APPENDIX G
SEVERE ACCIDENT MITIGATION ALTERNATIVES ANALYSIS

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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
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
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
RCIC	Reactor Core Isolation Cooling
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RHR	Residual Heat Removal
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
SPS	Surry Power Station
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

G.1 MELCOR ACCIDENT CONSEQUENCES CODE SYSTEM MODELING

G.1.1 Introduction

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

The severe accident consequence analysis was carried out with the Melcor Accident Consequence Code System code (Ref. G.1-2). 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. The Level 3 PRAs using the MACCS 2 computer code were prepared by Dominion and reviewed by Scientech and Dominion personnel, and are documented in Ref. G.1-11.

G.1.2.1 Core Inventory

The core inventory is for SPS at a power level of 2545 megawatts-thermal. These values were obtained by adjusting the end-of-cycle values for a 3,412 megawatt-thermal pressurized water reactor (Table G.1.1) by a linear scaling factor of 0.746 (Ref. G.1-2).

G.1.2.2 Source Terms

The source term input data to MACCS2 were the severe accident source terms presented in the probabilistic risk assessment in the SPS IPE (Ref. G.1-3). This document defines the releases in terms of release modes and demonstrates the method of calculating releases. There are 24 Plant Damage States (PDSs) which, when propagated through the containment event tree in Ref. G.1-3, lead to 25 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. Where other related source term data were not reported, such as release durations and energies, these were evaluated by comparison with similar releases reported in the NUREG-1150 studies for the Surry plant (Ref. G.1-4).

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 (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**

The MACCS2 input used one year's (1998) hourly meteorological data for the plant for a base case. Two additional years' (1996-1997) hourly met data was used for sensitivity comparison. The hourly data (wind direction, wind speed, stability category, and precipitation) were collected on-site at the Surry Power Station met tower (Ref. G.1-5). The wind direction and wind speed were recorded at vent height (tower upper elevation); the stability data were determined by a Delta T system measuring the temperature at 10 meters and at vent height; and precipitation was measured at ground level. The instruments were calibrated quarterly. The data were temporarily stored at the sites in dataloggers which were polled nightly to transfer the data to a personal computer at Innsbrook. The data were quality controlled each business day by EP&C personnel. Professional meteorologists resolved any unusual data situations. Each month, the data were transferred to the corporate mainframe computer and were converted to and stored in SAS data sets. SAS programs were written to produce the hourly data files in MACCS2 format.

Morning and afternoon mixing height values for 1996 through 1998 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.

MACCS2 calculations examine a representative subset of the 8,760 hourly observations in 1998 contained in one year’s data set (typically about 150 sequences). The representative subset is selected by sampling the weather sequences after sorting them into weather bins defined by wind speed, atmospheric stability, and rain conditions at various distances from the site.

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.1-6]. This code contains a database extracted from Bureau of the Census PL 94-171 (block level census) CD-ROMS [Ref. G.1-7], 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.

The plant location for SPS Unit 1 is Latitude 37º 9’ 59’’N and Longitude 76º 41’ 55’’W as listed in the Surry UFSAR Section 2.2.1. 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. A picture of the rosette for Surry 50 mile radius is shown in Figure G.1-1.

The SECPOP90-prepared data was then modified and updated using the SPS UFSAR (Ref. G.1-8) Section 2.1 50 mile population distribution for the year 2030 in place of the 1990 Census SECPOP90 data.

G.1.2.5 Emergency Response

The EARLY module of the MACCS code models the time period immediately following a radioactive release. This transient 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 average evacuation speed is estimated (see Table G.2-1 of Ref. G.1-4) to be on the order of 4 mph (1.8 m/s). For the purposes of this analysis an average evacuation speed of 1.8 m/s is used with a 7200 second delay between the alarm and start of evacuation, with no sheltering for the base case.

To demonstrate the possible significance of these assumptions, a sensitivity MACCS2 run was made with the alarm times and the delay times arbitrarily reduced by 0.5 hours (-1800 s). The results, which are reported in Section G.2.4, 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.1-6). It contains a database extracted from Bureau of the Census PL 94-171 (block level census) CD-ROMS (Ref. G.1-7), 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 1999 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 1999 Census of Agriculture (Ref. G.1-9). This was accomplished by replacing the SECPOP90 data for the counties within the fifty mile radius by the 1999 value. 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.

Economic consequences were estimated 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.

Costs associated with damage to the reactor, the purchase of replacement power, medical care, life-shortening, and litigation are not calculated by MACCS2.

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 expected to occur within 1 year of the accident (early health effects) and the delayed (latent) cancer fatalities and injuries expected 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 sensitivity cases are shown in Table G.1-3.

Table G.1.1
SPS 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.1-2.

Table G.1-2
SPS Release Fraction By Nuclide Group

Source Term Category	Noble Gases	I	Cs	Te	Sr	Ru	La	Ce	Ba
2	7.20E-02	8.60E-07	8.60E-07	0.0	0.0	5.40E-06	0.0	3.30E-07	0.0
5	6.10E-01	7.80E-03	6.90E-03	1.50E-03	6.50E-04	2.60E-03	2.60E-03	1.50E-05	5.30E-04
7	9.00E-01	7.40E-02	9.70E-02	1.80E-02	1.50E-02	2.50E-02	8.10E-06	2.40E-07	8.70E-03
*8 (1)	7.80E-01	4.10E-02	6.00E-02	5.00E-03	6.00E-05	1.50E-02	1.50E-05	2.20E-06	3.70E-03
(2)	1.60E-01	6.70E-02	9.70E-02	1.40E-02	1.70E-02	2.40E-03	5.30E-06	1.00E-07	6.10E-03
11	8.20E-01	2.30E-06	1.40E-05	1.80E-05	3.20E-04	3.90E-04	0.0	0.0	1.30E-05
13	9.80E-01	4.60E-03	3.20E-03	2.00E-05	0.0	0.0	0.0	0.0	2.60E-06
15	9.00E-01	1.10E-04	3.40E-04	1.00E-04	3.20E-04	4.10E-04	0.0	0.0	9.20E-05
18	8.50E-01	3.30E-03	3.30E-03	3.80E-04	2.20E-03	2.50E-03	1.20E-06	0.0	6.00E-04
21	6.80E-04	7.60E-05	7.60E-05	0.0	2.70E-07	2.90E-07	0.0	0.0	0.0
22	9.40E-01	5.10E-02	5.40E-02	2.70E-03	4.10E-02	5.10E-02	6.40E-05	0.0	9.60E-02
23	9.40E-01	2.90E-01	3.10E-01	1.50E-02	2.30E-01	2.80E-01	3.60E-04	4.60E-07	5.40E-01
24	1.00E-00	5.20E-01	5.40E-01	2.40E-02	3.40E-02	1.40E-01	5.50E-05	1.10E-05	2.10E-02

* STC-8 is divided into 2 plumes

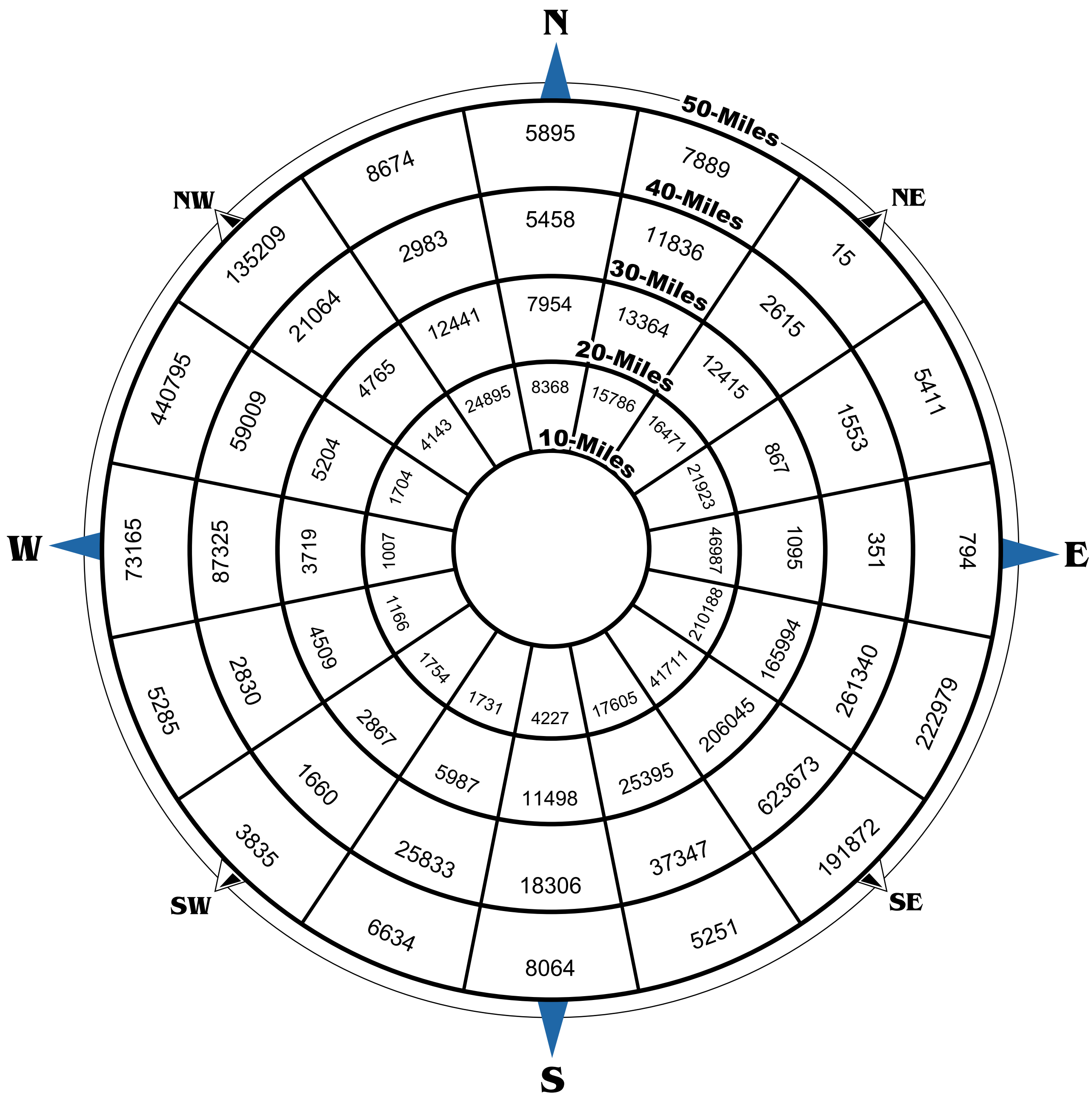
STCs 1 and 20 have a release fraction of 0.0 for all radionuclides.
STCs 3, 10 and 12 are assigned the release fractions for STC 5.
STCs 4, 6 and 19 are assigned the release fractions for STC 8.
STCs 9, 16 are assigned the release fractions for STC 11.
STC 14 is assigned the release fractions for STC 15.
STC 17 is assigned the release fractions for STC 2.

