APPENDIX A

BFN SEVERE ACCIDENT MITIGATION ALTERNATIVES ANALYSIS

Abbreviations and Acronyms

AC .... Alternating Current

ADS.................... Automatic Depressurization System

AFW .... Auxiliary Feed Water

ATWS................. Anticipated Transient Without Scram

BFN .... Browns Ferry Nuclear Plant

BWR................... Boiling Water Reactor

CDF.................... Core Damage Frequency

CFR.................... Code of Federal Regulations

CRD .... Control Rod Drive

CS .... Core Spray

CV .... Check Valve

DC .... Direct Current

DW .... Dry Well

ECCS .... Emergency Core Cooling System

EECW .... Emergency Equipment Cooling Water

ENMKCTT.......... ATWS Core Damage End State

EOP.................... Emergency Operating Procedure

EPU.................... Extended Power Uprate

HFO.................... High Winds, Floods, Transportation and Other External Events

HP .... High Pressure

HPCI................... High Pressure Coolant Injection

HPGTET............. High Pressure General Transient (Event Tree)

HVAC .... Heating, Ventilation and Air Conditioning

IPE .... Individual Plant Examination

IPEEE................ Individual Plant Examination of External Events

ISLOCA .... Interfacing System Loss Of Coolant Accident

LERF .... Large Early Release Frequency

LLOCA .... Large Loss Of Coolant Accident (Event Tree)

LOCA .... Loss Of Coolant Accident

LPGTET .... Low Pressure General Transient Event Tree

MAAP................ Modular Accident Analysis Program

MLOCA .... Medium Loss Of Coolant Accident (Event Tree)

MOV .... Motor Operated Valve

MSIV .... Main Steam Isolation Valve

NLERF .... "No" Large Early Release Frequency

NPSH .... Net Positive Suction Head

PORV................ Power Operated Relief Valve

PSA................... Probabilistic Safety Analysis

PSW .... Plant Service Water

PWR.................. Pressurized Water Reactor

RBCCW............. Reactor Building Closed Cooling Water

RCP................... Reactor Coolant Pump

RCIC .... Reactor Core Isolation Cooling

RHR .... Residual Heat Removal

RHRSW............. Residual Heat Removal Service Water

ROM.................. Rough Order of Magnitude

RPV................... Reactor Pressure Vessel

RWCU .... Reactor Water Clean Up

RWST................ Reactor Water Storage Tank

SAMA .... Severe Accident Mitigation Alternative

SBO.................... Station Blackout

SG .... Steam Generator

SGTR .... Steam Generator Tube Rupture

SLC .... Standby Liquid Control

SQUG................. Seismic Qualification Utility Group

SRV.................... Safety/Relief Valve

TRANCDBIN ...... Event Tree for Binning Transient Core Damage Sequences

TVA .... Tennessee Valley Authority

UFSAR .... Updated Final Safety Analysis Report

USNRC .... United States Nuclear Regulatory Commission

UV .... Under Voltage

Contents

Page

Tables

Figures

I. Methodology

The methodology selected for this analysis involves identifying those Severe Accident Mitigation Alternatives (SAMA) candidates that have the most potential for reducing core damage frequency and person-rem risk. The phased approach consists of:

- Extending the Browns Ferry Nuclear Plant (BFN) Probabilistic Safety Analysis (PSA) results to a Level 3 analysis by determining offsite dose and economic baseline risk values.
- Determining the maximum averted risk that is possible based on the BFN baseline risk.
- Identifying potential SAMA candidates based on BFN PSA results, the USNRC, and industry documents.
- Screening out potential SAMA candidates that are not applicable to the BFN design or are of low benefit in boiling water reactors.
- Screening out SAMA candidates whose estimated cost exceeds the maximum possible averted risk.
- Performing a more detailed cost estimate and Level 3 dose and economic risk evaluation of remaining candidates to see if any have a benefit in risk aversion that exceeds the expected cost.

II. Level 3 PSA Analysis

The MACCS2 code was used to perform the Level 3 consequence analysis for the BFN. Plant-specific release data includes the time-nuclide distribution of releases, release frequencies, and release locations. The behavior of the population during a release (evacuation/sheltering parameters) was based on the generic MACCS2 model. This data was used in combination with site-specific meteorology and population data to simulate the impact risks (exposure and economic) to the surrounding (within 50 miles) population from the release accident sequences at the BFN.

