery charging capability	Improved DC power reliability. Either cross tie of AC buses, or a portable diesel-driven battery charger.	(10), (11), (12), (13)	B	Screened out. Bounded by SAMA #60.
65	Increase/improve DC bus load shedding	Improved battery life in station blackout.	(10), (11), (12), (13)	B	Screened out. MPS2 procedures already direct appropriate DC load shedding during an SBO.
66	Replace batteries	Improved reliability.	(10)	B	Screened out. Maintenance program is already in place. Battery Service Test SP-2736E. Battery Perf Discharge Test SP 2736F. Battery Charger Capacity Test SP 2736G. Weekly and Quarterly Surveil SP 2736H
67	Create AC power cross tie capability across units	Improved AC power reliability.	(11), (12), (13)	B	Screened out. AC power crosstie already exists at MP2

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
68	Create a cross-unit tie for diesel fuel oil	Adds diesel fuel oil redundancy.	(13)	B	Screened out. Each EDG has its own diesel oil supply tank, each with a capacity of 12,000 gallons. The diesel oil supply tanks are cross-tied via two locked closed valves, such that an operating diesel generator can utilize the 24,000 gallon capacity of both diesel oil supply tanks in the event that one diesel fails to operate. In addition, MP2 has a 25,000-gallon above ground fuel oil storage tank, which can refill either diesel oil supply tank. This above ground fuel oil storage tank can receive fuel oil from offsite via delivery trucks. Based on bullets above, no additional benefit would be expected from the proposed EDG fuel oil cross-tie capability.
69	Develop procedures to repair or change out failed 4KV breakers	Offers a recovery path from a failure of breakers that perform transfer of 4.16 kV non-emergency buses from unit station service transformers to system station service transformers, leading to loss of emergency AC power (i.e., in conjunction with failures of the diesel generators).	(13)	B	Screened out. Operating Procedure 2348 is already in place.
70	Emphasize steps in recovery of offsite power after a SBO.	Reduced human error probability of offsite power recovery.	(13)	B	Screened out. Procedure EOP-2530 already exists for recovery of offsite power.
71	Develop a severe weather conditions procedure	For plants that do not already have one, reduces the likelihood of external events CDF.	(13)	B	Screened out. Procedure AOP-2560 already exists.
72	Procedures for replenishing diesel fuel oil	Allow long term diesel operation.	(13)	B	Screened out. MPS2 already has a procedure for replenishing fuel oil.
73	Install diesel turbine generators	Improve on-site AC power reliability.	(13)	B	Screened out. Have a cross-tie to MP3 via SBO diesel, NSST, and RSST.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
74	Install tornado protection on gas turbine generator	If the unit has a gas turbine, the tornado-induced SBO frequency would be reduced.	(16), (17)	A	Screened out. Not applicable at MPS2.
75	Create water backup for diesel cooling.	Provides redundant source of diesel cooling.	(13)		Not initially screened. Considered further in the cost benefit analysis.
76	Use firewater as a backup for diesel cooling	Redundancy in diesel support systems.	(13)	B	Screened out. Backup already in place.
77	Provide a connection to alternate offsite power source (the nearby dam)	Increase offsite power redundancy.	(13)		Not initially screened. Considered further in the cost benefit analysis.
78	Implement underground offsite power lines	Could improve offsite power reliability, particularly during severe weather.	(13)	A	Screened out. This item is screened out based on the fact that underground high voltage lines would not be installed across the service area of Connecticut. Placing the offsite power lines underground for the section that they run through the MPS2-controlled area would be a negligible benefit since this area is negligible compared to the total span across which they would be exposed to severe weather.
79	Replace anchor bolts on diesel generator oil cooler	Millstone 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.	(13)	B	Screened out. Anchor bolts already installed.
80	Create an auto-loading of the SBO diesel	Removes the human error portion to reduce SBO frequency.		B	Screened out. The SBO DG is shared between MP2 and MP3. Since MP3 takes priority over the SBO DG human intervention will always be required.
81	Install a fast acting MG output breaker	With a fast acting breaker, a turbine runback would be possible, reducing the likelihood of a reactor trip in some cases.			Not initially screened. Considered further in the cost benefit analysis.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
82	Proceduralize use of pressurizer vent valves during SGTR sequences	MPS2 procedures just direct RCS cooldown.	(13)	B	Screened out. If Pressurizer's main spray and auxiliary spray are not available, the existing EOPs provide direction to reduce RCS pressure using the PORVs. This action recovers pressurizer level in order to meet the HPSI throttle stop criteria. RCS pressure can be then be reduced by riding down the HPSI head-flow curve. Therefore, proceduralizing the use of the Pressurizer vent path would provide minimal benefit since three methods already exist.
83	Install a redundant spray system to depressurize the primary system during a SGTR.	Enhanced depressurization ability during SGTR.	(16), (17)	B	Screened out. This feature is already installed in the plant.
84	Improved SGTR coping abilities	Improved instrumentation to detect SGTR, or additional systems to scrub fission product releases.	(7), (9), (10), (13), (14), (16), (17)	B	Screened out. Existing plant EOPs provide adequate guidance to identify a steam generator tube rupture event. Also, Millstone Unit 2 has recently added new N-16 radiation monitors to help identify small primary-to-secondary tube leaks. This additional instrumentation will enhance the operator's ability to diagnose a steam generator tube rupture. Since noble gases are the typical radiological releases associated with a SGTR, installing additional systems to scrub fission product releases would not be helpful since the noble gases are non-condensable.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
85	Adding other SGTR coping features	(a)A highly reliable (closed loop) steam generator shell-side heat removal system that relies on natural circulation and stored water sources, (b)a system which returns the discharge from the steam generator relief valve back to the primary containment, (c)an increased pressure capability on the steam generator shell side with corresponding increase in the safety valve setpoints.	(7), (8), (17)	A	Screened out. Parts (a) and (c) are screened as not being feasible for an existing plant. Part (b) is also screened because adding such a steam load to the containment building would require a redesign of the containment pressure capacity.
86	Increase secondary side pressure capacity such that a SGTR would not cause the relief valves to lift	SGTR sequences would not have a direct release pathway.	(8), (17)	B	Screened out. The combined capacity of the ADVs and main condenser steam dump valves at MP2 will ensure avoiding the challenge of the main steam safety valves following a reactor trip from full power. Furthermore, in accordance with the CE Owners Group Emergency Procedure Guidelines, following a SGTR, the operators are directed to cool down both the affected and unaffected steam generators using either the main condenser dump valves or the ADVs until the RCS hot leg temperature is reduced below 515 degrees. This action avoids any future challenge to the main steam safety valves. Should an ADV stick open, the release pathway could be isolated outside the control room via a separate isolation valve.
87	Replace steam generators with new design	Lower frequency of SGTR.	(13)		Not initially screened. Considered further in the cost benefit analysis.
88	Revise EOPs to direct that a faulted steam generator be isolated.	For plants whose EOPs don't already direct this, would reduce consequences of a SGTR.	(13)	B	Screened out. EOPs already isolate faulted SG when < 515 F T hot.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
89	Direct steam generator flooding after a SGTR, prior to core damage.	Would provide for improved scrubbing of SGTR releases.	(14), (15)	B	Screened out. MPS2 procedures direct SG level to be maintained at approximately 40% indicated level to prevent flooding of SG. Contingencies are in place.
90	A maintenance practice that inspects 100% of the tubes in a steam generator	Reduce chances of tube rupture.	(16), (17)	B	Screened out. MPS2 already practices 100% SG tube inspection.
91	Locate RHR inside of containment	Would prevent ISLOCA out the RHR pathway.	(8)	A	Screened out. This item is not applicable to an existing plant.
92	Self-actuating containment isolation valves	For plants that don't have this, it would reduce the frequency of isolation failure.	(8)	B	Screened out. Already exists at MPS2.
93	Additional instrumentation and inspection to prevent ISLOCA sequences	Install additional instrumentation for detecting ISLOCA events. Implement a comprehensive piping inspection program to detect precursors to breaches in RCS integrity. The benefit assumes that the programs are so effective all ISLOCAs are eliminated.	(5), (6), (11), (13)		Not initially screened. Considered further in the cost benefit analysis.
94	Increase frequency of valve leak testing	Decrease ISLOCA frequency.	(12)		Not initially screened. Considered further in the cost benefit analysis.
95	Improvement of operator training on ISLOCA coping	Decrease ISLOCA effects.	(12), (13)	A	Screened out. Operators are already trained for ISLOCA coping.
96	Install relief valves in the component cooling water system	Would relieve pressure buildup from an RCP thermal barrier tube rupture, preventing an ISLOCA.	(13)	B	Screened out. The RBCCW system already has relief valves installed for overpressure protection.
97	Provide leak testing of valves in ISLOCA paths	At Kewaunee, four MOVs isolating RHR from the RCS were not leak tested. Will help reduce ISLOCA frequency.	(13)	B	Screened out. Program already in place for leak testing of valves.
98	Revise EOPs to improve ISLOCA identification	Salem had a scenario in which an RHR ISLOCA could direct initial leakage back to the PRT, giving indication that the LOCA was inside containment. Procedure enhancement would ensure LOCA outside containment would be observed.	(13)	B	Screened out. Procedures are already in place for ISLOCA identification.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
99	Ensure all ISLOCA releases are scrubbed	Would scrub ISLOCA releases. One suggestion was to plug drains in the break area so the break point would cover with water.	(14), (15)		Not initially screened. Considered further in the cost benefit analysis.
100	Add redundant and diverse limit switch to each containment isolation valve.	Enhanced isolation valve position indication, which would reduce frequency of containment isolation failure and ISLOCAs.	(16), (17)		Not initially screened. Considered further in the cost benefit analysis.
101	Add a check valve downstream of the LHSI pumps on the cold leg injection line.	ISLOCA frequency is usually dominated by the LHSI injection lines to the cold legs, which have 2 check valves each. Adding another check valve in the common injection line would essentially eliminate the frequency of the ISLOCA sequence through these pathways.		B	Screened out. Redundant check valves already exist downstream of the LHSI pumps at MPS2.
102	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment	For a plant where internal flooding from turbine building to safeguards areas is a concern, this modification can prevent flood propagation. The AFP is vulnerable to flooding at MPS2 turbine building basement.	(13)	B	Screened out. Circ pumps are tripped on high level in pit in turbine building basement.
103	Improve inspection of rubber expansion joints on main condenser	For a plant where internal flooding due to failure of circulating water expansion joint is a concern, this can help reduce the frequency.	(13)	B	Screened out. Chemistry is monitored in condenser to detect breakdown of rubber expansion joint.
104	Internal flood prevention and mitigation enhancements	1)Use of submersible MOV operators. 2)Back flow prevention in drain lines.	(13)	A	Screened out. Internal flooding is not a vulnerability.
105	Internal flooding improvements at Fort Calhoun	Prevention or mitigation of 1)A rupture in the RCP seal cooler of the CCW system, 2)An ISLOCA in a shutdown cooling line, 3)An AFW flood involving the need to possibly remove a watertight door. For a plant where any of these apply, would reduce flooding risk.	(13)	A	Screened out. Internal flooding is not a vulnerability.
106	Digital feedwater upgrade	Reduces chance of loss of MFW following a plant trip.	(13)	B	Screened out. Upgrade already exists at MPS2.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
107	Perform surveillances on manual valves used for backup AFW pump suction	Improves success probability for providing alternate water supply to AFW pumps.	(13)	B	Screened out. AFW valves are cycled every refueling outage.
108	Install manual isolation valves around AFW turbine driven steam admission valves	Reduces the dual turbine driven pump maintenance unavailability.	(13)	A	Screened out. Based on current plant configuration i.e. plant only has one Terry Turbine. Electric isolation valves are DC operated MOVs operated from the Control Room.
109	Install accumulators for turbine driven AFW pump flow control valves	Provide control air accumulators for the turbine driven AFW flow control valves, the motor driven AFW pressure control valves, and S/G PORVs. This would eliminate the need for local manual action to align nitrogen bottles for control air during a LOP.	(11)	B	Screened out. Back-up air bottles are connected to the air operators.
110	Install a new Auxiliary Feedwater Storage Tank	Either replace old tanks with larger ones, or install another backup tank.	(13), (16), (17)	B	Screened out. Makeup to the tank is possible.
111	Cooling of steam driven AFW pump in a SBO	1)Use firewater to cool pump, or 2)Make the pump self-cooled. Would improve success chances in a SBO.	(13)	B	Screened out. MPS2 steam driven AFW pump is self cooled by the water that is being pumped.
112	Proceduralize local manual operation of AFW when control power is lost	Lengthen AFW availability in SBO. Also provides a success path should AFW control power be lost in non-SBO sequences.	(13)	B	Screened out. Procedure already exists.
113	Provide portable generators to be hooked in to the turbine driven AFW, after battery depletion	Extend AFW availability in a SBO (assuming the turbine-driven AFW requires DC power). Procedure is in place to do it manually.	(16), (17)	B	Screened out. Procedure EOP-2530 is in place to perform this task manually in lieu of installing a portable generator to the TDAFW system.
114	Add a motor train of AFW to the steam trains.	For PWRs that do not have any motor trains of AFW, this can increase reliability in non-SBO sequences.	(13)	B	Screened out. MPS2 has 2 MD AFW pumps.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
115	Create ability for emergency connections of existing or alternate water sources to feedwater/condensate	Would be a backup water supply for the feedwater/condensate systems.	(12)	B	Screened out. City water provides makeup to the CST. In addition Fire Water is piped to the suction of the MD and TDAF pumps.
116	Use firewater as a backup for steam generator inventory	Would create a backup to main and auxiliary feedwater for steam generator water supply.	(13)	B	Screened out. Firewater is already a backup for SG inventory. In addition Fire Water is piped to the suction of the MD and TDAF pumps.
117	Procure a portable diesel pump for isolation condenser makeup	Backup to the city water supply and diesel fire water pump in providing isolation condenser makeup.	(13)	A	Screened out. Not applicable at MPS2. For BWRs only.
118	Install an independent diesel for the condensate storage tank makeup pumps	Would allow continued inventory in CST during a SBO.	(13)	A	Screened out. MPS2 uses fire water tanks that have a direct hookup to the AFW pump suction point.
119	Change failure position of condenser makeup valve.	If the condenser makeup valve fails open on loss of air or power, this can cause CST flow diversion to condenser. Allows less inventory for the AFW pumps.	(13)	A	Screened out. The Condenser make-up valve, 2-CN-221 is a "Fails Closed" air operated valve.
120	Create passive secondary side coolers	Provide a passive heat removal loop with a condenser and heat sink. Would reduce CDF from the loss of feedwater.	(17)	B	Screened out. Since the ADVs and the main steam dump valves are available for secondary side heat removal, a passive secondary side cooler would be an additional means of meeting the RCS decay heat removal safety function and, hence, of minimal benefit.
121	Automate air bottle swap for S/G PORVs	Manual action is required to swap air source to the air bottles. Automatic swap on low pressure would eliminate the operator action.	Suggested by the VA Power PRA staff or from the review of the top 100 cutsets	A	Screened out. No air bottles are used to perform this function for the atmospheric dump valves (SG PORV's) at MPS2. Instrument air is used for this function.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
122	Condenser dump after SI	Utilize bypass around the main steam trip valves to use the condenser dump after an SI (the PRA assumes the function can not be recovered after an SI signal).		B	Screened out. This feature already exists at MP2.
123	Provide capability for diesel driven, low pressure vessel makeup	Extra water source in sequences in which the reactor is depressurized and all other injection is unavailable (e.g., firewater).	(4), (5), (13)		Not initially screened. Considered further in the cost benefit analysis.
124	Provide an additional high pressure injection pump with independent diesel	Reduce frequency of core melt from small LOCA sequences, and from SBO sequences.	(6), (16), (17)		Not initially screened. Considered further in the cost benefit analysis.
125	Install independent AC high pressure injection system	Would allow make up and feed and bleed capabilities during a SBO.	(11)		Not initially screened. Considered further in the cost benefit analysis. Subsumed into "Provide an additional high pressure injection pump with independent diesel."
126	Create the ability to manually align ECCS recirculation	Provides a backup should automatic or remote operation fail.	(12)	B	Screened out. This feature already exists. No further action is required for this mod.
127	Implement an RWST makeup water source.	Decrease core damage frequency from ISLOCA scenarios, some smaller break LOCA scenarios, and SGTR. An additional RWST makeup water source would enhance longterm cooling of the core and containment.	(12), (13)		Not initially screened. Considered further in the cost benefit analysis.
128	Stop low pressure injection pumps earlier in medium or large LOCAs	Would give more time to perform recirculation swapover.	(13)	A	Screened out. At MPS2 auto swapover is used and therefore there is plenty of time to perform the swapover process.
129	Emphasize timely recirc swapover in operator training	Reduce human error probability of recirculation failure.	(13)	A	Screened out. At MPS2 auto swapover is used.
130	Upgrade CVCS to mitigate small LOCAs	For a plant like the AP600 where CVCS can't mitigate small LOCA, an upgrade would decrease CDF from small LOCA.	(8)	A	Screened out. Not applicable for MPS2
131	Install an active high pressure SI system	For a plant like the AP600, where an active high pressure injection system does not exist, would add redundancy in high pressure injection.	(8)	A	Screened out. Not applicable for MPS2

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
132	Change "in-containment" RWST suction from 4 check valves to 2 check and 2 air operated valves	Remove common mode failure of all four injection paths.	(8)	A	Screened out. Not applicable for MPS2
133	Replace two of the four safety injection pumps with diesel pumps	Intended for System 80+, which has four trains of SI. This would reduce common cause failure probability.	(16), (17)	A	Screened out. Not applicable for MPS2
134	Align LPCI or core spray to CST on loss of supp pool cooling	Low pressure ECCS can be maintained in loss of suppression pool cooling scenarios.	(10), (13)	A	Screened out. Not applicable for MPS2. Applies to a BWR design.
135	Raise HPCI/RCIC backpressure trip setpoints	Ensures HPCI/RCIC availability when high suppression pool temperatures exist.	(13)	A	Screened out. Not applicable for MPS2. Applies to a BWR design.
136	Improve the reliability of the ADS	Reduce frequency high pressure core damage sequences.	(4)	A	Screened out. Not applicable for MPS2. Applies to a BWR design.
137	Disallow automatic vessel depressurization in non-ATWS scenarios	Improve operator control of plant.	(13)	A	Screened out. Not applicable for MPS2
138	Create automatic swapover to recirculation on RWST depletion	Would remove human error contribution from recirculation failure.	(5), (6), (11)	B	Screened out. Already exists at MPS2.
139	Enlarge the RWST	Greater water capacity for injection.		B	Screened out. MPS2 already has ample capacity of water in the RWST.
140	Modify EOPs for ability to align diesel power to more air compressors.	For plants which do not have diesel power to all normal and backup air compressors, this change allows increased reliability of instrument air after a LOP.	(13)	B	Screened out. MP2 has backup instrument air from MP3.
141	Replace old air compressors with more reliable ones.	Improve reliability and increase availability of instrument air compressors.	(13)	A	Screened out. Current instrument air compressors are considered reliable.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
142	Install Nitrogen bottles as backup gas supply for SRVs	Extend operation of Safety Relief Valves during SBO and loss of air events (BWRs).	(13)	A	Screened out. Not applicable for MPS2
143	Install MG set trip breakers in control room	Provides trip breakers for the motor generator sets in the control room. Currently, at Watts Bar, an ATWS would require an immediate action outside the control room to trip the MG sets. Would reduce ATWS CDF.	(11)	B	Screened out. Already exists at MPS2.
144	Add capability to remove power from the bus powering the control rods	Decrease time to insert control rods if the reactor trip breakers fail (during a loss of feedwater ATWS which has rapid pressure excursion).	(13)	B	Screened out. Already exists at MPS2.
145	Create cross-connect ability for standby liquid control (SLC) trains	Improved reliability for boron injection during ATWS.	(13)	A	Screened out. Not applicable for MPS2. Applies to a BWR design.
146	Create an alternate boron injection capability (backup to SLC)	Improved reliability for boron injection during ATWS.	(13)	A	Screened out. Not applicable for MPS2. Applies to a BWR design.
147	Remove or allow override of LPCI injection during ATWS	On failure of HPCI and condensate, the Susquehanna units direct reactor depressurization followed by 5 minutes of automatic LPCI injection. Would allow control of LPCI immediately.	(13)	A	Screened out. Not applicable for MPS2. Applies to a BWR design.
148	A system of relief valves that prevents any equipment damage from a pressure spike during an ATWS	Would improve equipment availability after an ATWS.	(16), (17)	A/B	Screened out. Overpressure concerns are more applicable for a BWR design. A PWR design like MPS2 has safety relief valves on the pressurizer to prevent equipment damage.
149	Create a boron injection system to back up the mechanical control rods.	Provides a redundant means to shut down the reactor.	(16), (17)	B	Screened out. Already exists at MPS2.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
150	Provide an additional I&C system (e.g., AMSAC).	Improve I&C redundancy and reduce ATWS frequency.	(16), (17)	MP2 has an ATWS system in place but not AMSAC.	Not initially screened. Considered further in the cost benefit analysis. The ATWS system only trips the plant i.e. drops rods and starts the AFW pumps. AMSAC will in addition to the above, also trip the turbine.
151	Provide capability for remote operation of secondary side PORVs in SBO	Manual operation of these valves is required in a SBO scenario. High area temperatures may be encountered in this case (no ventilation to main steam areas), and remote operation could improve success probability.	(2)	B	Screened out. Manual operation of the ADVs is required during an SBO event. Since the contribution of SBO to the CDF is about 3%, the benefit of this SAMA is expected to be minimal.
152	Create/enhance reactor coolant system depressurization ability	Either with a new depressurization system, or with existing PORVs, head vents and secondary side valve, RCS depressurization would allow low pressure ECCS injection. Even if core damage occurs, low RCS pressure alleviates some concerns about high pressure melt ejection.	(5), (6), (9), (11), (12), (13), (14), (15), (16), (17)	A	Screened out. HPME and DCH are no longer containment challenged.
153	Make procedural changes only for the RCS depressurization option	Reduce RCS pressure without cost of a new system.	(7), (9), (13)	B	Screened out. Procedures for RCS depressurization are already in place.
154	Defeat 100% load rejection capability	Eliminates the possibility of a stuck open PORV after a LOP, since PORV opening wouldn't be needed.	(13)	A	Screened out. This item is not applicable to MPS2, since MPS2 does not have 100% load rejection capability.
155	Change CRD flow control valve failure position	Change failure position to the 'fail-safest' position.	(13)	A	Screened out. Applies to a BWR.
156	Secondary side guard pipes up to the MSIVs.	Would prevent secondary side depressurization should a steam line break occur upstream of the MSIVs. Would also guard against or prevent consequential multiple SGTR following a main steam line break event.	(16), (17)	B	Screened out. Nuclear grade piping already exists upstream of the MSIV's.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
157	Digital large break LOCA protection	Upgrade plant instrumentation and logic to improve the capability to identify symptoms/precursors of a large break LOCA (a leak before break).	(17)	A	Screened out. Large break LOCA has a low initiating event frequency (viewed as a "rare event" by most PRAs). Its contribution to CDF is also small and, hence, does not justify upgrading plant instrumentation and logic to improve the ability to identify symptoms/precursors of a large break LOCA (i.e., a leak before break) beyond what currently exists at the plant.
158	Increase seismic capacity of the plant to a HCLPF of twice the SSE	Reduced seismic CDF to a high confidence low probability failure (HCLPF) of twice the safe shutdown earthquake (SSE).	(17)	A	Screened out. Not a concern for MPS2 since it is located in a low seismic activity area. The seismic contribution to CDF is small for MPS2. This improvement is intended for a new design, not an existing one.
159	Install turbine driven AF pump	Additional TDAFW pump would provide a backup to existing pump.	(21)		Not initially screened. Considered further in the cost benefit analysis.
160	Create an independent RCP seal cooling system, with dedicated diesel	This modification would prevent RCP seal failure given the affected RCP(s) have been tripped.			Subsumed by SAMA 10
161	Install redundant isolation valves on pressurizer PORV.	Isolation valves would provide capability to isolate stuck open PORV on the pressurizer.	(21)	B	Screened out. Have MOV block valves.
162	Install additional RBCCW pump.	An additional RBCCW pump will provide redundancy should an existing pump fail.	(21)	B	Screened out. Have an installed spare RBCCW pump.
163	Add a 4th RBCCW pump of different design.	A 4th RBCCW of different design would protect against CCF of existing 3 pumps.	(21)	B	Screened out. Minimal benefit since common cause failure of the RBCCW pumps is already low.
164	Install redundant Feed Breaker (similar to D0103/D0203) to 125VDC vital facility bus.	An additional Feed Breaker would improve the reliability of the vital facility bus.	(21)	B	Screened out. Breaker reliability improvement program is in place.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
165	Install independent RBCCW/ESFRS AOV similar to 2-RB-68.1A	An additional RBCCW/ESFRS AOV would improve the reliability of cooling water for SFGD room cooling.	(21)		Not initially screened. Considered further in the cost benefit analysis.
166	Install additional MD AFW pump	Provides redundancy in case existing MD AFW pump fails.	(21)		Not initially screened. Considered further in the cost benefit analysis.
167	Automate feed and bleed.	This would enhance the manual operation performed by operator.	(21)	B	Screened out. The determination of whether feed and bleed (F*B) is required is dependent upon many plant conditions and is highly unlikely to ever be utilized by the Control Room Operators. The manual actions to initiate F&B cooling are reasonably simple and proceduralized. Contrary to the recommendation of this SAMA, automating F&B initiation based on plant conditions introduces the potential for a LOCA via a stuck-open PORV. Hence, this SAMA is not beneficial.
168	Provide training for feed and bleed use.	To lower the human error probability of 1E-1.	(21)	B	Screened out. Operators have already been extensively trained on once-through cooling per E37-010C, EOP2537 and E37-01-S, EOP2537 so additional training will make little improvement.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
169	Automate makeup to CST	Automatic feature would provide backup to the manual operation.	(21)	B	Screened out. MP2 has capability of automated makeup to the CST via Ionics (which is the name of the water treatment vendor). However, this capability is not available in the event of a loss of AC power (powered from the Flanders line). In addition, if this makeup capability is unavailable, the Millstone Station Emergency Response Organization (SERO) would develop an accident management strategy for makeup to the CST via the fire water system (where the fire water can be aligned to the AFW pump suction should the CST inventory be depleted). Hence, this recommended SAMA is of minimal benefit to the plant.
170	Install redundant parallel valve equivalent to 2-CS-16.1A and 1B.	These additional parallel valves would provide additional flow path for the CS and HPSI pumps during containment swapover in recirculation mode. These valves are assumed FTO.	(21)		Not initially screened. Considered further in the cost benefit analysis.
171	Automate LPSI/HPSI mini-flow line valve position.	Operator fails to position the SI pump mini-flow line valves to operate.	(21)	B	Screened out. Flow diversion via the mini-flow line is small and is not expected to impact CDF.
172	Add a redundant 125VDC bus equivalent to bus 201A and 201B.	Loss of 125VDC Bus 201A or 201B.	(21)		Not initially screened. Considered further in the cost benefit analysis.
173	Install redundant diverse bypass valve around AOV's SW-8.1A/B/C	CCF of 2/3 SW AOV's SW-8.1A/B/C to open RBCCW FCV's.	(21)		Not initially screened. Considered further in the cost benefit analysis.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
174	Install redundant valve in line for backup to valve RB-8.1A/B	Air operated valves RB-8.1A/B fail to close due to mechanical failure.	(21)		Not initially screened. Considered further in the cost benefit analysis.
175	Install redundant diverse bypass valve equivalent to 2-CS-16.1A/B.	CCF of 2/2 CS MOV's 2-CS-16.1A&B to open on demand.	(21)		Not initially screened. Considered further in the cost benefit analysis.
176	Install additional SW AOV similar to SW-8.1A to provide a reliable flowpath.	SW AOV SW-8.1A fails to operate.	(21)		Not initially screened. Considered further in the cost benefit analysis.
177	Install MOV isolation valves for HPSI, CS and LPI mini flow.	CCF of 2/2 mini flow isolation AOV's 2-SI-659 and 660 to close.	(21)	B	Screened out. SI minimum flow isolation is important post-LOCA following SRAS to isolate a potential release path for containment sump water to the environment via the RWST. However for this to occur, several air-operated valves in series (that rely on accumulators and backup air bottles to keep closed) will have to fail open. Hence, adding additional MOV(s) to this line would not be beneficial.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
178	Install redundant valve equivalent to RB-210 to assure isolation from primary drain tank.	Air operated valve RB-210 fails to close due to mechanical failure.	(21)	B	Screened out. Valve 2-RB-210 is a valve that isolates RBCCW flow from the primary sample coolers and the degasifier upon receipt of a SIAS, not the primary drain tank as noted in the SAMA. Currently, there is no automatic isolation of the primary drain tank on the "A" RBCCW header. With respect to the isolation of RBCCW flow from the primary sample coolers and the degasifier following a SIAS, there would be no benefit to adding additional isolation redundancy. The post accident RBCCW flow through this flow path would be approximately 300 gpm should the valve fail to close on a SIAS. This additional flow would not jeopardize either containment integrity or the "B" RBCCW header operation.
179	Automate RCP trip circuitry on loss of seal cooling.	Operator fails to trip the RCP's.	(21)		Not initially screened. Considered further in the cost benefit analysis.
180	Install backup 125VDC ventilation.	Operator fails to recover 125VDC ventilation.	(21)	B	Screened out. If needed, the plant EOPs direct the operators to maintain DC switchgear cooling by opening an outside door. Hence, this SAMA would not be beneficial to the plant.
181	Install a bypass line around SW-8.1C to provide additional flow capability.	SW AOV SW-8.1C fails to open.	(21)	B	Screened out. There are 6" bypass lines around SW-8.1A/C.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
182	Automate the start and alignment of the RBCCW pump.	Operator fails to manually start and align available pump.	(21)		Not initially screened. Considered further in the cost benefit analysis.
183	Automate isolation feature of faulted SG.	Operator fails to isolate faulted SG.	(21)		Not initially screened. Considered further in the cost benefit analysis.
184	Install redundant AFW Reg valve following Reg valve FTO.	Operator fails to open AFW reg valve bypass following reg valve FTO.	(21)		Not initially screened. Considered further in the cost benefit analysis.
185	Install redundant ESFRS fan equivalent to F-15B.	ESFRS Fan F-15B OOS for maintenance.	(21)		Not initially screened. Considered further in the cost benefit analysis.
186	Install diverse strainers L-1A, B, C to all 3 SW pump discharge lines to prevent CCF.	CCF of strainers L-1A, B and C to operate.	(21)		Not initially screened. Considered further in the cost benefit analysis.
187	Automate start capability of Terry Turbine.	Operator fails to start the Terry Turbine.	(21)		Not initially screened. Considered further in the cost benefit analysis.
188	Install more reliable reactor control rod assembly or a diverse boron injection system.	Reactor trip fails due to mechanical rod binding.	(21)	B	Screened out. ATWS contribution to CDF is small.
189	Automate emergency boration of RCS.	Operator fails to initiate emergency boration.	(21)		Not initially screened. Considered further in the cost benefit analysis.
190	Install redundant line to RWST equivalent to 2-CH-192.	RWST isolation valve 2-CH-192 fails to open on demand.	(21)		Not initially screened. Considered further in the cost benefit analysis.
191	Add additional AFW bypass line with diverse reg valve to protect against CCF of existing valves 2-FW-43A and 43B.	CCF to open AFW reg valves 2-FW-43A and 2-FW-43B.	(21)		Not initially screened. Considered further in the cost benefit analysis.