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

	Population Dose (Sieverts)			Offsite Economic Costs (Dollars)		
CET End Point (Release Mode)	Basecase (100% Evac)	95% Evac	-50% Timing	Basecase (100% Evac)	95% Evac	-50% Timing
STC-2	5.98E+00	6.02E+00	6.05E+00	7.73E+06	6.68E+01	9.31E+06
STC-5	8.23E+03	8.28E+03	7.60E+03	7.34E+08	7.50E+08	8.32E+08
STC-7	2.59E+04	2.62E+04	2.80E+04	5.58E+09	5.77E+09	5.37E+09
STC-8	1.74E+04	1.76E+04	1.72E+04	3.38E+09	3.48E+09	3.44E+09
STC-11	2.50E+02	2.51E+02	2.64E+02	6.23E+06	3.19E+05	5.63E+06
STC-13	2.89E+03	2.90E+03	2.87E+03	1.60E+08	1.59E+08	1.71E+08
STC-15	7.10E+02	7.12E+02	7.45E+02	9.34E+06	3.54E+06	8.30E+06
STC-18	4.71E+03	4.72E+03	4.44E+03	3.32E+08	3.35E+08	2.87E+08
STC-21	1.19E+02	1.19E+02	1.23E+02	9.40E+06	9.53E+04	8.93E+06
STC-22	2.75E+04	2.81E+04	2.80E+04	4.85E+09	5.01E+09	5.08E+09
STC-23	6.81E+04	7.00E+04	6.94E+04	1.22E+10	1.26E+10	1.27E+10
STC-24	5.07E+04	5.18E+04	4.59E+04	1.27E+10	1.31E+10	1.12E+10

STCs 3, 10 and 12 are assigned the release fractions for STC 5.
STCs 4, 6 and 19 are assigned the release fractions for STC 8.
STCs 9, 16 are assigned the release fractions for STC 11.
STC 14 is assigned the release fractions for STC 15.
STC 17 is assigned the release fractions for STC 2.

Figure G.1-1
Population Distribution Within 50 Miles



POPULATION BY ANNULUS

ANNULUS	0 TO 10	10 TO 20	20 TO 30	30 TO 40	40 TO 50	TOTAL
POPULATION	176,308	419,666	484,117	1,163,183	1,121,767	3,365,040

G.1.4 **References**

Ref. G.1-2 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. G.1-3 Surry Power Station IPE, Virginia Electric And Power Company, August 1991.

Ref. G.1-4 Evaluation of Severe Accident Risks: Surry 1 Main Report, NUREG/CR-4551, Vol. 3, Rev. 1, Part 1, Breeding, R. J., et al, October 1990.

Ref. G.1-5 RF-Memo, Philip C. Knause, "Nuclear Relicensing Meteorological Data Documentation", December 29, 1999. (See Appendix II).

Ref. G.1-6 RF-Report, S. L. Humphreys, et al., "SECPOP90: Sector Population, Land Fraction, and Economic Estimation Program, " NUREG/CR-6525, September, 1997.

Ref. G.1-7 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.1-8 Surry Power Station UFSAR.

Ref. G.1-9 RF-Report, U.S. Dept. of Agriculture, "1997 Census of Agriculture," National Agricultural Statistics Service.

Ref. G.1-10 Evaluation of Severe Accident Risks: Quantification of Major Input Parameters MACCS Input, NUREG/CR 4557, Vol. 2, Rev. 1., Part 7, Sprung, J. L. et al, December 1990.

Ref. G.1-11 RF-CALC, Dominion/Virginia Power Calculation SM-1242, Rev. 0, "MACCS2 Model For North Anna Level 3 Application."

G.2 EVALUATION OF CANDIDATE SAMAs

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

G.2.1 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 SPS IPE submittal (only items not already evaluated and/or implemented during the IPE) (Ref. G.2-1)
- The Watts Bar Nuclear Plant Unit 1 PRA/IPE submittal (Ref. G.2-2)
- The Limerick SAMDA cost estimate report (Ref. G.2-3)
- NUREG-1437 description of Limerick SAMDA (Ref. G.2-4)
- NUREG-1437 description of Comanche Peak SAMDA (Ref. G.2-5)
- Watts Bar SAMDA submittal (Ref. G.2-6)
- TVA response to NRC's RAI on the Watts Bar SAMDA submittal (Ref. G.2-7)
- Westinghouse AP600 SAMDA (Ref. G.2-8)
- Safety Assessment Consulting (SAC) presentation by Wolfgang Werner at the NUREG-1560 conference (Ref. G.2-9)
- NRC IPE Workshop - NUREG-1560 NRC Presentation (Ref. G.2-10)
- NUREG-0498, supplement 1, Section 7 (Ref. G.2-11)
- NUREG/CR-5567, PWR Dry Containment Issue Characterization (Ref. G.2-12)
- NUREG-1560, Volume 2, NRC Perspectives on the IPE Program (Ref. G.2-13)
- NUREG/CR-5630, PWR Dry Containment Parametric Studies (Ref. G.2-14)
- NUREG/CR-5575, Quantitative Analysis of Potential Performance Improvements for the Dry PWR Containment (Ref. G.2-15)
- CE System 80+ Submittal (Ref. G.2-16)
- NUREG-1462, NRC Review of ABB/CE System 80+ Submittal (Ref. G.2-17)
- An ICONE paper by C. W. Forsberg, et. al, on a core melt source reduction system (Ref. G.2-18)
- The SPS IPEEE submittal (only items not already evaluated and/or implemented during the IPEEE) (Ref. G.2-19)
- Additional items from the SPS PRA staff or from the review of the top 100 cutsets

Although SPS is a Westinghouse design, each of the above documents were reviewed for potential SAMAs even if they were not necessary applicable to a Westinghouse plant. Those items not applicable to SPS were subsequently screened from this list. The containment performance improvement programs for boiling water reactors and ice condenser plants were not reviewed (and the NUREG-1560 portion of the containment performance improvement for these were not reviewed). Conceptual enhancement for which no specific details were available (e.g., "improve diesel reliability" or "improve procedures for loss of support systems") were not included, unless they were considered as vulnerabilities in the SPS IPE.

G.2.2 Qualitative Screening of SAMAs

The initial list of 160 potential SAMAs are presented in Table G.2-1. Table G.2-1 also presents a qualitative screening of the initial list. Items were eliminated from further evaluation based on one of the following criteria:

- The SAMA is not applicable at SPS, either because the enhancement is only for boiling water reactors, the Westinghouse AP600 design or PWR ice condenser containments, or it is a plant specific enhancement that does not apply at SPS (Criterion A – Not applicable); or
- The SAMA has already been implemented at SPS (or the SPS design meets the intent of the SAMA) (Criterion B – Implemented or intent met).
- 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). The SPS does not have this vulnerability because the charging pumps do not rely on CCW. However, other RCP seal LOCA improvements will still be considered (Criterion C).

Based on preliminary screening, 107 improvements were either eliminated or combined with other potential improvements, leaving 53 subject to the final screening process. These improvements are listed in Table G.2-2.

The final screening process involved identifying and eliminating those items whose cost exceeded their benefit. Table G.2-2 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 each 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.2-2 was arbitrary, but provided confidence that even when uncertainties are considered, the cost would still exceed the benefit.

G.2.3 Analysis of Potential SAMAs

The quantitative analysis of the SAMAs was performed using the North Anna Probabilistic Risk Assessment (PRA). The PRA model used for the SAMA analysis consists of the usual three elements: The level I model looks at accident scenarios from initiation to the point of a plant damage state (core damage with containment heat removal status). The level II model assesses the likelihood that the plant damage state will result in each of the release categories. Finally, the level III model considers the distribution of the released radionuclides to the environment.

The level I 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 model was completed in August 1991. A minor update of the models was performed to support the IPEEE fire analysis which was completed in December 1994. The last major update was in 1997 as part of an upgrade to support implementation of the maintenance rule. At this time several more support system models were updated. The three year plant specific unavailability developed for the maintenance rule program was also used to update the maintenance unavailability basic events.

A full level II model was developed for the IPE and completed at the same time as the level I model. The level II 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 II 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 II model.