A. Population

Population estimates for the year 2036 within 50 miles of the BFN plant were provided by TVAN (Reference 11) and are shown in Tables II-1 and II-2.

B. Meteorological Data Sampling Method

The atmospheric dispersion of radioactive material from a postulated accident depends on the meteorological conditions that exist from the start of the accident through a period of tens to hundreds of hours following the accident. Since the weather that could occur coincident with the accident is diverse, representative meteorological data sequences are selected as input to the dispersion model to reflect the dependence of the transport and dispersion process on the site weather. The selection process is done by means of sampling techniques from a full year of hourly weather data taken from the BFN on-site meteorological tower. For this analysis, the technique referred to as weather bin sampling in the MACCS2 V1.12 code was used for the 1980 year of data. This year was selected because it was deemed to be a representative year of meteorological data from the site area. The data recovery rate for all pertinent parameters was nearly 100%. Wind roses and joint frequency distributions that were run on this year of data all showed that it was typical for Browns Ferry. In general, annual meteorology does not vary markedly from year to year. Each year will have some anomalies, but as long as the site instrumentation was working properly one year should be as representative as the next.

This sampling method ensures a complete coverage of diurnal, seasonal, and 4-day cycles without the statistical noise of methods that utilize random sampling and includes the important “rain tails” (deposition due to delayed rain).

The meteorological data assessment is done by sorting the weather sequence into categories that provide a realistic representation of the year's weather without overlooking weather conditions that are instrumental in producing major consequences. A set of 40 weather categories has been selected for the MACCS2 V1.12 model to reflect these requirements. Up to eight meteorological scenarios are selected for each category, limited by the number of meteorological scenarios available for that category.

Table II-1. Estimated Population Distribution Within a 10-Mile Radius of BFN, Year 2036

Sector	0-1 mile	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10 miles total
N	2	18	203	379	501	2,501	3,604
NNE	0	5	33	379	521	1,931	2,869
NE	2	10	65	114	278	8,350	8,819
ENE	6	82	365	289	432	2,273	3,447
E	11	54	25	13	53	5,170	5,326
ESE	5	9	208	0	0	86	308
SE	2	0	0	0	2	7,626	7,630
SSE	0	0	1	0	1	16,037	16,039
S	0	3	29	59	25	1,768	1,884
SSW	0	2	12	235	343	3,708	4,300
SW	0	0	3	90	381	1,523	1,997
WSW	0	0	70	122	79	168	439
W	0	55	200	15	3	69	342
WNW	0	0	1	4	2	85	92
NW	0	2	8	4	33	640	687
NNW	52	467	272	84	104	3,104	4,083
TOTAL	80	707	1,495	1,787	2,758	55,039	61,866

Reference 11.

Table II-2. Estimated Population Distribution Within a 50-Mile Radius of BFN, Year 2036

Sector	0-10 mile	10-20 miles	20-30 miles	30-40 miles	40-50 miles	50 miles total
N	3,604	2,710	6,269	19,130	8,662	40,375
NNE	2,869	10,929	3,393	3,965	5,432	26,588
NE	8,819	21,034	23,783	16,920	17,488	88,044
ENE	3,447	35,534	69,528	63,014	10,840	182,363
E	5,326	5,731	136,377	105,268	12,263	264,965
ESE	308	1,096	4,229	20,885	17,799	44,317
SE	7,630	40,473	12,373	11,248	36,295	108,019
SSE	16,039	28,541	26,702	36,087	42,023	149,392
S	1,884	7,038	4,083	8,813	15,505	37,323
SSW	4,300	12,873	1,467	2,417	6,519	27,576
SW	1,997	6,376	3,318	4,075	19,955	35,721
WSW	439	3,957	3,895	29,617	4,376	42,284
W	342	3,855	17,460	37,892	4,842	64,391
WNW	92	3,124	28,974	51,789	11,954	95,933
NW	687	11,805	9,717	6,912	4,615	33,736
NNW	4,083	3,232	3,110	24,997	16,467	51,889
TOTAL	61,866	198,308	354,678	443,029	235,035	1,292,916

Given a postulated large accident, large numbers of early fatalities and injuries are normally associated with relatively low probability weather events such as rainfall or wind speed slowdowns within 50 miles of the plant site or with stable weather and moderate wind speeds at the start of the release. In MACCS2 V1.12, these weather data types have been selected to be among the 40 categories utilized in the assessment process.