Table F.3-1.
Initial List Of Candidate Improvements For The MPS2 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section F.3.1)	Screening criterion or grouping (see Section F.3.2)	Evaluation
192	Install additional MOV on VCT outlet line similar to MOV-CH-501 for closure to assure boric acid flow to charging pump.	MOV CH-501 fails to close on demand.	(21)		Not initially screened. Considered further in the cost benefit analysis.
193	Install additional AFW bypass line with diverse check valves and reg valves similar to check valves 2-FW-12A and 2-FW-12B and reg valves 2-FW-43A and 43B to SG's.	AFW reg valve 2-FW-43A and air operated valve 2-FW-43B fails to open on demand. Also CCF to open of check valves 2-FW-12A and 2-FW-12B.	(21)		Not initially screened. Considered further in the cost benefit analysis.
194	Install additional MD AFW pump	This modification will mitigate the condition when operator fails to align condensate system for decay heat removal.			Subsumed by SAMA 166.
195	Add additional MOV around valves 2-RB-68.1A&B.	CCF of 2/2 RBCCW 2-RB-68.1A&B AOVs to open.	(21)		Not initially screened. Considered further in the cost benefit analysis.
196	Install redundant ADV control and power supply circuitry.	Loss of local manual operation of an atmospheric dump valve (ADV).	(21)	B	Screened out. ADVs have a redundant system called Steam Dump Valves (SDVs) to the main condenser.

Table F.3-2.
Summary Of MPS2 SAMAS Considered In Cost-benefit Analysis.

SAMA Number	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
3	Enhance Loss of RBCCW procedure to ensure cool down of RCS prior to seal LOCA	Potential reduction in the probability of RCP seal failure. The RBCCW provides seal, thermal barrier, upper and lower bearing cooling for the RCP's	7.77%	4.86%	$173,337	<2 x Benefit	Screen In	Estimate Range: $100,000 - $200,000 Cost beneficial, since benefit is within estimated cost range.
8	Eliminate RCP thermal barrier dependence on RBCCW, such that loss of RBCCW does not result directly in core damage.	Would prevent loss of RCP seal integrity after a loss of RBCCW. Watts Bar IPE said this could be done with SW connection to charging pump seals. **Notes:** Assumes separate cooling train	6.89%	4.56%	$155,543	>2 x Benefit	Screen out	Estimate Range: $5M - $8M Not cost beneficial: since cost is greater than twice the benefit.
10	Create an independent RCP seal cooling system, with dedicated diesel	Would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of seal cooling or SBO. **Notes:** Based on ranges for similar projects inside Containment	5.99%	3.94%	$135,409	>2 x Benefit	Screen out	Estimate Range: $6M - $10M Not cost beneficial: since cost is greater than twice the benefit.
11	Create an independent RCP seal cooling system, without dedicated diesel	Would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of seal cooling, but not SBO.	5.99%	3.94%	$135,409	>2 x Benefit	Screen out	Estimate Range: $5M - $8M Not cost beneficial: since cost is greater than twice the benefit.
22	Improve ability to cool RHR heat exchangers	Reduced chance of loss of RHR by 1)Performing procedure and hardware modification to allow manual alignment of fire protection system to the RBCCW system, or 2)Installing a RBCCW header cross-tie	0.29%	0.33%	$7,321	>2 x Benefit	Screen out	Estimate Range: $2.5M - $5M Not cost beneficial: since cost is greater than twice the benefit.
34	Install a containment vent large enough to remove ATWS decay heat	Assuming injection is available, would provide alternative decay heat removal in an ATWS.	9.93%	4.01%	$204,311	>2 x Benefit	Screen out	Estimate Range: $10M - $15M Not cost beneficial: since cost is greater than twice the benefit.
35	Install a filtered containment vent to remove decay heat	Assuming injection is available (non-ATWS sequences), would provide alternate decay heat removal with the released fission products being scrubbed.	16.23%	16.04%	$414,336	>2 x Benefit	Screen out	Estimate Range: $12M - $18M Not cost beneficial: since cost is greater than twice the benefit.

Table F.3-2.
Summary Of MPS2 SAMAS Considered In Cost-benefit Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
36	Install an unfiltered hardened containment vent.	Provides an alternate decay heat removal method (non-ATWS), which is not filtered.	16.23%	16.04%	$414,336	>2 x Benefit	Screen out	Estimate Range: $10M - $15M Not cost beneficial: since cost is greater than twice the benefit.
43	Create a reactor cavity flooding system	Would enhance debris coolability, reduce core concrete interaction and provide fission product scrubbing.	0.00%	16.41%	$84,732	>2 x Benefit	Screen out	Estimate Range: $18M - $24M Not cost beneficial: since cost is greater than twice the benefit.
44	Creating other options for reactor cavity flooding	Flood cavity via systems such as diesel driven fire pumps.	0.00%	16.41%	$84,732	>2 x Benefit	Screen out	Estimate Range: $18M - $24M Not cost beneficial: since cost is greater than twice the benefit.
75	Create a water backup for diesel cooling.	Provides redundant source of diesel cooling. **Notes:** Assumes sound water	1.51%	2.83%	$44,593	>2 x Benefit	Screen out	Estimate Range: $10M - $20M Not cost beneficial: since cost is greater than twice the benefit.
77	Provide a connection to alternate offsite power source (the nearby dam).	Increaseoffsitepowerredundancy **Notes:** Assumes dedicated poles & overhead HV line approx 20 miles to Hydro facility at Norwich via existing right of ways. Includes transformers, breakers, etc. Assumes all necessary right of ways exist no clearing or access fees required.	8.29%	13.94%	$234,886	>2 x Benefit	Screen out	Estimate Range: $6M - $10M Not cost beneficial: since cost is greater than twice the benefit.
81	Install a fast acting MG output breaker	With a fast acting breaker, a turbine runback would be possible, reducing the likelihood of a reactor trip in some cases.	1.04%	1.71%	$29,224	>2 x Benefit	Screen out	Estimate Range: $3M - $8M Not cost beneficial: since cost is greater than twice the benefit.
87	Replace steam generators with new design	Lower frequency of SGTR **Notes:** Based on actual costs from Unit 2 replacement $200M actual	2.99%	12.69%	$126,876	>2 x Benefit	Screen out	Estimate Range: $200M - $250M Not cost beneficial: since cost is greater than twice the benefit.

Table F.3-2.
Summary Of MPS2 SAMAS Considered In Cost-benefit Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
93	Install additional instrumentation and inspection to prevent ISLOCA sequences.	Install additional instrumentation for detecting ISLOCA events. Implement a comprehensive piping inspection program to detect precursors to breaches in RCS integrity. The benefit assumes that the programs are so effective all ISLOCAs are eliminated.	0.15%	2.40%	$22,082	>2 x Benefit	Screen out	Estimate Range: $12M - $18M Not cost beneficial: since cost is greater than twice the benefit.
94	Increase frequency of valve leakage testing.	Decrease ISLOCA frequency.	0.15%	2.40%	$22,082	>2 x Benefit	Screen out	Estimate Range: $2M - $4M Cost per refueling outage. Not cost beneficial: since cost is greater than twice the benefit.
99	Ensure all ISLOCA releases are scrubbed	Would scrub ISLOCA releases. One suggestion was to plug drains in the break area so the break point would cover with water.	0.15%	2.40%	$22,082	>2 x Benefit	Screen out	Estimate Range: $4M - $6M Not cost beneficial: since cost is greater than twice the benefit.
100	Add redundant and diverse limit switch to each containment isolation valve.	Enhanced isolation valve position indication, which would reduce frequency of containment isolation failure and ISLOCAs.	0.15%	2.40%	$28,707	>2 x Benefit	Screen out	Estimate Range: $18M - $24M Not cost beneficial: since cost is greater than twice the benefit.
123	Provide capability for diesel driven, low pressure vessel makeup	Extra water source in sequences in which the reactor is depressurized and all other injection is unavailable (e.g., firewater)	0.00%	0.00%	$0	>2 x Benefit	Screen out	Estimate Range: $7.5M - $12M Not cost beneficial: since cost is greater than twice the benefit.
124/125	Provide an additional high pressure injection pump with independent diesel	Reduce frequency of core melt from small LOCA sequences, and from SBO sequences.	10.48%	13.03%	$286,137	>2 x Benefit	Screen out	Estimate Range: $10M - $16M Not cost beneficial: since cost is greater than twice the benefit.
127	Implement an RWST makeup procedure	Decrease core damage frequency from ISLOCA scenarios, some smaller break LOCA scenarios, and SGTR	0.21%	0.50%	$7,356	>2 x Benefit	Screen out	Estimate Range: $50,000 - $100,000 Not cost beneficial: since cost is greater than twice the benefit.

Table F.3-2.
Summary Of MPS2 SAMAS Considered In Cost-benefit Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
150	Provide an additional I&C system (e.g., AMSAC).	Improve I&C redundancy and reduce ATWS frequency. Currently MPS2 only has the ATWS system in place. The ATWS system only trips the plant i.e. drops rods and starts the AFW pumps. AMSAC in addition to the above will also trip the main turbine. **Notes:** Assumes DCP to add controls and interlocks	8.66%	3.45%	$177,909	>2 x Benefit	Screen out	Estimate Range: $600,000 - $2M Not cost beneficial: since cost is greater than twice the benefit.
159	Install turbine driven AF pump	Additional TDAFW pump would provide a backup to existing pump.	8.04%	5.07%	$178,128	>2 x Benefit	Screen out	Estimate Range: $12M - $16M Not cost beneficial: since cost is greater than twice the benefit.
165	Install independent RBCCW/ESFRS AOV similar to 2-RB-68.1A	An additional RBCCW/ESFRS AOV would improve the reliability of cooling water for SFGD room cooling.	0.15%	0.32%	$4,912	>2 x Benefit	Screen out	Estimate Range: $4M - $6M Not cost beneficial: since cost is greater than twice the benefit.
166	Install additional MD AFW pump	Provides redundancy in case existing MD AFW pump fails.	2.24%	1.12%	$47,403	>2 x Benefit	Screen out	Estimate Range: $12M - $16M Not cost beneficial: since cost is greater than twice the benefit.
170	Install redundant parallel valve equivalent to 2-CS-16.1A.	This additional parallel valve would provide additional flow path for the CS and HPSI pumps during containment swapover in recirculation mode. **Notes:** Assumes DCP, valve, piping	6.00%	5.28%	$146,859	>2 x Benefit	Screen out	Estimate Range: $2M - $5M Not cost beneficial: since cost is greater than twice the benefit.
172	Add a redundant 125VDC bus equivalent to bus 201A and 201B.	Loss of 125VDC Bus 201A or 201B	0.14%	0.26%	$4,070	>2 x Benefit	Screen out	Estimate Range: $5M - $8M Not cost beneficial: since cost is greater than twice the benefit.
173	Install diverse bypass valve around AOV's SW-8.1A/B/C	CCF of 2/3 SW AOV's SW-8.1A/B/C to open **Notes:** Assumes DCP, valve, piping	8.01%	4.64%	$175,003	>2 x Benefit	Screen out	Estimate Range: $1M - $3M Not cost beneficial: since cost is greater than twice the benefit.

Table F.3-2.
Summary Of MPS2 SAMAS Considered In Cost-benefit Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
174	Install redundant valve in line for backup to valve RB-8.1A/B	Air operated valves RB-8.1A/B fail to close due to mechanical failure	3.38%	2.09%	$74,872	>2 x Benefit	Screen out	Estimate Range: $2M - $4M Not cost beneficial: since cost is greater than twice the benefit.
175	Install redundant diverse bypass valve equivalent to 2-CS-16.1A/B.	CCF of 2/2 CS MOV's 2-CS-16.1A&B to open on demand **Notes:** Assumes DCP, valve, piping	13.79%	12.16%	$338,405	>2 x Benefit	Screen out	Estimate Range: $1.5M - $3.5M Not cost beneficial: since cost is greater than twice the benefit.
176	Install additional SW AOV similar to SW-8.1A to provide a reliable flowpath.	SW AOV SW-8.1A fails to operate	2.21%	1.33%	$48,635	>2 x Benefit	Screen out	Estimate Range: $3M - $5M Not cost beneficial: since cost is greater than twice the benefit.
179	Automate RCP trip circuitry on loss of seal cooling.	Operator fails to trip the RCP's.	5.99%	3.94%	$135,409	>2 x Benefit	Screen out	Estimate Range: $3M - $5M Not cost beneficial: since cost is greater than twice the benefit.
182	Automate the start and alignment of the RBCCW pump.	Operator fails to manually start and align available pump. **Notes:** Assumes DCP, controls modifications	0.00%	0.00%	$0	>2 x Benefit	Screen out	Estimate Range: $1M - $3M Not cost beneficial: since cost is greater than twice the benefit.
183	Automate isolation feature of faulted SG.	Operator fails to isolate faulted SG.	1.33%	0.56%	$27,418	>2 x Benefit	Screen out	Estimate Range: $5M - $7M Not cost beneficial: since cost is greater than twice the benefit.
184	Install redundant AFW Reg valve following Reg valve FTO.	Operator fails to open AFW reg valve bypass following reg valve FTO. **Notes:** Assumes DCP, valve, piping	0.74%	0.42%	$15,947	>2 x Benefit	Screen out	Estimate Range: $2M - $5M Not cost beneficial: since cost is greater than twice the benefit.
185	Install redundant ESFRS fan equivalent to F-15B.	ESFRS Fan F-15B OOS for maintenance. **Notes:** Assumes DCP, procedures, new 15hp Safety Related fan, dampers, controls to Main Control Room. -	0.15%	0.32%	$4,857	>2 x Benefit	Screen out	Estimate Range: $450K - $650K Not cost beneficial: since cost is greater than twice the benefit.

Table F.3-2.
Summary Of MPS2 SAMAS Considered In Cost-benefit Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
186	Install diverse strainers L-1A, B, C to all 3 SW pump discharge lines to prevent CCF.	CCF of strainers L-1A, B and C to operate. **Notes:** Assumes DCP, 3 SS strainers, large piping mods, etc.	0.49%	0.70%	$13,185	>2 x Benefit	Screen out	Estimate Range: $2M - $4M Not cost beneficial: since cost is greater than twice the benefit.
187	Automate start capability of Terry Turbine.	Operator fails to start the Terry Turbine.	0.15%	0.28%	$4,477	>2 x Benefit	Screen out	Estimate Range: $1.5M - $3M Not cost beneficial: since cost is greater than twice the benefit.
189	Automate emergency boration of RCS.	Operator fails to initiate emergency boration.	0.88%	0.46%	$18,736	>2 x Benefit	Screen out	Estimate Range: $2M - $4M Not cost beneficial: since cost is greater than twice the benefit.
190	Install redundant line to RWST equivalent to 2-CH-192.	RWST isolation valve 2-CH-192 fails to open on demand. **Notes:** Assumes DCP, piping, valve, controls, etc.	1.03%	0.53%	$22,063	>2 x Benefit	Screen out	Estimate Range: $1M - $3M Not cost beneficial: since cost is greater than twice the benefit.
191	Add additional AFW bypass line with diverse reg valve to protect against CCF of existing valves 2-FW-43A and 43B.	CCF to open AFW reg valves 2-FW-43A and 2-FW-43B. **Notes:** Assumes DCP, piping, valves, etc.	0.74%	0.42%	$15,947	>2 x Benefit	Screen out	Estimate Range: $1M - $3M Not cost beneficial: since cost is greater than twice the benefit.
192	Install additional MOV on VCT outlet line similar to MOV-CH-501 for closure to assure boric acid flow to charging pump.	MOV CH-501 fails to close on demand.	0.73%	0.40%	$15,540	>2 x Benefit	Screen out	Estimate Range: $2M - $4M Not cost beneficial: since cost is greater than twice the benefit.
193	Install additional AFW bypass line with diverse check valves and reg valves similar to check valves 2-FW-12A and 2-FW-12B and reg valves 2-FW-43A and 43B to SG's.	AFW reg valve 2-FW-43A and air operated valve 2-FW-43B fails to open on demand. Also CCF to open of check valves 2-FW-12A and 2-FW-12B. **Notes:** Assumes DCP, piping, valves, controls, instrumentation, etc.	1.03%	0.49%	$21,682	>2 x Benefit	Screen out	Estimate Range: $1M - $3M Not cost beneficial: since cost is greater than twice the benefit.

Table F.3-2.
Summary Of MPS2 SAMAS Considered In Cost-benefit Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
195	Add additional MOV around valves 2-RB-68.1A&B.	CCF of 2/2 RBCCW 2-RB-68.1A&B AOVs to open. **Notes:** Assumes DCP, MOV, piping, and controls	0.35%	0.70%	$11,646	>2 x Benefit	Screen out	Estimate Range: $500,000 - $1.5M Not cost beneficial: since cost is greater than twice the benefit.

Table F.3-3.
MPS2 Sensitivity Analysis Results.

SAMA No.	Potential Improvement	Baseline 2000 Met Data	Case 1 (3%DR)	Case 2 (15%DR)	Case 3 WTFRAC =0.95	Case 4 ESPEED =1.8m/s	Case 5 DLTSHL =9000s	Case 6 CORSCA = Qx1.1	Case 7 1999 Met Data
3	Enhance Loss of RBCCW procedure to ensure cool down of RCS prior to seal LOCA	$173,337	$228,435	$85,773	$173,143	$173,115	$173,675	$175,869	$179,268
8	Eliminate RCP thermal barrier dependence on RBCCW, such that loss of RBCCW does not result directly in core damage.	$155,543	$205,128	$77,137	$155,370	$155,331	$155,870	$157,920	$161,051
10	Create an independent RCP seal cooling system, with dedicated diesel	$135,409	$178,581	$67,158	$135,262	$135,261	$135,624	$137,468	$140,187
11	Create an independent RCP seal cooling system, without dedicated diesel	$135,409	$178,581	$67,158	$135,262	$135,261	$135,624	$137,468	$140,187
22	Improve ability to cool RHR heat exchangers	$7,321	$9,708	$3,693	$7,308	$7,271	$7,409	$7,488	$7,713
34	Install a containment vent large enough to remove ATWS decay heat	$204,311	$267,886	$99,486	$204,103	$203,876	$205,072	$206,328	$209,134
35	Install a filtered containment vent to remove decay heat	$414,336	$550,189	$209,921	$413,988	$414,207	$414,176	$423,129	$433,400
36	Install an unfiltered hardened containment vent.	$414,336	$550,189	$209,921	$413,988	$414,207	$414,176	$423,129	$433,400
43	Create a reactor cavity flooding system	$84,732	$118,401	$49,871	$84,653	$82,125	$89,026	$92,576	$105,627
44	Creating other options for reactor cavity flooding	$84,732	$118,401	$49,871	$84,653	$82,125	$89,026	$92,576	$105,627
75	Create a water backup for diesel cooling.	$44,593	$59,633	$23,087	$44,492	$44,111	$45,434	$46,026	$47,921
77	Provide a connection to alternate offsite power source (the nearby dam).	$234,886	$313,514	$120,907	$234,377	$232,542	$238,980	$241,931	$251,259
81	Install a fast acting MG output breaker	$29,224	$38,987	$15,019	$29,161	$28,934	$29,736	$30,089	$31,239
87	Replace steam generators with new design	$126,876	$173,207	$69,860	$126,870	$126,842	$126,059	$132,916	$139,864

Table F.3-3.
MPS2 Sensitivity Analysis Results. (Cont.)

SAMA No.	Potential Improvement	Baseline 2000 Met Data	Case 1 (3%DR)	Case 2 (15%DR)	Case 3 WTFRAC =0.95	Case 4 ESPEED =1.8m/s	Case 5 DLTSHL =9000s	Case 6 CORSCA = Qx1.1	Case 7 1999 Met Data
93	Install additional instrumentation and inspection to prevent ISLOCA sequences.	$22,082	$30,653	$12,757	$22,048	$22,059	$21,668	$13,135	$23,649
94	Increase frequency of valve leakage testing.	$22,082	$30,653	$12,757	$22,048	$22,059	$21,668	$13,135	$23,649
99	Ensure all ISLOCA releases are scrubbed	$22,082	$30,653	$12,757	$22,048	$22,059	$21,668	$13,135	$23,649
100	Add redundant and diverse limit switch to each containment isolation valve.	$28,707	$39,849	$16,584	$28,662	$28,677	$28,168	$17,076	$30,743
123	Provide capability for diesel driven, low pressure vessel makeup	$0	$0	$0	$0	$0	$0	$0	$0
124/125	Provide an additional high pressure injection pump with independent diesel	$286,137	$381,249	$146,496	$285,839	$285,251	$287,072	$293,446	$302,843
127	Implement an RWST makeup procedure	$7,356	$9,902	$3,885	$7,345	$7,301	$7,435	$7,629	$7,973
150	Provide an additional I&C system (e.g., AMSAC).	$177,909	$233,246	$86,604	$177,729	$177,543	$178,550	$179,646	$182,062
159	Install turbine driven AF pump	$178,128	$234,639	$88,015	$177,922	$177,589	$179,051	$180,729	$184,110
165	Install independent RBCCW/ESFRS AOV similar to 2-RB-68.1A	$4,912	$6,589	$2,567	$4,904	$4,868	$4,987	$5,083	$5,299
166	Install additional MD AFW pump	$47,403	$62,274	$23,225	$47,351	$47,270	$47,630	$47,970	$48,747
170	Install redundant parallel valve equivalent to 2-CS-16.1A.	$146,859	$194,578	$73,894	$146,722	$146,807	$146,900	$149,675	$152,969
172	Add a redundant 125VDC bus equivalent to bus 201A and 201B.	$4,070	$5,440	$2,104	$4,062	$4,025	$4,151	$4,200	$4,367
173	Install diverse bypass valve around AOV's SW-8.1A/B/C	$175,003	$230,324	$86,237	$174,786	$174,698	$175,486	$177,386	$180,806

Table F.3-3. MPS2 Sensitivity Analysis Results. (Cont.)

SAMA No.	Potential Improvement	Baseline 2000 Met Data	Case 1 (3%DR)	Case 2 (15%DR)	Case 3 WTFRAC =0.95	Case 4 ESPEED =1.8m/s	Case 5 DLTSHL =9000s	Case 6 CORSCA = Qx1.1	Case 7 1999 Met Data
174	Install redundant valve in line for backup to valve RB-8.1A/B	$74,872	$98,619	$36,989	$74,780	$74,743	$75,072	$75,950	$77,483
175	Install redundant diverse bypass valve equivalent to 2-CS-16.1A/B.	$338,405	$448,413	$170,332	$338,100	$338,345	$338,392	$344,901	$352,420
176	Install additional SW AOV similar to SW-8.1A to provide a reliable flowpath.	$48,635	$64,040	$24,002	$48,575	$48,561	$48,750	$49,317	$50,291
179	Automate RCP trip circuitry on loss of seal cooling.	$135,409	$178,581	$67,158	$135,262	$135,261	$135,624	$137,468	$140,187
182	Automate the start and alignment of the RBCCW pump.	$0	$0	$0	$0	$0	$0	$0	$0
183	Automate isolation feature of faulted SG.	$27,418	$35,960	$13,363	$27,389	$27,349	$27,538	$27,699	$28,088
184	Install redundant AFW Reg valve following Reg valve FTO.	$15,947	$20,972	$7,838	$15,928	$15,888	$16,052	$16,159	$16,445
185	Install redundant ESFRS fan equivalent to F-15B.	$4,857	$6,515	$2,538	$4,849	$4,812	$4,933	$5,025	$5,235
186	Install diverse strainers L-1A, B, C to all 3 SW pump discharge lines to prevent CCF.	$13,185	$17,547	$6,727	$13,158	$13,071	$13,384	$13,539	$14,018
187	Automate start capability of Terry Turbine.	$4,477	$5,984	$2,314	$4,468	$4,428	$4,566	$4,620	$4,803
189	Automate emergency boration of RCS.	$18,736	$24,621	$9,188	$18,714	$18,677	$18,841	$18,970	$19,291
190	Install redundant line to RWST equivalent to 2-CH-192.	$22,063	$28,997	$10,824	$22,040	$22,003	$22,162	$22,334	$22,698
191	Add additional AFW bypass line with diverse reg valve to protect against CCF of existing valves 2-FW-43A and 43B.	$15,947	$20,972	$7,838	$15,928	$15,888	$16,052	$16,159	$16,445
192	Install additional MOV on VCT outlet line similar to MOV-CH-501 for closure to assure boric acid flow to charging pump.	$15,540	$20,428	$7,628	$15,523	$15,486	$15,637	$15,740	$16,009

Table F.3-3.
MPS2 Sensitivity Analysis Results. (Cont.)

SAMA No.	Potential Improvement	Baseline 2000 Met Data	Case 1 (3%DR)	Case 2 (15%DR)	Case 3 WTFRAC =0.95	Case 4 ESPEED =1.8m/s	Case 5 DLTSHL =9000s	Case 6 CORSCA = Qx1.1	Case 7 1999 Met Data
193	Install additional AFW bypass line with diverse check valves and reg valves similar to check valves 2-FW-12A and 2-FW-12B and reg valves 2-FW-43A and 43B to SG's.	$21,682	$28,466	$10,601	$21,659	$21,619	$21,795	$21,929	$22,267
195	Add additional MOV around valves 2-RB-68.1A&B.	$11,646	$15,648	$6,116	$11,635	$11,602	$11,698	$12,041	$12,512

Table F.3-3.
MPS2 Sensitivity Analysis Results. (Cont'd)

SAMA No.	Potential Improvement	Case 8 1998 MetData	Case 9 PLHITE =2(X)	Case 10 PLDUR =2(X)	Case 11 ESPEED =1.2m/s	Case 12 PLHEAT X-10%	Case 13 STC M9 and M11 = M10	Case 14 Add STC M12	Case 15 Use MP3 STC for M1A
3	Enhance Loss of RBCCW procedure to ensure cool down of RCS prior to seal LOCA	$176,965	$173,203	$173,339	$173,614	$174,046	$173,337	$173,407	$173,407
8	Eliminate RCP thermal barrier dependence on RBCCW, such that loss of RBCCW does not result directly in core damage.	$158,952	$155,466	$155,539	$155,809	$156,170	$155,543	$155,602	$155,602
10	Create an independent RCP seal cooling system, with dedicated diesel	$138,340	$135,399	$135,459	$135,594	$135,904	$135,409	$135,456	$135,456
11	Create an independent RCP seal cooling system, without dedicated diesel	$138,340	$135,399	$135,459	$135,594	$135,904	$135,409	$135,456	$135,456
22	Improve ability to cool RHR heat exchangers	$7,583	$7,267	$7,270	$7,385	$7,418	$7,321	$7,321	$7,321
34	Install a containment vent large enough to remove ATWS decay heat	$207,358	$203,611	$203,936	$204,860	$205,355	$204,311	$204,632	$204,632
35	Install a filtered containment vent to remove decay heat	$426,694	$416,066	$416,387	$414,493	$414,815	$414,336	$414,371	$414,371
36	Install an unfiltered hardened containment vent.	$426,694	$416,066	$416,387	$414,493	$414,815	$414,336	$414,371	$414,371
43	Create a reactor cavity flooding system	$97,294	$78,816	$82,011	$87,799	$88,759	$324,301	$84,732	$84,732
44	Creating other options for reactor cavity flooding	$97,294	$78,816	$82,011	$87,799	$88,759	$324,301	$84,732	$84,732
75	Create a water backup for diesel cooling.	$46,892	$44,154	$44,106	$45,209	$45,261	$44,593	$44,593	$44,593
77	Provide a connection to alternate offsite power source (the nearby dam).	$246,159	$232,719	$232,476	$237,876	$238,168	$234,886	$234,909	$234,909
81	Put a fast acting MG output breaker on both units	$30,607	$28,948	$28,913	$29,596	$29,655	$29,224	$29,224	$29,224
87	Replace steam generators with new design	$135,837	$127,726	$131,899	$126,922	$126,938	$126,876	$126,876	$126,876
93	Install additional instrumentation and inspection to prevent ISLOCA sequences.	$22,624	$22,082	$24,962	$22,105	$22,082	$22,082	$22,082	$33,484

Table F.3-3.
MPS2 Sensitivity Analysis Results. (Cont'd)

SAMA No.	Potential Improvement	Case 8 1998 MetData	Case 9 PLHITE =2(X)	Case 10 PLDUR =2(X)	Case 11 ESPEED =1.2m/s	Case 12 PLHEAT X-10%	Case 13 STC M9 and M11 = M10	Case 14 Add STC M12	Case 15 Use MP3 STC for M1A
94	Increase frequency of valve leakage testing.	$22,624	$22,082	$24,962	$22,105	$22,082	$22,082	$22,082	$33,484
99	Ensure all ISLOCA releases are scrubbed	$22,624	$22,082	$24,962	$22,105	$22,082	$22,082	$22,082	$33,484
100	Add redundant and diverse limit switch to each containment isolation valve.	$29,411	$28,707	$32,450	$28,737	$28,707	$28,707	$28,707	$43,529
123	Provide capability for diesel driven, low pressure vessel makeup	$0	$0	$0	$0	$0	$0	$0	$0
124/125	Provide an additional high pressure injection pump with independent diesel	$297,196	$285,626	$288,604	$287,262	$287,796	$286,137	$286,294	$286,294
127	Implement an RWST makeup procedure	$7,780	$7,323	$7,394	$7,426	$7,438	$7,356	$7,356	$7,356
150	Provide an additional I&C system (e.g., AMSAC).	$180,526	$177,311	$177,598	$178,371	$178,804	$177,909	$178,189	$178,189
159	Install turbine driven AF pump	$182,064	$177,589	$177,749	$178,811	$179,144	$178,128	$178,330	$178,330
165	Install independent RBCCW/ESFRS AOV similar to 2-RB-68.1A	$5,180	$4,879	$4,896	$4,971	$4,992	$4,912	$4,912	$4,912
166	Install additional MD AFW pump	$48,272	$47,219	$47,311	$47,571	$47,684	$47,403	$47,473	$47,473
170	Install redundant parallel valve equivalent to 2-CS-16.1A.	$150,765	$147,457	$147,085	$146,923	$147,055	$146,859	$146,859	$146,859
172	Add a redundant 125VDC bus equivalent to bus 201A and 201B.	$4,279	$4,031	$4,021	$4,129	$4,150	$4,070	$4,070	$4,070
173	Install diverse bypass valve around AOV's SW-8.1A/B/C	$178,481	$174,546	$174,880	$175,383	$175,928	$175,003	$175,073	$175,073
174	Install redundant valve in line for backup to valve RB-8.1A/B	$76,442	$74,700	$74,843	$75,034	$75,281	$74,872	$74,895	$74,895

Table F.3-3.
MPS2 Sensitivity Analysis Results. (Cont'd)

SAMA No.	Potential Improvement	Case 8 1998 MetData	Case 9 PLHITE =2(X)	Case 10 PLDUR =2(X)	Case 11 ESPEED =1.2m/s	Case 12 PLHEAT X-10%	Case 13 STC M9 and M11 = M10	Case 14 Add STC M12	Case 15 Use MP3 STC for M1A
175	Install redundant diverse bypass valve equivalent to 2-CS-16.1A/B.	$347,373	$339,924	$339,009	$338,475	$338,719	$338,405	$338,405	$338,405
176	Install additional SW AOV similar to SW-8.1A to provide a reliable flow path.	$49,621	$48,533	$48,610	$48,727	$48,882	$48,635	$48,646	$48,646
179	Automate RCP trip circuitry on loss of seal cooling.	$138,340	$135,399	$135,459	$135,594	$135,904	$135,409	$135,456	$135,456
182	Automate the start and alignment of the RBCCW pump.	$0	$0	$0	$0	$0	$0	$0	$0
183	Automate isolation feature of faulted SG.	$27,848	$27,316	$27,354	$27,504	$27,567	$27,418	$27,464	$27,464
184	Install redundant AFW Reg valve following Reg valve FTO.	$16,277	$15,874	$15,889	$16,023	$16,062	$15,947	$15,971	$15,971
185	Install redundant ESFRS fan equivalent to F-15B.	$5,122	$4,824	$4,840	$4,916	$4,937	$4,857	$4,857	$4,857
186	Install diverse strainers L-1A, B, C to all 3 SW pump discharge lines to prevent CCF.	$13,748	$13,072	$13,066	$13,330	$13,366	$13,185	$13,185	$13,185
187	Automate start capability of Terry Turbine.	$4,706	$4,433	$4,423	$4,542	$4,558	$4,477	$4,477	$4,477
189	Automate emergency boration of RCS.	$19,095	$18,654	$18,680	$18,812	$18,867	$18,736	$18,759	$18,759
190	Install redundant line to RWST equivalent to 2-CH-192.	$22,478	$21,986	$22,039	$22,138	$22,193	$22,063	$22,097	$22,097
191	Add additional AFW bypass line with diverse reg valve to protect against CCF of existing valves 2-FW-43A and 43B.	$16,277	$15,874	$15,889	$16,023	$16,062	$15,947	$15,971	$15,971
192	Install additional MOV on VCT outlet line similar to MOV-CH-501 for closure to assure boric acid flow to charging pump.	$15,849	$15,472	$15,487	$15,610	$15,654	$15,540	$15,564	$15,564

Table F.3-3.
MPS2 Sensitivity Analysis Results. (Cont'd)

SAMA No.	Potential Improvement	Case 8 1998 MetData	Case 9 PLHITE =2(X)	Case 10 PLDUR =2(X)	Case 11 ESPEED =1.2m/s	Case 12 PLHEAT X-10%	Case 13 STC M9 and M11 = M10	Case 14 Add STC M12	Case 15 Use MP3 STC for M1A
193	Install additional AFW bypass line with diverse check valves and reg valves similar to check valves 2-FW-12A and 2-FW-12B and reg valves 2-FW-43A and 43B to SG's.	$22,062	$21,595	$21,621	$21,764	$21,815	$21,682	$21,717	$21,717
195	Add additional MOV around valves 2-RB-68.1A&B.	$12,238	$11,656	$11,766	$11,705	$11,726	$11,646	$11,646	$11,646

Table F.3-4.
MPS2 List of Sorted Basic Events.