The level III model was constructed for the SAMA analysis under the leadership of SCIENTECH. The meteorological data have been collected by the Dominion meteorology department. Population data were determined based on software purchased from the federal government (SEGPOP). The MACCS2 code was used to do the evaluation of the source term distribution.

The information used in the level I model was verified using plant walkdowns. An independent peer review was conducted of the level I and level II models prior to submittal to

NRC. The level I model used for the SAMA analysis was also reviewed as the pilot plant for the Westinghouse Owners Group (WOG) PRA certification project.

The methodology used for this evaluation was based upon the NRC's guidance for the performance of cost-benefit analyses (Ref. G.2-20). 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 Ref. G.2-20,

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 in below.

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

Present Worth

The present worth was determined by:

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

Where:

r is the discount rate = 7% (assumed throughout these analyses)

t 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.2-20.

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. G.2-20. 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.2-20, 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% 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.2-20 can be expressed as:

$$W_{LTO} = (F_S D_{LTO_S} - F_A D_{LTOA}) R \frac{1 - e^{-rt_g}}{r} \quad (1)$$

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_{LTO} = 3,300 person-rems /accident (best estimate)

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

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

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

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

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

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

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.2-20 can be expressed as:

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

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%, assuming FA is zero, the best estimate of the limiting saving is

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

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

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

$$= F_S * \$3.18E + 8, \$$$

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

Combining equations (1) and (2) above, using delta (D) 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:

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

where the Δ represents the change from the base case.

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

a) **Cleanup/Decontamination**

Ref. G.2-20 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

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

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

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.

used. For a "generic" plant of 910 MWe, the present value of replacement power is calculated as follows:

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

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.2-20). This equation was developed per NUREG/BR-0184 for discount rates between 5% and 10% only.

For discount rates between 1% and 5%, Ref. G.2-20 indicates that a linear interpolation is appropriate between present values of $1.2E+9 at 5% and $1.6E+9 at 1%. 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

rs = Discount rate (small), between 1% and 5%.

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

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

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% to 10%. NUREG/BR-0184 states the for lower discount rates, linear interpolations for U_{RP} are recommended between $1.9E+10 at 1% and $1.2E+10 at 5%. The following equation was used to perform this linear interpolations:

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

Where

rs = Discount rate (small), between 1% and 5%.

The SPS has a gross electrical output of 855.4 MWe and a net of 801 MWe, compared to the "generic" plant of 910 MWe. Therefore, the replacement power cost formulae could be reduced by a factor of 0.94, but the generic formulae will be conservatively used.

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 SPS. Costs associated with these doses were calculated using the following equation:

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

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:

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

Accident-Related Off-Site Property Damage Costs

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

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

PD = offsite property loss factor (dollars/event)

The evaluation process described in Ref. G.2-20 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% as described 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 SPS.

The PSA results used in this analysis are calculated using internal event results only. To account for the potential impact of external events on the results of these SAMA evaluations, since SPS does not currently have an external events model that can be easily quantified, it was assumed that the benefits of each SAMA would be doubled for purposes of comparing with its cost. 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 doubled.

The doubling of the benefit bounds any contribution that would be expected from the external events effects. The following summarizes the IPEEE at Surry:

The high winds and external flooding analyses performed for the IPEEE resulted in the finding that the plant is adequately designed to protect against the effects of these natural events. The plant is not designed to the latest probable maximum precipitation criteria. However, the analysis of this phenomenon shows that the plant is not vulnerable to core damage from such a storm because no safe shutdown equipment fails during the 1hr - 1mi2 PMP. Transportation and nearby facility accidents are not potential sources of damage at the plant because it is still in a very rural area with no major roads or facilities within the exclusion area of the plant. The other external events were evaluated and found to be insignificant contributors to CDF. There is military aviation traffic, primarily helicopters near the plant. However, based on a conservative PRA analysis, as recommended in the SRP, it is very unlikely that an accident would occur.

The total fire contribution to CDF is 5.0E-6/year. The total seismic contribution to CDF is 8.0E-6/yr. Therefore, the total CDF from external events is 1.3E-5/year.

The external events contribution of 1.3E-5/year compares to a base CDF of 3.7E-5/year from the internal events model used to calculate SAMA benefit. Therefore, the doubling approach is considered conservative since an argument could me made that the internal events benefit numbers would only need to be increased by as little as 35% to account for the external events contribution.

The maximum theoretical benefit (also called Maximum Attainable Benefit, or MAB) is based upon the elimination of all plant risk 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. If a SAMA involved a hardware modification, it was assumed that the cost would be at least $100,000. For the generation of a new procedure and its implementation, it was assumed that the cost would be at least $30,000.

G.2.4 Sensitivity Analyses

The PRA calculations of SAMA benefit are recognized to have some uncertainty around the mean frequencies used in the analyses. Some of the uncertainty is related to quantifiable uncertainty distributions of the data, while other stems from 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% real (i.e., inflation-adjusted) discount rate for value-impact analysis and notes that a 3% discount rate 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.2.3 used the 7% discount rate in calculating benefits of all the unscreened SAMAs. Dominion 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% discount rate, which is judged to be more realistic for Dominion.

Nine additional sensitivity cases were analyzed, each varying an aspect of the MAACS input deck. The base case in Section G.2.3 used the best estimate values with year 2030 population projections, 1998 meteorological data and assumes 100% population evacuation. A sensitivity run on evacuation modeling was carried out by assuming an evacuation scenario wherein 95% of the population are evacuated normally and 5% are not evacuated at all (within the 10 mile emergency zone). Two sensitivity runs were made using 1997 and 1996 meteorological data respectively. Two more sensitivity runs were made using a 10% increase and a 50% decrease in the source term energy (MACCS parameter PLHEAT) respectively. Two more sensitivity runs were made using a 50% increase and 50% decrease in the timing data for the MACCS parameters OALARM, PLDUR and PDELAY. One sensitivity run was made for the time to take shelter (MACCS parameter DLTSHL) which used 5400 seconds, whereas the base case used 7200 seconds. The last sensitivity case used a multiplier of 1.46 vs. 1.17 for the farm and non-farm decontamination parameters CDFRM and CDNFRM in the CHRONC input file.

A summary of the sensitivity cases is as follows:

Case 1 - 3% Discount Rate

Case 2 - 15% Discount Rate

Case 3 - MAACS Input Sensitivity: 95% Evac

Case 4 - MAACS Input Sensitivity: 1997 Met Data

Case 5 - MAACS Input Sensitivity: 1996 Met Data

Case 6 - MAACS Input Sensitivity: +10% ST PLHEAT

Case 7 - MAACS Input Sensitivity: -50% ST PLHEAT

Case 8 - MAACS Input Sensitivity: +50% Timing

Case 9 - MAACS Input Sensitivity: -50% Timing

Case 10 - MAACS Input Sensitivity: DLTSHL= 5400

Case 11 - MAACS Input Sensitivity: CDFRM & CDNFRM x 1.46

The benefits calculated for each of these sensitivities are presented in Table G.2-3. 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.2-2 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.

Table G.2-1
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	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)	A	Screened out
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
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
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
5	Provide hardware connections to allow another SW 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
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
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