With this information, weather sequences can be sampled to reflect the weather data for the full year. This ensures representation of each type of weather sequence, those important to realistic representation of the weather data set, and those important to the occurrence of the most serious accident consequences due to rainout in high population areas.

C. Atmospheric Transport and Dispersion

The dispersion model implemented in MACCS2 V1.12 is described in detail in NUREG/CR-4691, Volume 2. It is a Gaussian, time-dependent, plume segment model that has been in use for consequence assessments since the Reactor Safety Study (RSS) in 1975. The plume is assumed to be transported in a straight line downwind in accordance with the measured wind direction.

For each start hour selected by the meteorological sampling technique, the MAACS2 V1.12 dispersion model uses the subsequent meteorological conditions to predict the dispersion and transport of the released plume of radioactive material. The sequence of hourly recordings is used to account for changing meteorological conditions.

In MACCS2 V1.12, the effects of release duration, mixing layer depth, building wake, plume rise due to sensible heat buoyancy, and dry and wet removal processes are included. The ground concentration is calculated from the air concentration and the deposition rate.

D. Nuclide Release

The current design basis core inventory is provided in Table II-3 (Reference 9). Data from three district fuel types each representing Extended Power Uprate (EPU) conditions are found in the table. Each of the major hypothetical accidents identified in the IPE study (Reference 12) was assigned to one of several release categories based on the primary system and containment responses to the accident conditions calculated by the Modular Accident Analysis Program (MAAP). Each release category has associated release fractions of the initial core radionuclide inventory, which are used as input data to the consequence analysis model. In addition to the release magnitude, the parameters that characterize the various releases due to hypothetical accident sequences are time of release, duration of release, warning time for evacuation, height of release, and energy content of the released radioactive plume.

The time of start of release was taken from MAAP runs and refers to the time interval between the start of the hypothetical accident and the release of radioactive material from the containment building to the atmosphere. This parameter is used to calculate the decay of radioactivity as well as timing used in computing dose accumulated by evacuees in relation to plume location and deposited material. The duration of release is the total time during which radioactive material is emitted into the atmosphere; it is used to account for continuous releases by adjusting for horizontal dispersion due to changes in wind direction.

Table II-3. BFN Core Inventory

Isotope Number	Isotope Name	Release Group	Activity, Bq		
			GE Uprated 35 GWD/MTU	Framatome Commercial 37 GWD/MTU	Framatome Blended LEU 37 GWD/MTU
1	Cr-51	6	1.733959E+17	1.888302E+17	1.690426E+17
2	Mn-54	6	9.240809E+15	1.419054E+16	1.413400E+16
3	Mn-56	6	3.508059E+17	4.014056E+17	3.618304E+17
4	Fe-55	6	5.283289E+16	6.162424E+16	5.597064E+16
5	Co-58	6	2.133386E+16	2.100312E+16	2.128580E+16
6	Co-60	6	2.124906E+16	1.014821E+16	9.469780E+15
7	As-78	4	2.493803E+16	2.730689E+16	2.725035E+16
8	Ge-78	4	2.430765E+16	2.696767E+16	2.691114E+16
9	Se-81	4	2.229497E+17	2.040950E+17	2.066391E+17
10	Se-81m	4	6.230267E+15	1.452975E+16	1.458629E+16
11	Se-83	4	1.985262E+17	2.326456E+17	2.374512E+17
12	Br-82	2	2.410412E+16	1.215524E+16	1.175949E+16
13	Br-83	2	5.110854E+17	4.946900E+17	5.059972E+17
14	Br-84	2	8.935515E+17	9.215368E+17	9.498048E+17
15	Kr-83m	1	5.119335E+17	4.975168E+17	5.116508E+17
16	Kr-85	1	5.356786E+16	5.286116E+16	5.370920E+16
17	Kr-85m	1	1.093124E+18	1.034609E+18	1.071357E+18
18	Kr-87	1	2.108227E+18	2.080525E+18	2.156848E+18
19	Kr-88	1	2.970967E+18	2.883336E+18	2.996408E+18
20	Rb-86	3	9.503702E+15	6.925660E+15	6.840856E+15
21	Rb-88	3	3.016196E+18	2.968140E+18	3.081212E+18
22	Rb-89	3	3.875543E+18	3.872716E+18	4.042324E+18
23	Sr-89	5	3.997417E+18	4.014169E+18	4.155507E+18
24	Sr-90	5	4.271295E+17	4.635952E+17	4.720756E+17
25	Sr-91	5	4.980885E+18	5.031732E+18	5.201340E+18
26	Sr-92	5	5.359613E+18	5.314384E+18	5.483992E+18
27	Y-90	7	4.533537E+17	4.840330E+17	4.896018E+17
28	Y-91	7	5.122977E+18	5.173762E+18	5.343362E+18
29	Y-91m	7	2.891816E+18	2.911604E+18	3.024676E+18
30	Y-92	7	5.384116E+18	5.371140E+18	5.512477E+18
31	Y-93	7	6.185039E+18	4.070594E+18	4.155398E+18
32	Y-94	7	6.207698E+18	6.416896E+18	6.529967E+18
33	Y-95	7	6.642980E+18	6.671248E+18	6.756052E+18