Basic Event	Prob	Description	FV	RRW
BUS24C	1.00E+00	Station blackout flag - BUS24C	2.12E-01	1.269
FWXMOD1	1.43E-01	Failure of terry turbine	1.95E-01	1.242
BUS24D	1.00E+00	Station blackout flag - BUS24D	1.81E-01	1.221
HPSIFAILS	1.00E+00	HPSI system fails flag	1.42E-01	1.165
RCPSF	8.91E-05	RCP seal failure given the affected RCP(s) have been tripped	1.38E-01	1.160
%GPT	2.43E+00	General plant transient	1.09E-01	1.122
ACSWING24C	6.40E-01	BUS 24C aligned to power swing BUS 24E	1.04E-01	1.117
RB2P11COP	8.33E-01	RBCCW pump P-11C is operating	1.00E-01	1.111
STUCKPORV	1.00E-01	Stuck open porv or safety valve	9.05E-02	1.099
%RBP4RP11CFN	2.90E-01	RBCCW pump P-11C fails to run (initiator)	8.78E-02	1.096
OPSAFETY	1.00E-01	Fraction of the time safety will open (screening)	8.53E-02	1.093
RB1P11AOP	8.33E-01	RBCCW pump P-11A is operating	6.45E-02	1.069
%RBP433FTRFN	6.55E-03	CCF of 3/3 RBCCW pumps to run (initiator)	6.32E-02	1.067
DC1BKD0103NF	2.40E-05	BUS feed breaker D0103 fails to remain closed (supply to 201A)	5.90E-02	1.063
RTELEC	1.44E-05	Reactor trip failure (signal, coils, breaker)	5.34E-02	1.056
%RBP4RP11AFN	2.90E-01	RBCCW pump P-11A fails to run (initiator)	5.25E-02	1.055
%LNPPC	2.25E-02	Loss of normal power - plant centered	5.18E-02	1.055
RB1AVH681ANN	7.80E-03	RBCCW/ESFRS AOV 2-RB-68.1A fails to open	5.14E-02	1.054
FW2MOD1	4.02E-03	'B' motor driven AFW pump fails	4.70E-02	1.049
FW1MOD1	4.02E-03	'A' motor driven AFW pump fails	4.69E-02	1.049

Table F.3-4.
MPS2 List of Sorted Basic Events. (Cont.)

Basic Event	Prob	Description	FV	RRW
%SLOCA1A	5.06E-04	Small LOCA initiator in loop 1A	4.68E-02	1.049
%SLOCA1B	5.06E-04	Small LOCA initiator in loop 1B	4.68E-02	1.049
%SLOCA2A	5.06E-04	Small LOCA initiator in loop 2A	4.68E-02	1.049
%SLOCA2B	5.06E-04	Small LOCA initiator in loop 2B	4.68E-02	1.049
DC2BKD0203NF	2.40E-05	BUS feed breaker D0203 fails to remain closed (supply to 201B)	4.50E-02	1.047
PRXRVRC201FF	6.50E-03	Safety relief valve RC-201 fails to close due to mechanical failure	4.26E-02	1.045
PRXRVRC200FF	6.50E-03	Safety relief valve RC-200 fails to close due to mechanical failure	4.26E-02	1.045
OARDC	1.00E-01	Failure to recover DC power	4.24E-02	1.044
FW2P8FWP9BBQ	3.38E-03	Motor driven AFW pump P-9B OOS for maintenance	3.95E-02	1.041
OABAF	1.00E-01	Operator fails to establish bleed and feed	3.93E-02	1.041
SW2P5COP	8.33E-01	Service water pump P-5C operating	3.74E-02	1.039
%SWP3P5ABCFN	3.41E-03	CCF of 3/3 Service water pumps P- 5A, B, and C to run (initiator)	3.62E-02	1.038
RBCAVR81ABNN	7.80E-04	CCF of 2/2 RBCCW 2-RB-68.1A & B AOVS to open	3.54E-02	1.037
%SSLOCA	7.50E-04	Small LOCA initiator	3.52E-02	1.036
AC1DGDGH7AFN	1.11E-01	Diesel generator 'A' (15G-12U) fails to run	3.51E-02	1.036
%LMFW	2.88E-01	Loss of main feedwater	3.50E-02	1.036
RB2AVHV81BNN	7.80E-03	RBCCW/ESFRS AOV 2-RB-68.1B fails to open	3.46E-02	1.036
%LNPW	5.20E-03	Loss of normal power - weather related	3.32E-02	1.034
FW1P8FWP9AAQ	2.80E-03	Motor driven AFW pump P-9A OOS for maintenance	3.25E-02	1.034
AC2DGDGH7BFN	1.11E-01	Diesel generator 'B' (15G-13U) fails to run	3.17E-02	1.033

Table F.3-4.
MPS2 List of Sorted Basic Events. (Cont.)

Basic Event	Prob	Description	FV	RRW
OACST	1.00E-02	Operator fails to provide makeup to the CST	3.13E-02	1.032
CS1MVCS16ANN	1.11E-02	Motor operated valve 2-CS-16.1A fails to open on demand	3.08E-02	1.032
OALPMINI	1.00E-03	Operator fails to position the SI pump mini-flow line valves to operate	3.04E-02	1.031
%LDCA	2.50E-02	Loss of 125VDC BUS 201A (plant specific data)	3.00E-02	1.031
DC2BTBATTBFF	5.00E-04	Battery 201B Fails to provide output on demand (DB2-201B)	2.94E-02	1.030
MTC	5.00E-02	Probability of an adverse MTC with turbine trip	2.91E-02	1.030
%LDCB	2.50E-02	Loss of 125VDC BUS 201B (plant specific data)	2.87E-02	1.030
SWCAV81BCONN	7.49E-04	CCF of 2/3 service water AOVS SW-8.1A/B/C to open	2.86E-02	1.029
RB1AVRB81AFF	1.02E-02	Air operated valve RB-8.1A fails to close due to mechanical failure	2.84E-02	1.029
SW5P5BOPB	1.67E-01	Service water pump P-5B operating on HDR 'B	'2.84E-02	1.029
RB5P11BOPB	1.67E-01	RBCCW pump P-11B operating on HDR 'B	'2.81E-02	1.029
DC1BTBATTAFF	5.00E-04	Battery 201A fails to provide output on demand (DB1-201A)	2.79E-02	1.029
RECMFW	5.00E-01	Failure to recover MFW or condensate	2.64E-02	1.027
RB1X18AOP	1.00E+00	RBCCW HX X-18A is operating	2.58E-02	1.027
SW1P5AOP	8.33E-01	Service water pump P-5A operating	2.43E-02	1.025
CS2MVCS16BNN	1.11E-02	Motor operated valve 2-CS-16.1B fails to open on demand	2.35E-02	1.024
FWCP8FP9ABNN	2.05E-04	CCF To start of motor driven AFW pumps P-9A and P-9B	2.33E-02	1.024
CSCMVCS161NN	7.55E-04	CCF of 2/2 CS motor operated valves 2-CS-16.1A&B to open on demand	2.29E-02	1.023
%SWP3SWP5CFN	1.51E-01	Service water pump P-5C fails to run (initiator)	2.28E-02	1.023
%DCBKD0103NF	8.76E-03	BUS feed breaker D0103 fails to remain closed (supply to 201A)	2.24E-02	1.023

Table F.3-4.
MPS2 List of Sorted Basic Events. (Cont.)

Basic Event	Prob	Description	FV	RRW
SW1AVSW81ANN	7.80E-03	Service water AOV SW-8.1A fails to operate	2.17E-02	1.022
%DCBKD0203NF	8.76E-03	BUS feed breaker D0203 fails to remain closed (supply to 201B)	2.12E-02	1.022
SICAVSI659FF	6.94E-04	CCF of 2/2 mini flow isolation AOVS 2-SI-659 & 660 to close	2.11E-02	1.022
RB2AVRB81BFF	1.02E-02	Air operated valve RB-8.1B fails to close due to mechanical failure	2.10E-02	1.021
RB2AVRB210FF	1.02E-02	Air operated valve RB-210 fails to close due to mechanical failure	2.09E-02	1.021
OATRIPRCP	1.00E-04	Operator fails to trip the RCPS	2.06E-02	1.021
%DCBSBATTAFN	8.76E-04	125VDC electrical BUS fault (battery BUS 201A)	2.05E-02	1.021
%DCBSB201AFN	8.76E-04	125VDC electrical BUS 201A fault	2.05E-02	1.021
RB2X18COP	1.00E+00	RBCCW HX X-18C is operating	1.97E-02	1.020
%DCBSB201BFN	8.76E-04	125VDC electrical BUS 201B fault	1.93E-02	1.020
%DCBSBATTBFN	8.76E-04	125VDC electrical BUS fault (battery BUS 201B)	1.93E-02	1.020
%SLOCA	2.25E-04	Small LOCA initiator	1.84E-02	1.019
OAADV1	1.00E-01	Local manual operation of an ADV	1.82E-02	1.019
OADCRVENT	1.00E-02	Operator fails to recover 125V DC ventilation	1.64E-02	1.017
SW2AVSW81CNN	7.80E-03	Service water AOV SW-8.1C fails to open	1.59E-02	1.016
%SWP3SWP5AFN	1.51E-01	Service water pump P-5A fails to run (initiator)	1.45E-02	1.015
OEP9BMAINT	1.21E-03	Operator fails to restore motor driven AFW pump P-9B after maintenance	1.38E-02	1.014
OEP9AMAINT	1.21E-03	Operator fails to restore motor driven AFW PUMP P-9A after maintenance	1.37E-02	1.014
OARBPUMP	5.00E-02	Operator fails to manually start and align available pump	1.27E-02	1.013
OASGI	1.00E-02	Operator fails to isolate faulted SG	1.26E-02	1.013

Table F.3-4.
MPS2 List of Sorted Basic Events. (Cont.)

Basic Event	Prob	Description	FV	RRW
OABYPASS	1.00E-01	Operator fails to open AFW reg valve bypass following reg valve FTO	1.19E-02	1.012
RUPTLPSI	2.91E-01	Rupture of 6" - GCB-2 at 1300 PSIG (HPSI discharge pressure)	1.05E-02	1.011
%SLBUO	4.80E-04	Steamline break Upstream of the NRVS and outside CTMT	1.03E-02	1.010
OASWSTRAIN	1.00E-02	Operator fails to recover strainer	1.02E-02	1.010
SG2FAULTED	5.00E-01	Steam generator #2 faulted	1.01E-02	1.010
OEP4TM	7.97E-03	Failure to restore the terry turbine after test or maintenance	9.77E-03	1.010
EV2FNHV15BNQ	2.17E-03	ESFRS fan F-15B OOS for maintenance	8.19E-03	1.008
%SWSTSWABCNF	7.53E-02	CCF of strainers L-1A, B, and C to operate (initiator)	8.01E-03	1.008
FWXP9TDAP4NQ	6.56E-03	Terry turbine (P4) OOS for maintenance	7.96E-03	1.008
OATDAFW	6.40E-03	Operator fails to start the terry turbine (P4)	7.77E-03	1.008
RTMECH	2.10E-06	Reactor trip fails due to mechanical rod binding	7.72E-03	1.008
SG1FAULTED	5.00E-01	Steam generator #1 faulted	7.69E-03	1.008
OAEMBOR	1.30E-02	Operator fails to initiate emergency boration	7.57E-03	1.008
CHXAVCH192NN	7.80E-03	RWST isolation valve 2-CH-192 fails to open on demand	7.42E-03	1.007
FWCAVF43ABNN	9.67E-05	CCF to open of AFW REG valves 2-FW-43A and 2-FW-43B	6.70E-03	1.007
%LNPGR	3.10E-03	Loss of normal power - grid related	6.57E-03	1.007
EV1FNHV15ANQ	1.17E-03	ESFRS fan F-15A OOS for maintenance	6.19E-03	1.006
DC1BSBATTAFN	2.40E-06	125VDC electrical bus fault (battery BUS 201A)	6.17E-03	1.006
%SGTR	3.86E-03	Steam generator tube rupture	6.17E-03	1.006
AC1DGDGH7AAQ	1.93E-02	Diesel generator 'A' (15G-12U) OOS for maintenance	6.15E-03	1.006

Table F.3-4.
MPS2 List of Sorted Basic Events. (Cont.)

Basic Event	Prob	Description	FV	RRW
SW2P3SWP5CCQ	2.81E-02	Service water pump P-5C OOS for maintenance	5.56E-03	1.006
AC2DGDGH7BBQ	1.07E-02	Diesel generator 'B' (15G-13U) OOS for maintenance	5.20E-03	1.005
CH1MVCH501FF	8.89E-03	MOV CH-501 fails to close on demand	5.17E-03	1.005
%SLBUI	1.80E-04	Steamline break upstream of the NRVS and inside CTMT	5.14E-03	1.005
FW2AVFW43BNN	7.80E-03	Air operated valve 2-FW-43B fails to open on demand	4.67E-03	1.005
FW1AVFW43ANN	7.80E-03	AFW reg valve 2-FW-43A fails to open on demand	4.67E-03	1.005
FWCCVF12ABNN	6.80E-06	CCF to open of check valves 2-FW-12A and 2-FW-12B	4.66E-03	1.005
OAPCONDDC	9.80E-03	Operator fails to align condensate system for decay heat removal	4.65E-03	1.005

F.4 Results and Conclusions

An Integrated Plant Assessment has been made in accordance with 10CFR54.21, Ref. F.4-1. After all screening and cost-benefit analyses, there is only one SAMA which fell within the estimated cost estimate range; SAMA #3, whose improvement includes enhancing the loss of RBCCW procedure to consider RCS cooldown and depressurization prior to a seal LOCA. The RBCCW provides seal, thermal barrier, upper and lower bearing cooling for the RCP's. Dominion actively participates in a comprehensive industry initiative, in response to NRC Generic Issue 23 (GI-23), "Reactor Coolant Pump Seal Failure." Dominion is following the industry efforts on this issue and will implement the appropriate recommendations resulting from this guidance prior to entering the period of extended operation.

The PRA calculations supporting this conclusion are recognized to have some uncertainty around the mean frequencies used in the analyses. To account for the possible uncertainty, several sensitivity analyses were performed to bound the analysis. These sensitivity cases did not alter the benefit calculations by more than a factor of two, which were shown within the report to still be less than the costs of each SAMA with the exception discussed above.

F.4.1 References

Ref. F.4-1 10 CFR 54.21, Code of Federal Regulations.

F.5 Acronyms Used In Appendix F

AAC	Alternate Alternating Current
AC	Alternating Current
ADS	Automatic Depressurization System
AFW	Auxiliary Feedwater
AFWST	Auxiliary Feedwater Storage Tank
AMSAC	ATWS Mitigating System Actuation Circuitry
AOV	Air Operated Valve
ATWS	Anticipated Transient Without Scram
BWR	Boiling Water Reactor
BWST	Borated Water Storage Tank
CCW	Component Cooling Water
CDF	Core Damage Frequency
CE	Combustion Engineering
CRD	Control Rod Drive
CST	Condensate Storage Tank
CV	Control Valve
CVCS	Charging and Volume Control System
DC	Direct Current
DER	Design Electrical Rating
DG	Diesel Generator
DHR	Decay Heat Removal
ECCS	Emergency Core Cooling System
EFIC	Emergency Feedwater Initiation and Control
EFW	Emergency Feedwater
EOP	Emergency Operating Procedure
ERCW	Emergency Raw Cooling Water
FW	Feedwater
HCLPF	High Confidence of Low Probability of Failure

HPCI	High Pressure Coolant Injection
HPCS	High Pressure Core Spray
HPI	High Pressure Injection
HPSI	High Pressure Safety Injection
HR	Heat Removal
HVAC	Heating, Ventilation and Air Conditioning
I&C	Instrumentation and Control
ICONE	International Conference on Nuclear Engineering
ICW	Intermediate Cooling Water
IPA	Individual Plant Assessment
IPE	Individual Plant Examination
ISLOCA	Interfacing System LOCA
KV	Kilo-Volts
LOCA	Loss of Coolant Accident
LOP	Loss of Power
LOSW	Loss of Service Water
LPCI	Low Pressure Coolant Injection
LPI	Low Pressure Injection
LPSI	Low Pressure Safety Injection
MAB	Maximum Attainable Benefit
MCC	Motor Control Center
MD	Motor Driven
MFW	Main Feed Water
MG	Motor Generator
MOV	Motor Operated Valve
MPS2	Millstone Power Station Unit 2
MSIV	Main Steam Isolation Valve
NRC	Nuclear Regulatory Commission
PMP	Probable Maximum Precipitation

PORV	Power Operated Relief Valve
PRA	Probabilistic Risk Analysis
PRT	Pressurizer Relief Tank
PSA	Probabilistic Safety Assessment
PWR	Pressurized Water Reactor
RAI	Request for Additional Information
RB	Reactor Building
RBCCW	Reactor Building Component Cooling Water
RCIC	Reactor Core Isolation Cooling
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RHR	Residual Heat Removal
RRW	Risk Reduction Worth
RV	Relief Valve
S/G	Steam Generator
SAMA	Severe Accident Mitigation Alternative
SAMDA	Severe Accident Mitigation Design Alternative
SAMG	Severe Accident Management Guideline
SBO	Station Blackout
SI	Safety Injection
SGTR	Steam Generator Tube Rupture
SLC	Standby Liquid Control
SOV	Solenoid Operated Valve
SRV	Safety Relief Valve
SSE	Safe Shutdown Earthquake
SW	Service Water
TD	Turbine Driven
TDP	Turbine Driven Pump
TVA	Tennessee Valley Authority

V	Volts
WBN	Watts Bar Nuclear Plant

APPENDIX G
MPS3 SEVERE ACCIDENT MITIGATION ALTERNATIVES ANALYSIS

Appendix G contains the following sections:

G.1 Melcor Accident Consequences Code System Modeling

G.1.1 Introduction

The following sections describe the assumptions made and the results of the Level 3 modeling performed to assess the offsite risks and consequences of severe accidents (U.S. Nuclear Regulatory Commission Class 9) at MPS3.

The severe accident consequence analysis was carried out with the Melcor Accident Consequence Code System code (MACCS2) (Ref. G 1-1). MACCS2 simulates the impact of severe accidents at nuclear power plants on the surrounding environment. The principal phenomena considered in MACCS2 are atmospheric transport, mitigating actions based on dose projection, dose accumulation by a number of pathways including food and water ingestion, early and latent health effects, and economic costs.

G.1.2 Input

The input data required by MACCS2 are outlined below. MACCS2 requires five separate input files or modules to simulate an accident scenario. These include EARLY, ATMOS, CHRONC, MET, and SITE modules. The Level 3 PRAs using the MACCS2 computer code were prepared by Dominion and reviewed by Dominion personnel.

The Level 3 model was constructed specifically for the license renewal SAMA analysis. The meteorological data have been collected and stored by the Dominion environmental personnel at Millstone Power Station. The population distribution and land use data for the region surrounding the site were determined based on software purchased from the federal government (SECPOP90). The source term data were generated using the MAAP 4 computer code. The MACCS2 code was used to do the evaluation of the source term distribution.

G.1.2.1 Core Inventory

The core inventory is for MPS3 at a power level of 3,411 megawatts-thermal. These values were obtained by adjusting the end-of-cycle values for a 3,412 megawatts-thermal pressurized water reactor (Table G.1-1) by a linear scaling factor of 1.0 in the MACCS2 input file (Ref. G 1-1). Potential core power uprate is accounted for by running a MACCS2 sensitivity with a 10 percent increase on the core scaling parameter. See Section G.3.4 below which discusses this sensitivity.

G.1.2.2 Source Terms

The source term input data to MACCS2 was generated using the MAAP 4 computer code for the dominant core damage sequences presented in the probabilistic risk assessment in the MPS3 IPE (Ref. G 1-2). The source term release fractions described in the MPS3 IPE were regenerated for 13 source term categories. There are 27 Plant Damage States (PDSs) in Ref. G 1-2, which were assigned to 13 source term categories. Table G.1-2 lists the conditional input release fractions for each MACCS2 nuclide group. The assignment of the radionuclides in Table G.1-1 to these nuclide groups is the same as that given in the standard MACCS2 input.

The amounts (becquerels) of each radionuclide released to the atmosphere for each accident sequence or release category are obtained by multiplying the core inventory at the time of the hypothetical accident (Table G.1-1) by the release fractions (Table G.1-2) assigned to each of the nuclide groups.

The offsite consequences are summed for all the release modes weighted by the annual frequency to obtain the total annual accident risk, for the base case and for each of the SAMA concepts evaluated. (This summation calculation is performed outside of the MACCS2 code as part of the SAMA cost-benefit analyses.)

G.1.2.3 Meteorological Data

Yearly meteorological data has been generated for 1998 through 2000. The hourly data (wind direction, wind speed, and stability category) were collected on-site at Millstone Power Station. The wind direction and wind speed were recorded at the most probable release height (tower 142 foot elevation), as well as 33 feet, 374 feet, and 447 feet; the stability data were determined by a Delta T system measuring the temperature at the most probable release height, as well as at 374 feet and 447 feet. The data was collected and stored by the environmental personnel at Millstone Power Station. The data was provided to EES personnel at the Innsbrook Technical Center where the data were transferred to the corporate mainframe computer and any remaining unresolved data situations were resolved by professional meteorologists. Precipitation data were recorded at Green Airport near Providence, RI, the closest first order weather station to Millstone.

Morning and afternoon mixing height values for 1998 through 2000 were obtained from the National Climatic Data Center. Missing values were replaced where possible as prescribed in the USEPA document "Procedures for Substituting Values for Missing NWS Meteorological Data for Use in Regulatory Air Quality Models." All non-missing values greater than zero were considered valid.

A washout model which predicts how much radionuclide material is deposited on the ground by rainfall was used. Washout is a function of both rain duration and rain intensity. MACCS2 default washout coefficient values were assumed to be appropriate for this evaluation.

G.1.2.4 Population Distribution

The population distribution and land use information for the region surrounding the site are specified in the Site Data File. Contained in the Site Data file are the geometry data used for the site (spatial intervals and wind directions), population distribution, fraction of the area that is land, watershed data for the liquid pathways model, information on agricultural land use and growing seasons, and regional economic information. Some of the detailed data in this file supercedes certain data in the EARLY input file.

Much of the data was initially prepared by the computer program SECPOP90 (Ref. G 1-3). This code contains a database extracted from Bureau of the Census PL 94-171 (block level census) CD-ROMS (Ref. G 1-4), the 1992 Census of Agriculture CD ROM Series 1B, the 1994 US Census County and City Data Book CD-ROM, the 1993 and 1994 Statistical Abstract of the United States, and other minor sources. The reference contains details on how its database was created and checked. The output from SECPOP90 is a file in the MACCS2 site file format based on the data in its reference data base for the specified site.

Millstone Unit 3 is located in Waterford, Connecticut on the Long Island Sound. The 50 mile radius area around the plant was divided into sixteen directions that are equivalent to a standard navigational compass rosette. This rosette was further divided into 10 "inner" radial rings, each with sixteen azimuthal sections.

The SECPOP90-prepared Site data file was then modified and updated using the MPS3 50 mile population distribution for the year 2040 in place of the 1990 Census SECPOP90 data, based on 2000 census data, projected out to 2040. Pictures of the rosette for Millstone site 0-10 mile and 10-50 mile radii are shown in Figure G.1-1 and Figure G.1-2 respectively.

G.1.2.5 Emergency Response

The EARLY module of the MACCS2 code models the time period immediately following a radioactive release. This period is commonly referred to as the emergency phase. It may extend up to 1 week after the arrival of the first plume at any downwind spatial interval. The subsequent intermediate and long term periods are treated by CHRONC. In the EARLY module the user may specify emergency response scenarios that include evacuation, sheltering, and dose-dependent relocation. The EARLY module has the capability for combining results from up to three different emergency response scenarios. This is accomplished by appending change records to the EARLY input file. The first emergency-response scenario is defined in the main body of the EARLY input file.

Up to two additional emergency-response scenarios can be defined through change record sets positioned at the end of the file.

The emergency evacuation model has been modeled as a single evacuation zone extending out 10 miles from the plant. The evacuation speed was estimated at an average of 1.49 m/s (3.3mph) and a 7200 second delay time from the off-site alarm reference time point. One sensitivity case was made using an evacuation speed of 1.8 m/s to bound different weather conditions. The sensitivity results have shown that there is a small impact on population dose and practically no impact on the economic cost based on the evacuation speed change.

To demonstrate the possible significance of these assumptions, a sensitivity MACCS2 run was made with the delay time from the reference time point, parameter DLTSHL, increased by 0.5 hours (+1800 s) to 9000 seconds. The results, which are reported in Reference G.1-9, demonstrate that the MACCS2 consequences are not significantly sensitive to the timings used.

G.1.2.6 Economic Data

Land use statistics including farmland values, farm product values, dairy production, and growing season information were provided on a countywide basis within 50 miles.

Much of the data is prepared by the computer program SECPOP90 (Ref. G 1-3). It contains a database extracted from Bureau of the Census PL 94-171 (block level census) CD-ROMS (Ref. G 1-4), the 1992 Census of Agriculture CD ROM Series 1B, the 1994 US Census County and City Data Book CD-ROM, the 1993 and 1994 Statistical Abstract of the United States, and other minor sources. The reference contains details on how the database was created and checked. The SECPOP90 regional economic values were updated to 2001 using cost of living and other data from the Bureau of the Census and the Department of Agriculture. Agricultural data is taken from data available in the 1997 Census of Agriculture (Ref. G 1-5). This was accomplished by replacing the SECPOP90 data for the counties within the fifty mile radius by the values from this census. That is, the SECPOP90 county data base was modified so that the results produced by the code were correctly assigned to the various economic regions.

Offsite economic consequences were estimated using the MACCS2 code by summing the following costs:

- Costs of evacuation,
- Costs for temporary relocation (food, lodging, lost income),

- Costs of decontaminating land and buildings,
- Lost return-on-investments from properties that are temporarily interdicted to allow contamination to be decreased by decay of nuclides,
- Costs of repairing temporarily interdicted property,
- Value of crops destroyed or not grown because they were contaminated by direct deposition or would be contaminated by root uptake, and
- Value of farmland and of individual, public, and nonfarm commercial property that is condemned.

Onsite impacts (occupational exposure and facility clean-up costs) and replacement power costs are not calculated by MACCS2 but are instead derived from the methodology in NUREG/BR-0184, as described later in this appendix. In addition, the MACCS2 code does not assign a monetary cost to radiological exposure. An NRC-recommended conversion factor is subsequently applied for this purpose.

G.1.3 **Results**

Based on the preceding input data, MACCS2 was used to estimate the following:

- The downwind transport, dispersion, and deposition of the radioactive materials released to the atmosphere from the failed reactor containment.
- The short- and long-term radiation doses received by exposed populations via direct (cloudshine, plume inhalation, groundshine, and resuspension inhalation) and indirect (ingestion) pathways.
- The mitigation of those doses by protective actions (evacuation, sheltering, and post-accident relocation of people; disposal of milk, meat, and crops; and decontamination, temporary interdiction, or condemnation of land and buildings).
- The early fatalities and injuries projected to occur within 1 year of the hypothetical accident (early health effects) and the delayed (latent) cancer fatalities and injuries projected to occur over the lifetime of the exposed individuals.
- The offsite costs of short-term emergency response actions (evacuation, sheltering, and relocation), of crop and milk disposal, and of the decontamination, temporary interdiction, or condemnation of land and buildings.

The consequences calculated with the MACCS2 model in terms of the population dose and offsite economic costs for the SAMA base case and two sample sensitivity cases are shown in Table G.1-3.