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	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)	C	Screened out
9	Provide additional SW pump	Providing another pump would decrease core damage frequency due to a loss of SW	(5)		The SPS Service Water system is fed by the canal inventory. The eight circ water pumps are enough to judge that another would not be beneficial. The 3 emergency service water pumps are not usually needed except in certain rare situation. However, this item will be retained for a cost-benefit analysis on the emergency service water pumps.
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
13	Replace ECCS pump motors with air cooled motors	Remove dependency on CCW	(10), (13)	C	Screened out
14	Install improved RCP seals	RCP seal O-rings constructed of improved materials would reduce chances of RCP seal LOCA	(11), (13)		Not initially screened. Considered further in the cost-benefit analysis.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
15	Add a third CCW pump	Reduce chance of loss of CCW	(13)		Not initially screened. Considered further in the cost-benefit analysis.
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
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
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
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.
20	Procedural guidance for use of cross-tied CCW or SW pumps	Can reduce the frequency of the loss of either of these.	(13)	B	Screened out. The CCW system is already cross tied between loops and between the two SPS units.
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.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
22	Improve ability to cool RHR heat exchangers	Reduced chance of loss of DHR by 1)Performing procedure and hardware modification to allow manual alignment of fire protection system to the CCW system, or 2)Installing a CCW header cross-tie	(12), (13)	A for the first option; B for the second option	The first is screened out because the fire water system does not have sufficient flow to cool the RHR heat exchangers. The second is screened because the CCW system is already cross-tied between loops and between units.
23	Alter circ water valve power supply arrangement	Because all eight waterboxes have a valve powered by 1J1-1A, its failure challenges all eight waterboxes to isolate. By changing the power supplies on the 2-CN-SC-1A and 1B waterboxes to 2J1-1A, a failure of the 1J bus will only challenge 4 waterboxes.	Suggested by the SPS PRA staff or from the review of the top 100 cutsets		After a LOOP, the CW valves will be powered from the #3 diesel whether it aligns to the 1J or 2J bus. However, this item will be evaluated in the cost-benefit analysis to see if the non-LOOP cases have any significant benefit.
24	Stage backup fans in Switchgear rooms	Provides alternate ventilation in the event of a loss of switchgear ventilation.	(13)	A	This item is screened 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 item 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)	Recategorized as "Provide a non-safety related, redundant train of switchgear ventilation"	Not initially screened. Considered further in the cost-benefit analysis.
26	Procedures for temporary HVAC	Provides for improved credit to be taken for loss of HVAC sequences	(11), (13)	B	Screened out.
27	Add a switchgear room high temp alarm	Improve diagnosis of a loss of switchgear HVAC	(13)		Not initially screened. Considered further in the cost-benefit analysis.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
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 (Surry's turbine AFW can operate during an SBO)	Screened out.
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.
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)		Not initially screened. Considered further in the cost-benefit analysis.
31	Install an independent method of suppression pool cooling	Would decrease frequency of loss of containment heat removal	(3), (4)	A	Screened out.
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)		Not initially screened. Considered further in the cost-benefit analysis.
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), (5), (6), (11)		Not initially screened. Considered further in the cost-benefit analysis.
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.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
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)		Not initially screened. Considered further in the cost-benefit analysis.
38	Create a passive hydrogen ignition system	Reduce hydrogen detonation potential without requiring electric power	(7), (11), (16), (17)		Not initially screened. Considered further in the cost-benefit analysis.
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)		Not initially screened. Considered further in the cost-benefit analysis.
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)		Not initially screened. Considered further in the cost-benefit analysis.
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.
42	Enhance fire protection system and/or standby gas treatment system hardware and procedures	Improve fission product scrubbing in severe accidents	(4)		Not initially screened. Considered further in the cost-benefit 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.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
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 SPS	Part b is 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.
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)		Not initially screened. Considered further in the cost-benefit analysis.
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)		Not initially screened. Considered further in the cost-benefit analysis.
48	Provide containment inerting capability	Would prevent combustion of hydrogen and carbon monoxide gases	(6), (9), (11), (14)		Not initially screened. Considered further in the cost-benefit analysis.
49	Use fire water spray pump for containment spray	Redundant containment spray method without high cost	(7), (9), (10), (12)		Not initially screened. Considered further in the cost-benefit analysis.
50	Install a passive containment spray system	Containment spray benefits at a very high reliability, and without support systems	(8)		Not initially screened. Considered further in the cost-benefit analysis.
51	Secondary containment filtered ventilation	For plants with a secondary containment, would filter fission products released from the primary containment	(8)	A	Screened out.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
52	Increase containment design pressure	Reduce chance of containment overpressure	(8)	A (this improvement is intended for a new plant)	Screened out.
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 (this improvement is intended for a new plant)	Screened out
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)		Not initially screened. Considered further in the cost-benefit analysis.
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)		Not initially screened. Considered further in the cost-benefit analysis.
56	Add ribbing to the containment shell	Would reduce the chance of buckling of containment under reverse pressure loading.	(17)	A (this improvement is intended for a new plant)	Screened out.
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.
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.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	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. SPS 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)	B	Screened out. This capability already exists at Surry in the form of the 'Black' battery.
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.
63	Improved bus cross tie ability	Improved AC power reliability	(10), (13)	B	There is already a cross-tie ability between the buses at each SPS unit, and further cross-tie features would have minimal benefit.
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	SPS procedures already direct appropriate DC load shedding during an SBO.
66	Replace batteries	Improved reliability	(10)	A	Screened out. Recent Surry data has not shown any vulnerability from battery reliability, so no benefit would be recognized.
67	Create AC power cross tie capability across units	Improved AC power reliability	(11), (12), (13)	B	There is already substantial cross-tie abilities between the SPS units, and further cross-tie features would to have minimal benefit.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
68	Create a cross-unit tie for diesel fuel oil	Adds diesel fuel oil redundancy.	(13)	B	At Surry, the cross-tie already exists with the installation of a spool piece. No further action is required on this mod.
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)		Not initially screened. Considered further in the cost-benefit analysis.
70	Emphasize steps in recovery of offsite power after a SBO.	Reduced human error probability of offsite power recovery.	(13)		Not initially screened. Considered further in the cost-benefit analysis.
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.
72	Procedures for replenishing diesel fuel oil	Allow long term diesel operation	(13)	A	This item is screened out because the diesel fuel tanks are already large enough to provide fuel well beyond the PRA assumed mission time of 24 hours.
73	Install gas turbine generators	Improve on-site AC power reliability	(13)	B	This feature is already installed at Surry in the form of the Gravel Neck C/T's. In addition, Surry has installed an SBO diesel for extra emergency power reliability. Therefore, this item is screened out.
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.
75	Create a river water backup for diesel cooling.	Provides redundant source of diesel cooling.	(13)	A - diesels are air cooled	Screened out.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
76	Use firewater as a backup for diesel cooling	Redundancy in diesel support systems	(13)	A - diesels are air cooled	Screened out.
77	Provide a connection to alternate offsite power source (the Gravel Neck fossil units)	Increase offsite power redundancy	(13) and suggested by the SPS PRA staff		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	In order for underground offsite power lines to provide real protection from severe weather, the high voltage lines would have to be installed not only in the SPS-controlled area, but also throughout the offste distribution grid. Such a plan is clearly not feasible, so this item is screened.
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
80	Provide ability for alternate bus loading by diesels	The 1H bus has one dedicated diesel; 1J has a swing diesel plus the AAC diesel; 2H has a dedicated diesel plus the AAC diesel; 2J has just the swing diesel. This leaves the 2J bus somewhat more vulnerable to a LOOP than the others.	Suggested by the SPS PRA staff or from the review of the top 100 cutsets	A	Surry requires that the SBO diesel start and auto-load on one of two buses within ten seconds. However, the required CW valves which are powered from the 2J bus retain power no matter which way the J bus aligns. This would negate the need for this mod. Once an additional bus is added to the loading scheme, the automatic selection of which bus to align to becomes nearly impossible. No further action on this mod is required.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
81	Alter electric power dependency to BC and CC SW valves	These valves require closing after a LOOP	Suggested by the SPS PRA staff or from the review of the top 100 cutsets		Not initially screened. Considered further in the cost-benefit analysis.
82	Relocate transfer buses to different rooms	All of the transfer buses are located within the same room, which results in a high CDF fire sequence.	Suggested by the SPS PRA staff or from the review of the top 100 cutsets		Not initially screened. Considered further in the cost-benefit analysis.
83	Put a fast acting MG output breaker on both units	With a fast acting breaker, a turbine runback would be possible, reducing the likelihood of a reactor trip in some cases.	Suggested by the SPS PRA staff or from the review of the top 100 cutsets		Not initially screened. Considered further in the cost-benefit analysis.
84	Proceduralize use of pressurizer vent valves during SGTR sequences	SPS procedures direct the use of pressurizer sprays to reduce RCS pressure after a SGTR. Use of the vent valves provides a backup method.	(13)	A	Screened out because the vent valves are too small to provide adequate pressure relief.
85	Install a redundant spray system to depressurize the primary system during a SGTR.	Enhanced depressurization ability during SGTR.	(16), (17)	B	This feature is already installed in the plant. The charging pumps have an existing line that feeds water from the VCT directly to the pressurizer spray nozzles. Some operating restrictions apply related to nozzle delta temperature. In a severe accident scenario nozzle damage may be an acceptable equipment casualty. No further action is required for this modification.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