Table II-3. BFN Core Inventory (Continued)

Isotope Number	Isotope Name	Release Group	Activity, Bq GE Uprated 35 GWD/MTU	Activity, Bq Framatome Commercial 37 GWD/MTU	Activity, Bq Framatome Blended LEU 37 GWD/MTU
34	Zr-95	7	7.233216E+18	7.205513E+18	7.279010E+18
35	Nb-95	7	7.262049E+18	7.228128E+18	7.304451E+18
36	Nb-95m	7	5.266046E+16	8.002671E+16	8.076168E+16
37	Zr-97	7	7.387842E+18	7.052866E+18	7.041559E+18
38	Nb-97	7	7.444378E+18	7.081134E+18	7.098095E+18
39	Nb-97m	7	7.004245E+18	6.688209E+18	6.705170E+18
40	Mo-99	6	7.588759E+18	7.519596E+18	7.491320E+18
41	Mo-101	6	6.788063E+18	6.756120E+18	6.699582E+18
42	Tc-99m	6	6.628846E+18	6.642980E+18	6.642980E+18
43	Tc-101	6	6.790889E+18	6.756120E+18	6.699582E+18
44	Tc-104	6	4.921459E+18	4.918632E+18	4.692488E+18
45	Ru-103	6	6.049352E+18	6.105888E+18	5.908012E+18
46	Rh-103m	6	5.450070E+18	6.105888E+18	5.908012E+18
47	Ru-105	6	4.008402E+18	4.042324E+18	3.816180E+18
48	Rh-105	6	3.779432E+18	3.816180E+18	3.618304E+18
49	Ru-106	6	2.176919E+18	2.219038E+18	2.060737E+18
50	Rh-106	6	2.336916E+18	2.385819E+18	2.202077E+18
51	Rh-106m	6	7.194206E+16	7.434484E+16	6.247228E+16
52	Rh-107	6	2.245045E+18	2.303842E+18	2.114446E+18
53	Pd-109	6	1.192344E+18	1.325769E+18	1.207044E+18
54	Ag-109m	6	1.191779E+18	1.325769E+18	1.207044E+18
55	Ag-110m	6	1.578485E+16	1.263580E+16	1.057223E+16
56	Ag-111	6	2.589349E+17	2.202077E+17	2.015508E+17
57	Ag-112	6	1.373825E+17	1.011994E+17	9.384976E+16
58	Cd-115	6	7.198474E+16	3.109480E+16	2.939872E+16
59	Cd-117	6	4.053691E+16	3.081212E+16	2.939872E+16
60	In-113m	6	5.515087E+15	1.158988E+16	1.125066E+16
61	In-115m	6	7.211167E+16	3.109480E+16	2.939872E+16
62	In-116m	6	3.129323E+16	1.984414E+16	1.851554E+16
63	In-117m	6	4.737773E+16	2.823973E+16	2.688287E+16
64	In-117	6	3.742913E+16	2.304144E+16	2.188243E+16
65	Sn-113	4	5.515087E+15	1.156161E+16	1.125066E+16
66	Sn-121	4	8.791065E+16	5.303077E+16	5.113681E+16
67	Sn-123m	4	6.024632E+16	3.280366E+16	3.138964E+16

Table II-3. BFN Core Inventory (Continued)