Table G.1-1.
Generic 3412 MWt Core Inventory.[a]

Nuclide	Core Inventory (becquerels)	Nuclide	Core Inventory (becquerels)
Cobalt-58	3.22E+16	Tellurium-131M	4.68E+17
Cobalt-60	2.47E+16	Tellurium-132	4.66E+18
Krypton-85	2.48E+16	Iodine-131	3.21E+18
Krypton-85M	1.16E+18	Iodine-132	4.73E+18
Krypton-87	2.12E+18	Iodine-133	6.78E+18
Krypton-88	2.86E+18	Iodine-134	7.44E+18
Rubidium-86	1.89E+15	Iodine-135	6.39E+18
Strontium-89	3.59E+18	Xenon-133	6.78E+18
Strontium-90	1.94E+17	Xenon-135	1.27E+18
Strontium-91	4.62E+18	Cesium-134	4.32E+17
Strontium-92	4.80E+18	Cesium-136	1.32E+17
Yttrium-90	2.08E+17	Cesium-137	2.42E+17
Yttrium-91	4.37E+18	Barium-139	6.28E+18
Yttrium-92	4.82E+18	Barium-140	6.22E+18
Yttrium-93	5.45E+18	Lanthanum-140	6.35E+18
Zirconium-95	5.53E+18	Lanthanum-141	5.83E+18
Zirconium-97	5.76E+18	Lanthanum-142	5.62E+18
Niobium-95	5.22E+18	Cerium-141	5.65E+18
Molybdium-99	6.10E+18	Cerium-143	5.49E+18
Technetium-99M	5.26E+18	Cerium-144	3.41E+18
Ruthenium-103	4.54E+18	Praseodymium-143	5.40E+18
Ruthenium-105	2.95E+18	Neodymium-147	2.41E+18
Ruthenium-106	1.03E+18	Neptunium-239	6.46E+19
Rhodium-105	2.05E+18	Plutonium-238	3.66E+15
Antimony-127	2.79E+17	Plutonium-239	8.26E+14
Antimony-129	9.87E+17	Plutonium-240	1.04E+15
Tellurium-127	2.69E+17	Plutonium-241	1.76E+17
Tellurium-127M	3.56E+16	Americium-241	1.16E+14
Tellurium-129	9.27E+17	Curium-242	4.44E+16
Tellurium-129M	2.44E+17	Curium-244	2.60E+15

a. Ref. G 1-1.

Table G.1-2.
MPS3 Release Fraction by Nuclide Group.

Source Term Category	Noble Gases	I	Cs	Te	Sr	Ru	La	Ce	Ba
M-1A	1.0E+00	7.6E-01	7.8E-01	3.5E-01	1.2E-02	1.2E-01	2.6E-03	1.1E-02	4.3E-02
M-1B	9.5E-01	1.3E-01	1.1E-01	9.2E-07	6.8E-04	3.0E-02	9.4E-05	1.7E-04	8.0E-03
M-2	1.0E+00	6.2E-02	6.5E-02	3.0E-03	5.6E-04	1.9E-02	2.1E-04	1.2E-03	5.4E-03
M-3	1.0E+00	1.5E-01	1.6E-01	1.0E-10	3.9E-04	1.3E-02	1.0E-04	3.6E-04	4.4E-03
M-4	9.3E-01	1.5E-02	1.4E-02	3.0E-01	1.2E-02	1.3E-02	1.2E-02	1.2E-02	1.2E-02
M-5	1.0E+00	3.3E-02	3.3E-02	1.9E-02	1.8E-02	1.6E-02	1.8E-02	1.8E-02	1.7E-02
M-6	1.0E+00	3.2E-02	3.2E-02	2.6E-02	2.4E-02	2.3E-02	2.4E-02	2.4E-02	2.3E-02
M-7	9.6E-01	2.0E-03	4.2E-03	2.8E-03	2.6E-03	2.4E-03	2.6E-03	2.6E-03	2.5E-03
M-8	1.0E+00	2.3E-02	2.6E-02	7.0E-04	6.5E-07	8.1E-06	1.0E-07	6.2E-07	2.6E-06
M-9	1.0E+00	1.3E-02	2.0E-02	1.8E-04	1.6E-06	1.1E-05	1.7E-07	1.3E-06	3.8E-06
M-10	1.6E-01	5.7E-05	7.2E-05	1.4E-03	1.3E-06	1.5E-05	1.6E-06	2.0E-06	6.7E-06
M-11	1.5E-01	3.9E-05	4.2E-05	3.9E-04	7.2E-07	1.0E-05	8.6E-07	1.1E-06	4.1E-06
M-12	2.8E-03	7.9E-06	7.7E-06	3.3E-05	3.2E-05	2.9E-05	3.2E-05	3.2E-05	3.1E-05

Table G.1-3.
MPS3 Summary of Offsite Consequence Results and Sensitivities for Each Release Mode.

CET End Point (Release Mode)	Release Category Description	Population Dose (Sieverts)			Offsite Economic Costs (Dollars)		
		Basecase (100% Evac)	ESPEED = 1.8m/s	DLTSHL = 9000s	Basecase (100% Evac)	ESPEED = 1.8m/s	DLTSHL = 9000s
M-1A	Containment Bypass, V-Sequence	1.01E+05	1.01E+05	9.03E+04	1.29E+10	1.29E+10	1.29E+10
M-1B	Containment Bypass, SGTR	2.77E+04	2.77E+04	2.49E+04	5.87E+09	5.87E+09	5.87E+09
M-2	Early Failure/Early Melt, No Sprays	1.72E+04	1.69E+04	1.75E+04	4.90E+09	4.90E+09	4.90E+09
M-3	Early Failure/Late Melt, No Sprays	2.14E+04	2.10E+04	2.18E+04	7.13E+09	7.13E+09	7.13E+09
M-4	Containment Isolation Failure	2.67E+04	2.59E+04	2.75E+04	4.45E+09	4.45E+09	4.45E+09
M-5	Intermediate Failure / Late Melt, No Sprays	2.17E+04	2.17E+04	2.18E+04	5.55E+09	5.55E+09	5.55E+09
M-6	Intermediate Failure / Early Melt, No Sprays	2.55E+04	2.55E+04	2.57E+04	5.99E+09	5.99E+09	5.99E+09
M-7	Late Failure, No Sprays	6.52E+03	6.52E+03	6.52E+03	1.07E+09	1.07E+09	1.07E+09
M-8	Intermediate Failure With Sprays	1.08E+04	1.08E+04	1.08E+04	1.83E+09	1.83E+09	1.83E+09
M-9	Late Failure With Sprays	9.49E+03	9.49E+03	9.49E+03	1.38E+09	1.38E+09	1.38E+09
M-10	Basemat Failure, No Sprays	2.04E+02	2.04E+02	2.04E+02	1.21E+07	1.21E+07	1.21E+07
M-11	Basemat Failure With Sprays	1.14E+02	1.14E+02	1.14E+02	8.51E+06	8.51E+06	8.51E+06
M-12	No Containment Failure	1.65E+02	1.63E+02	1.67E+02	1.70E+07	1.70E+07	1.70E+07

A fractional breakdown of the population dose (person-rem per year) by containment release mode is shown on Table G.1-4.

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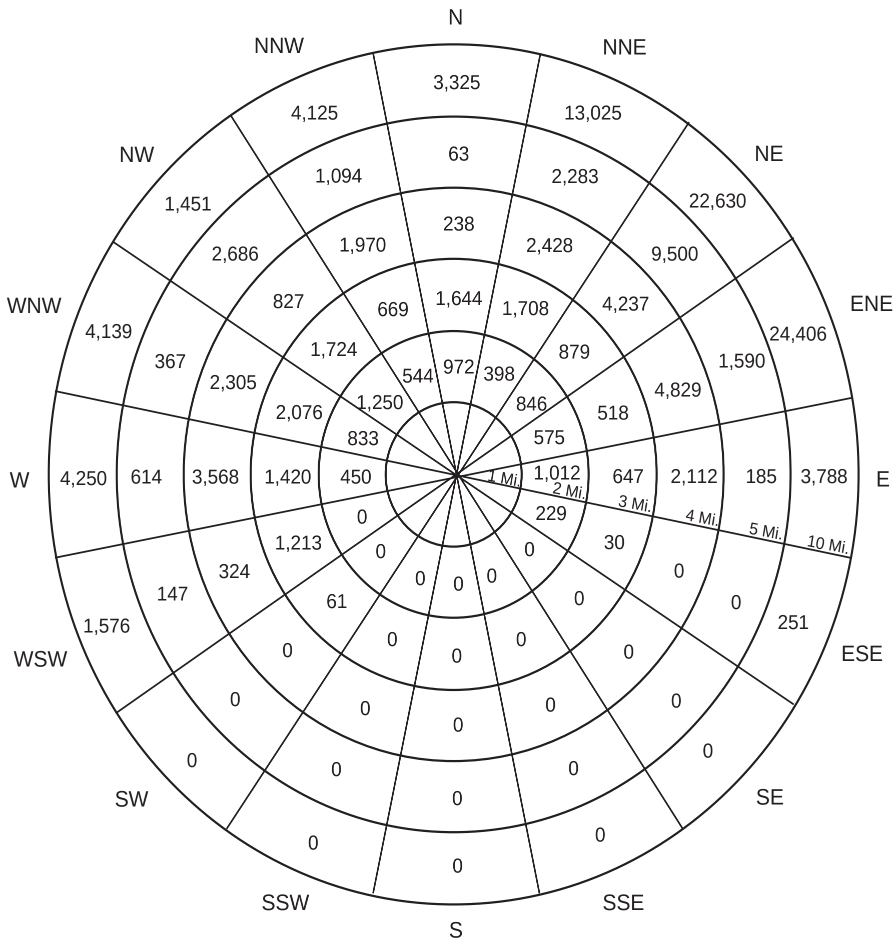
Table G.1-4.
MPS3 Summary of Offsite Consequence Results for Each Release Model.

CET End Point (Release Mode)	Release Category Description	Basecase Frequency	Basecase Dose Person-rem	Person-rem/yr	%Person-rem/yr
M-1A	Containment Bypass, V-Sequence	2.21E-07	1.01E+07	2.23E+00	17.42%
M-1B	Containment Bypass, SGTR	1.00E-06	2.77E+06	2.77E+00	21.61%
M-2	Early Failure/Early Melt, No Sprays	0.00E+00	1.72E+06	0.00E+00	0.00%
M-3	Early Failure/Late Melt, No Sprays	0.00E+00	2.14E+06	0.00E+00	0.00%
M-4	Containment Isolation Failure	0.00E+00	2.67E+06	0.00E+00	0.00%
M-5	Intermediate Failure / Late Melt, No Sprays	1.96E-07	2.17E+06	4.25E-01	3.32%
M-6	Intermediate Failure / Early Melt, No Sprays	1.96E-07	2.55E+06	5.00E-01	3.90%
M-7	Late Failure, No Sprays	7.79E-06	6.52E+05	5.08E+00	39.63%
M-8	Intermediate Failure With Sprays	0.00E+00	1.08E+06	0.00E+00	0.00%
M-9	Late Failure With Sprays	1.60E-06	9.49E+05	1.52E+00	11.85%
M-10	Basemat Failure, No Sprays	1.60E-06	2.04E+04	3.26E-02	0.25%
M-11	Basemat Failure With Sprays	1.60E-06	1.14E+04	1.82E-02	0.14%
M-12	No Containment Failure	1.46E-05	1.65E+04	2.41E-01	1.88%
		Total	2.68E+07	1.28E+01	100.00%

Figure G.1-1
Year 2040 Population Data
Population Distribution Within 10 Miles



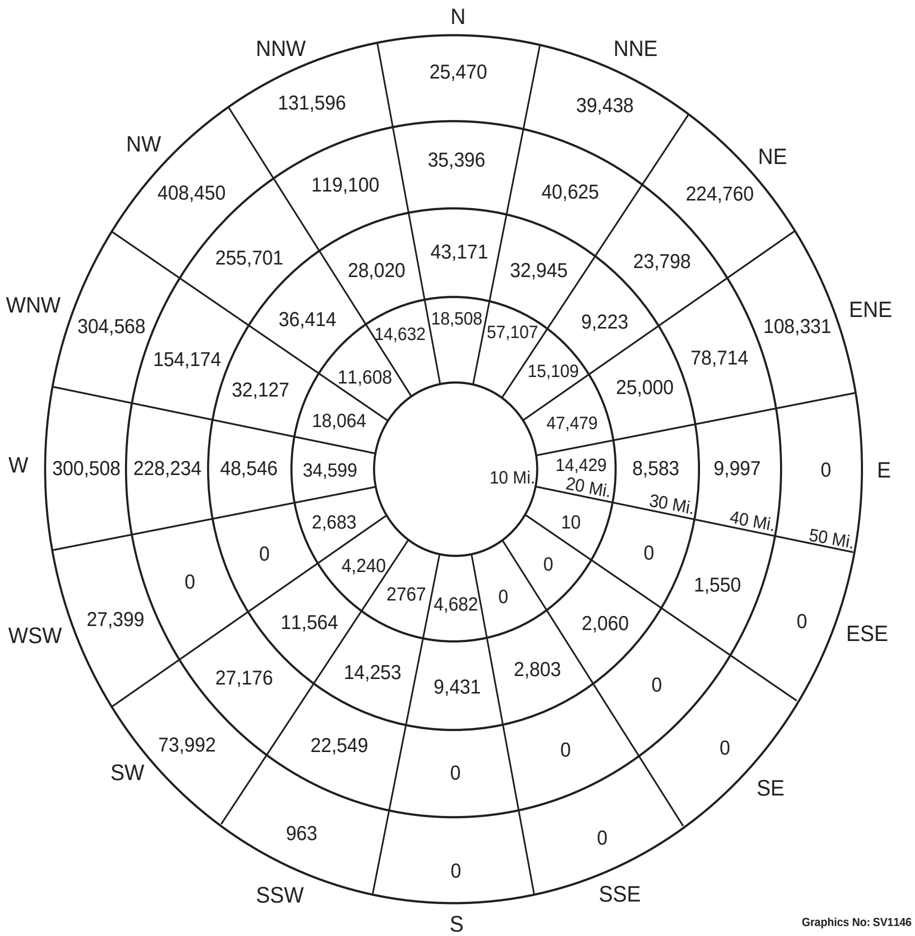
Graphics No: SV1147

POPULATION BY ANNULUS

Annulus	0 To 2	2 To 3	3 To 4	4 To 5	5 To 10	**Total**
Population	7,109	12,589	22,838	18,529	82,966	**144,031**

Figure G.1-2
Year 2040 Population Data

MILLSTONE UNIT 3
Population Distribution Within 50 Miles



POPULATION BY ANNULUS

Annulus	0 To 10	10 To 20	20To 30	30 To 40	40 To 50	Total
Population	144,031	245,917	304,140	997,014	1,645,475	**3,336,577**

G.1.3 **References**

Ref. G.1-1 Code Manual for MACCS2: Volume 1, User's Guide, Chanin, D. I., et al, SAND07-054, March 1997. SEE ALSO: MACCS2 V.1.12, CCC-652 Code Package, ORNL (Oak Ridge National Laboratory RISCC Computer Code Collection), 1997. SEE ALSO: MELCOR Accident Consequence Code System (MACCS) Model Description, Jow, H. N, et al, NUREG/CR-4691, SAND86-1562, February 1990.

Ref. G.1-2 NUSCO 171, "MP3 Individual Plant Examination (IPE) for Severe Accident Vulnerabilities," Northeast Utilities Service Company, Aug. 1990.

Ref. G.1-3 RF-Report, S. L. Humphreys, et al., "SECPOP90: Sector Population, Land Fraction, and Economic Estimation Program," NUREG/CR-6525, September, 1997.

Ref. G.1-4 RF-Report, Bureau of the Census, "Census of Population and Housing, 1990: Public Law (P. L.) 94-171, Data Technical Documentation", CD-ROM set, 1991.

Ref. G.1-5 RF-Report, U.S. Dept. of Agriculture, "1997 Census of Agriculture," National Agricultural Statistics Service.

G.2 Probabilistic Risk Assessment Model

This section describes the Millstone Unit 3 PRA model used for the quantification of the reduction in CDF due to the SAMA changes to the model. The resulting source term category frequencies were calculated using this model for all the SAMAs that were screened in.

G.2.1 Introduction

The quantitative analysis of the SAMAs was performed using the Millstone Unit 3 Probabilistic Risk Assessment (PRA) model. The PRA model used for the SAMA analysis consists of the usual three elements: The Level 1 model looks at accident scenarios from initiation to the point of a plant damage state (core damage with containment heat removal status). The Level 2 model assesses the likelihood that the plant damage state (PDS) will result in each of the release categories. The Level 3 model considers the distribution of the released radionuclides to the environment which is discussed in Section G.1 above. A discussion of the external events model and how it was accounted for in the SAMA benefit calculation is shown below.

G.2.2 Level 1 Model

The Level 1 model was originally developed in response to the request for information contained in Generic Letter 88-20. The fault tree linking approach was used and all event trees and fault trees were developed based on plant drawings and procedures. The model includes detailed fault tree models of all front line (accident mitigating) systems and their support systems (HVAC, Electrical, Air). The model also included detailed event trees which delineate accident sequences based primarily on the temporal response of the systems needed to mitigate the initiating event. The MPS3 PRA model chronology follows:

Table G.2-1.
MP3 PRA Model Chronology.

Date	Description
8/83	Millstone 3 PSS submitted
9/83	Amendment 1: Corrected consequence analysis
1/84	Transfer of PSS technology from Westinghouse, the PSS contractor, to the licensee
4/84	Amendment 2: Reanalysis of seismic fragilities by Structural Mechanics Associates
11/84	Amendment 3: Correction of mathematical error in seismic analysis
8/85	Published Millstone 3 risk evaluation report (NUREG-1152)
8/87	Amendment 4 (internal): Reanalysis of the Level 1 PRA to account for actual surveillance intervals, main feedwater recovery, etc.
1988	First round of evaluation of projects under internal Integrated Safety Assessment Program (ISAP)
1989	Second round of internal ISAP evaluations
1989-1990	Transferred PSS from mini-computer to PC
5/90	5th update: Correction of math and logic errors discovered in transfer
6/90	6th update: Updated transient frequencies (plant data), revised V sequence model, and coupled the Level 2 PRA to the Level 1
Fall 1990	Coupled the Level 3 PRA to Levels 1 and 2; third round of ISAP evaluations
8/90	Submittal of IPE
5/92	NRC staff evaluation report concludes IPE meets the intent of Generic Letter 88-20. The report contains recommendations to explicitly model 1) total loss of service water initiating event, 2) HVAC dependency, and 3) DC power dependency
12/95	Model converted from support state to linked fault tree methodology Ventilation dependency explicitly modeled DC power dependency explicitly modeled Total loss of service water initiator modeled
2/96	LERF model developed using original PSS model
10/98	Station Blackout (SBO) diesel generator battery limitation modeled Transfer to sump recirculation analyzed using simulator data Plant-specific data update
8/99	Time-dependent SBO model incorporated Loss of ventilation/room heat-up calculation conclusions incorporated
9/99	Westinghouse Owner's Group peer review completed
6/00	Incorporated loss of offsite power and offsite power restoration calculations
9/02	NUREG/CR-5750 used as source of general initiating event frequencies Incorporated some of level A and B peer review comments

The information used in the Level 1 model was verified using plant walkdowns. An independent peer review was conducted of the Level 1 and Level 2 models prior to submittal to the NRC.

A peer review was performed on the current PRA model used for the SAMA analysis during September 1999.

A breakdown of the CDF by initiating event (i.e. LOOP, General Transients, LOCAs, SGTR, etc.) plus other initiators are shown in Figure G.2-1. A list of the top 30 cutsets from the Level 1 model is shown in Table G.2-2 below.

Figure G.2-1
MPS3 Breakdown of CDF by Initiating Event

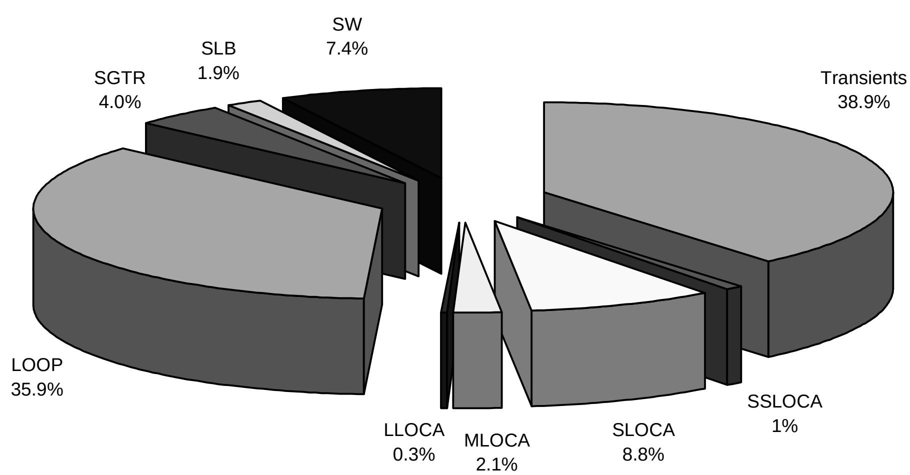


Table G.2-2.
MPS3 Summary of Top 30 Cutsets of PRA Model.

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
1	%GPT	General plant transient		1.24	1.24E+00	1.29E-06
	FWCP0FWAP1N2	CCF to start of MD AUX feedwater pumps FW*P1A and FW*P1B	1.42E-04	1.00	1.42E-04	
	FWXP5FWAP2FN	AFW turbine driven pump FW*P2 fails to run	5.00E-03	24.00	1.20E-01	
	OAPBAF	operators fail to establish bleed and feed		0.06	6.10E-02	
2	%GPT	General plant transient		1.24	1.24E+00	8.18E-07
	STUCKROD35	CCF of 35 or more control rods to insert		6.60E-07	6.60E-07	
3	%SGTR	Steam generator tube rupture		7.00E-03	7.00E-03	3.77E-07
	FWBP0FWP1BBQ	Motor driven auxiliary feedwater pump FWP1B OOS for maintenance	7.35E-03	1.00	7.35E-03	
	FWXP5FWAP2FN	AFW turbine driven pump FW*P2 fails to run	5.00E-03	24.00	1.20E-01	
	MODE1	Mode 1		1.00	1.00E+00	
	OAPBAF	Operators fail to establish bleed and feed		0.06	6.10E-02	
4	%GPT	General plant transient		1.24	1.24E+00	3.63E-07
	FWCP0FWAP1N2	CCF to start of MD AUX feedwater pumps FW*P1A and FW*P1B	1.42E-04	1.00	1.42E-04	
	FWXP5FWAP2NN	AFW turbine driven pump FW*P2 fails to start	3.38E-02	1.00	3.38E-02	
	OAPBAF	Operators fail to establish bleed and feed		0.06	6.10E-02	
5	%MLOCA	Medium break LOCA initiating event frequency		4.00E-05	4.00E-05	2.40E-07
	OAPREC	Operators fail to establish sump recirculation (large or medium LOCA)		6.00E-03	6.00E-03	
6	%SLOCA	Small break LOCA initiating event frequency		3.33E-04	3.33E-04	1.99E-07
	SWCMSV50ABF1	CCF to close MOV50A and MOV50B (MOV 54A,B,C,D permissive)	5.97E-04	1.00	5.97E-04	
7	%SLOCA	Small break LOCA initiating event frequency		3.33E-04	3.33E-04	1.99E-07
	SWCMSV71ABF1	CCF to close 3SWP*MOV71A and 3SWP*MOV71B (flow diversion path)	5.97E-04	1.00	5.97E-04	
8	%RHRSUCTION	ISLOCA via RHR suction lines		1.93E-07	1.93E-07	1.93E-07

Table G.2-2.
MPS3 Summary of Top 30 Cutsets of PRA Model. (Cont.)

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
9	%SLBO	Steamline break outside containment		1.00E-02	1.00E-02	1.92E-07
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
10	%GPT	General plant transient		1.24	1.24E+00	1.82E-07
	FWXTKFDWSTTN	DWST ruptures	1.00E-07	24.00	2.40E-06	
	OAPBAF	Operators fail to establish bleed and feed		0.06	6.10E-02	
11	%GPT	General plant transient		1.24	1.24E+00	1.69E-07
	FWCP0FWAP1N2	CCF to start of MD AUX feedwater pumps FW*P1A and FW*P1B	1.42E-04	1.00	1.42E-04	
	FWXP5FWAP2NQ	AFW turbine driven pump FW*P2 OOS for maintenance	1.57E-02	1.00	1.57E-02	
	OAPBAF	Operators fail to establish bleed and feed		0.06	6.10E-02	
12	%GPT	General plant transient		1.24	1.24E+00	1.34E-07
	FWAP0FWP1ANN	Motor driven auxiliary feedwater pump FWP1A fails to start	2.01E-03	1.00	2.01E-03	
	FWBP0FWP1BBQ	Motor driven auxiliary feedwater pump FWP1B OOS for maintenance	7.35E-03	1.00	7.35E-03	
	FWXP5FWAP2FN	AFW turbine driven pump FW*P2 fails to run	5.00E-03	24.00	1.20E-01	
	MODE1	Mode 1		1.00	1.00E+00	
	OAPBAF	Operators fail to establish bleed and feed		0.06	6.10E-02	
13	%LOOPWR	loss of offsite power (weather related events)		5.20E-03	5.20E-03	1.21E-07
	ACADG3EGSAFN	Diesel generator a fails to run	3.39E-03	24.00	8.14E-02	
	ACBDG3EGSBFN	Diesel generator b fails to run	3.39E-03	24.00	8.14E-02	
	ACXBGSBODGFN	SBO diesel fails to run	2.00E-03	24.00	4.80E-02	
	OSPRN1WR	Failure to recover weather-related loop - PORVs, AFW AVAIL (0-400 GPM)		0.14	1.35E-01	
	RCPSL1	21 GPM per RCP seal leak		0.79	7.90E-01	
	CDF990	Mission time adjustment since core damage occurs in 16.5 hours		0.69	6.88E-01	

Table G.2-2.
MPS3 Summary of Top 30 Cutsets of PRA Model. (Cont.)

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
14	%SGTR	Steam generator tube rupture		7.00E-03	7.00E-03	1.06E-07
	FWBP0FWP1BBQ	Motor driven auxiliary feedwater pump FWP1B OOS for maintenance	7.35E-03	1.00	7.35E-03	
	FWXP5FWAP2NN	AFW turbine driven pump FW*P2 fails to start	3.38E-02	1.00	3.38E-02	
	MODE1	Mode 1		1.00	1.00E+00	
	OAPBAF	Operators fail to establish bleed and feed		0.06	6.10E-02	
15	%SGTR	Steam generator tube rupture		7.00E-03	7.00E-03	1.03E-07
	FWBP0FWP1BNN	Motor driven auxiliary feedwater pump FWP1B fails to start	2.01E-03	1.00	2.01E-03	
	FWXP5FWAP2FN	AFW turbine driven pump FW*P2 fails to run	5.00E-03	24.00	1.20E-01	
	MODE1	Mode 1		1.00	1.00E+00	
	OAPBAF	Operators fail to establish bleed and feed		0.06	6.10E-02	
16	%LOOPPC	Loss of offsite power (plant-centered events)		0.02	2.25E-02	9.85E-08
	ACADG3EGSAFN	Diesel generator a fails to run	3.39E-03	24.00	8.14E-02	
	FWBP0FWP1BBQ	Motor driven auxiliary feedwater pump FWP1B OOS for maintenance	7.35E-03	1.00	7.35E-03	
	FWXP5FWAP2FN	AFW turbine driven pump FW*P2 fails to run	5.00E-03	24.00	1.20E-01	
	MODE1	Mode 1		1.00	1.00E+00	
	OAPBAF	Operators fail to establish bleed and feed		0.06	6.10E-02	
17	%SLOCA	small break LOCA initiating event frequency		3.33E-04	3.33E-04	9.76E-08
	HVCACAC2ABN2	CCF of RSS ACU units to start	2.93E-04	1.00	2.93E-04	
18	%GPT	General plant transient		1.24	1.24E+00	9.58E-08
	FWAP0FWP1AAQ	Motor driven auxiliary feedwater pump FWP1A OOS for maintenance	5.25E-03	1.00	5.25E-03	
	FWBP0FWP1BNN	Motor driven auxiliary feedwater pump FWP1B fails to start	2.01E-03	1.00	2.01E-03	
	FWXP5FWAP2FN	AFW turbine driven pump FW*P2 fails to run	5.00E-03	24.00	1.20E-01	

Table G.2-2.
MPS3 Summary of Top 30 Cutsets of PRA Model. (Cont.)

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
	MODE1	Mode 1		1.00	1.00E+00	
	OAPBAF	Operators fail to establish bleed and feed		0.06	6.10E-02	
19	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV20AFF	Steam generator atmos relief valve (PV20A) fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
20	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV20BFF	Steam generator atmos relief valve (PV20B) fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
21	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV20CFF	Steam generator ATMOS relief valve (PV20C) fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
22	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV20DFF	Steam generator ATMOS relief valve (PV20D) fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
23	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV47AFF	Air operated valve PV47A fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
24	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV47BFF	Air operated valve PV47B fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
25	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV47CFF	Air operated valve PV47C fails to close on demand	3.32E-03	1.00	3.32E-03	

Table G.2-2.
MPS3 Summary of Top 30 Cutsets of PRA Model. (Cont.)

#	Inputs	Description	Fail Rate	Exposure	Event Prob	Probability
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
26	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV48AFF	Air operated valve PV48A fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
27	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV48BFF	Air operated valve PV48B fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
28	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV48CFF	Air operated valve PV48C fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
29	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV49AFF	Air operated valve PV49A fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	
30	%GPT	General plant transient		1.24	1.24E+00	7.90E-08
	MSXAVPV49BFF	Air operated valve PV49B fails to close on demand	3.32E-03	1.00	3.32E-03	
	RPSFAILURE	Electrical failure of RPS (excluding CCF of RX trip breakers)		1.92E-05	1.92E-05	

G.2.3 Level 2 Model

A full Level 2 model was developed for the PSS in 1983 and completed at the same time as the Level 1 model. The Level 2 model consists of containment event trees with nodes that represent phenomenological events. The nodes were quantified using subordinate trees and logic rules. The Level 2 model was submitted within the IPE in 1990 (Ref. G 2-1). A list of the Plant Damage States (PDS) and descriptions, used for the Level 2 analysis is shown in Table G.2-3 below.

Table G.2-3.
Notation and Definitions for MPS3 Plant Damage States Description.

PDS	Description
AE	Large or medium LOCA, early core damage
AEQ	Large or medium LOCA, early core damage, quench spray available
AER	Large or medium LOCA, early core damage, recirculation spray available
AES	Large or medium LOCA, early core damage, quench and recirculation spray available
AL	Large or medium LOCA, late core damage
ALQ	Large or medium LOCA, late core damage, quench spray available
ALR	Large or medium LOCA, late core damage, recirculation spray available
ALS	Large or medium LOCA, late core damage, quench and recirculation spray available
SE	Small LOCA, early core damage
SEQ	Small LOCA, early core damage, quench spray available
SER	Small LOCA, early core damage, recirculation spray available
SES	Small LOCA, early core damage, quench and recirculation spray available
SL	Small LOCA, late core damage
SLQ	Small LOCA, late core damage, quench spray available
SLR	Small LOCA, late core damage, recirculation spray available
SLS	Small LOCA, late core damage, quench and recirculation spray available
TE	Transient, early core damage
TEQ	Transient, early core damage, quench spray available
TER	Transient, early core damage, recirculation spray available
TES	Transient, early core damage, quench and recirculation spray available
TL	Transient, late core damage
TLQ	Transient, late core damage, quench spray available
TLR	Transient, late core damage, recirculation spray available
TLS	Transient, late core damage, quench and recirculation spray available
V	Interfacing System LOCA
V2E	Steam Generator Tube Rupture, early core damage
V2L	Steam Generator Tube Rupture, late core damage

Table G.2-4 is an expression of the MPS3 Level 2 IPE in a form consistent with the current MPS3 PRA practice. This table shows the transformation formulae used to convert the PDS frequencies to the STC (defined in Table G.2-5) frequencies. The new baseline release category frequencies are shown in Table G.2-6 below.