86	Improved SGTR coping abilities	Improved instrumentation to detect SGTR, or additional systems to scrub fission product releases.	(7), (9), (10), (13), (14), (16), (17)		Not initially screened. Considered further in the cost-benefit analysis.
87	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.
88	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)		Not initially screened. Considered further in the cost-benefit analysis.
89	Replace steam generators with new design	Lower frequency of SGTR	(13)		Not initially screened. Considered further in the cost-benefit analysis.
90	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. SPS procedures already direct this.
91	Direct steam generator flooding after a SGTR, prior to core damage.	Would provide for improved scrubbing of SGTR releases.	(14), (15)	B	Screened out. SPS procedures already direct this.
92	A maintenance practice that inspects 100% of the tubes in a steam generator	Reduce chances of tube rupture	(16), (17)	A	Inspecting 100% of the tubes in each steam generator would result in a substantial dosage incurred by personnel every outage, and is judged to offset any possible benefit in reduced SGTR frequency.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
93	Locate RHR inside of containment	Would prevent ISLOCA out the RHR pathway	(8)	A - this item is not applicable to an existing plant	Screened out.
94	Self-actuating containment isolation valves	For plants that don't have this, it would reduce the frequency of isolation failure	(8)	B	Screened out.
95	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)	A	This mod is not feasible. Existing inspection activities could not identify ISLOCA precursors using a sampling technique. 100% inspection at each outage is not feasible since many of the inspections require the complete disassembly of valves, pumps and other complex components. This would significantly extend the duration of each outage. Even if a 100% inspection program could be instituted, the failures that cause ISLOCAs may go from generation of an initial fault to complete failure within one refueling cycle.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
96	Increase frequency of valve leak testing	Decrease ISLOCA frequency	(12)	A	This mod is not feasible. The dominant ISLOCA sequence involves failure of the LHSI valves, which are currently tested on a sampling frequency. The two valves in one line are tested each outage. There are a total of three lines and six valves. Valve testing was recently reduced to the sampling technique for two reasons. 1) Costs for running the test are very high. 2) Test results and disassembly inspections have confirmed that these valves remain in excellent condition. The testing of these valves occurs on critical path during an outage, is very expensive to run and is a high dose activity.
97	Improvement of operator training on ISLOCA coping	Decrease ISLOCA effects	(12), (13)	A	The dominant ISLOCA sequence at SPS is an unisolable ISLOCA, so additional training is expected to have a very small benefit.
98	Install relief valves in the component cooling water system	Would relieve pressure buildup from an RCP thermal barrier tube rupture, preventing an ISLOCA	(13)	A	Screened out.
99	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. As described in item 96, the valves are already tested.
100	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.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
101	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.
102	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)	A	The dominant ISLOCA sequence at SPS is due to failure of check valves, so a limit switch would not be effective.
103	Add a check valve downstream of the LHSI pumps on the cold leg injection line.	The ISLOCA frequency is 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.	Suggested by the SPS PRA staff or from the review of the top 100 cutsets		Not initially screened. Considered further in the cost-benefit analysis.
104	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)	B	Screened out.
105	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.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
106	Internal flood prevention and mitigation enhancements	1) Use of submersible MOV operators. 2) Back flow prevention in drain lines.	(13)	A	Screened out. Submersible MOVs have already been evaluated as part of the IPE on a cost-benefit basis (Reference 21) and will not be reviewed further in this report. The SPS IPE identified drains where back flow prevention devices would provide noticeable benefit, and these were installed. Back flow devices in any other areas would provide negligible benefit.
107	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. The SPS flooding analyses did not show any significant CDF from any of these sequences, so these SAMAs do not apply to Surry.
108	Digital feedwater upgrade	Reduces chance of loss of MFW following a plant trip.	(13)	B	Screened out - this feature already exists at Surry.
109	Perform surveillances on manual valves used for backup AFW pump suction	Improves success probability for providing alternate water supply to AFW pumps.	(13)	A	Screened out.
110	Install manual isolation valves around AFW turbine driven steam admission valves	Reduces the dual turbine driven pump maintenance unavailability.	(13)	A	Screened out.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
111	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)		Not initially screened. Considered further in the cost-benefit analysis.
112	Install a new Auxiliary Feedwater Storage Tank	Either replace old tanks with a larger ones, or install another backup tank	(13), (16), (17)	B	The Condensate Storage Tanks are cross-connected to the Emergency Condensate Storage Tanks via a gravity feed. The effective volume of the ECST includes most of the CST volume as well. Since this feature already exists, no further action on this mod is required.
113	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)	A	Screened out. Surry's turbine AFW can operate during an SBO.
114	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 at SPS.
115	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)	(16), (17)		Not initially screened. Considered further in the cost-benefit analysis.
116	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.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
117	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	The Condensate Storage Tanks are cross-connected to the Emergency Condensate Storage Tanks via a gravity feed. The effective volume of the ECST includes most of the CST volume as well. Since this feature already exists, no further action on this mod is required.
118	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	The Condensate Storage Tanks are cross-connected to the Emergency Condensate Storage Tanks via a gravity feed. The effective volume of the ECST includes most of the CST volume as well. Since this feature already exists, no further action on this mod is required.
119	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.
120	Install an independent diesel for the condensate storage tank makeup pumps	Would allow continued inventory in CST during a SBO	(13)	A	The Condensate Storage Tanks are cross-connected to the Emergency Condensate Storage Tanks via a gravity feed. The effective volume of the ECST includes most of the CST volume as well. Since this feature already exists, no further action on this mod is required.
121	Change failure position of condenser makeup valve.	If the condenser makeup valve fails open on loss of air or power, this can prevent CST flow diversion to condenser. Allows greater inventory for the AFW pumps.	(13)	A	Screened out.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
122	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.
123	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 SPS PRA staff or from the review of the top 100 cutsets		Not initially screened. Considered further in the cost-benefit analysis.
124	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)	Suggested by the SPS PRA staff or from the review of the top 100 cutsets		Not initially screened. Considered further in the cost-benefit analysis.
125	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.
126	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.
127	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."
128	Create the ability to manually align ECCS recirculation	For plants that do not already have this, it provides a backup should automatic or remote operation fail	(12)	B	Screened out.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
129	Implement an RWST makeup procedure	Decrease core damage frequency from ISLOCA scenarios, some smaller break LOCA scenarios, and SGTR	(12), (13)	B	Screened out because this feature already exists. The use of the PG tanks along with the BASTs is already installed. Furthermore, there is a cross-connect from the opposite unit's RWST.
130	Stop low pressure injection pumps earlier in medium or large LOCAs	Would give more time to perform recirculation swapover.	(13)	A	Screened out. This is not feasible. Raising the low level setpoint reduces the total useable volume of the RWST. This negatively affects the containment analysis which relies on cold RWST water to return the containment to subatmoshpheric within one hour after an event. In addition, an automatic swap exists so operator reliability is not an issue
131	Emphasize timely recirc swapover in operator training	Reduce human error probability of recirculation failure	(13)	B	Screened out. SPS has an automatic swap.
132	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)	B	Screened out.
133	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.
134	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.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
135	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.
136	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.
137	Raise HPCI/RCIC backpressure trip setpoints	Ensures HPCI/RCIC availability when high suppression pool temperatures exist.	(13)	A	Screened out.
138	Improve the reliability of the ADS	Reduce frequency high pressure core damage sequences	(4)	A	Screened out.
139	Disallow automatic vessel depressurization in non-ATWS scenarios	Improve operator control of plant.	(13)	A	Screened out.
140	Create automatic swapover to recirculation on RWST depletion	Would remove human error contribution from recirculation failure.	(5), (6), (11)	B	Screened out.
141	Enlarge the RWST	Greater water capacity for injection	Suggested by the SPS PRA staff or from the review of the top 100 cutsets	A/B	This SAMA is screened because SPS already has makeup capability to the RWST (see item 128) and has an automatic swap to recirculation.
142	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)	A	Screened out.
143	Replace old air compressors with more reliable ones.	Improve reliability and increase availability of instrument air compressors.	(13)	A	Screened out. Recent Surry data has not shown any vulnerability from air compressor reliability, so no benefit would be recognized.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
144	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.
145	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)		Not initially screened. Considered further in the cost-benefit analysis.
146	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)		Grouped into the category "Install MG set trip breakers in control room"
147	Create cross-connect ability for standby liquid control (SLC) trains	Improved reliability for boron injection during ATWS	(13)	A	Screened out.
148	Create an alternate boron injection capability (backup to SLC)	Improved reliability for boron injection during ATWS	(13)	A	Screened out.
149	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.
150	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)	B	Screened out.
151	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.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
152	Provide an additional I&C system (e.g., AMSAC).	Improve I&C redundancy and reduce ATWS frequency.	(16), (17)	B	Screened out. (AMSAC already implemented at Surry)
153	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 because SPS already has this feature.
154	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)		Not initially screened. Considered further in the cost-benefit analysis.
155	Make procedural changes only for the RCS depressurization option	Reduce RCS pressure without cost of a new system	(7), (9), (13)		Subsumed into "Create/enhance reactor coolant system depressurization ability"
156	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	This item is not applicable to SPS since SPS does not have 100% load rejection capability.
157	Change CRD flow control valve failure position	Change failure position to the 'fail-safest' position	(13)	A	Screened out.
158	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.
159	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)		Not initially screened. Considered further in the cost-benefit analysis.