The current version of the PRA model was used for the SAMA analysis. The quantification of the CDF change due to the SAMA changes was made using the CAFTA computer code at a truncation value of 1.0E-11.

G.2.4 **PRA IPEEE Model**

The PSA results used in this analysis are calculated using internal event results only, because MPS3 does not currently have a complete external events model that can be easily quantified. To account for the potential impact of external events on the results of these SAMA evaluations, the benefits of each SAMA were multiplied by a factor for the purposes of comparing with its cost.

The following summarizes the IPEEE at Millstone Unit 3:

The high winds and external flooding analyses resulted in the finding that the plant is adequately designed to protect against the effects of these natural events. Other external events were evaluated and found to be insignificant contributors to CDF. In summary, none of these external events were significant enough contributors to do a rigorous CDF calculation.

The external events contribution to the CDF consists mostly of fire events but other events were considered. The fire analysis found that three fire areas required detailed analysis: the Cable Spreading Room, the Main Control Room and the charging and component cooling zone which together contributed more than half of the total CDF from fires. The total CDF from fires, internal/external floods, and seismic at Millstone Unit 3 is 1.48E-5/year.

Table G.2-4.
Transformation of MPS3 IPE PDS Frequencies into Containment Release Category Frequencies.

Release Category	Formulae
M1A	= V
M1B	= V2E + V2L
M2	= 0
M3	= 0
M4	= 0
M5	= (0.62 * AE) + (0.54 * AL) + (0.06 * SE) + (0.01 * SL)
M6	= (0.62 * AE) + (0.54 * AL) + (0.06 * SE) + (0.01 * SL)
M7	= (0.29 * AE) + (0.35 * AL) + (0.89 * SE) + (0.79 * SL) + (0.90 * TE) + AEQ + ALQ + SEQ + SLQ + TEQ + TLQ
M8	= 0
M9	= (0.09 * AE) + (0.11 * AL) + (0.05 * SE) + (0.20 * SL) + (0.10 * TE) + 0.05 * (AES + ALS + SES + SLS + TES + TLS) + 0.99 * (AER + ALR + SER + SLR + TER + TLR)
M10	= (0.09 * AE) + (0.11 * AL) + (0.05 * SE) + (0.20 * SL) + (0.10 * TE) + 0.05 * (AES + ALS + SES + SLS + TES + TLS) + 0.99 * (AER + ALR + SER + SLR + TER + TLR)
M11	= (0.09 * AE) + (0.11 * AL) + (0.05 * SE) + (0.20 * SL) + (0.10 * TE) + 0.05 * (AES + ALS + SES + SLS + TES + TLS) + 0.99 * (AER + ALR + SER + SLR + TER + TLR)
M12	= 0.95 * (AES + ALS + SES + SLS + TES + TLS) + 0.01 * (AER + ALR + SER + SLR + TER + TLR)

Table G.2-5.
Notation and Definitions for MPS3 Containment Release Categories.

Release Category	Description
M1A	Containment Bypass, V-Sequence
M1B	Containment Bypass, SGTR
M2	Early Failure/Early Melt, No Sprays
M3	Early Failure/Late Melt, No Sprays
M4	Containment Isolation Failure
M5	Intermediate Failure/Late Melt, No Sprays
M6	Intermediate Failure/Early Melt, No Sprays
M7	Late Failure, No Sprays
M8	Intermediate Failure With Sprays
M9	Late Failure With Sprays
M10	Basemat Failure, No Sprays
M11	Basemat Failure With Sprays
M12	No Containment Failure

Table G.2-6.
MPS3 Baseline Source Term Category Frequencies.

STC	Base Frequency
M1A	2.21E-07
M1B	1.00E-06
M2	0.00E+00
M3	0.00E+00
M4	0.00E+00
M5	1.96E-07
M6	1.96E-07
M7	7.79E-06
M8	0.00E+00
M9	1.60E-06
M10	1.60E-06
M11	1.60E-06
M12	1.46E-05
Sum	2.88E-05

G.2.5 References

Ref. G.2-1 NUSCO 171, "MP3 Individual Plant Examination (IPE) for Severe Accident Vulnerabilities," Northeast Utilities Service Company, Aug. 1990.

G.3 Evaluation Of Candidate SAMAs

This section describes the generation of the initial list of potential SAMAs for MPS3, screening methods and the analysis of the remaining SAMAs.

G.3.1 SAMA List Compilation

Dominion generated a list of candidate SAMAs by reviewing industry documents and considering plant-specific enhancements not considered in published industry documents. Industry documents reviewed include the following:

- The MPS3 IPE submittal (only items not already evaluated and/or implemented during the IPE) (Ref. G 1-3)
- The Watts Bar Nuclear Plant Unit 1 PRA/IPE submittal (Ref. G 3-2)
- The Limerick SAMDA cost estimate report (Ref. G 3-3)
- NUREG-1437 description of Limerick SAMDA (Ref. G 3-4)
- NUREG-1437 description of Comanche Peak SAMDA (Ref. G 3-5)
- Watts Bar SAMDA submittal (Ref. G 3-6)
- TVA response to NRC's RAI on the Watts Bar SAMDA submittal (Ref. G 3-7)
- Westinghouse AP600 SAMDA (Ref. G 3-8)
- Safety Assessment Consulting (SAC) presentation by Wolfgang Werner at the NUREG-1560 conference (Ref. G 3-9)
- NRC IPE Workshop - NUREG-1560 NRC Presentation (Ref. G 3-10)
- NUREG-0498, supplement 1, section 7 (Ref. G 3-11)
- NUREG/CR-5567, PWR Dry Containment Issue Characterization (Ref. G 3-12)
- NUREG-1560, Volume 2, NRC Perspectives on the IPE Program (Ref. G 3-13)
- NUREG/CR-5630, PWR Dry Containment Parametric Studies (Ref. G 3-14)
- NUREG/CR-5575, Quantitative Analysis of Potential Performance Improvements for the Dry PWR Containment (Ref. G 3-15)
- CE System 80+ Submittal (Ref. G 3-16)
- NUREG-1462, NRC Review of ABB/CE System 80+ Submittal (Ref. G 3-17)
- An ICONE paper by C. W. Forsberg, et. al, on a core melt source reduction system (Ref. G 3-18)

- Additional items from the Millstone PRA staff from the review of the most significant Basic Events which were sorted by the Fussell-Vesely parameter.
- The Calvert Cliffs Nuclear Power Plant Application for License Renewal (Ref. G 3-21)
- The North Anna and Surry Nuclear Power Plant Applications for License Renewal (Ref. G 3-22)

Although MPS3 is a Westinghouse design, each of the above documents were reviewed for potential SAMAs, even if they were not necessarily applicable to a Westinghouse plant. SAMAs not applicable to MPS3 were subsequently screened from this list. The document reviews did not include sections pertaining to containment performance improvement programs for boiling water reactors and ice condenser plants. Conceptual enhancement for which no specific details were available (e.g., "improve diesel reliability" or "improve procedures for loss of support systems") were not adopted as potential SAMAs, unless they were considered as vulnerabilities in the MPS3 IPE or updated PRA analyses.

Also, Basic Events were considered whose Fussell-Vesely parameter was greater than 0.005 or whose RRW was greater than 1.005 which yielded a significant number of SAMAs used for this evaluation. A partial list of these sorted Basic Events is shown on Table G.3-4.

G.3.2 Qualitative Screening of SAMAs

Table G.3-1 lists the 185 potential SAMAs that were identified for consideration. SAMA items 159-185 of this list were obtained by review of the most significant Basic Events which were sorted by the Fussell-Vesely (FV) parameter and corresponding Risk Reduction Worth (RRW) parameter. Those Basic Events were considered whose Fussell-Vesely parameter was greater than 0.005 or whose RRW was greater than 1.005. Table G.3-1 also presents a qualitative screening of these SAMAs. Items were eliminated from further evaluation based on one of the following criteria:

- (Criterion A): The SAMA is not applicable at MPS3, either because the enhancement is only for boiling water reactors, the Combustion Engineering design or PWR ice condenser containment, or it is a plant specific enhancement that does not apply at MPS3.
- (Criterion B): The SAMA has already been implemented at MPS3 (or the MPS3 design meets the intent of the SAMA).

- (Criterion C): The SAMA is related to a Reactor Coolant pump (RCP) seal vulnerability at many PWRs stemming from charging pump dependency on Component Cooling Water (CCW). MPS3 does not have this vulnerability because the charging pumps do not rely on component cooling water (CCW). However, other RCP seal LOCA improvements will still be considered.

Based on preliminary screening of the 185 SAMAs, 133 were eliminated, leaving 52 subject to the cost/benefit process. The 52 SAMAs left after the initial screening are listed in Table G.3-2.

The final screening process involved identifying and eliminating those items whose cost exceeded their benefit. Table G.3-2 provides a description of the evaluation of each and provides the basis for their elimination or describes their final resolution. In general, the conclusion of most quantitative analysis resulted in a cost that exceeded the benefit by at least a factor of two. The presentation of the factor of two in Table G.3-2 provided confidence that even when uncertainties are considered, the cost would still exceed the benefit. No SAMAs were considered to be cost beneficial.

G.3.3 Analysis of Potential SAMAs

The methodology used for this evaluation was based upon the NRC's guidance for the performance of cost-benefit analyses (Ref. G 3-20). This guidance involves determining the net value for each SAMA according to the following formula:

Net Value = (APE + AOC + AOE + AOSC) – COE

where:

APE = present value ($) of averted public exposure from the results of the MACCS2 model,

AOC = present value ($) of averted offsite property damage costs from the results of the MACCS2 model,

AOE = present value ($) of averted occupational exposure from the guidance provided in Ref. G.3-20,

AOSC = present value ($) of averted onsite costs including cleanup/ decontamination costs, repair/refurbishment costs, replacement power costs,

COE = cost of enhancement ($).

If the net value of a SAMA is negative, the cost of implementing the SAMA is larger than the benefit associated with the SAMA and is not considered beneficial. The derivation of each of these costs is described below.

The following specific values were used for various terms in the analyses:

Present Worth

The present worth was determined by:

$$PW = \frac{1 - e^{-rt}}{r}$$

where:

r is the discount rate = 7 percent (as prescribed by Ref. G.3-20)

r is the duration of the license renewal = 20 years

PW is the present worth of a string of annual payments = 10.76

Dollars per REM

The conversion factor used for assigning a monetary value to on-site and off-site exposures was $2,000/person-rem averted. This is consistent with the NRC's regulatory analysis guidelines presented in and used throughout NUREG/BR-0184, Ref. G 3-20.

On-site Person REM per Accident

The occupational exposure associated with severe accidents was assumed to be 23,300 person-rem/accident. This value includes a short-term component of 3,300 person-rem/accident and a long-term component of 20,000 person-rem/accident. These estimates are consistent with the "best estimate" values presented in Section 5.7.3 of Ref. G 3-20. In the cost/benefit analyses, the accident-related on-site exposures were calculated using the best estimate exposure components applied over the on-site cleanup period.

On-site Cleanup Period

In the cost/benefit analyses, the accident-related on-site exposures were calculated over a 10-year cleanup period.

Present Worth On-site Cleanup Cost per Accident

The estimated cleanup cost for severe accidents was assumed to be \$1.5E+09/accident (undiscounted). This value was derived by the NRC in Ref. G 3-20, Section 5.7.6.1, Cleanup and Decontamination. This cost is the sum of equal annual costs over a 10-year cleanup period. At a 7 percent discount rate, the present value of this stream of costs is \$1.1E+09.

Methods for Calculating Averted Costs Associated with Onsite Accident Dose and Property Loss Costs

a) **Immediate Doses** (at time of accident and for immediate management of emergency)

For the case where the plant is in operation, the equations in Ref. G 3-20 can be expressed as:

$$W_{IO} = \left(F_S D_{IO_S} - F_A D_{IO_A}\right) R \frac{1 - e^{-rt_f}}{r} \qquad (1)$$

where:

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

R = monetary equivalent of unit dose, (\$/person-rem)

F = accident frequency (events/yr)

D_{IO} = immediate occupational dose (person-rems/event)

S = status quo (current conditions)

A = after implementation of proposed action

r = real discount rate

t_f = years remaining until end of facility life.

The values used are:

R = \$2000/person rem

r = .07

D_{IO} = 3,300 person-rems /accident (best estimate)

The license renewal time of 20 years is used for t_f.

For the base discount rate, assuming F_A is zero, the best estimate of the limiting saving is

$$W_{IO} = \left(F_S D_{IO_S}\right) R \frac{1-e^{-rt_f}}{r}$$

$$= 3300 * F * \$2000 * \frac{1-e^{-.07*20}}{.07}$$

$$= F * \$6{,}600{,}000 * 10.763$$

$$= F * \$0.71E+8, (\dot{\$}).$$

b) **Long-Term Doses** (process of cleanup and refurbishment or decontamination)

For the case where the plant is in operation, the equations in Ref. G 3-20 can be expressed as:

$$W_{LTO} = \left(F_S D_{LTO} - F_A D_{LTO_A}\right) R * \frac{1-e^{-rt_f}}{r} * \frac{1-e^{-rm}}{rm} \qquad (2)$$

where:

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

m = years over which long-term doses accrue.

The values used are:

R = \$2000/person rem

r = .07

D_{LTO} = 20,000 person-rem /accident (best estimate)

m = "as long as 10 years"

The license extension period of 20 years is used for t_f.

For the discount rate of 7 percent, assuming F_A is zero, the best estimate of the limiting saving is

$$W_{LTO} = \left(F_S D_{LTO_S}\right) R * \frac{1 - e^{-rt_f}}{r} * \frac{1 - e^{-rm}}{rm}$$

$$= (F_S\ 20{,}000)\ \$2000 * \frac{1 - e^{-.07*20}}{.07} * \frac{1 - e^{-.07*10}}{.07 * 10}$$

$$= F_S * \$40{,}000{,}000 * 10.763 * 0.719$$

$$= F_S * \$3.095E + 8,\ (\$)$$

c) **Total Accident-Related Occupational (On-site) Exposures**

Combining equations (1) and (2) above, using delta (Δ) to signify the difference in accident frequency resulting from the proposed actions, and using the above numerical values, the long term accident related on-site (occupational) exposure avoided (AOE) is:

Best Estimate:

$$AOE = DW_{IO} + DW_{LTO} \Delta F * \$(0.71 + 3.1)E + 8 = DF * \$3.81E + 8(\$)$$

where:

Δ = annual frequency of the event

Methods of Calculation of Averted Costs Associated with Accident-Related On-Site Property Damage

a) **Cleanup/Decontamination**

Ref. G 3-20 assumes a total cleanup/decontamination cost of $1.5E+9 as a reasonable estimate and this same value was adopted for these analyses. Considering a 10-year cleanup period, the present value of this cost is:

$$PV_{CD} = \left(\frac{C_{CD}}{m}\right)\left(\frac{1 - e^{-rm}}{r}\right)$$

where:

PV_{CD} = Present value of the cost of cleanup/decontamination.

C_{CD} = Total cost of the cleanup/decontamination effort.

m = Cleanup period.

r = Discount rate.

Based upon the values previously assumed:

$$PV_{CD} = \left(\frac{\$1.5E+9}{10}\right)\left(\frac{1-e^{-.07*10}}{.07}\right)$$

$$PV_{CD} = \$1.079E+9$$

This cost is integrated over the term of the proposed license extension as follows

$$U_{CD} = PV_{CD}\frac{1-e^{-rt_f}}{r}$$

Based upon the values previously assumed:

U_{CD} = \$1.079E + 9 [10.763]

U_{CD} = \$1.161E + 10

b) **Replacement Power Costs**

Replacement power costs, U_{RP}, are an additional contributor to onsite costs. These are calculated in accordance with NUREG/BR-0184, Section 5.6.7.2.[1] Since replacement power will be needed for that time period following a severe accident, for the remainder of the expected generating plant life, long-term power replacement calculations have been used. For a ‘generic’ plant of 910 MWe, the present value of replacement power is calculated as follows:

$$PV_{RP} = \left(\frac{\$1.2E+8}{r}\right)\left(1-e^{-rt_f}\right)^2$$

1. The section number for Section 5.6.7.2 apparently contains a typographical error. This section is a subsection of 5.7.6 and follows 5.7.6.1. However, the section number as it appears in the NUREG will be used in this document.

where:

PV_{RP} = Present value of the cost of replacement power for a single event.

t_f = Years remaining until end of facility life.

r = Discount rate.

The $1.2E+8 value has no intrinsic meaning but is a substitute for a string of non-constant replacement power costs that occur over the lifetime of a "generic" reactor after an event (from Ref. G 3-20). This equation was developed per NUREG/BR-0184 for discount rates between 5 percent and 10 percent only.

For discount rates between 1 percent and 5 percent, Ref. G 3-20 indicates that a linear interpolation is appropriate between present values of $1.2E+9 at 5 percent and $1.6E+9 at 1 percent. So for discount rates in this range the following equation was used to perform this linear interpolation.

$$PV_{RP} = (\$1.6E+9) - \left(\frac{[(\$1.6E+9) - (\$1.2E+9)]}{[5\% - 1\%]} * [r_s - 1\%]\right)$$

where:

r_s = Discount rate (small), between 1 percent and 5 percent.

To account for the entire lifetime of the facility, U_{RP} was then calculated from PV_{RP}, as follows:

$$U_{RP} = \frac{PV_{RP}}{r}\left(1 - e^{-rt_f}\right)^2$$

where:

U_{RP} = Present value of the cost of replacement power over the life of the facility.

Again, this equation is only applicable in the range of discount rates from 5 percent to 10 percent. NUREG/BR-0184 states that for lower discount rates, linear interpolations for U_{RP} are recommended between $1.9E+10 at 1 percent and $1.2E+10 at 5 percent. The following equation was used to perform this linear interpolation:

$$U_{RP} = (\$1.9E+10) - \left(\frac{[(\$1.9E+10) - (\$1.2E+10)]}{[5\% - 1\%]} * [r_s - 1\%]\right)$$

where:

r_s = Discount rate (small), between 1 percent and 5 percent.

MPS3 has a design electrical rating (DER) of 1154 Mwe. The DER of 1154 MWe will be used in this calculation, yielding a scaling factor of 1.268 (1154/910) to be applied to these formulae.

c) **Repair and Refurbishment**

It is assumed that the plant would not be repaired.

d) **Total Onsite Property Damage Costs**

The total averted onsite damage cost is, therefore:

$$AOSC = F^*(U_{CD} + U_{RP})$$

Where F = Annual frequency of the event.

Accident-Related Off-Site Dose Costs

Offsite doses were determined using the MACCS2 model developed for MPS3. Costs associated with these doses were calculated using the following equation:

$$APE = \left(F_S D_{P_S} - F_A D_{P_A}\right) R \frac{1 - e^{-rt_f}}{r} \qquad (1)$$

where:

APE = monetary value of accident risk avoided due to population doses, after discounting

R = monetary equivalent of unit dose, ($/person-rem)

F = accident frequency (events/yr)

D_P = population dose factor (person-rems/event)

S = status quo (current conditions)

A = after implementation of proposed action

r = real discount rate

t_f = years remaining until end of facility life.

Using the values for r, t_f, and R given above:

$$W_P = (\$2.15E + 4)\left(F_S D_{P_S} - F_A D_{P_A}\right)$$

Accident-Related Off-Site Property Damage Costs

$$AOC = \left(F_S P_{D_S} - F_A P_{D_A}\right)\frac{1 - e^{-rt_f}}{r}$$

AOC = monetary value of accident risk avoided due to offsite property damage, after discounting

P_D = offsite property loss factor (dollars/event)

The evaluation process prescribed in Ref. G 3-20 calculates the value of averted risk on an annual basis. Therefore, a method of "discounting" is used to calculate the "present value" or "present worth of averted risk" based on a specified period of time. For this analysis, a discount factor of 7 percent as prescribed in the NRC Regulatory Analysis Technical Evaluation Handbook was used to determine the present worth of averted risk over the 20 year license renewal period for MPS3.

The PSA results used in this analysis are calculated using internal event results only, because MPS3 does not currently have a complete external events model that can be easily quantified. To account for the potential impact of external events on the results of these SAMA evaluations, the benefits of each SAMA were multiplied by a factor of 1.6 for purposes of comparing with its cost. Further description of how the 1.6 multiplier was calculated is described below. However, for some SAMAs that relate only to specific internal events initiators (e.g., some SGTR and ISLOCA SAMAs), the benefits will not necessarily be multiplied. In addition, the benefit of each SAMA listed in Table G.3-2 is doubled for purposes of the comparison with its cost, except for SGTR and ISLOCA SAMAs.

The 1.6 multiplier and doubling of the benefit bounds any contribution that would be expected from the external events effects. The following summarizes the IPEEE at Millstone Unit 3:

The external events contribution of 1.48E-5/year (from Section G.2.4) compares to a base CDF of 2.88E-5/year from the internal events model used to calculate SAMA benefit. The ratio of the internal events plus the external events, over the internal events yields a value of 1.51, (rounded up to 1.6) was used as an external events multiplier, on all SAMA benefits except for the SGTR and ISLOCA events. In addition as an extra measure of conservatism to account for parameter uncertainties, these SAMA benefits were doubled when compared to the cost values.

The maximum theoretical benefit (also called Maximum Attainable Benefit, or MAB) is based upon the elimination of all plant risk (CDF = 0.0) and equates to the previously calculated base case risk. The monetary value of the risk associated with those SAMAs that involve major plant modifications may simply be compared with this benefit as a means of eliminating them from further consideration (e.g., a SAMA that would require construction of a large structure might be compared with the MAB).

The SAMA cost estimates do not always require rigorous effort, since the benefit from many of the SAMAs is found to be much less than even an order of magnitude estimate of the cost. Detailed cost estimating is only applied in those situations in which the benefit is significant and application of judgement would be questioned.

G.3.4 Sensitivity Analyses

The PRA calculations of SAMA benefit are recognized to have some uncertainty around the mean frequencies used in the analyses. The uncertainty is related to both quantifiable uncertainty distributions of the data, and unquantifiable uncertainty in the PRA assumptions. To account for the possible uncertainty, rather than perform a quantitative uncertainty analysis, the following sensitivity analyses were performed to bound the analysis.

NUREG/BR-0184 recommends using a 7 percent real (i.e., inflation-adjusted) discount rate for value-impact analysis and notes that a 3 percent discount rate (Case 1) should be used for sensitivity analysis to indicate the sensitivity of the results to the choice of discount rate. This reduced discount rate takes into account the additional uncertainties (i.e., interest rate fluctuations) in predicting costs for activities that would take place several years in the future. Analyses presented in Section G.3.3 used the 7 percent discount rate (Baseline Case) in calculating benefits of all the unscreened SAMAs. Dominion also performed a sensitivity analysis by substituting the lower discount rate and recalculating the benefit of the candidate SAMAs. In addition, a sensitivity case was run using a 15 percent discount rate (Case 2), which is judged to be more realistic for Dominion.

A total of thirteen sensitivity cases were analyzed, each varying an aspect of the MACCS2 input deck. These MACCS2 runs included 1 Baseline case plus 13 sensitivity cases. The Baseline case used the best estimate values with year 2040 population projections, an evacuation speed of 1.49 m/s and year 2000 meteorological data. The Baseline case assumed that 100 percent of the population within the 10 mile radius of the plant will evacuate. A sensitivity run (Case 3) on evacuation modeling was carried out by assuming an evacuation scenario wherein 95 percent of the population are evacuated normally and 5 percent are not evacuated at all (within the 10 mile emergency zone). A sensitivity run was made to evaluate the evacuation speed (ESPEED) and another to evaluate the delay time to take shelter from the reference time point parameter (DLTSHL). Case 4 was made to evaluate the sensitivity on evacuation speed (ESPEED = 1.8m/s). Case 5 evaluated a delay time to take shelter from the reference time point of 9000 seconds. Another sensitivity run (Case 6) was made to determine the impact of a 10 percent increase in the core power (CORSCA) on the resulting population dose. Two sensitivity runs (Case 7 and 8) were made using 1999 and 1998 meteorological data respectively. A sensitivity run (Case 9) was made to determine the impact of doubling the plume release height (PLHITE) on the resulting population dose. Sensitivity Case 10 was made to determine the sensitivity of doubling the duration of source term release time, parameter (PLDUR), to determine the impact on the resulting population dose. Sensitivity Case 11 was made to determine the impact of a 10 percent increase in the population relocation cost (POPCST) on the overall damage cost due to the accident. Cases12 and 13 were made to determine the sensitivity on the M7a and M7b source term release fractions (RELFRC).

A summary of the sensitivity cases is as follows:

- Baseline Case - Year 2000 Met Data, 100 percent Evacuation
- Case 1 - Sensitivity Case: 3 percent Discount Rate
- Case 2 - Sensitivity Case: 15 percent Discount Rate
- Case 3 - Sensitivity Case: WTFRAC = 0.95
- Case 4 - Sensitivity Case: ESPEED = 1.8 m/s
- Case 5 - Sensitivity Case: DLTSHL = 9000 s
- Case 6 - Sensitivity Case: CORSCA = x 1.1
- Case 7 - Sensitivity Case: 1999 Met Data
- Case 8 - Sensitivity Case: 1998 Met Data
- Case 9 - Sensitivity Case: PLHITE = 2(x)
- Case 10 - Sensitivity Case: PLDUR = 2(x)
- Case 11 - Sensitivity Case: POPCST = 8910 $/person
- Case 12 - Sensitivity Case: Same as Baseline Case except RELFRC M7 = M7a
- Case 13 - Sensitivity Case: Same as Baseline Case except RELFRC M7 = M7b

It is to be noted that Cases 1 and 2 are same as the Baseline case except for the change in the discount rate. Cases 3 to 13 required changes to the MACCS2 input file. The benefits calculated for each of these sensitivities are presented in Table G.3-3. As seen in the table, all of the sensitivity cases result in less than a factor of 2 increase in the benefit calculation. Table G.3-2 showed that all of the SAMAs screened with costs at least twice the benefit, so it is concluded that the cost-benefit results hold true even when the many uncertainties are considered.

G.3.5 References

Ref. G.3-1 NUSCO 171, "MP3 Individual Plant Examination (IPE) for Severe Accident Vulnerabilities," Northeast Utilities Service Company, Aug. 1990.

Ref. G.3-2 RF-REPORT, Letter from Mr. M. O. Medford (TVA) to NRC Document Control Desk, dated September 1, 1992. "Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Generic Letter (GL) 88-20 - Individual Plant Examination (IPE) for Severe Accident Vulnerabilities - Response - (TAC M74488)."

Ref. G.3-3 RF-REPORT, "Cost Estimate for Severe Accident Mitigation Design Alternatives, Limerick Generating Station for Philadelphia Electric Company," Bechtel Power Corporation, June 22, 1989.

Ref. G.3-4 RF-REPORT, NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," Volume 1, Table 5.35, Listing of SAMDAs considered for the Limerick Generating Station, NRC, May 1996.

Ref. G.3-5 RF-REPORT, NUREG-1437, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," Volume 1, Table 5.36, Listing of SAMDAs considered for the Comanche Peak Steam Electric Station, NRC, May 1996.

Ref. G.3-6 RF-REPORT, Letter from Mr. W. J. Museler (TVA) to NRC Document Control Desk, dated June 5, 1993, "Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Severe Accident Mitigation Design Alternatives (SAMDA) - (TAC Nos. M77222 and M77223)."

Ref. G.3-7 RF-REPORT, Letter from Mr. D. E. Nunn (TVA) to NRC Document Control Desk, dated October 7, 1994, "Watts Bar Nuclear Plant (WBN) Units 1 and 2 - Severe Accident Mitigation Design Alternatives (SAMDA) - Response to Request for Additional Information (RAI) - (TAC Nos. M77222 and M77223)."

Ref. G.3-8 RF-REPORT, Letter from N. J. Liparulo (Westinghouse Electric Corporation) to NRC Document Control Desk, dated December 15, 1992, "Submittal of Material Pertinent to the AP600 Design Certification Review."

Ref. G.3-9 RF-REPORT, Brookhaven National Laboratory, Department of Advanced Technology, Technical Report FIN W-6449, "NRC - IPE Workshop Summary/ Held in Austin Texas; April 7-9 1997," dated July 17, 1997/Appendix F - Industry Presentation Material, Contribution by Swedish Nuclear Power Inspectorate (SKI) and Safety Assessment Consulting (SAC): "Insights from PSAs for European Nuclear Power Plants," presented by Wolfgang Werner, SAC.

Ref. G.3-10 RF-REPORT, Brookhaven National Laboratory, Department of Advanced Technology, Technical Report FIN W-6449, "NRC - IPE Workshop Summary/ Held in Austin Texas; April 7-9 1997," dated July 17, 1997/Appendix D - NRC Presentation Material on Draft NUREG-1560.

Ref. G.3-11 RF-REPORT, NUREG-0498, "Final Environmental Statement related to the operation of Watts Bar Nuclear Plant, Units 1 and 2," Supplement No. 1, NRC, April 1995.

Ref. G.3-12 RF-REPORT, NUREG/CR-5567, "PWR Dry Containment Issue Characterization," NRC, August 1990.

Ref. G.3-13 RF-REPORT, NUREG-1560, "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance," Volume 2, NRC, December 1997.

Ref. G.3-14 RF-REPORT, NUREG/CR-5630, "PWR Dry Containment Parametric Studies," NRC, April 1991.

Ref. G.3-15 RF-REPORT, NUREG/CR-5575, "Quantitative Analysis of Potential Performance Improvements for the Dry PWR Containment," NRC, August 1990.

Ref. G.3-16 RF-REPORT, CESSAR Design Certification, Appendix U, Section 19.15.5, Use of PRA in the Design Process, December 31, 1993.

Ref. G.3-17 NUREG-1462, "Final Safety Evaluation Report Related to the Certification of the System 80+ Design," NRC, August 1994.

Ref. G.3-18 Forsberg, C. W., E. C., Beahm, and G. W. Parker, "Core-Melt Source Reduction System (COMSORS) to Terminate LWR Core-Melt Accidents," Second International Conference on Nuclear Engineering (ICONE-2) San Francisco, California, March 21-24, 1993.

Ref. G.3-19 NUSCO 171, "MP3 Individual Plant Examination (IPE) for Severe Accident Vulnerabilities," Northeast Utilities Service Company, Aug. 1990.

Ref. G.3-20 NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook," January 1997.

Ref. G.3-21 BGE Letter to NRC, Calvert Cliffs Nuclear Power Plant Unit Nos. 1 &2; Docket Nos. 50-317& 50-318, Application for License Renewal, April 8, 1998.

Ref. G.3-22 Dominion License Renewal Applications, North Anna Units 1 and 2, Surry Units 1 and 2, May 2001.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis.