Table G.2-1 (continued)
Initial List of Candidate Improvements for the SPS SAMA Analysis

SAMA Number	Potential Improvement	Discussion	Reference (see Section G.2.5)	Screening criterion or grouping (see Section G.2.2)	Evaluation
160	Increase seismic capacity of the plant to a HCLPF of twice the SSE	Reduced seismic CDF	(17)	A (this improvement is intended for a new plant)	Screened out.

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

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
9	Provide additional SW pump	Providing another pump would decrease core damage frequency due to a loss of SW	2.0%	0.3%	$34k	>2 x Benefit	Screen Out	Analysis case SWP determined the maximum benefit to be $34k. Not cost-beneficial; cost is expected to exceed twice the benefit.
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.	4.0%	0.3%	$63k	>2 x benefit	Screen out	Analysis case SLO determined the maximum benefit to be $63k. Not cost-beneficial; cost is expected to exceed twice the benefit.
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.	4.0%	0.3%	$63k	>2 x benefit	Screen out	Analysis case SLO determined the maximum benefit to be $63k. Not cost-beneficial; cost is expected to exceed twice the benefit.
14	Install improved RCP seals	RCP seal O-rings constructed of improved materials would reduce chances of RCP seal LOCA	4.0%	0.3%	$63k	>2 x benefit	Screen out	Analysis case SLO determined the maximum benefit to be $63k. Not cost-beneficial; cost is expected to exceed twice the benefit.
15	Add a third CCW pump	Reduce chance of loss of CCW	0.02%	0.3%	$5k	>2 x benefit	Screen out	Analysis case CCP determined the maximum benefit to be $5k. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
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.	0.02%	0.3%	$5k	>2 x benefit	Screen out	The cross-tied system already exists at SPS. The other options would not provide any significant benefit because although they might delay system failure slightly, they would not prevent it. Analysis case CCP further demonstrates the low benefit from even a significant change to the CC system, showing a benefit of on only $5k if a new, completely independent, pump were added. Not cost-beneficial; cost is expected to exceed twice the benefit.
23	Alter circ water valve power supply arrangement	The circ water valve inlet/outlet power supplies are 1J-A/1H and 1J-A/2H. The reliability during a LOOP could be improved by having one of the 1J-A supplies changed to 1H	-0.5%	-0.08%	-$4k	>2 x benefit	Screen out	Analysis case CWV showed that there is actually an increase to the CDF and offsite release by rearranging these power supplies. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
25	Provide a non-safety related, redundant train of switchgear ventilation	Provide a non-safety related, redundant train of switchgear ventilation	13.9%	5.0%	$278k	>2 x benefit	Screen out	Analysis case HVC determined the maximum benefit to be $278k. The critical cost is associated with finding room for the AHUs within the Control Room envelope. The AHUs would need to be located outside the existing envelope in an airtight pressure retaining enclosure and ducted through the envelope walls. Use of the existing ductwork would not be feasible nor would installation of new ductwork to support the operation of these new AHUs. They would simply terminate at the envelope walls for both their suction and return air flows. Space for the equipment outside the envelope may not be available making this modification not feasible. If space could be found, the cost for relocation of existing equipment for space considerations and then installation of this system would be $15-25M. Not cost-beneficial; cost is expected to exceed twice the benefit.
27	Add a switchgear room high temp alarm	Improve diagnosis of a loss of switchgear HVAC	0.02%	0.00%	<$1k	>2 x benefit	Screen out	Analysis case HVA determined the maximum benefit to be less than $1k. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
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.	0.00%	0.00%	$0	>2 x benefit	Screen out	Analysis case CSP shows a no benefit from this SAMA.
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	0.00%	0.00%	$0	>2 x benefit	Screen out	Analysis case CSP shows a no benefit from this SAMA.
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.	0.00%	0.00%	$0	>2 x benefit	Screen out	Analysis case CSP shows a no benefit from this SAMA.
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	4.9%	1.6%	$90k	>2 x benefit	Screen out	Analysis case DHR determined the maximum benefit to be less than $90k. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
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.	4.9%	5.5%	$135k	>2 x benefit	Screen out	Analysis case DHR shows the maximum possible benefit of a containment vent as $90k. Analysis case SCB shows the maximum possible benefit of the filtering of the fission products in the containment (all non-isolation releases) to be $45k. The combined benefit is $135k. Not cost-beneficial; cost is expected to exceed twice the benefit.
36	Install an unfiltered hardened containment vent	Provides an alternate decay heat removal method (non-ATWS), which is not filtered	4.9%	1.6%	$90k	>2 x benefit	Screen out	Analysis case DHR determined the maximum benefit to be less than $90k. Not cost-beneficial; cost is expected to exceed twice the benefit.
37	Create/enhanc e 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.	0.00%	0.02%	$1k	>2 x benefit	Screen out	Analysis case HYD determined the maximum benefit of eliminating containment failure due to hydrogen burns to be less than $1k. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
38	Create a passive hydrogen ignition system	Reduce hydrogen detonation potential without requiring electric power	0.00%	0.02%	$1k	>2 x benefit	Screen out	Analysis case HYD determined the maximum benefit of eliminating containment failure due to hydrogen burns to be less than $1k. Not cost-beneficial; cost is expected to exceed twice the benefit.
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.	0.00%	100%	$1.64 million	>2 x benefit	Screen out	The baseline analysis shows a maximum possible benefit of removing all offsite releases to be $1.64 million. It is judged that this SAMA would likely have a cost an order of magnitude larger than this possible benefit. Not cost-beneficial; cost is expected to exceed twice the benefit.
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.	0.00%	100%	$1.64 million	>2 x benefit	Screen out	The baseline analysis shows a maximum possible benefit of removing all offsite releases to be $1.64 million. It is judged that this SAMA would likely have a cost and order of magnitude larger than this possible benefit. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
42	Enhance fire protection system and/or standby gas treatment system hardware and procedures	Improve fission product scrubbing in severe accidents	0.00%	4.9%	$45k	>2 x benefit	Screen out	Analysis case SCB shows the maximum possible benefit of the filtering of the fission products in the containment to be $44,800. It is judged that this SAMA would be at a greater cost than this benefit when all necessary hardware and procedural changes are included. Not cost-beneficial; cost is expected to exceed 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%	0.00%	$0	>2 x benefit	Screen out	Analysis case DEB found no benefit in the SPS level 2 analysis for flooding the reactor cavity. Not cost-beneficial; cost is expected to exceed twice the benefit.
44	Creating other options for reactor cavity flooding	Flood cavity via systems such as diesel driven fire pumps	0.00%	0.00%	$0	>2 x benefit	Screen out	Analysis case DEB found no benefit in the SPS level 2 analysis for flooding the reactor cavity. Not cost-beneficial; cost is expected to exceed twice the benefit.
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.	0.00%	0.00%	$0	>2 x benefit	Screen out	This failure mode was not found to be a concern in the SPS Level 2 analysis, so it is judged to have a negligible benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
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).	0.00%	100%	$1.64 million	>2 x benefit	Screen out	The baseline analysis shows a maximum possible benefit of removing all offsite releases to be $1.64 million. It is judged that this SAMA would likely have a cost and order of magnitude larger than this possible benefit. Not cost-beneficial; cost is expected to exceed twice the benefit.
48	Provide containment inerting capability	Would prevent combustion of hydrogen and carbon monoxide gases	0.00%	0.02%	$1k	>2 x benefit	Screen out	Analysis case HYD determined the maximum benefit of eliminating containment failure due to hydrogen burns to be less than $1k. Not cost-beneficial; cost is expected to exceed twice the benefit.
49	Use fire water spray pump for containment spray	Redundant containment spray method without high cost	0.00%	0.00%	$0	>2 x benefit	Screen out	Analysis case CSP shows a no benefit from this SAMA.
50	Install a passive containment spray system	Containment spray benefits at a very high reliability, and without support systems	0.00%	0.00%	$0	>2 x benefit	Screen out	Analysis case CSP shows a no benefit from this SAMA.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
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.	0.00%	4.9%	$45k	>2 x benefit	Screen out	Analysis case SCB shows the maximum possible benefit of the filtering of the fission products in the containment to be $44,800. This is judged to also be applicable to preventing a molten core from escaping into containment Not cost-beneficial; cost is expected to exceed twice the benefit.
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.	0.00%	100%	$1.64 million	>2 x benefit	Screen out	The baseline analysis shows a maximum possible benefit of removing all offsite releases to be $1.64 million. It is judged that this SAMA would likely have a cost and order of magnitude larger than this possible benefit. Not cost-beneficial; cost is expected to exceed twice the benefit.
61	Use fuel cells instead of lead-acid batteries	Extend DC power availability in a SBO	5.4%	0.8%	$88k	>2 x benefit	Screen out	The System 80+ submittal (References 16 and 17) estimated the cost to be $2 million. The cost to an existing plant would be larger, while the maximum possible benefit calculated in analysis case BCH is only $88k, so this item is screened out. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	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.	5.4%	0.8%	$88k	>2 x benefit	Screen out	Analysis case BCH determined the maximum benefit of extended battery life during an accident to be $88k. The total battery load of the DC emergency buses during a four hour SBO event would require a 50KW battery charger. A portable unit with appropriate disconnects on the batteries for hook up during full power operation could be installed. The hookup would need to be brought out the alleyways where the diesel would be located when needed. Temporary cables would also be provided. Total cost for the diesel and plant modifications for its use $1.5-3M. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
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).	1.9%	2.0%	$62k	>2 x benefit	Screen out	The concept of capturing significant benefit through generation of a procedure is not realistic because the maintenance crews are already trained on the plant procedures for failed breakers. Therefore, the only portion of this SAMA given merit is the hardware portion (i.e., prestaged replacement breakers). Analysis case 4KV determined the maximum benefit to be $88k if half of all 4 KV breaker failures could be replaced in the timeframe considered in the PRA. The cost would be much greater than the actual benefit in order to have the many necessary breakers prestaged for this procedure to be effective. Not cost-beneficial; cost of purchasing, sheltering, and maintaining multiple prestaged 4KV breakers would exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
70	Emphasize steps in recovery of offsite power after a SBO.	Reduced human error probability of offsite power recovery.	1.8%	0.5%	$33k	>2 x benefit	Screen out	Analysis case OPR determined the maximum benefit to be less than $33k. The case was calculated using a 25% reduction in offsite power non-recovery terms. It is judged that this benefit is very optimistic given that training is already provided for offsite power recovery, and the fact that failure to recovery offsite power is likely to be governed by actual failures in the grid and not personnel failure. Not cost-beneficial; cost is expected to exceed twice the true obtainable benefit.
77	Provide a connection to alternate offsite power source (the Gravel Neck fossil units)	Increase offsite power redundancy	5.5%	1.5%	$105k	>2 x benefit	Screen out	Analysis case OSP determined the maximum benefit to be $105k. Assuming that the switchyard has been incapacitated, then a weather proof duct bank would need to be installed. The duct band would extend nearly ¾ of a mile and traverse under the Intake Canal for the plant. Switchgear would need to be provided at each end to disconnect from the normal sources and align the C/T to the Station buses. Total cost would be $2-5M. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
81	Alter electric power dependency to BC and CC SW valves	These valves require closing after a LOOP	0.7%	0.5%	$17k	>2 x benefit	Screen out	Analysis case BCC determined the maximum benefit to be $17k. The least expensive option would be to replace the BC and CC isolation valves with AOVs of a fail close design. Total cost to replace the operators, and install air lines, SOVs, etc would be $900K-1.5M. Not cost-beneficial; cost is expected to exceed twice the benefit.
82	Relocate transfer buses to different rooms	All of the transfer buses are located within the same room, which results in a high CDF fire sequence.	5.0%	0.7%	$41k	>2 x benefit	Screen out	Analysis case RTB determined the maximum benefit to be $41k. Not cost-beneficial; cost is expected to exceed twice the benefit.
83	Put a fast acting MG output breaker on both units	With a fast acting breaker, a turbine runback would be possible, reducing the likelihood of a reactor trip in some cases.	0.1%	0.04%	$3k	>2 x benefit	Screen out	Analysis case MGB determined the maximum benefit to be $3k. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
86	Improved SGTR coping abilities	Improved instrumentation to detect SGTR, or additional systems to scrub fission product releases.	2.8%	27%	$256k	>2 x benefit	Screen out	Analysis case SGI determined the maximum benefit to be 256k. This SAMA would involve the installation of numerous control circuits within the racks. Existing radiation alarms could be used to generate the high radiation signal. Close signals would be sent to the affected SG PORV, MSTV and Bypass valve, SG Blowdown Trip Valves and to the Terry Turbine steam supply valves (currently a manual valve but the valve would be changed to an AOV or MOV). Auto close to the auxiliary feedwater pumps would not be included to allow the operator time to assure that the SG had at least an 11% level before securing AFW. The mod would include the changeout of the Terry Turbine steam supply valves with control circuits to the racks and control room, instrumentation feeds from an existing rad monitor to the racks, appropriate annunciation in the control room to indicate the automatic action (including an automatic reactor trip) and wiring mods in the racks to the aforementioned components. Total cost would be $1.5-3M. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
88	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	5.7%	60%	$576k	>2 x benefit	Screen out	Analysis case SGR shows a maximum possible benefit of removing all SGTR to be $576k. It is judged that this SAMA would likely have a cost an order of magnitude larger than this possible benefit. Not cost-beneficial; cost is expected to exceed twice the benefit.
89	Replace steam generators with new design	Lower frequency of SGTR	5.7%	60%	$576k	>2 x benefit	Screen out	Analysis case SGR shows a maximum possible benefit of removing all SGTR to be $576k. It is judged that this SAMA would likely have a cost an order of magnitude larger than this possible benefit. Not cost-beneficial; cost is expected to exceed twice the benefit.
101	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.	0.00%	5.3%	$40k	>2 x benefit	Screen out	Analysis case ISS shows a maximum possible benefit of this SAMA to be $40k. Assuming the break of concern is in the Safeguards building, a firewater line would be added to flood this area. The line would be remotely operated from the control room. The line would run from the main firewater header to a discharge point in the Safeguards building. The cost is estimated at $125k. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
103	Add a check valve downstream of the LHSI pumps on the cold leg injection line.	The ISLOCA frequency is 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. However, a single check valve in the common line would create a single failure point for the system. Either a redundant line would have to be added with a check valve in each, or add a check valve to each of the 3 cold leg injection paths.	4.3%	30%	$253k	>2 x benefit	Screen out	Analysis case ISL shows a maximum possible benefit of removing all ISLOCA to be $253k. 3 check valves per unit can be added inside containment. There is an enduring cost associated with testing these check valves. Current testing is critical path, expensive and dose intensive. Present value cost of installing the mods and performing the future testing is $750K-1.25M. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
111	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.	0.1%	0.04%	$4k	>2 x benefit	Screen out	Analysis case FWS shows the maximum possible benefit to be $4k. Not cost-beneficial; cost is expected to exceed twice the benefit.
115	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)	0.1%	0.04%	$4k	>2 x benefit	Screen out	Analysis case FWS shows the maximum possible benefit to be $4k. Not cost-beneficial; cost is expected to exceed twice the benefit.
122	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.	12.8%	17.2%	$490k	>2 x benefit	Screen out	Analysis case FDW shows the maximum possible benefit as $490k. It is judged that this SAMA would likely be an order of magnitude greater than this benefit. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
123	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.	0.00%	0.03%	<$1k	>2 x benefit	Screen out	Analysis case SGP shows the maximum possible benefit to be less than $1k. Not cost-beneficial; cost is expected to exceed twice the benefit.
124	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)	2.2%	0.01%	$33k	>2 x benefit	Screen out	Analysis case CND shows the maximum possible benefit to be $33k. Not cost-beneficial; cost is expected to exceed twice the benefit.
125	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)	5.0%	0.01%	$76k	>2 x benefit	Screen out	Analysis case LHI shows the benefit to be $76k. The total cost would include adding a line from the firewater header, a post indicator valve in the yard and SR double isolation valves to the connection with the LHSI system. Total cost would be $350-600K. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
126/127	Provide an additional high pressure injection pump with independent diesel	Reduce frequency of core melt from small LOCA sequences, and from SBO sequences.	3.5%	2.1%	$89k	>2 x benefit	Screen out	Analysis case HPI shows the maximum possible benefit to be $89k. Not cost-beneficial; cost is expected to exceed twice the benefit.
145/146	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	0.01%	0.00%	<1k	>2 x benefit	Screen out	Analysis case ATW shows the maximum possible benefit to be less than $1k. Not cost-beneficial; cost is expected to exceed twice the benefit.
154	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.	0.00%	0.00%	$0	>2 x benefit	Screen out	The SPS Level 2 analysis shows that high pressure melt ejection is not a threat to containment failure. SPS procedures already direct depressurization in the appropriate Level 1 sequences. Analysis case DEB shows that there is no benefit in the Level 2 analysis for low pressure injection after core damage. Therefore, revision to existing procedures or creation of a new system would not be expected to provide any benefit.