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
1	Cap downstream piping of normally closed CCW drain and vent valves.	Reduces the frequency of loss of CCW initiating event, a large portion of which was derived from catastrophic failure of one of the many single isolation valves.	(13)	C	Screened out. Loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW.
2	Enhance Loss of CCW procedure to facilitate stopping RCPs.	Reduces potential for RCP seal damage due to pump bearing failure.	(2), (10), (13)	C	Screened out. Loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW.
3	Enhance Loss of CCW procedure to present desirability of cooling down RCS prior to seal LOCA.	Potential reduction in the probability of RCP seal failure.	(2)	C	Screened out. Loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW.
4	Additional training on the Loss of CCW.	Potential improvement in success rate of operator actions after a loss of CCW.	(2)	C	Screened out. Loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW.
5	Provide hardware connections to allow another SW loop to cool charging pump seals	Reduce effect of loss of CCW by providing a means to maintain the charging pump seal injection after a loss of CCW. Note, in Watts Bar, this capability was already there for one charging pump at one unit, and the potential enhancement identified was to make it possible for all the charging pumps.	(2), (6), (11), (13)	C	Screened out. At MPS3 SW is already used to cool an intermediate closed loop which cools the lube oil for the Charging pump. Loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW.
6	On loss of SW, proceduralize shedding CCW loads to extend the CCW heatup time	Increase time before the loss of CCW (and RCP seal failure) in the loss of ERCW sequences.	(2)	C	Screened out. Loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW.
7	Increase charging pump lube oil capacity	Would lengthen time before charging pump failure due to lube oil overheating in loss of CCW sequences.	(2)	C	Screened out. Loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW.
8	Eliminate RCP thermal barrier dependence on CCW, such that loss of CCW does not result directly in core damage.	Would prevent loss of RCP seal integrity after a loss of CCW. Watts Bar IPE said this could be done with SW connection to charging pump seals.	(2), (13)	C	Screened out. Loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW. Although the RCP thermal barrier cooling is dependent on CCW, but the RCP seal cooling is not. RCP seal integrity after a loss of CCW will still be maintained.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
9	Provide additional SW pump that can be connected to either SW header.	Providing another pump would decrease core damage frequency due to a loss of SW.	(5)		Not initially screened. Considered further in the cost benefit analysis.
10	Create an independent RCP seal injection system, with dedicated diesel.	Would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of seal cooling or SBO.	(6), (11), (13)		Not initially screened. Considered further in the cost benefit analysis.
11	Create an independent RCP seal injection system, without dedicated diesel.	Would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of seal cooling, but not SBO.	(11)		Not initially screened. Considered further in the cost benefit analysis.
12	Use existing hydro test pump for RCP seal injection.	Independent seal injection source, without cost of a new system.	(7)	A	Screened out. Plant specific enhancement does not apply at MPS3.
13	Replace ECCS pump motors with air cooled motors.	Remove dependency on CCW.	(10), (13)	B	Screened out. At MPS3 all ECCS pump motors are air cooled. Secondly loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW.
14	Install improved RCP seals.	RCP seal O-rings constructed of improved materials would reduce chances of RCP seal LOCA.	(11), (13)	B	Screened out. New O-rings installed already.
15	Add a third CCW pump.	Reduce chance of loss of CCW.	(13)	B	Screened out. The MPS3 design is that it already has 3 CCW pumps, one per each train with a swing pump that can be aligned to either train. This design provides sufficient redundancy.
16	Prevent charging pump flow diversion from the relief valves.	If relief valve opening causes a flow diversion large enough to prevent RCP seal injection, then modification can reduce frequency of loss of RCP seal cooling.	(13)	A	Screened out. There are no relief valves in the MPS3 design, instead there is a mini recirc flow of 60 gpm around the charging pump that prevents deadheading of the pump.
17	Change procedures to isolate RCP seal letdown flow on loss of CCW, and guidance on loss of injection during seal LOCA.	Reduce CDF from loss of seal cooling.	(13)	C	Screened out. Loss of CCW will not result in loss of RCP seal cooling because charging pumps do not rely on CCW.
18	Procedures to stagger charging pump use after a loss of SW.	Allow high pressure injection to be extended after a loss of SW.	(13)	B	Screened out. A method of feed and bleed to cool the charging pumps is used instead of staggering the use of the charging pumps.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
19	Use firewater pumps as a backup seal injection and high pressure makeup.	Reduce RCP seal LOCA frequency and SBO core damage frequency.	(13)	A	Screened out. This SAMA is considered not feasible since the fire pumps cannot deliver sufficient head to provide seal injection. FW is used to backup SW in cooling the CH pump cooling system.
20	Procedural guidance for use of cross-tied CCW or SW pumps.	Can reduce the frequency of the loss of either of these. Also consider installing a CCW header cross-tie.	(13)		Not initially screened. Considered further in the cost benefit analysis.
21	Procedure & operator training enhancements in support system failure sequences, with emphasis on anticipating problems and coping.	Potential improvement in success rate of operator actions after support system failures.	(2), (13)	Grouped into a category called "Loss of CCW or SW procedural enhancements	Not initially screened. Considered further in the cost benefit analysis.
22	Improve ability to cool RHR heat exchangers.	Reduced chance of loss of RHR by: Performing procedure and hardware modification to allow manual alignment of fire protection system to the CCW system.	(12), (13)	A	Screened out. This is screened out because the fire water system does not have sufficient flow to cool the RHR heat exchangers plus there is no firewater connection or procedures in place.
23	Improve SW pump alignments when a header is out for maintenance.	An optimal alignment would improve SW availability during these periods.		B	Screened out. Individual SW pumps, but not entire headers are removed from service during normal operation. The AOT for an individual SW pump removed from service was determined using PRA methods.
24	Stage backup fans in Switchgear rooms.	Provides alternate ventilation in the event of a loss of switchgear ventilation.	(13)	A	Screened out. This item is screened out on the basis that fans alone would not remove the heat from the Switchgear rooms. Some method of heat removal would be required, as evaluated in SAMA #25.
25	Provide redundant train of ventilation to 480V board room.	Would improve reliability of 480V HVAC. At Watts Bar, only one train of HVAC cools the 480V board room that contains the unit vital inverters, and recovery actions are heavily relied on. Watts Bar IPE said their corrective action program is dealing with this.	(2), (13)	B	Screened out. MPS3 has 2 trains of HVAC available to cool the ESGR which are powered independently.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
26	Procedures for temporary HVAC.	Provides for improved credit to be taken for loss of HVAC sequences.	(11), (13)	B	Screened out. This item is screened out on the basis that temporary fans alone would not remove the heat from the Switchgear rooms. MPS3 has 2 trains of HVAC available to cool the ESGR which are powered independently.
27	Add a switchgear room high temp alarm.	Improve diagnosis of a loss of switchgear HVAC.	(13)	B	Screened out. A high temp alarm exists at MPS3 and procedures tell operators what to do.
28	Create ability to switch fan power supply to DC in SBO.	(was created for a BWR RCIC room, Fitzpatrick; possible for turbine AFW to have its own fan) Allow continued operation in SBO.	(13)	A (MPS3 turbine AFW can operate during an SBO)	Screened out. MPS3 TDAFW pump was designed to operate during SBO.
29	Delay containment spray actuation after large LOCA.	When ice remains in the ice condenser at such plants, containment sprays have little impact on containment performance, yet rapidly drain down the RWST. This improvement would lengthen time of RWST availability.	(2), (6)	A	Screened out. MPS3 is a large dry containment and has a large liquid inventory in the RWST which is sufficient for containment and core cooling. Operator can terminate Containment Spray if not needed to depressurize containment.
30	Install containment spray throttle valves.	Can extend the time over which water remains in the RWST, when full containment spray flow is not needed.	(11), (12), (13)	A	Screened out. MPS3 has ample RWST volume inventory to depressurize the containment and core cooling capability. Operator can terminate Containment Spray if not needed to depressurize containment.
31	Install an independent method of suppression pool cooling.	Would decrease frequency of loss of containment heat removal.	(3), (4)	A	Screened out. Applies to BWR only.
32	Develop an enhanced containment spray system.	Would provide a redundant source of water to the containment to control containment pressure, when used in conjunction with containment heat removal.	(3), (4), (16), (17)	B	Screened out. Risk significance of adding an AC-independent containment spray system has been previously evaluated in Ref. G.2-21 Section 5.3.4 to not be "cost effective by a substantial margin."
33	Provide a dedicated existing containment spray system.	Identical to the previous concept, except that one of the existing spray loops would be used instead of developing a new spray system.	(3), (4) (similar PWR containment spray option in (5), (6), (11))	B	Screened out. Bounded by SAMA #32.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
34	Install a containment vent large enough to remove ATWS decay heat.	Assuming injection is available, would provide alternative decay heat removal in an ATWS.	(3), (4)		Not initially screened. Considered further in the cost benefit analysis.
35	Install a filtered containment vent to remove decay heat.	Assuming injection is available (non-ATWS sequences), would provide alternate decay heat removal with the released fission products being scrubbed.	(3), (4) (similar options in (5), (6), (8), (11), (12), (16), (17)		Not initially screened. Considered further in the cost benefit analysis.
36	Install an unfiltered hardened containment vent.	Provides an alternate decay heat removal method (non-ATWS), which is not filtered.	(3), (4), (9), (14)		Not initially screened. Considered further in the cost benefit analysis.
37	Create/enhance hydrogen ignitors with independent power supply.	Use either a new, independent power supply, a non-safety grade portable generator, existing station batteries, or existing AC/DC independent power supplies such as the security system diesel. Would reduce hydrogen detonation at lower cost.	(3), (5), (6), (7), (9), (12), (13), (14), (15), (16), (17)	B	Screened out. Hydrogen igniters are not necessary because the operators are instructed by procedure OP 33E to purge containment of hydrogen using pneumatic valves which require only 125v Vital DC.
38	Create a passive hydrogen ignition system.	Reduce hydrogen detonation potential without requiring electric power.	(7), (11), (16), (17)	B	Screened out. Requirements on hydrogen mitigation systems in 10 CFR 50.44 are being changed to eliminate the need for hydrogen recombiners and other passive systems.
39	Create a giant concrete crucible with heat removal potential under the basemat to contain molten debris.	A molten core escaping from the vessel would be contained within the crucible. The water cooling mechanism would cool the molten core, preventing a meltthrough.	(3), (4), (16), (17)	B	Screened out. Impractical to add heat removal system under an existing basemat.
40	Create a water cooled rubble bed on the pedestal.	This rubble bed would contain a molten core dropping onto the pedestal, and would allow the debris to be cooled.	(3), (4), (8), (16), (17)	B	Screened out. MPS3 has a basaltic concrete basemat. Due to the chemical nature of this basemat type less concrete ablation by molten corium / concrete interaction (MCCI) would be expected compared to a limestone concrete type. Also, for core melt sequences where the vessel would breach at low RCS pressure, it is most likely that some concrete ablation may occur but most of the ex-vessel molten material will freeze in the cavity below the vessel.
41	Provide modification for flooding of the drywell head.	Would help mitigate accidents that result in leakage through the drywell head seal.	(4), (9)	A	Screened out. Applies to BWR only.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
42	Enhance fire protection system and/or standby gas treatment system hardware and procedures.	Improve fission product scrubbing in severe accidents.	(4)	A	Screened out. MPS3 does not have a standby gas treatment system. See SAMA #49 for fire protection system analysis.
43	Create a reactor cavity flooding system.	Would enhance debris coolability, reduce core concrete interaction and provide fission product scrubbing.	(5), (6), (9), (11), (12), (13), (15), (16), (17)		Not initially screened. Considered further in the cost benefit analysis.
44	Creating other options for reactor cavity flooding.	(a) Use water from dead-ended volumes, the condensed blowdown of the RCS, or secondary system by drilling pathways in the reactor vessel support structure to allow drainage from the steam generator compartments, refueling canal, sumps, etc., to the reactor cavity. Also (for ice condensers), allow drainage of water from melted ice into the reactor cavity. (b) Flood cavity via systems such as diesel driven fire pumps.	(7), (9), (13)	(a) - the ice condenser portion of this alternative is not applicable to MPS3	Not initially screened. Considered further in the cost benefit analysis.
45	Enhance air return fans (ice condenser containment).	Provide an independent power supply for the air return fans, reducing containment failure in SBO sequences.	(6), (11)	A	Screened out. Does not apply for MPS3.
46	Provide a core debris control system.	Would prevent the direct core debris attack of the primary containment steel shell by erecting a barrier between the seal table and containment shell.	(6), (11)	B	Screened out. Primary containment steel liner attacked by ejected molten debris is not a dominant failure mode for MPS3.
47	Create a core melt source reduction system (COMSORS).	Place enough glass underneath the reactor vessel such that a molten core falling on the glass would melt and combine with the material. Subsequent spreading and heat removal from the vitrified compound would be facilitated, and concrete attack would not occur (such benefits are theorized in the reference).	(19)	B	Screened out. MPS3 concrete basemat is of basaltic type. This concrete type has a high SiO_2 concentration.
48	Provide containment inerting capability.	Would prevent combustion of hydrogen and carbon monoxide gases.	(6), (9), (11), (14)	B	Screened out. Not practical because steam generated during a severe accident is sufficient to inert containment.
49	Use fire water spray pump for containment spray.	Redundant containment spray method without high cost.	(7), (9), (10), (12)	B	Screened out. Fire water pump does not provide sufficient head to reach spray rings and provide adequate spray flow.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
50	Install a passive containment spray system.	Containment spray benefits at a very high reliability, and without support systems.	(8)	B	Screened out. Bounded by SAMA #32 and #33.
51	Secondary containment filtered ventilation.	For plants with a secondary containment, would filter fission products released from the primary containment.	(8)	B	Screened out. At MPS3 the secondary containment gas space is filtered during an accident. On an SI signal the SLCRS is diverted to a filter bank in the Auxiliary building.
52	Increase containment design pressure.	Reduce chance of containment overpressure.	(8)	A	Screened out. This improvement is intended for a new design, not an existing one.
53	Increase the depth of the concrete basemat, or use an alternative concrete material to ensure melt through does not occur.	Prevent basemat melt through.	(16), (17)	A	Screened out. This improvement is intended for a new design, not an existing one.
54	Provide a reactor vessel exterior cooling system.	Potential to cool a molten core before it causes vessel failure, if the lower head can be submerged in water.	(16), (17)	A	Screened out. Not practical given the containment lower compartment's configuration.
55	Create another building, maintained at a vacuum to be connected to containment.	In an accident, connecting the new building to containment would depressurize containment and reduce any fission product release.	(17)	A	Screened out. This improvement is intended for a new design, not an existing one. MPS3 has a large dry containment that is normally operated only 1 psi below atmospheric pressure. MPS3 also has a secondary containment with a SLCRS that directs gas to a filter bank. The existing secondary containment is not designed to withstand a design basis LOCA pressure.
56	Add ribbing to the containment shell.	Would reduce the chance of buckling of containment under reverse pressure loading.	(17)	A	Screened out. This improvement is intended for a new design, not an existing one.
57	Train operations crew for response to inadvertent actuation signals.	Improves chances of a successful response to the loss of two 120V AC buses, which causes inadvertent signals.	(13)	B	Screened out. Operators are already trained for inadvertent actuation signals.
58	Proceduralize alignment of spare diesel to shutdown board after LOP and failure of the diesel normally supplying it.	Reduced SBO frequency.	(2)	B	Screened out. Procedures are already in place for this.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
59	Provide an additional diesel generator.	Would increase on-site emergency AC power reliability and availability (decrease SBO).	(5), (6), (10), (13) (16), (17)	B	Screened out. MPS3 already has installed an SBO diesel.
60	Provide additional DC battery capability.	Would ensure longer battery capability during a SBO, reducing frequency of long term SBO sequences.	(5), (6), (13), (16), (17)		Not initially screened. Considered further in the cost benefit analysis.
61	Use fuel cells instead of lead-acid batteries.	Extend DC power availability in a SBO.	(16), (17)		Not initially screened. Considered further in the cost benefit analysis.
62	Procedure to cross tie HPCS diesel.	(BWR 5/6).	(10)	A	Screened out. Applies to BWR only.
63	Improve the ability to mitigate loss of one emergency AC bus.	This will improve AC power reliability by using the SBO diesel. This improvement will require changes to existing procedures for new alignments.	(10), (13)		Not initially screened. Considered further in the cost benefit analysis.
64	Alternate battery charging capability.	Improved DC power reliability. Either cross tie of AC buses, or a portable diesel-driven battery charger.	(10), (11), (12), (13)	The bus cross-tie portion is grouped into a category "Improved bus cross-tie ability	"Not initially screened. Considered further in the cost benefit analysis.
65	Increase/improve DC bus load shedding.	Improved battery life in station blackout.	(10), (11), (12), (13)	B	Screened out. MPS3 procedures already direct appropriate DC load shedding during an SBO.
66	Replace batteries.	Improved reliability.	(10)	B	Screened out. Batteries are replaced based on expiration of seismic qualification. When their seismic qualification expires, they are replaced.
67	Create AC power cross tie capability across units.	Improved AC power reliability.	(11), (12), (13)		Not initially screened. Considered further in the cost benefit analysis.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
68	Create a cross-unit tie for diesel fuel oil.	Adds diesel fuel oil redundancy.	(13)	B	Screened out. The emergency generator fuel oil system has the following features: 1.Two tanks installed in an underground concrete vault, one for each diesel engine. Each emergency generator fuel oil storage tank is sized to store approximately 35,000 gallons of diesel fuel oil. 2.Four full-capacity, electric motor-driven, emergency generator fuel oil transfer pumps are supplied-two pumps for each emergency generator fuel oil storage tank. Each pump has sufficient capacity to fill both day tanks with both emergency generators running. 3.Two emergency generator fuel oil day tanks--one for each diesel engine. Each emergency generator fuel oil day tank is sized to store approximately 550 U.S. gallons of diesel fuel oil. 4.An interconnection with two normally locked-closed valves between the two emergency generator fuel oil supply headers is supplied to facilitate the use of either tank to supply either emergency generator. One pump on each tank is arranged to allow transfer from the A electrical bus to the B electrical bus, or vice versa, by means of a 480 V, seismically qualified Class 1E, manually operated transfer switch, under administrative control, thus ensuring approximately a 6-day supply of fuel for one diesel generator. Based on the above, no additional benefit would be expected from the proposed EDG fuel oil cross-tie capability.
69	Develop procedures to repair or change out failed 4KV breakers.	Offers a recovery path from a failure of breakers that perform transfer of 4.16 kV non-emergency buses from unit station service transformers to system station service transformers, leading to loss of emergency AC power (i.e., in conjunction with failures of the diesel generators).	(13)	B	Screened out. The offsite supply to the non-emergency AC buses is not interrupted unless there is a fault in the NSST which is a low probability event. This is because MPS3 is equipped with a generator output breaker which opens on a reactor trip; hence, no transfer of AC power is required.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
70	Emphasize steps in recovery of offsite power after a SBO.	Reduced human error probability of offsite power recovery.	(13)	B	Screened out. Procedure EOP 35 GA-3 already exists for recovery of offsite power.
71	Develop a severe weather conditions procedure.	For plants that do not already have one, reduces the likelihood of external events CDF.	(13)	B	Screened out. Procedure already exists.
72	Procedures for replenishing diesel fuel oil.	Allow long term diesel operation.	(13)	B	Screened out. MPS3 already has a procedure for replenishing fuel oil.
73	Install gas turbine generators.	Improve on-site AC power reliability.	(13)		Not initially screened. Considered further in the cost benefit analysis.
74	Install tornado protection on gas turbine generator.	If the unit has a gas turbine, the tornado-induced SBO frequency would be reduced.	(16), (17)	A	Screened out. No gas turbine exists at MPS3.
75	Create a river water backup for diesel cooling.	Provides redundant source of diesel cooling.	(13)		Not initially screened. Considered further in the cost benefit analysis. EDG is cooled by SW and SBO diesel is air cooled.
76	Use firewater as a backup for diesel cooling.	Redundancy in diesel support systems.	(13)		Not initially screened. Considered further in the cost benefit analysis.
77	Provide a connection to alternate offsite power source (the nearest dam).	Increase offsite power redundancy.	(13)		Not initially screened. Considered further in the cost benefit analysis.
78	Implement underground offsite power lines.	Could improve offsite power reliability, particularly during severe weather.	(13)	A	Screened out. This item is screened out based on the fact that underground high voltage lines would not be installed across the service area of Connecticut. Placing the offsite power lines underground for the section that they run through the MPS3-controlled area would be a negligible benefit since this area is negligible compared to the total span across which they would be exposed to severe weather.
79	Replace anchor bolts on diesel generator oil cooler.	Millstone 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.	(13)	B	Screened out. Anchor bolts already installed.
80	Create an auto-loading of the SBO diesel.	Removes the human error portion to reduce SBO frequency.			Not initially screened. Considered further in the cost benefit analysis.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
81	Install a fast acting MG output breaker.	With a fast acting breaker, a turbine runback would be possible, reducing the likelihood of a reactor trip in some cases.		B	Screened out. A fast acting MG output breaker has already been installed at MPS3.
82	Proceduralize use of pressurizer vent valves during SGTR sequences.	MPS3 procedures direct the use of the pressurizer vent valves during a SGTR event.	(13)	B	Screened out. Procedure already in place.
83	Install a redundant spray system to depressurize the primary system during a SGTR.	Enhanced depressurization ability during SGTR.	(16), (17)	B	Screened out. This feature is already installed in the plant. Charging pump provides auxiliary spray and RCPs provide normal spray.
84	Improved SGTR coping abilities.	Improved instrumentation to detect SGTR, or additional systems to scrub fission product releases.	(7), (9), (10), (13), (14), (16), (17)	B	Screened out. The MPS3 SGTR system has the following features: 1.Existing plant EOPs provide adequate guidance to identify a steam generator tube rupture event. 2.Also, Millstone Unit 3 has recently added new N-16 radiation monitors to help identify small primary-to-secondary tube leaks. This additional instrumentation will enhance the operator's ability to diagnose a steam generator tube rupture. Since noble gases are the typical radiological releases associated with a SGTR, installing additional systems to scrub fission product releases would not be helpful since the noble gases are non-condensable.
85	Adding other SGTR coping features.	(a)A highly reliable (closed loop) steam generator shell-side heat removal system that relies on natural circulation and stored water sources, (b)a system which returns the discharge from the steam generator relief valve back to the primary containment, (c)an increased pressure capability on the steam generator shell side with corresponding increase in the safety valve setpoints.	(7), (8), (17)	A	Screened out. Parts (a) and (c) are screened as not being feasible for an existing plant. Part (b) is also screened because adding such a steam load to the containment building would require a redesign of the containment pressure capacity.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
86	Increase secondary side pressure capacity such that a SGTR would not cause the relief valves to lift.	SGTR sequences would not have a direct release pathway.	(8), (17)	A	Screened out. Not applicable for existing plants.
87	Replace steam generators with new design.	Lower frequency of SGTR.	(13)		Not initially screened. Considered further in the cost benefit analysis.
88	Revise EOPs to direct that a faulted steam generator be isolated.	For plants whose EOPs don't already direct this, would reduce consequences of a SGTR.	(13)	B	Screened out. Procedures are already in place.
89	Direct steam generator flooding after a SGTR, prior to core damage.	Would provide for improved scrubbing of SGTR releases.	(14), (15)	B	Screened out. MPS3 procedures already direct this.
90	A maintenance practice that inspects 100 percent of the tubes in a steam generator.	Reduce chances of tube rupture.	(16), (17)	B	Screened out. MPS3 already practices 100 percent SG tube inspection.
91	Locate RHR inside of containment.	Would prevent ISLOCA out the RHR pathway.	(8)	A	Screened out. This item is not applicable to an existing plant.
92	Self-actuating containment isolation valves.	For plants that don't have this, it would reduce the frequency of isolation failure.	(8)	B	Screened out. MPS3 already has self-actuating containment isolation valves.
93	Additional instrumentation and inspection to prevent ISLOCA sequences.	Install additional instrumentation for detecting ISLOCA events. Implement a comprehensive piping inspection program to detect precursors to breaches in RCS integrity. The benefit assumes that the programs are so effective all ISLOCAs are eliminated.	(5), (6), (11), (13)		Not initially screened. Considered further in the cost benefit analysis.
94	Increase frequency of valve leak testing.	Decrease ISLOCA frequency.	(12)		Not initially screened. Considered further in the cost benefit analysis. MPS3 follows the Appendix J test program. Valve leakage testing is done every 60 months. If a failure occurs then go to outage testing. When 2 tests in a row are passed then go back to 60 month test again. All valves that go back to the RWST are tested every outage.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
95	Improvement of operator training on ISLOCA coping.	Decrease ISLOCA effects.	(12), (13)	B	Screened out. Operators are already trained for ISLOCA coping via lesson plan S03203C.
96	Install relief valves in the component cooling water system.	Would relieve pressure buildup from an RCP thermal barrier tube rupture, preventing an ISLOCA.	(13)	B	Screened out. The CCW system isolates on high CCW flow and that portion of the system is designed for RCS pressure.
97	Provide leak testing of valves in ISLOCA paths.	At Kewaunee, four MOVs isolating RHR from the RCS were not leak tested. Will help reduce ISLOCA frequency.	(13)	B	Screened out. Already done, see item 94.
98	Revise EOPs to improve ISLOCA identification.	Salem had a scenario in which an RHR ISLOCA could direct initial leakage back to the PRT, giving indication that the LOCA was inside containment. Procedure enhancement would ensure LOCA outside containment would be observed.	(13)	B	Screened out. Procedure already exists to identify ISLOCA sequence.
99	Ensure all ISLOCA releases are scrubbed.	Would scrub ISLOCA releases. One suggestion was to plug drains in the break area so the break point would cover with water.	(14), (15)		Not initially screened. Considered further in the cost benefit analysis.
100	Add redundant and diverse limit switch to each containment isolation valve.	Enhanced isolation valve position indication, which would reduce frequency of containment isolation failure and ISLOCAs.	(16), (17)		Not initially screened. Considered further in the cost benefit analysis.
101	Add a check valve downstream of the LHSI pumps on the cold leg injection line.	ISLOCA frequency is dominated by the LHSI lines, which has 2 check valves. Adding another check valve in the common injection line would essentially eliminate the frequency of the ISLOCA sequence through these pathways.		B	Screened out. At MPS3 two RHR pumps are used to provide LHSI core cooling. Redundant check valves already exist on these lines at MPS3.
102	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	For a plant where internal flooding from turbine building to safeguards areas is a concern, this modification can prevent flood propagation.	(13)	A	Screened out. At MPS3 there are no potential pathways for flooding of SFGD equipment.
103	Improve inspection of rubber expansion joints on main condenser.	For a plant where internal flooding due to failure of circulating water expansion joint is a concern, this can help reduce the frequency.	(13)	B	Screened out. Inspection of rubber expansion joints on main condenser is already done. The contribution to CDF due to flooding is small at MPS3.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
104	Internal flood prevention and mitigation enhancements.	(1) Use of submersible MOV operators. (2) Back flow prevention in drain lines.	(13)	B	Screened out. There is a small potential for flooding at MPS3 in the RHR and RSS pump cubicles from a pipe break. A water level alarm exists. The contribution to CDF due to flooding is small at MPS3.
105	Internal flooding improvements at Fort Calhoun.	Prevention or mitigation of 1)A rupture in the RCP seal cooler of the CCW system, 2)An ISLOCA in a shutdown cooling line, 3)An AFW flood involving the need to possibly remove a watertight door. For a plant where any of these apply, would reduce flooding risk.	(13)	A	Screened out. Does not apply to MPS3.
106	Digital feedwater upgrade.	Reduces chance of loss of MFW following a plant trip.	(13)	B	Screened out. By design Main Feedwater is automatically isolated on a reactor trip coincident with low TAVE. In addition, given a total loss of feedwater event, the EOP directs the operators to align the motor-driven MFW pump which is normally in standby and therefore, its reliability is not improved by a digital control system.
107	Perform a surveillance on manual valves used for backup AFW pump suction.	Improves success probability for providing alternate water supply to AFW pumps.	(13)	B	Screened out. Surveillance is already performed at MPS3.
108	Install manual isolation valves around AFW turbine driven steam admission valves.	Reduces the dual turbine driven pump maintenance unavailability.	(13)	A	Screened out. No manual valves exist but the MOV can be manually closed. MPS3 only has one TD AFW pump.
109	Install accumulators for turbine driven AFW pump flow control valves.	Provide control air accumulators for the turbine driven AFW flow control valves, the motor driven AFW pressure control valves, and S/G PORVs. This would eliminate the need for local manual action to align nitrogen bottles for control air during a LOP.	(11)	B	Screened out. The control valves are solenoid operated and therefore, only dependent upon DC power rather than instrument air.
110	Install a new Auxiliary Feedwater Storage Tank.	Either replace old tanks with larger ones, or install another backup tank.	(13), (16), (17)	B	Screened out. MPS3 uses a CST and a Demineralized water storage tank (DWST) that have lines connected near the AFW pump suction point. The CST provides an alternate suction path to the AFW pumps. Since this feature already exists, no further action on this mod is required.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
111	Cooling of steam driven AFW pump in a SBO.	Use firewater to cool pump, or Make the pump self-cooled. Would improve success chances in a SBO.	(13)	A	Screened out. MPS3 steam driven AFW pump is self cooled by the water that is being pumped.
112	Proceduralize local manual operation of AFW when control power is lost.	Lengthen AFW availability in SBO. Also provides a success path should AFW control power be lost in non-SBO sequences.	(13)		Not initially screened. Considered further in the cost benefit analysis.
113	Provide portable generators to be hooked in to the turbine driven AFW train, after battery depletion.	Extend AFW availability in a SBO (assuming the turbine-driven AFW requires DC power).	(16), (17)		Not initially screened. Considered further in the cost benefit analysis.
114	Add a motor train of AFW to the steam trains.	For PWRs that do not have any motor trains of AFW, this can increase reliability in non-SBO sequences.	(13)	B	Screened out. MPS3 has 2 MD AFW pumps.
115	Create ability for emergency connections of existing or alternate water sources to feedwater/condensate.	Would be a backup water supply for the feedwater/condensate systems.	(12)	B	Screened out. MPS3 uses a CST and a Demineralized water storage tank that have lines connected near the AFW pump suction point. The CST can also get water from the Condensate Surge Tank.
116	Use firewater as a backup for steam generator inventory.	Would create a backup to main and auxiliary feedwater for steam generator water supply.	(13)	A	Screened out. No firewater backup is available. MPS3 uses a CST and a Demineralized water storage tank that have lines connected near the AFW pump suction point.
117	Procure a portable diesel pump for isolation condenser makeup.	Backup to the city water supply and diesel fire water pump in providing isolation condenser makeup.	(13)	A	Screened out. No isolation condenser exists at MPS3.
118	Install an independent diesel for the condensate storage tank makeup pumps.	Would allow continued inventory in CST during a SBO.	(13)	B	Screened out. MPS3 uses a Demineralized Water Storage Tank as primary AFW inventory source (capacity of 360,000 gal) with the Condensate Storage Tank as the backup (capacity of 300,000 gal) needing one AOV to open to cross-tie the CST to the DWST. Tech specs require that a cumulative minimum capacity be maintained within both tanks. Sufficient capacity is assumed between the 2 tanks in the SBO sequence.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
119	Change failure position of condenser makeup valve.	If the condenser makeup valve fails open on loss of air or power, this can cause CST flow diversion to condenser. Allows less inventory for the AFW pumps.	(13)	A	Screened out. During an emergency, condenser makeup valve fails closed.
120	Create passive secondary side coolers.	Provide a passive heat removal loop with a condenser and heat sink. Would reduce CDF from the loss of feedwater.	(17)		Not initially screened. Considered further in the cost benefit analysis.
121	Automate air bottle swap for S/G PORVs.	Manual action is required to swap air source to the air bottles. Automatic swap on low pressure would eliminate the operator action.		A	Screened out. No air bottles are used to perform this function at MPS3.
122	Condenser dump after SI.	Utilize bypass around the main steam trip valves to use the condenser dump after an SI (the PRA assumes the function can not be recovered after an SI signal).		B	Screened out. Condenser dump is preferably used at MPS3.
123	Provide capability for diesel driven, low pressure vessel makeup.	Extra water source in sequences in which the reactor is depressurized and all other injection is unavailable (e.g., firewater).	(4), (5), (13)		Not initially screened. Considered further in the cost benefit analysis.
124	Provide an additional high pressure injection pump with independent diesel.	Reduce frequency of core melt from small LOCA sequences, and from SBO sequences.	(6), (16), (17)		Not initially screened. Considered further in the cost benefit analysis.
125	Install independent AC high pressure injection system.	Would allow make up and feed and bleed capabilities during a SBO.	(11)	Subsumed into "Provide an additional high pressure injection pump with independent diesel."	Not initially screened. Considered further in the cost benefit analysis.
126	Create the ability to manually align ECCS recirculation.	Provides a backup should automatic or remote operation fail.	(12)	B	Screened out. This feature already exists. No further action is required for this mod.
127	Implement an RWST makeup procedure.	Decrease core damage frequency from ISLOCA scenarios, some smaller break LOCA scenarios, and SGTR.	(12), (13)	B	Screened out. This feature already exists. No further action is required for this mod.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
128	Stop low pressure injection pumps earlier in medium or large LOCAs.	Would give more time to perform recirculation swapover.	(13)	A	Screened out. At MPS3 manual swapover occurs at approximately midlevel of the RWST and therefore there is plenty of time to perform the swapover process.
129	Emphasize timely recirc swapover in operator training.	Reduce human error probability of recirculation failure.	(13)	B	Screened out. Operators are already trained for this.
130	Upgrade CVCS to mitigate small LOCAs.	For a plant like the AP600 where CVCS can't mitigate small LOCA, an upgrade would decrease CDF from small LOCA.	(8)	A	Screened out. Not applicable to MPS3.
131	Install an active high pressure SI system.	For a plant like the AP600, where an active high pressure injection system does not exist, would add redundancy in high pressure injection.	(8)	B	Screened out. MPS3 already has an HPSI system.
132	Change "in-containment" RWST suction from 4 check valves to 2 check and 2 air operated valves.	Remove common mode failure of all four injection paths.	(8)	A	Screened out. Not applicable to MPS3.
133	Replace two of the four safety injection pumps with diesel pumps.	Intended for System 80+, which has four trains of SI. This would reduce common cause failure probability.	(16), (17)	A	Screened out. Not applicable to MPS3.
134	Align LPCI or core spray to CST on loss of supp pool cooling.	Low pressure ECCS can be maintained in loss of suppression pool cooling scenarios.	(10), (13)	A	Screened out. Not applicable to MPS3.
135	Raise HPCI/RCIC backpressure trip setpoints.	Ensures HPCI/RCIC availability when high suppression pool temperatures exist.	(13)	A	Screened out. Not applicable to MPS3.
136	Improve the reliability of the ADS.	Reduce frequency high pressure core damage sequences.	(4)	A	Screened out. Not applicable to MPS3. Applies to BWRs.
137	Disallow automatic vessel depressurization in non-ATWS scenarios.	Improve operator control of plant.	(13)	A	Screened out. Not applicable to MPS3.
138	Create automatic swapover to recirculation on RWST depletion.	Would remove human error contribution from recirculation failure.	(5), (6), (11)		Not initially screened. Considered further in the cost benefit analysis.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
139	Enlarge the RWST.	Greater water capacity for injection.		B	Screened out. MPS3 already has ample (i.e. greater than typical) capacity of water in the RWST.
140	Modify EOPs for ability to align diesel power to more air compressors.	For plants which do not have diesel power to all normal and backup air compressors, this change allows increased reliability of instrument air after a LOP.	(13)	B	Screened out. MPS3 has no risk significant dependence on instrument air. Auxiliary feedwater control valves, the RCS PORVs, and the atmospheric dump valves are all solenoid powered.
141	Replace old air compressors with more reliable ones.	Improve reliability and increase availability of instrument air compressors.	(13)	B	Screened out. Current instrument air compressors are considered reliable.
142	Install Nitrogen bottles as backup gas supply for SRVs.	Extend operation of Safety Relief Valves during SBO and loss of air events (BWRs).	(13)	A	Screened out. Not applicable to MPS3.
143-144	Install MG set trip breakers in control room.	Provides trip breakers for the motor generator sets in the control room. Currently, at Watts Bar, an ATWS would require an immediate action outside the control room to trip the MG sets. Would reduce ATWS CDF.	(11)	B	Screened out. MPS3 operators already have the ability to trip the MG set power supplies from the control room by tripping load centers 32B and 32N.
145	Create cross-connect ability for standby liquid control (SLC) trains.	Improved reliability for boron injection during ATWS.	(13)	A	Screened out. Not applicable to MPS3.
146	Create an alternate boron injection capability (backup to SLC).	Improved reliability for boron injection during ATWS.	(13)	A	Screened out. Not applicable to MPS3.
147	Remove or allow override of LPCI injection during ATWS.	On failure of HPCI and condensate, the Susquehanna units direct reactor depressurization followed by 5 minutes of automatic LPCI injection. Would allow control of LPCI immediately.	(13)	A	Screened out. Not applicable to MPS3. Applies to BWRs.
148	A system of relief valves that prevents any equipment damage from a pressure spike during an ATWS.	Would improve equipment availability after an ATWS.	(16), (17)	A	Screened out. Overpressure concerns are more applicable for a BWR design. A PWR design like MPS3 has safety relief valves on the pressurizer to prevent equipment damage.
149	Create a boron injection system to back up the mechanical control rods.	Provides a redundant means to shut down the reactor.	(16), (17)	B	Screened out. MPS3 has BAST to borate the RCS.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
150	Provide an additional I&C system (e.g., AMSAC).	Improve I&C redundancy and reduce ATWS frequency.	(16), (17)	B	Screened out. AMSAC will, in addition to the above, also trip the turbine.
151	Provide capability for remote operation of secondary side PORVs in SBO.	Manual operation of these valves is required in a SBO scenario. High area temperatures may be encountered in this case (no ventilation to main steam areas), and remote operation could improve success probability.	(2)	B	Screened out. Manual operation of the ADVs is required during an SBO event. Since the contribution of SBO to the CDF is about 3 percent, the benefit of this SAMA is expected to be minimal.
152	Create/enhance reactor coolant system depressurization ability.	Either with a new depressurization system, or with existing PORVs, head vents and secondary side valve, RCS depressurization would allow low pressure ECCS injection. Even if core damage occurs, low RCS pressure alleviates some concerns about high pressure melt ejection.	(5), (6), (9), (11), (12), (13), (14), (15), (16), (17)	B	Screened out. High Pressure Melt Ejection and Direct Containment Heating are no longer challenges to containment.
153	Make procedural changes only for the RCS depressurization option.	Reduce RCS pressure without cost of a new system.	(7), (9), (13)	B	Screened out. Procedures for RCS depressurization are already in place.
154	Defeat 100 percent load rejection capability.	Eliminates the possibility of a stuck open PORV after a LOP, since PORV opening wouldn't be needed.	(13)	A	Screened out. This item is not applicable to MPS3, since MPS3 does not have 100 percent load rejection capability. It has 50 percent capability.
155	Change CRD flow control valve failure position.	Change failure position to the 'fail-safest' position.	(13)	A	Screened out. Not applicable to MPS3. Applies to a BWR.
156	Secondary side guard pipes up to the MSIVs.	Would prevent secondary side depressurization should a steam line break occur upstream of the MSIVs. Would also guard against or prevent consequential multiple SGTR following a main steam line break event.	(16), (17)		Not initially screened. Considered further in the cost benefit analysis.
157	Digital large break LOCA protection.	Upgrade plant instrumentation and logic to improve the capability to identify symptoms/precursors of a large break LOCA (a leak before break).	(17)	B	Screened out. Large break LOCA has a low initiating event frequency (viewed as a "rare event" by most PRAs). Its contribution to CDF is also small and, hence, does not justify upgrading plant instrumentation and logic to improve the ability to identify symptoms/precursors of a large break LOCA (i.e., a leak before break) beyond what currently exists at the plant.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
158	Increase seismic capacity of the plant to a HCLPF of twice the SSE.	Reduced seismic CDF to a high confidence low probability failure (HCLPF) of twice the safe shutdown earthquake (SSE).	(17)	A	Screened out. Not a concern for MPS3 since it is located in a low seismic activity area. The seismic contribution to CDF is small for MPS3. This improvement is intended for a new design, not an existing one.
159	Redundant actuation RSS logic train.	Additional RSS logic train would reduce probability of total failure of core and containment cooling.	(19)	B	Screened out. Actuation of RSS for containment cooling is delayed 11 minutes after receipt of the containment depressurization actuation (CDA) signal which allows the sump to fill. During the 11 minute delay, the QSS system is supplying containment spray via the RWST, as well as, filling the sump and thus, providing adequate NPSH for the RSS pumps. Providing a redundant RSS actuation logic train does not address the NPSH requirement and does not provide a significant risk benefit since the operators would have at least 11 minutes to actuate the RSS spray function if the automatic feature failed.
160	Install turbine driven AF pump.	Additional TDAFW pump would provide a backup to existing pump.	(19)		Not initially screened. Considered further in the cost benefit analysis.
161	Install SBO diesel.	Additional SBO diesel dedicated to Unit 3 would provide added emergency power instead of relying on the swing SBO diesel.	(19)		Not initially screened. Considered further in the cost benefit analysis.
162	Install Charging system train.	Additional charging system train would provide additional flow path if valves fail to open or close in existing system.	(19)		Not initially screened. Considered further in the cost benefit analysis.
163	Install redundant isolation valve for RHR recirculation valve 3RHS*V43.	Additional isolation valve would assure core cooling in case existing system valves are misaligned.	(19)	B	Screened out.The LPSI function is not a significant contributor to core damage mitigation since the large break LOCA initiating event frequency is relatively low and the human reliability assessment of the operator action to close the valve and independent verification was conservative.
164	Install Safety Injection train.	Additional safety injection train would assure core cooling in case existing valves are failed or misaligned.	(19)		Not initially screened. Considered further in the cost benefit analysis.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
165	Install ESFAS logic train.	Additional ESFAS logic train would provide safe shutdown in case existing circuit is in test or out for maintenance.	(19)	B	Screened out.The possibility of ESFAS failing or being out of service for maintenance is currently modeled within the PRA and is a border line CDF contributor because not enough credit is taken for the EOPs to provide prompt guidance to actuate required accident mitigating equipment. This conservatism will be eliminated in future updates to the model.
166	Install QSS train.	An additional QSS train would assure containment spray function in case insufficient flow is experienced in existing train due to component failures.	(19)	B	Screened out. Bounded by SAMA #32.
167	Install redundant vent dampers to SLCRS.	Redundant vent dampers would provide assurance that SLCRS system provides adequate fission product removal in case existing dampers fail to reposition.	(19)	B	Screened out. Risk significance of SLCRS has been previously evaluated in Ref. G.2-22 to not be a significant contributor to risk and consequently not under the Maintenance Rule.
168	Automate Feed and Bleed.	A separate redundant auto Feed and Bleed process would provide reliability to the existing manual process.	(19)		Not initially screened. Considered further in the cost benefit analysis.
169	Improve boron injection reliability with new procedure and hardware.	Additional reliability is needed to assure reactor trip in case reactor trip fails due to mechanical rod binding.	(19)		Not initially screened. Considered further in the cost benefit analysis.
170	Add another AOV to isolate SW.	Currently MOVs are used to isolate SW, by including an AOV in the same flow path, this would preclude a common cause failure event.	(19)		Not initially screened. Considered further in the cost benefit analysis.
171	Install another RSS parallel flow path.	An additional flow path would assure that recirculation flow would still be delivered if the MOVs in the existing path fail to open.	(19)		Not initially screened. Considered further in the cost benefit analysis.
172	Add a redundant train of RSS.	An additional independent train of RSS would assure core cooling in case a CCF occurs on all the existing RSS trains.	(19)		Not initially screened. Considered further in the cost benefit analysis.
173	Add additional SW AOVs (ATC/ATO).	Additional air operated valves in the SW system would assure SW cooling in case a CCF of the existing MOVs occurred.	(19)		Not initially screened. Considered further in the cost benefit analysis.