Table G.2-2 (continued)
Summary of SPS SAMAs Considered in Cost-Benefit Analysis

SAMA No.	Potential Improvement	Discussion	Reduction in CDF (bounding)	Reduction in Person-Rem Offsite (bounding)	Benefit (bounding)	Estimated Cost	Conclusion	Cost Estimate And Basis For Conclusion
158	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.	0.00%	0.00%	$0	>2 x benefit	Screen out	Analysis case SLB shows there is an inconsequential benefit for MSLB SAMAs, so this item is screened out. Not cost-beneficial; cost is expected to exceed twice the benefit.
159	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).	3.3%	0.01%	$25k	>2 x benefit	Screen out	Analysis case LLO shows a benefit of $25k for this SAMA, which assumed a reduction in large LOCA frequency of 25%. It is judged that the cost of such instrumentation would be many times greater than $25k to be able to achieve this benefit. Not cost-beneficial; cost is expected to exceed twice the benefit.

Table G.2-3
Sensitivity Analysis Results

SAMA Number	Potential Improvement	Baseline	Case 1 (3% DR)	Case 2 (15% DR)	Case 3 (95% Evac)	Case 4 (1997 Met)	Case 5 (1996 Met)	Case 6 (+10% ST PLHEAT)	Case 7 (-50% ST PLHEAT)	Case 8 (+50% Timing)	Case 9 (-50% Timing)	Case 10 (DLTSHL = 5400)	Case 11 (CDFRM & CDNFRM x 1.46)
9	Provide additional SW pump	$34k	$58k	$22k	$34k	$34k	$34k	$34k	$34k	$34k	$34k	$34k	$34k
10	Create an independent RCP seal injection system, with dedicated diesel	$63k	$112k	$42k	$64k	$64k	$63k	$64k	$63k	$63k	$63k	$63k	$64k
11	Create an independent RCP seal injection system, without dedicated diesel	$63k	$112k	$42k	$64k	$64k	$63k	$64k	$63k	$63k	$63k	$63k	$64k
14	Install improved RCP seals	$63k	$112k	$42k	$64k	$64k	$63k	$64k	$63k	$63k	$63k	$63k	$64k
15	Add a third CCW pump	$5k	$8k	$3k	$5k	$5k	$5k	$5k	$5k	$6k	$5k	$5k	$6k
21	Loss of CCW or SW procedural enhancements	$5k	$8k	$3k	$5k	$5k	$5k	$5k	$5k	$6k	$5k	$5k	$6k
23	Alter circ water valve power supply arrangement	-$4k	-$7k	-$2k	-$4k	-$4k	-$4k	-$4k	-$4k	-$4k	-$4k	-$4k	-$4k
25	Provide a non-safety related, redundant train of switchgear ventilation	$278k	$470k	$178k	$278k	$282k	$284k	$278k	$280k	$282k	$274k	$280k	$281k

Table G.2-3 (continued)
Sensitivity Analysis Results

SAMA Number	Potential Improvement	Baseline	Case 1 (3% DR)	Case 2 (15% DR)	Case 3 (95% Evac)	Case 4 (1997 Met)	Case 5 (1996 Met)	Case 6 (+10% ST PLHEAT)	Case 7 (-50% ST PLHEAT)	Case 8 (+50% Timing)	Case 9 (-50% Timing)	Case 10 (DLTSHL = 5400)	Case 11 (CDFRM & CDNFRM x 1.46)
27	Add a switchgear room high temp alarm	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k
30	Install containment spray throttle valves	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
32	Develop an enhanced containment spray system	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
33	Provide a dedicated existing containment spray system	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
34	Install a containment vent large enough to remove ATWS decay heat	$90k	$154k	$58k	$90k	$91k	$90k	$90k	$90k	$90k	$90k	$90k	$91k
35	Install a filtered containment vent to remove decay heat	$135k	$207k	$85k	$133k	$141k	$151k	$136k	$136k	$136k	$136k	$136k	$137k
36	Install an unfiltered hardened containment vent	$90k	$154k	$58k	$90k	$91k	$90k	$90k	$90k	$90k	$90k	$90k	$91k
37	Create/enhance hydrogen ignitors with independent power supply.	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k

Table G.2-3 (continued)
Sensitivity Analysis Results

SAMA Number	Potential Improvement	Baseline	Case 1 (3% DR)	Case 2 (15% DR)	Case 3 (95% Evac)	Case 4 (1997 Met)	Case 5 (1996 Met)	Case 6 (+10% ST PLHEAT)	Case 7 (-50% ST PLHEAT)	Case 8 (+50% Timing)	Case 9 (-50% Timing)	Case 10 (DLTSHL = 5400)	Case 11 (CDFRM & CDNFRM x 1.46)
38	Create a passive hydrogen ignition system	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k
39	Create a giant concrete crucible with heat removal potential under the basemat to contain molten debris	$1.6 million	$2.3 million	$960k	$1.7 million	$1.7 million	$1.6 million	$1.7 million	$1.7 million	$1.8 million	$1.6 million	$1.7 million	$1.8 million
40	Create a water cooled rubble bed on the pedestal	$1.6 million	$2.3 million	$960k	$1.7 million	$1.7 million	$1.6 million	$1.7 million	$1.7 million	$1.8 million	$1.6 million	$1.7 million	$1.8 million
42	Enhance fire protection system and/or standby gas treatment system hardware and procedures	$45k	$63k	$27k	$44k	$50k	$61k	$46k	$46k	$46k	$46k	$46k	$46k
43	Create a reactor cavity flooding system	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
44	Creating other options for reactor cavity flooding	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
46	Provide a core debris control system	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Table G.2-3 (continued)
Sensitivity Analysis Results