Table G.3-1.
Initial List of Candidate Improvements for the MPS3 SAMA Analysis. (Cont.)

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.3.1)	Screening Criterion or Grouping (see Section G.3.2)	Evaluation
174	Add a redundant RCS instrumentation train to mitigate failure.	An additional RCS instrumentation train would mitigate the likelihood of simultaneous failure of existing systems.	(19)	B	Screened out. Bounded by SAMA #165.
175	Add a redundant DC bus.	A redundant DC bus would preclude the likelihood of complete DC bus failure.	(19)		Not initially screened. Considered further in the cost benefit analysis.
176	Add a redundant charging pump.	An additional charging pump would assure core cooling in case existing charging pump fails to run.	(19)		Not initially screened. Considered further in the cost benefit analysis.
177	Add a redundant block valve for the PORV.	An redundant block valve would assure isolation of the PORV in case an automatic reseat circuitry failure occurs.	(19)		Not initially screened. Considered further in the cost benefit analysis.
178	Add redundant MSIVs.	A redundant MSIV would prevent a common cause failure to close any 2 of 4 MSIVs.	(19)		Not initially screened. Considered further in the cost benefit analysis.
179	Add a redundant SW pump ventilation train.	A redundant SW pump would prevent a common cause failure of SW pump ventilation.	(19)		Not initially screened. Considered further in the cost benefit analysis.
180	Add a redundant valve in series to isolate the steam line dumps to condenser.	A redundant valve in series to isolate the steam line would prevent a common cause failure of existing AOV's to close on demand.	(19)		Not initially screened. Considered further in the cost benefit analysis.
181	Add parallel strainer for charging system.	A parallel strainer would ensure RCP seal injection in case the existing strainer plugs.	(19)	B	Screened out. A parallel strainer used for seal cooling already exists and is not credited because failure of the in-service RCP seal injection strainer is not considered risk significant.
182	Add redundant AC bus.	A redundant AC bus would preclude the likelihood of complete AC bus failure.	(19)		Not initially screened. Considered further in the cost benefit analysis.
183	Add redundant AFW flow path.	A redundant AFW flow path would preclude the likelihood of a CCF to open 2 of 4 injection checkvalves and a random failure of the unaffected checkvalve.	(19)		Not initially screened. Considered further in the cost benefit analysis.
184	Add redundant demineralized water storage tank (DWST).	An additional DWST would provide sufficient demineralized water to the AFW pumps for secondary cooling in case existing DWST ruptures.	(19)		Not initially screened. Considered further in the cost benefit analysis.
185	Add redundant RWST.	An additional RWST would provide sufficient borated water to the QSS pumps for core and containment cooling in case existing RWST ruptures.	(19)	B	Screened out. MPS3 has a very large RWST (~1.2E+06 gallons).

Table G.3-2.
Summary of MPS3 SAMAs Considered in Cost-Benefit Analysis.

SAMA No.	Potential Improvement	Discussion	Reduction in CDF	Reduction in Person-Rem Offsite (Bounding)	Benefit (Bounding)	Estimated Cost	Conclusion	Cost Estimate and Basis for Conclusion
9	Provide additional SW pump that can be connected to either SW header	Providing another pump would decrease core damage frequency due to a loss of SW.	8.54%	9.56%	$164,796	>2x Benefit	Screen out	Estimate Range: $10M - $15M. Not cost beneficial: since cost is greater than twice the benefit.
10	Create an independent RCP seal cooling system, with dedicated diesel	Would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of seal cooling or SBO.	22.82%	22.33%	$419,846	>2x Benefit	Screen out	Estimate Range: $10M - $15M. Not cost beneficial: since cost is greater than twice the benefit.
11	Create an independent RCP seal cooling system, without dedicated diesel	Would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of seal cooling, but not SBO.	22.82%	22.33%	$419,846	>2x Benefit	Screen out	Estimate Range: $5M - $8M. Not cost beneficial: since cost is greater than twice the benefit.
20	Procedural guidance for use of cross-tied CCW or SW pumps	Can reduce the frequency of the loss of either of these.	1.67%	0.32%	$14,099	>2x Benefit	Screen out	Engineering 3,000 MH @$75/Hr. = $225K Estimate Range: $150K - $300K. Not cost beneficial: since cost is greater than twice the benefit.
21	Loss of CCW or SW procedural enhancements	The suggested improvements in the reference documents include staggering CCW pump operation when SW fails, cross-tying pumps, or shedding CCW loads to extend heatup time.	1.67%	0.32%	$14,099	>2x Benefit	Screen out	Engineering 1,000 MH @$75/Hr. = $75K Estimate Range: $50K - $100K. Not cost beneficial: since cost is greater than twice the benefit.
34	Install a containment vent large enough to remove ATWS decay heat	Assuming injection is available, would provide alternative decay heat removal in an ATWS.	9.27%	1.27%	$103,371	>2x Benefit	Screen out	Estimate Range: $10M - $15M. Not cost beneficial: since cost is greater than twice the benefit.
35	Install a filtered containment vent to remove decay heat	Assuming injection is available (non-ATWS sequences), would provide alternate decay heat removal with the released fission products being scrubbed.	5.84%	6.36%	$110,796	>2x Benefit	Screen out	Estimate Range: $12M - $18M. Not cost beneficial: since cost is greater than twice the benefit.

Table G.3-2.
Summary of MPS3 SAMAs Considered in Cost-Benefit Analysis. (Cont.)

SAMA No.	Potential Improvement	Discussion	Reduction in CDF	Reduction in Person-Rem Offsite (Bounding)	Benefit (Bounding)	Estimated Cost	Conclusion	Cost Estimate and Basis for Conclusion
36	Install an unfiltered hardened containment vent	Provides an alternate decay heat removal method (non-ATWS), which is not filtered.	5.84%	6.36%	$110,796	>2x Benefit	Screen out	Estimate Range: $10M - $15M. Not cost beneficial: since cost is greater than twice the benefit.
43	Create a reactor cavity flooding system	Would enhance debris coolability, reduce core concrete interaction and provide fission product scrubbing.	0.02%	41.91%	$344,756	>2x Benefit	Screen out	Estimate Range: $18M - $24M. Not cost beneficial: since cost is greater than twice the benefit.
44	Creating other options for reactor cavity flooding	Flood cavity via systems such as diesel driven fire pumps.	0.02%	41.91%	$344,756	>2x Benefit	Screen out	Estimate Range: $18M - $24M. Not cost beneficial: since cost is greater than twice the benefit.
60	Provide additional DC battery capability	Would ensure longer battery capability during a SBO, reducing frequency of long term SBO sequences.	2.15%	2.60%	$42,753	>2x Benefit	Screen out	<u>Hours</u> <u>Rate</u> <u>Cost</u> Engineering 3,000 MH $75/Hr. $225,000 Construction Labor 2,500 MH $50/Hr. $125,000 Material $200,000 Services $25,000 Other Station Support @10% $57,500 Capital Interest @6% $38,000 Total Estimate $670,500 Estimate Range: $600K - $3M. Not cost beneficial: since cost is greater than twice the benefit.
61	Use fuel cells instead of lead-acid batteries	Extend DC power availability in a SBO.	2.15%	2.60%	$42,753	>2x Benefit	Screen out	Estimate Range: $3M - $5M. Not cost beneficial: since cost is greater than twice the benefit.
63	Improved bus cross tie ability	Improved AC power reliability within same unit.	27.84%	17.90%	$429,606	>2x Benefit	Screen out	Estimate Range: $2M - $5M. Not cost beneficial: since cost is greater than twice the benefit.

Table G.3-2.
Summary of MPS3 SAMAs Considered in Cost-Benefit Analysis. (Cont.)

SAMA No.	Potential Improvement	Discussion	Reduction in CDF	Reduction in Person-Rem Offsite (Bounding)	Benefit (Bounding)	Estimated Cost	Conclusion	Cost Estimate and Basis for Conclusion
64	Alternate battery charging capability	Provide a portable diesel-driven battery charger.	2.15%	2.60%	$42,753	>2x Benefit	Screen out	Estimate Range: $5M - $8M. Not cost beneficial: since cost is greater than twice the benefit.
67	Create AC power cross tie capability across units	Improved AC power reliability across 2 units.	8.60%	10.41%	$170,796	>2x Benefit	Screen out	Estimate Range: $4M - $6M. Not cost beneficial: since cost is greater than twice the benefit.
73	Install gas turbine generators	Improve on-site AC power reliability.	29.87%	24.15%	$500,060	>2x Benefit	Screen out	Estimate Range: $8M - $10M. Not cost beneficial: since cost is greater than twice the benefit.
75	Create a river water backup for diesel cooling.	Provides redundant source of diesel cooling.	0.74%	0.46%	$11,116	>2x Benefit	Screen out	Estimate Range: $10M - $20M. Not cost beneficial: since cost is greater than twice the benefit.
76	Use firewater as a backup for diesel cooling	Redundancy in diesel support system.	0.74%	0.46%	$11,116	>2x Benefit	Screen out	Estimate Range: $750K - $1.5M. Not cost beneficial: since cost is greater than twice the benefit.
77	Provide a connection to alternate offsite power source (the nearest dam)	Increase offsite power redundancy. Notes: Assumes dedicated poles & overhead HV line approximately 20 miles to Hydro Facility at Norwich via existing right of ways. Includes transformers, breakers, etc. Assumes all necessary right of ways exists, no clearing or access fees required.	38.44%	30.04%	$635,074	>2x Benefit	Screen out	Estimate Range: $6M - $10M. Not cost beneficial: since cost is greater than twice the benefit.
80	Create an auto-loading of the SBO diesel.	Removes the human error portion to reduce SBO frequency.	2.40%	2.88%	$47,432	>2x Benefit	Screen out	Estimate Range: $7M - $10M. Not cost beneficial: since cost is greater than twice the benefit.
87	Replace steam generators with new design	Lower frequency of SGTR.	3.47%	21.61%	$144,816	>2x Benefit	Screen out	Estimate Range: $175M - $200M. Not cost beneficial: since cost is greater than twice the benefit.

Table G.3-2.
Summary of MPS3 SAMAs Considered in Cost-Benefit Analysis. (Cont.)

SAMA No.	Potential Improvement	Discussion	Reduction in CDF	Reduction in Person-Rem Offsite (Bounding)	Benefit (Bounding)	Estimated Cost	Conclusion	Cost Estimate and Basis for Conclusion
93	Additional instrumentation and inspection to prevent ISLOCA sequences.	Install additional instrumentation for detecting ISLOCA events. Implement a comprehensive piping inspection program to detect precursors to breaches in RCS integrity. The benefit assumes that the programs are so effective all ISLOCAs are eliminated.	0.77%	17.42%	$83,596	>2x Benefit	Screen out	Estimate Range: $9M - $12M. Not cost beneficial: since cost is greater than twice the benefit.
94	Increase frequency of valve leak testing	Decrease ISLOCA frequency.	0.77%	17.42%	$83,596	>2x Benefit	Screen out	Estimate Range: $2M - $4M per Refueling Outage. Not cost beneficial: since cost is greater than twice the benefit.
99	Ensure all ISLOCA releases are scrubbed	Would scrub ISLOCA releases. One suggestion was to plug drains in the break area so the break point would cover with water.	0.77%	17.42%	$83,596	>2x Benefit	Screen out	Estimate Range: $4M - $6M. Not cost beneficial: since cost is greater than twice the benefit.
100	Add redundant and diverse limit switch to each containment isolation valve.	Enhanced isolation valve position indication, which would reduce frequency of containment isolation failure and ISLOCAs.	0.77%	17.42%	$133,754	>2x Benefit	Screen out	Estimate Range: $18M - $24M. Not cost beneficial: since cost is greater than twice the benefit.
112	Proceduralize local manual operation of AFW when control power is lost	Lengthen AFW availability in SBO. Also provides a success path should AFW control power be lost in non-SBO sequences.	2.15%	2.60%	$42,753	>2x Benefit	Screen out	Engineering 2,000 MH @ $75/Hr. = $150,000 Construction $100,000 Labor, Material, Services, Other Station Support @10% = $25,000 Capital Interest @6% = $16,500 Total Estimate: $291,500 Estimate Range: $100K - $300K Not cost beneficial: since cost is greater than twice the benefit.

Table G.3-2.
Summary of MPS3 SAMAs Considered in Cost-Benefit Analysis. (Cont.)

SAMA No.	Potential Improvement	Discussion	Reduction in CDF	Reduction in Person-Rem Offsite (Bounding)	Benefit (Bounding)	Estimated Cost	Conclusion	Cost Estimate and Basis for Conclusion
113	Provide portable generators to be hooked in to the turbine driven AFW train, after battery depletion	Extend AFW availability in a SBO (assuming the turbine-driven AFW requires DC power).	1.94%	2.34%	$38,403	>2x Benefit	Screen out	Estimate Range: $5M - $8M. Not cost beneficial: since cost is greater than twice the benefit.
120	Create passive secondary side coolers	Provide a passive heat removal loop with a condenser and heat sink. Would reduce CDF from the loss of feedwater.	40.63%	15.41%	$532,887	>2x Benefit	Screen out	Estimate Range: $50M - $100M. Not cost beneficial: since cost is greater than twice the benefit.
123	Provide capability for diesel driven, low pressure vessel makeup	Extra water source in sequences in which the reactor is depressurized and all other injection is unavailable (e.g., firewater).	19.70%	22.93%	$396,036	>2x Benefit	Screen out	Estimate Range: $7.5 - $12M. Not cost beneficial: since cost is greater than twice the benefit.
124/ 125	Provide an additional high pressure injection pump with independent diesel	Reduce frequency of core melt from small LOCA sequences, and from SBO sequences.	3.45%	0.96%	$42,800	>2x Benefit	Screen out	Estimate Range: $10M - $16M. Not cost beneficial: since cost is greater than twice the benefit.
138	Create automatic swapover to recirculation on RWST depletion	Would remove human error contribution from recirculation failure.	1.71%	0.32%	$19,802	>2x Benefit	Screen out	Estimate Range: $2M - $3M. Not cost beneficial: since cost is greater than twice the benefit.
156	Secondary side guard pipes up to the MSIVs.	Would prevent secondary side depressurization should a steam line break occur upstream of the MSIVs. Would also guard against or prevent consequential multiple SGTR following a main steam line break event.	13.38%	22.54%	$335,690	>2x Benefit	Screen out	Estimate Range: $10M - $15M. Not cost beneficial: since cost is greater than twice the benefit.
160	Install turbine driven AF pump	Additional TDAFW pump would provide a backup to existing pump.	42.01%	33.53%	$712,156	>2x Benefit	Screen out	Estimate Range: $12M - $16M. Not cost beneficial: since cost is greater than twice the benefit.
161	Install SBO diesel	Additional SBO diesel dedicated to Unit 3 would provide added emergency power instead of relying on the swing SBO diesel.	5.32%	6.41%	$105,417	>2x Benefit	Screen out	Estimate Range: $8M - $10M. Not cost beneficial: since cost is greater than twice the benefit.

Table G.3-2.
Summary of MPS3 SAMAs Considered in Cost-Benefit Analysis. (Cont.)

SAMA No.	Potential Improvement	Discussion	Reduction in CDF	Reduction in Person-Rem Offsite (Bounding)	Benefit (Bounding)	Estimated Cost	Conclusion	Cost Estimate and Basis for Conclusion
162	Install Charging system train	Additional charging system train would provide additional flow path if valves fail to open or close in existing system.	7.22%	3.63%	$103,348	>2x Benefit	Screen out	Estimate Range: $20M - $30M. Not cost beneficial: since cost is greater than twice the benefit.
164	Install Safety Injection train	Additional safety injection train would assure core cooling in case existing valves are failed or misaligned.	3.45%	0.96%	$42,800	>2x Benefit	Screen out	Estimate Range: $20M - $30M. Not cost beneficial: since cost is greater than twice the benefit.
168	Automate Feed and Bleed	A separate redundant auto Feed and Bleed process would provide reliability to the existing manual process.	28.84%	21.45%	$480,825	>2x Benefit	Screen out	Estimate Range: $1M - $3M. Not cost beneficial: since cost is greater than twice the benefit.
169	Improve boron injection reliability with new procedure and hardware.	Additional reliability is needed to assure reactor trip in case reactor trip fails due to mechanical rod binding.	0.00%	0.00%	$0	>2x Benefit	Screen out	Estimate Range: $2M - $4M. Not cost beneficial: since cost is greater than twice the benefit.
170	Add another AOV to isolate SW	Currently MOVs are used to isolate SW, by including an AOV in the same flow path, this would preclude a common cause failure event.	7.10%	8.85%	$143,769	>2x Benefit	Screen out	Estimate Range: $2M - $3M. Not cost beneficial: since cost is greater than twice the benefit.
171	Install another RSS parallel flow path.	An additional flow path would assure that recirculation flow would still be delivered if the MOVs in the existing path fail to open.	1.68%	1.46%	$28,804	>2x Benefit	Screen out	Estimate Range: $10M - $20M. Not cost beneficial: since cost is greater than twice the benefit.
172	Add a redundant train of RSS.	An additional independent train of RSS would assure core cooling in case a CCF occurs on all the existing RSS trains.	1.68%	1.46%	$28,804	>2x Benefit	Screen out	Estimate Range: $20M - $40M. Not cost beneficial: since cost is greater than twice the benefit.
173	Add additional SW AOVs (ATC/ATO)	Additional air operated valves in the SW system would assure SW cooling in case a CCF of the existing MOVs occurred.	7.10%	8.85%	$143,769	>2x Benefit	Screen out	Estimate Range: $2M - $3M. Not cost beneficial: since cost is greater than twice the benefit.
175	Add a redundant DC bus.	A redundant DC bus would preclude the likelihood of complete DC bus failure.	0.30%	0.46%	$6,967	>2x Benefit	Screen out	Estimate Range: $5M - $8M. Not cost beneficial: since cost is greater than twice the benefit.

Table G.3-2.
Summary of MPS3 SAMAs Considered in Cost-Benefit Analysis. (Cont.)

SAMA No.	Potential Improvement	Discussion	Reduction in CDF	Reduction in Person-Rem Offsite (Bounding)	Benefit (Bounding)	Estimated Cost	Conclusion	Cost Estimate and Basis for Conclusion
176	Add a redundant charging pump.	An additional charging pump would assure core cooling in case existing charging pump fails to run.	7.22%	3.63%	$103,348	>2x Benefit	Screen out	Estimate Range: $10M - $16M. Not cost beneficial: since cost is greater than twice the benefit.
177	Add a redundant block valve for the PORV.	An redundant block valve would assure isolation of the PORV in case an automatic reseat circuitry failure occurs.	3.43%	2.54%	$55,118	>2x Benefit	Screen out	Estimate Range: $2M - $4M. Not cost beneficial: since cost is greater than twice the benefit.
178	Add redundant MSIVs.	A redundant MSIV would prevent a common cause failure to close any 2 of 4 MSIVs.	0.82%	0.21%	$10,010	>2x Benefit	Screen out	Estimate Range: $5M - $8M. Not cost beneficial: since cost is greater than twice the benefit.
179	Add a redundant SW pump ventilation train.	A redundant SW pump would prevent a common cause failure of SW pump ventilation.	2.05%	1.67%	$34,651	>2x Benefit	Screen out	Estimate Range: $1M - $2M. Not cost beneficial: since cost is greater than twice the benefit.
180	Add a redundant valve in series to isolate the steam line dumps to condenser.	A redundant valve in series to isolate the steam line would prevent a common cause failure of existing AOV's to close on demand.	3.99%	0.51%	$44,258	>2x Benefit	Screen out	Estimate Range: $5M - $8M. Not cost beneficial: since cost is greater than twice the benefit.
182	Add redundant AC bus.	A redundant AC bus would preclude the likelihood of complete AC bus failure.	27.84%	17.90%	$429,606	>2x Benefit	Screen out	Estimate Range: $15M - $20M. Not cost beneficial: since cost is greater than twice the benefit.
183	Add redundant AFW flow path.	A redundant AFW flow path would preclude the likelihood of a CCF to open 2 of 4 injection checkvalves and a random failure of the unaffected checkvalve.	0.86%	0.30%	$11,234	>2x Benefit	Screen out	Estimate Range: $15M - $20M. Not cost beneficial: since cost is greater than twice the benefit.
184	Add redundant demineralized water storage tank (DWST).	An additional DWST would provide sufficient demineralized water to the AFW pumps for secondary cooling in case existing DWST ruptures.	0.84%	0.17%	$9,844	>2x Benefit	Screen out	Estimate Range: $5M - $8M. Not cost beneficial: since cost is greater than twice the benefit.

Table G.3-3.
MPS3 Sensitivity Analysis Results.

SAMA No.	Potential Improvement	Baseline 2000 Met Data	Case1 (3%DR)	Case2 (15%DR)	Case3 WTFRAC =0.95	Case4 ESPEED =1.8m/s	Case5 DLTSHL =9000s	Case6 CORSCA =x1.1
9	Provide additional SW pump that can be connected to either SW header	$164,796	$215,984	$87,787	$165,111	$164,793	$164,835	$170,579
10	Create an independent RCP seal cooling system, with dedicated diesel.	$419,846	$548,481	$222,509	$420,807	$419,829	$420,031	$433,250
11	Create an independent RCP seal cooling system, without dedicated diesel.	$419,846	$548,481	$222,509	$420,807	$419,829	$420,031	$433,250
20	Procedural guidance for use of cross-tied CCW or SW pumps.	$14,099	$16,900	$6,494	$14,027	$14,095	$14,200	$13,923
21	Loss of CCW or SW procedural enhancements.	$14,099	$16,900	$6,494	$14,027	$14,095	$14,200	$13,923
34	Install a containment vent large enough to remove ATWS decay heat.	$103,371	$128,931	$50,848	$103,037	$103,356	$103,387	$104,112
35	Install a filtered containment vent to remove decay heat.	$110,796	$145,053	$58,920	$110,884	$110,793	$110,501	$114,672
36	Install an unfiltered hardened containment vent.	$110,796	$145,053	$58,920	$110,884	$110,793	$110,501	$114,672
43	Create a reactor cavity flooding system.	$344,756	$481,712	$202,891	$347,688	$344,833	$344,746	$370,811
44	Creating other options for reactor cavity flooding.	$344,756	$481,712	$202,891	$347,688	$344,833	$344,746	$370,811
60	Provide additional DC battery capability.	$42,753	$56,138	$22,843	$42,824	$42,753	$42,758	$44,328
61	Use fuel cells instead of lead-acid batteries.	$42,753	$56,138	$22,843	$42,824	$42,753	$42,758	$44,328
63	Improved bus cross tie ability.	$429,606	$553,718	$222,843	$429,787	$429,575	$429,724	$440,439
64	Alternate battery charging capability.	$42,753	$56,138	$22,843	$42,824	$42,753	$42,758	$44,328
67	Create AC power cross tie capability across units.	$170,796	$224,274	$91,258	$171,077	$170,796	$170,814	$177,111
73	Install gas turbine generators.	$500,060	$648,762	$262,117	$500,511	$500,035	$500,175	$514,687
75	Create a river water backup for diesel cooling.	$11,116	$14,301	$5,749	$11,113	$11,115	$11,118	$11,390

Table G.3-3.
MPS3 Sensitivity Analysis Results. (Cont.)

SAMA No.	Potential Improvement	Baseline 2000 Met Data	Case1 (3%DR)	Case2 (15%DR)	Case3 WTFRAC =0.95	Case4 ESPEED =1.8m/s	Case5 DLTSHL =9000s	Case6 CORSCA =x1.1
76	Use firewater as a backup for diesel cooling.	$11,116	$14,301	$5,749	$11,113	$11,115	$11,118	$11,390
77	Provide a connection to alternate offsite power source (the nearest dam).	$635,074	$823,088	$332,348	$635,589	$635,042	$635,222	$653,263
80	Create an auto-loading of the SBO diesel.	$47,432	$62,270	$25,335	$47,509	$47,432	$47,438	$49,179
87	Replace steam generators with new design.	$144,816	$198,728	$82,896	$144,386	$144,816	$138,789	$151,059
93	Additional instrumentation and inspection to prevent ISLOCA sequences.	$83,596	$116,011	$48,686	$83,596	$83,596	$78,506	$85,023
94	Increase frequency of valve leak testing.	$83,596	$116,011	$48,686	$83,596	$83,596	$78,506	$85,023
99	Ensure all ISLOCA releases are scrubbed.	$83,596	$116,011	$48,686	$83,596	$83,596	$78,506	$85,023
100	Add redundant and diverse limit switch to each containment isolation valve.	$133,754	$185,618	$77,897	$133,754	$133,754	$125,610	$136,038
112	Proceduralize local manual operation of AFW when control power is lost.	$42,753	$56,138	$22,843	$42,824	$42,753	$42,758	$44,328
113	Provide portable generators to be hooked in to the turbine driven AFW train, after battery depletion.	$38,403	$50,419	$20,514	$38,465	$38,403	$38,407	$39,819
120	Create passive secondary side coolers.	$532,887	$676,631	$269,843	$532,046	$532,832	$532,949	$542,291
123	Provide capability for diesel driven, low pressure vessel makeup.	$396,036	$520,438	$211,863	$396,928	$396,022	$394,979	$409,411
124/ 125	Provide an additional high pressure injection pump with independent diesel.	$42,800	$54,025	$21,467	$42,677	$42,795	$42,661	$43,328
138	Create automatic swapover to recirculation on RWST depletion.	$19,802	$24,811	$9,813	$19,741	$19,799	$19,786	$19,984
156	Secondary side guard pipes up to the MSIVs.	$335,690	$446,689	$183,157	$334,878	$335,676	$327,383	$346,699
160	Install turbine driven AF pump.	$712,156	$924,826	$373,870	$710,770	$712,103	$703,950	$729,875

Table G.3-3.
MPS3 Sensitivity Analysis Results. (Cont.)

SAMA No.	Potential Improvement	Baseline 2000 Met Data	Case1 (3%DR)	Case2 (15%DR)	Case3 WTFRAC =0.95	Case4 ESPEED =1.8m/s	Case5 DLTSHL =9000s	Case6 CORSCA =x1.1
161	Install SBO diesel.	$105,417	$138,402	$56,311	$105,588	$105,417	$105,428	$109,304
162	Install Charging system train.	$103,348	$132,333	$53,046	$103,310	$103,338	$103,292	$105,498
164	Install Safety Injection train.	$42,800	$54,025	$21,467	$42,677	$42,795	$42,661	$43,328
168	Automate Feed and Bleed.	$480,825	$623,605	$251,904	$479,371	$480,782	$473,173	$491,278
169	Improve boron injection reliability with new procedure and hardware.	$0	$0	$0	$0	$0	$0	$0
170	Add another AOV to isolate SW.	$143,769	$189,012	$76,964	$143,953	$143,766	$143,434	$149,203
171	Install another RSS parallel flow path.	$28,804	$37,436	$15,141	$28,815	$28,802	$28,766	$29,704
172	Add a redundant train of RSS.	$28,804	$37,436	$15,141	$28,815	$28,802	$28,766	$29,704
173	Add additional SW AOVs (ATC/ATO).	$143,769	$189,012	$76,964	$143,953	$143,766	$143,434	$149,203
175	Add a redundant DC bus.	$6,967	$9,230	$3,775	$6,991	$6,967	$6,961	$7,241
176	Add a redundant charging pump.	$103,348	$132,333	$53,046	$103,310	$103,338	$103,292	$105,498
177	Add a redundant block valve for the PORV.	$55,118	$71,277	$28,743	$55,130	$55,115	$55,124	$56,664
178	Add redundant MSIVs.	$10,010	$12,622	$5,012	$9,977	$10,009	$9,963	$10,120
179	Add a redundant SW pump ventilation train.	$34,651	$44,985	$18,182	$34,577	$34,649	$34,293	$35,552
180	Add a redundant valve in series to isolate the steam line dumps to condenser.	$44,258	$55,161	$21,744	$44,112	$44,251	$44,265	$44,556
182	Add redundant AC bus.	$429,606	$553,718	$222,843	$429,787	$429,575	$429,724	$440,439
183	Add redundant AFW flow path.	$11,234	$14,263	$5,688	$11,202	$11,233	$11,168	$11,396
184	Add redundant demineralized water storage tank (DWST).	$9,844	$12,355	$4,892	$9,816	$9,843	$9,836	$9,946

Table G.3-3.
MPS3 Sensitivity Analysis Results. (Cont'd)

SAMA No.	Potential Improvement	Case 7 1999 Met Data	Case8 1998 Met Data	Ca se9 PLHITE =50m	Case10 PLDUR =2X	Case11 POPCST =8910s	Case12 RELFRC M7=M7a	Case13 RELFRC M7=M7b
9	Provide additional SW pump that can be connected to either SW header.	$180,764	$168,544	$166,506	$167,637	$164,796	$149,657	$189,054
10	Create an independent RCP seal cooling system, with dedicated diesel.	$455,372	$427,390	$423,923	$426,989	$419,846	$387,369	$471,883
11	Create an independent RCP seal cooling system, without dedicated diesel.	$455,372	$427,390	$423,923	$426,989	$419,846	$387,369	$471,883
20	Procedural guidance for use of cross-tied CCW or SW pumps.	$13,558	$13,901	$14,050	$13,889	$14,099	$14,953	$12,729
21	Loss of CCW or SW procedural enhancements.	$13,558	$13,901	$14,050	$13,889	$14,099	$14,953	$12,729
34	Install a containment vent large enough to remove ATWS decay heat.	$105,175	$103,912	$103,510	$103,499	$103,371	$103,249	$103,567
35	Install a filtered containment vent to remove decay heat.	$122,046	$113,799	$111,735	$112,677	$110,796	$97,854	$131,533
36	Install an unfiltered hardened containment vent.	$122,046	$113,799	$111,735	$112,677	$110,796	$97,854	$131,533
43	Create a reactor cavity flooding system.	$421,385	$362,479	$352,064	$357,449	$344,756	$249,644	$497,149
44	Creating other options for reactor cavity flooding.	$421,385	$362,479	$352,064	$357,449	$344,756	$249,644	$497,149
60	Provide additional DC battery capability.	$47,173	$43,839	$43,218	$43,501	$42,753	$38,602	$49,404
61	Use fuel cells instead of lead-acid batteries.	$47,173	$43,839	$43,218	$43,501	$42,753	$38,602	$49,404
63	Improved bus cross tie ability.	$459,021	$436,351	$432,641	$434,679	$429,606	$402,257	$473,426
64	Alternate battery charging capability.	$47,173	$43,839	$43,218	$43,501	$42,753	$38,602	$49,404
67	Create AC power cross tie capability across units.	$188,582	$175,178	$172,643	$173,766	$170,796	$153,824	$197,988
73	Install gas turbine generators.	$540,340	$509,538	$504,241	$506,963	$500,060	$462,088	$560,899

Table G.3-3.
MPS3 Sensitivity Analysis Results. (Cont'd)

SAMA No.	Potential Improvement	Case 7 1999 Met Data	Case8 1998 Met Data	Ca se9 PLHITE =50m	Case10 PLDUR =2X	Case11 POPCST =8910s	Case12 RELFRC M7=M7a	Case13 RELFRC M7=M7b
75	Create a river water backup for diesel cooling.	$11,866	$11,303	$11,195	$11,240	$11,116	$10,505	$12,094
76	Use firewater as a backup for diesel cooling.	$11,866	$11,303	$11,195	$11,240	$11,116	$10,505	$12,094
77	Provide a connection to alternate offsite power source (the nearest dam).	$685,077	$646,828	$640,265	$643,643	$635,074	$588,190	$710,195
80	Create an auto-loading of the SBO diesel.	$52,344	$48,644	$47,945	$48,256	$47,432	$42,793	$54,866
87	Replace steam generators with new design.	$157,947	$152,781	$146,108	$154,073	$144,816	$144,816	$144,816
93	Additional instrumentation and inspection to prevent ISLOCA sequences.	$93,349	$91,208	$83,596	$96,203	$83,596	$83,596	$83,596
94	Increase frequency of valve leak testing.	$93,349	$91,208	$83,596	$96,203	$83,596	$83,596	$83,596
99	Ensure all ISLOCA releases are scrubbed.	$93,349	$91,208	$83,596	$96,203	$83,596	$83,596	$83,596
100	Add redundant and diverse limit switch to each containment isolation valve.	$149,358	$145,933	$133,754	$153,925	$133,754	$133,754	$133,754
112	Proceduralize local manual operation of AFW when control power is lost.	$47,173	$43,839	$43,218	$43,501	$42,753	$38,602	$49,404
113	Provide portable generators to be hooked in to the turbine driven AFW train, after battery depletion.	$42,390	$39,386	$38,818	$39,069	$38,403	$34,618	$44,467
120	Create passive secondary side coolers.	$559,156	$539,682	$535,180	$536,272	$532,887	$509,567	$570,252
123	Provide capability for diesel driven, low pressure vessel makeup.	$430,646	$404,307	$400,009	$404,500	$396,036	$366,611	$443,182
124/ 125	Provide an additional high pressure injection pump with independent diesel.	$44,086	$43,268	$42,914	$43,121	$42,800	$42,434	$43,387
138	Create automatic swapover to recirculation on RWST depletion.	$20,239	$19,946	$19,844	$19,873	$19,802	$19,802	$19,802
156	Secondary side guard pipes up to the MSIVs.	$360,585	$348,434	$338,031	$349,294	$335,690	$329,219	$346,059

Table G.3-3.
MPS3 Sensitivity Analysis Results. (Cont'd)

SAMA No.	Potential Improvement	Case 7 1999 Met Data	Case8 1998 Met Data	Ca se9 PLHITE =50m	Case10 PLDUR =2X	Case11 POPCST =8910s	Case12 RELFRC M7=M7a	Case13 RELFRC M7=M7b
160	Install turbine driven AF pump.	$755,765	$729,693	$716,165	$728,160	$712,156	$689,324	$748,738
161	Install SBO diesel.	$116,357	$108,115	$106,556	$107,247	$105,417	$95,039	$122,045
162	Install Charging system train.	$108,955	$104,688	$103,946	$104,444	$103,348	$98,953	$110,391
164	Install Safety Injection train.	$44,086	$43,268	$42,914	$43,121	$42,800	$42,434	$43,387
168	Automate Feed and Bleed.	$503,845	$492,806	$482,979	$493,188	$480,825	$479,116	$483,564
169	Improve boron injection reliability with new procedure and hardware.	$0	$0	$0	$0	$0	$0	$0
170	Add another AOV to isolate SW.	$159,686	$147,932	$145,090	$146,334	$143,769	$124,844	$174,091
171	Install another RSS parallel flow path.	$31,434	$29,484	$29,021	$29,199	$28,804	$25,751	$33,694
172	Add a redundant train of RSS.	$31,434	$29,484	$29,021	$29,199	$28,804	$25,751	$33,694
173	Add additional SW AOVs (ATC/ATO).	$159,686	$147,932	$145,090	$146,334	$143,769	$124,844	$174,091
175	Add a redundant DC bus.	$7,687	$7,131	$7,054	$7,128	$6,967	$6,357	$7,946
176	Add a redundant charging pump.	$108,955	$104,688	$103,946	$104,444	$103,348	$98,953	$110,391
177	Add a redundant block valve for the PORV.	$59,465	$56,195	$55,545	$55,795	$55,118	$50,966	$61,769
178	Add redundant MSIVs.	$10,259	$10,117	$10,031	$10,093	$10,010	$10,010	$10,010
179	Add a redundant SW pump ventilation train.	$36,967	$35,555	$34,860	$35,380	$34,651	$33,308	$36,803
180	Add a redundant valve in series to isolate the steam line dumps to condenser.	$44,976	$44,475	$44,311	$44,302	$44,258	$44,258	$44,258
182	Add redundant AC bus.	$459,021	$436,351	$432,641	$434,679	$429,606	$402,257	$473,426
183	Add redundant AFW flow path.	$11,621	$11,391	$11,268	$11,360	$11,234	$11,112	$11,430
184	Add redundant demineralized water storage tank (DWST).	$10,105	$9,924	$9,865	$9,881	$9,844	$9,722	$10,040

Table G.3-4.
MPS3 List of Sorted Basic Events.

Basic Event	Prob	Description	FV	RRW
%SMLOCA	3.00E-03	Small break LOCA	2.52E-01	1.336
%GPT	2.38E+00	General plant transient	2.33E-01	1.304
OADIRREC	5.00E-01	Operators fail to establish direct recirculation	2.12E-01	1.269
%LOOPPC	2.25E-02	Loss of offsite power (plant-centered events)	1.78E-01	1.216
FWMODX4	1.50E-01	Turbine driven AFW pump 3FWA*P2 fails	1.48E-01	1.174
OARECS	6.00E-04	Operators fail to establish sump recirculation following a small LOCA	1.41E-01	1.165
%ITLOCA	9.20E-04	Incore instrument LOCA	1.01E-01	1.112
OABAF	1.00E-02	Operators fail to establish bleed and feed	9.33E-02	1.103
ACBDG3EGSBFN	8.14E-02	Diesel generator 'B' fails after first hour	9.22E-02	1.102
ACADG3EGSAFN	8.14E-02	Diesel generator 'A' fails after first hour	8.25E-02	1.090
RSMODC2	1.19E-03	CCF to close of *8511A(B) or *8512A(B) (fails to satisfy *8804 opening logic)	7.29E-02	1.079
RTELEC	1.44E-05	Reactor trip failure (signal, coils, breaker)	6.48E-02	1.069
%LOOPWR	5.20E-03	Loss of offsite power (weather related events)	6.34E-02	1.068
RSMODA8	1.06E-02	MV8812A fails to close (Permits MV8837/8A to open)	5.28E-02	1.056
RSMODB12	1.06E-02	MV8812B fails to close (Permit 3RSS*MV8837/8B to open)	5.21E-02	1.055
RTMECH	1.80E-06	Reactor trip fails due to mechanical rod binding	4.40E-02	1.046
FWCP0FWAP1NN	2.01E-04	CCF to start of MD AUX feedwater pumps FW*P1A and FW*P1B (screening factor)	3.35E-02	1.035
RSMODA9	2.12E-02	3SIH*MV8920 or 3SIH*MV8814 fail to close	3.27E-02	1.034
OATRIP	1.00E-01	Operators fail to open supply breakers to MG sets	3.24E-02	1.034
RSMODA11	1.98E-02	3SWP*MOV71A fails to close	3.18E-02	1.033
RSMODB17	1.98E-02	3SWP*MOV71B fails to close	3.14E-02	1.032
%RT	5.27E-01	Reactor trip	3.03E-02	1.031
RSMODA7	5.95E-03	Motor operated valve 3RSS*8837A fails to open	2.88E-02	1.030

Table G.3-4.
MPS3 List of Sorted Basic Events. (Cont.)

Basic Event	Prob	Description	FV	RRW
RSMODB11	5.95E-03	Motor operated valve 3RSS*MV8837B fails to open	2.85E-02	1.029
RSMODCRSS	2.27E-04	CCF of all RSS trains for core cooling	2.65E-02	1.027
RSMODC6	1.19E-03	CCFs of SW valves 3SWP*MOV50A,B & 3SWP*MOV71A,B	2.38E-02	1.024
RCPSL400	8.34E-01	Probability of RCP seal leak (0-400 gpm)	2.37E-02	1.024
RHXVMRHV43NX	2.00E-04	Manual valve 3RHS*V43 misaligned open	2.32E-02	1.024
RSMODB10	1.06E-02	Motor operated valve 3SIH*MV8813 fails to close	2.27E-02	1.023
RSMODA5	1.06E-02	Motor operated valve 3CHS*MV8512A fails to close	2.24E-02	1.023
RSMODA16	1.06E-02	Motor operated valve 3CHS*MV8511A fails to close	2.24E-02	1.023
RSMODB16	1.06E-02	Motor operated valve 3CHS*MV8511B fails to close	2.23E-02	1.023
RSMODB7	1.06E-02	Motor operated valve 3CHS*MV8512B fails to close	2.23E-02	1.023
FWBP0FWP1BBQ	6.17E-03	Motor driven auxiliary feedwater pump FWP1B OOS for maintenance	2.22E-02	1.023
RSMODC4	3.59E-04	Common cause failures of RSS For high pressure recirc using SI or CHG	2.15E-02	1.022
%LOOPGR	3.10E-03	Loss of offsite power (grid related events)	2.12E-02	1.022
OSPRN1WR	1.44E-01	Failure to recover weather-related loop - PORVs, AFW AVAIL (0-400 gpm)	2.06E-02	1.021
RSMODA6	5.95E-03	Motor operated valve 3RHS*MV8804A fails to open	2.05E-02	1.021
RSMODB8	5.95E-03	Motor operated valve 3SIL*MV8804B fails to open	2.02E-02	1.021
QSMODC1	7.79E-04	Common cause failures	1.85E-02	1.019
ESBBIP456ENF	3.26E-03	Bistable P456E fails high output	1.69E-02	1.017
ESABIP455ENF	3.26E-03	Bistable P455E fails high output	1.69E-02	1.017
%DCBSI301AFN	8.76E-04	Metal enclosed DC bus 301A1 bus-to-ground short	1.49E-02	1.015
CHAP9CHP3AFN	2.05E-03	Charging pump 3CHS*P3A fails to run	1.47E-02	1.015
RSMODA3	9.21E-03	3SWP*MOV50A fails to close	1.46E-02	1.015
CHBP9CHP3BFN	2.05E-03	Charging pump 3CHS*P3B fails to run	1.44E-02	1.015
%DCBSI301BFN	8.76E-04	Metal enclosed DC bus 301B1 bus-to-ground short	1.44E-02	1.015

Table G.3-4.
MPS3 List of Sorted Basic Events. (Cont.)

Basic Event	Prob	Description	FV	RRW
RSMODB3	9.21E-03	3SWP*MOV50B fails to close	1.44E-02	1.015
RSBP6BTRAINQ	3.22E-03	RSS Train 'B' OOS for test/maintenance	1.43E-02	1.015
%SWMODA23	2.94E-01	Service water pump train 'A' fails to run	1.26E-02	1.013
CHMODB01	9.07E-03	CHS pump 3CHS*P3B fails to start	1.25E-02	1.013
%LMFW	1.13E-01	Loss of main feedwater	1.22E-02	1.012
%SWMODB24	2.94E-01	Service water pump train 'D' fails to run	1.17E-02	1.012
FWCP0FWAP1FN	7.20E-05	CCF to run of MD AUX feedwater pumps FW*P1A and FW*P1B (screening factor)	1.17E-02	1.012
RCMODA2	2.24E-03	PORV 455A automatic reseat circuitry failure	1.14E-02	1.012
RCMODB12	2.24E-03	PORV 456 automatic reseat circuitry failure	1.14E-02	1.012
ACMODB15	9.89E-03	Enclosure 'B' ventilation dampers fail to reposition	1.06E-02	1.011
RSAP6ATRAINQ	2.28E-03	RSS Train 'A' OOS for test/maintenance	1.01E-02	1.010
ACMODSBO	3.06E-02	SBO diesel fails	1.01E-02	1.010
%SWMODB23	2.94E-01	Service water pump train 'B' fails to run	1.00E-02	1.010
%SWMODA24	2.94E-01	Service water pump train 'C' fails to run	9.97E-03	1.010
ACBDG3EGSBBQ	1.24E-02	Diesel generator 'B' unavailable due to test or maintenance	9.73E-03	1.010
ACMODA15	9.89E-03	Enclosure 'A' ventilation dampers fail to reposition	9.48E-03	1.010
SWAP3SWP1CCQ	1.74E-02	Service water pump SWP1C OOS for maintenance	9.33E-03	1.009
SWBP3SWP1BBQ	1.62E-02	Service water pump SWP1B OOS for maintenance	8.53E-03	1.009
FWAP0FWP1AAQ	2.96E-03	Motor driven auxiliary feedwater pump FWP1A OOS for maintenance	8.46E-03	1.009
ACXBGSBODGFN	4.80E-02	SBO diesel fails to run	8.44E-03	1.009
NOTSUMMER	7.50E-01	Not summer operation	8.40E-03	1.008
FWBP0FWP1BNN	2.01E-03	Motor driven auxiliary feedwater pump FWP1B fails to start	8.07E-03	1.008
ACADG3EGSAAQ	1.09E-02	Diesel generator ’A’ unavailable due to test or mainteNANCE	7.51E-03	1.008
MSCMIC20F4FF	2.52E-04	Common cause failure to close any 2 of 4 MSIVs	7.22E-03	1.007

Table G.3-4.
MPS3 List of Sorted Basic Events. (Cont.)

Basic Event	Prob	Description	FV	RRW
ACCDG3EGSXFN	5.53E-03	CCF of diesel generators after first hour	7.17E-03	1.007
OASBODG	2.20E-02	Operators fail to manually start the SBO diesel	7.17E-03	1.007
FWXP5FWAP2NQ	1.16E-02	AFW Turbine driven pump FW*P2 OOS for maintenance	7.16E-03	1.007
HVCSWMOD1	1.14E-04	CCF of SW pump ventilation	6.89E-03	1.007
SWBP3SWP1DDQ	1.31E-02	Service water pump SWP1D OOS for maintenance	6.87E-03	1.007
%SLBO	6.04E-03	Steamline break outside containment	6.71E-03	1.007
SWAP3SWP1AAQ	1.25E-02	Service water pump SWP1A OOS for maintenance	6.63E-03	1.007
%LLOCA	4.40E-05	Large break LOCA	6.15E-03	1.006
DCMODA2	2.64E-05	Failure of DC panel 301A-1A	6.11E-03	1.006
DCMODB2	2.64E-05	Failure of DC panel 301B-1A	6.10E-03	1.006
ACMODA18	9.84E-05	Failure to supply bus 32R via BUS 34C	5.76E-03	1.006
%MLOCA	4.30E-05	Medium LOCA	5.73E-03	1.006
%ISLOCA	2.21E-07	Probability of incurring an interfacing systems LOCA	5.71E-03	1.006
ESBESESFTBBQ	2.70E-03	ESFAS train 'B' circuit OOS for test or maintenance	5.43E-03	1.005
RHACV8969ANN	1.20E-03	Check valve 3SIL*8969A fails to open on demand	5.29E-03	1.005
RHBCV8969BNN	1.20E-03	Check valve 3SIL*V8969B fails to open on demand	5.21E-03	1.005
ACMODB4	5.07E-03	Diesel 'B' output breaker fails to close	4.99E-03	1.005
ESAESESFTAAQ	2.70E-03	ESFAS train 'A' circuit OOS for test or maintenance	4.61E-03	1.005
%ACMODA28	5.25E-03	Failure associated with VIAC-1	4.53E-03	1.005
ACMODA3	5.07E-03	Diesel 'A' output breaker fails to close	4.52E-03	1.005
OAREC	2.00E-03	Operators fail to establish sump recirculation	4.49E-03	1.005

G.4 Results and Conclusions

G.4.1 Summary

An Integrated Plant Assessment has been made in accordance with 10CFR54.21, Reference G.4-1. After all screening and cost-benefit analyses, there were no SAMAs that were considered cost beneficial. The PRA calculations supporting this conclusion are recognized to have some uncertainty around the mean frequencies used in the analyses. To account for the possible uncertainty, several sensitivity analyses were performed to bound the analysis. These sensitivity cases did not alter the benefit calculations by more than a factor of two, which were shown within the report to still be less than the cost of each SAMA.

G.4.2 **References**

Ref. G.4-1 10 CFR54.21, Code of Federal Regulations.

G.5 Acronyms Used In Appendix G

AAC	Alternate Alternating Current
AC	Alternating Current
ADS	Automatic Depressurization System
AFW	Auxiliary Feedwater
AFWST	Auxiliary Feedwater Storage Tank
AMSAC	ATWS Mitigating System Actuation Circuitry
AOV	Air Operated Valve
ATWS	Anticipated Transient Without Scram
BWR	Boiling Water Reactor
BWST	Borated Water Storage Tank
CCW	Component Cooling Water
CDF	Core Damage Frequency
CE	Combustion Engineering
CRD	Control Rod Drive
CST	Condensate Storage Tank
CV	Control Valve
CVCS	Charging and Volume Control System
DC	Direct Current
DG	Diesel Generator
DHR	Decay Heat Removal
ECCS	Emergency Core Cooling System
EFIC	Emergency Feedwater Initiation and Control
EFW	Emergency Feedwater
EOP	Emergency Operating Procedure
ERCW	Emergency Raw Cooling Water
FV	Fussell-Vesely
FW	Feedwater
HCLPF	High Confidence of Low Probability of Failure

HPCI	High Pressure Coolant Injection
HPCS	High Pressure Core Spray
HPI	High Pressure Injection
HPSI	High Pressure Safety Injection
HR	Heat Removal
HVAC	Heating, Ventilation and Air Conditioning
I&C	Instrumentation and Control
ICONE	International Conference on Nuclear Engineering
ICW	Intermediate Cooling Water
IPE	Individual Plant Examination
ISLOCA	Interfacing System LOCA
KV	Kilo-Volts
LOCA	Loss of Coolant Accident
LOP	Loss of Power
LOSW	Loss of Service Water
LPCI	Low Pressure Coolant Injection
LPI	Low Pressure Injection
LPSI	Low Pressure Safety Injection
MAB	Maximum Attainable Benefit
MCC	Motor Control Center
MD	Motor Driven
MFW	Main Feed Water
MG	Motor Generator
MOV	Motor Operated Valve
MPS3	Millstone Power Station Unit 3
MSIV	Main Steam Isolation Valve
NRC	Nuclear Regulatory Commission
PMP	Probable Maximum Precipitation
PORV	Power Operated Relief Valve
PRA	Probabilistic Risk Analysis

PRT	Pressurizer Relief Tank
PSA	Probabilistic Safety Assessment
PWR	Pressurized Water Reactor
RAI	Request for Additional Information
RB	Reactor Building
RBCCW	Reactor Building Component Cooling Water
RCIC	Reactor Core Isolation Cooling
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RHR	Residual Heat Removal
RRW	Risk Reduction Worth
RV	Relief Valve
S/G	Steam Generator
SAMA	Severe Accident Mitigation Alternative
SAMDA	Severe Accident Mitigation Design Alternative
SAMG	Severe Accident Management Guideline
SBO	Station Blackout
SI	Safety Injection
SGTR	Steam Generator Tube Rupture
SLC	Standby Liquid Control
SOV	Solenoid Operated Valve
SRV	Safety Relief Valve
SSE	Safe Shutdown Earthquake
SW	Service Water
TD	Turbine Driven
TDP	Turbine Driven Pump
TVA	Tennessee Valley Authority
V	Volts
WBN	Watts Bar Nuclear Plant