SAMA Number	Potential Improvement	Baseline	Case 1 (3% DR)	Case 2 (15% DR)	Case 3 (95% Evac)	Case 4 (1997 Met)	Case 5 (1996 Met)	Case 6 (+10% ST PLHEAT)	Case 7 (-50% ST PLHEAT)	Case 8 (+50% Timing)	Case 9 (-50% Timing)	Case 10 (DLTSHL = 5400)	Case 11 (CDFRM & CDNFRM x 1.46)
47	Create a core melt source reduction system (COMSORS)	$1.6 million	$2.3 million	$960k	$1.7 million	$1.7 million	$1.6 million	$1.7 million	$1.7 million	$1.8 million	$1.6 million	$1.7 million	$1.8 million
48	Provide containment inerting capability	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k	$1k
49	Use fire water spray pump for containment spray	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
50	Install a passive containment spray system	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
54	Provide a reactor vessel exterior cooling system.	$45k	$63k	$27k	$44k	$50k	$61k	$46k	$46k	$46k	$46k	$46k	$46k
55	Create another building, maintained at a vacuum to be connected to containment	$1.6 million	$2.3 million	$960k	$1.7 million	$1.7 million	$1.6 million	$1.7 million	$1.7 million	$1.8 million	$1.6 million	$1.7 million	$1.8 million
61	Use fuel cells instead of lead-acid batteries	$88k	$154k	$58k	$88k	$89k	$92k	$88k	$88k	$88k	$88k	$88k	$88k
64	Alternate battery charging capability	$88k	$154k	$58k	$88k	$89k	$92k	$88k	$88k	$88k	$88k	$88k	$88k

Table G.2-3 (continued)
Sensitivity Analysis Results

SAMA Number	Potential Improvement	Baseline	Case 1 (3% DR)	Case 2 (15% DR)	Case 3 (95% Evac)	Case 4 (1997 Met)	Case 5 (1996 Met)	Case 6 (+10% ST PLHEAT)	Case 7 (-50% ST PLHEAT)	Case 8 (+50% Timing)	Case 9 (-50% Timing)	Case 10 (DLTSHL = 5400)	Case 11 (CDFRM & CDNFRM x 1.46)
69	Develop procedures to repair or change out failed 4KV breakers	$62k	$96k	$38k	$62k	$62k	$60k	$62k	$62k	$64k	$58k	$62k	$63k
70	Emphasize steps in recovery of offsite power after a SBO.	$33k	$57k	$22k	$34k	$34k	$34k	$34k	$34k	$34k	$34k	$34k	$34k
77	Provide a connection to alternate offsite power source (the Gravel Neck fossil units)	$105k	$180k	$68k	$106k	$106k	$106k	$106k	$106k	$106k	$104k	$106k	$106k
81	Alter electric power dependency to BC and CC SW valves	$17k	$27k	$11k	$17k	$17k	$17k	$17k	$17k	$17k	$17k	$17k	$17k
82	Relocate transfer buses to different rooms	$41k	$72k	$27k	$41k	$42k	$43k	$41k	$41k	$41k	$41k	$41k	$41k
83	Put a fast acting MG output breaker on both units	$3k	$4k	$2k	$3k	$3k	$3k	$3k	$3k	$3k	$3k	$3k	$3k
86	Improved SGTR coping abilities	$256k	$366k	$152k	$263k	$262k	$239k	$260k	$262k	$277k	$231k	$262k	$269k

Table G.2-3 (continued)
Sensitivity Analysis Results

SAMA Number	Potential Improvement	Baseline	Case 1 (3% DR)	Case 2 (15% DR)	Case 3 (95% Evac)	Case 4 (1997 Met)	Case 5 (1996 Met)	Case 6 (+10% ST PLHEAT)	Case 7 (-50% ST PLHEAT)	Case 8 (+50% Timing)	Case 9 (-50% Timing)	Case 10 (DLTSHL = 5400)	Case 11 (CDFRM & CDNFRM x 1.46)
88	Increase secondary side pressure capacity such that a SGTR would not cause the relief valves to lift	$576k	$821k	$342k	$590k	$590k	$537k	$584k	$588k	$624k	$518k	$588k	$605k
89	Replace steam generators with new design	$576k	$821k	$342k	$590k	$590k	$537k	$584k	$588k	$624k	$518k	$588k	$605k
101	Ensure all ISLOCA releases are scrubbed	$40k	$56k	$24k	$41k	$46k	$42k	$41k	$41k	$40k	$41k	$41k	$44k
103	Add a check valve downstream of the LHSI pumps on the cold leg injection line.	$253k	$366k	$151k	$259k	$284k	$261k	$259k	$258k	$264k	$260k	$259k	$269k
111	Install accumulators for turbine driven AFW pump flow control valves	$4k	$4k	$2k	$4k	$4k	$4k	$4k	$4k	$4k	$4k	$4k	$4k
115	Provide portable generators to be hooked in to the turbine driven AFW, after battery depletion	$4k	$4k	$2k	$4k	$4k	$4k	$4k	$4k	$4k	$4k	$4k	$4k

Table G.2-3 (continued)
Sensitivity Analysis Results

SAMA Number	Potential Improvement	Baseline	Case 1 (3% DR)	Case 2 (15% DR)	Case 3 (95% Evac)	Case 4 (1997 Met)	Case 5 (1996 Met)	Case 6 (+10% ST PLHEAT)	Case 7 (-50% ST PLHEAT)	Case 8 (+50% Timing)	Case 9 (-50% Timing)	Case 10 (DLTSHL = 5400)	Case 11 (CDFRM & CDNFRM x 1.46)
122	Create passive secondary side coolers	$490k	$762k	$302k	$498k	$500k	$472k	$496k	$498k	$518k	$460k	$498k	$507k
123	Automate air bottle swap for S/G PORVs	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k	<$1k
124	Condenser dump after SI	$33k	$59k	$22k	$33k	$33k	$33k	$33k	$33k	$33k	$34k	$34k	$34k
125	Provide capability for diesel driven, low pressure vessel makeup	$76k	$136k	$50k	$76k	$76k	$76k	$76k	$76k	$76k	$76k	$76k	$76k
126/127	Provide an additional high pressure injection pump with independent diesel	$89k	$146k	$56k	$90k	$90k	$88k	$90k	$90k	$92k	$86k	$90k	$91k
145/146	Install MG set trip breakers in control room	<1k	<1k	<1k	<1k	<1k	<1k	<1k	<1k	<1k	<1k	<1k	<1k
154	Create/enhance reactor coolant system depressurization ability	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
158	Secondary side guard pipes up to the MSIVs.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Table G.2-3 (continued)
Sensitivity Analysis Results

SAMA Number	Potential Improvement	Baseline	Case 1 (3% DR)	Case 2 (15% DR)	Case 3 (95% Evac)	Case 4 (1997 Met)	Case 5 (1996 Met)	Case 6 (+10% ST PLHEAT)	Case 7 (-50% ST PLHEAT)	Case 8 (+50% Timing)	Case 9 (-50% Timing)	Case 10 (DLTSHL = 5400)	Case 11 (CDFRM & CDNFRM x 1.46)
159	Digital large break LOCA protection	$25k	$45k	$17k	$25k	$25k	$25k	$25k	$25k	$25k	$25k	$25k	$25k

G.2.5 References

Ref. G.2-1 "Surry Power Station IPE," Virginia Electric And Power Company, August 1991.

Ref. G.2-2 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. G.2-3 "Cost Estimate for Severe Accident Mitigation Design Alternatives. Limerick Generating Station for Philadelphia Electric Company," Bechtel Power Corporation, June 22, 1989.

Ref. G.2-4 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. G.2-5 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. G.2-6 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. G.2-7 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. G.2-8 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. G.2-9 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. G.2-10 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. G.2-11 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. G.2-12 NUREG/CR-5567, "PWR Dry Containment Issue Characterization," NRC, August 1990.

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

Ref. G.2-14 NUREG/CR-5630, "PWR Dry Containment Parametric Studies," NRC, April 1991.

Ref. G.2-15 NUREG/CR-5575, "Quantitative Analysis of Potential Performance Improvements for the Dry PWR Containment," NRC, August 1990.

Ref. G.2-16 CESSAR Design Certification, Appendix U, Section 19.15.5, Use of PRA in the Design Process, December 31, 1993.

Ref. G.2-17 NUREG 1462, "Final Safety Evaluation Report Related to the Certification of the System 80+ Design," NRC, August 1994.

Ref. G.2-18 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.2-19 "Individual Plant Examination Of Non-Seismic External Events And Fires - Surry Power Station Units 1 And 2," Virginia Electric And Power Company, December 1994.

Ref. G.2-20 "Regulatory Analysis Technical Evaluation Handbook", NUREG/BR-0184, January 1997.

Ref. G.2-21 PA-CALC, "Individual Plant Examination Long-Term Modifications," Surry Power Station Units 1 and 2, Type 2 NP 2584H, September 1, 1992.

G.3 RESULTS AND CONCLUSIONS

After all screening and cost-benefit analyses, there are no SAMAs considered to be 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 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 outweigh the costs of each SAMA.