Isotope Number	Isotope Name	Release Group	Activity, Bq GE Uprated 35 GWD/MTU	Activity, Bq Framatome Commercial 37 GWD/MTU	Activity, Bq Framatome Blended LEU 37 GWD/MTU
68	Sn-127	4	2.649842E+17	1.325769E+17	1.263580E+17
69	Sn-128	4	6.456411E+17	5.512260E+17	5.399188E+17
70	Sb-125	4	7.809883E+16	4.576589E+16	4.418288E+16
71	Sb-131	4	3.341278E+18	3.137748E+18	3.137748E+18
72	Sn-125	4	6.875060E+16	1.970280E+16	1.901023E+16
73	Sb-127	4	4.169530E+17	3.307356E+17	3.166016E+17
74	Sb-129	4	1.261318E+18	1.257926E+18	1.232485E+18
75	Sb-130	4	4.079072E+17	4.183664E+17	4.098860E+17
76	Te-125m	4	1.681805E+16	9.995565E+15	9.647868E+15
77	Te-127	4	4.135640E+17	3.279102E+17	3.137761E+17
78	Te-127m	4	5.549027E+16	5.540528E+16	5.314384E+16
79	Te-129	4	1.241813E+18	1.192910E+18	1.167468E+18
80	Te-129m	4	1.856077E+17	2.408434E+17	2.351898E+17
81	Te-131m	4	5.704482E+17	7.688896E+17	7.462752E+17
82	Te-131	4	3.533500E+18	3.363892E+18	3.335624E+18
83	Te-132	4	5.673388E+18	5.710136E+18	5.653600E+18
84	Te-133	4	4.799906E+18	4.466344E+18	4.494612E+18
85	Te-133m	4	3.033156E+18	3.703108E+18	3.703108E+18
86	Te-134	4	6.883258E+18	7.321412E+18	7.406216E+18
87	I-128	2	5.017583E+16	3.505232E+16	3.250820E+16
88	I-130	2	1.324921E+17	8.084648E+16	7.208340E+16
89	I-131	2	3.980134E+18	3.957520E+18	3.900984E+18
90	I-132	2	5.758192E+18	5.794940E+18	5.766672E+18
91	I-133	2	8.189240E+18	8.254256E+18	8.225988E+18
92	I-134	2	9.011838E+18	9.158832E+18	9.158832E+18
93	I-135	2	7.660628E+18	7.830236E+18	7.801968E+18
94	Xe-131m	1	4.449383E+16	5.286116E+16	5.201312E+16
95	Xe-133	1	8.209027E+18	7.915040E+18	7.886772E+18
96	Xe-133m	1	2.545533E+17	2.586522E+17	2.566734E+17
97	Xe-135	1	2.863548E+18	2.660019E+18	2.939872E+18
98	Xe-135m	1	1.589510E+18	1.693253E+18	1.670639E+18
99	Xe-138	1	6.812588E+18	7.067000E+18	7.095268E+18
100	Cs-134	3	8.505841E+17	7.123536E+17	6.586444E+17
101	Cs-134m	3	2.184834E+17	1.537779E+17	1.413400E+17

Table II-3. BFN Core Inventory (Continued)

Isotope Number	Isotope Name	Release Group	Activity, Bq		
			GE Uprated 35 GWD/MTU	Framatome Commercial 37 GWD/MTU	Framatome Blended LEU 37 GWD/MTU
102	Cs-135m	3	1.007472E+17	1.305982E+17	1.116586E+17
103	Cs-136	3	2.894643E+17	2.374512E+17	2.374512E+17
104	Cs-137	3	5.622505E+17	6.021084E+17	5.992816E+17
105	Cs-138	3	7.536249E+18	7.632360E+18	7.660628E+18
106	Ba-137m	9	5.325691E+17	5.710136E+17	5.681868E+17
107	Ba-139	9	7.352507E+18	7.293144E+18	7.321412E+18
108	Ba-140	9	7.115056E+18	7.321412E+18	7.321412E+18
109	Ba-141	9	6.676902E+18	6.614712E+18	6.642980E+18
110	Ba-142	9	6.348993E+18	6.303764E+18	6.360300E+18
111	La-140	7	7.372294E+18	7.801968E+18	7.801968E+18
112	La-141	7	6.707996E+18	6.671248E+18	6.699516E+18
113	La-142	7	6.495986E+18	6.529908E+18	6.558176E+18
114	La-143	7	6.227440E+18	6.218960E+18	6.303764E+18
115	Ce-141	8	6.764532E+18	6.699516E+18	6.727784E+18
116	Ce-143	8	6.267016E+18	6.275496E+18	6.332032E+18
117	Ce-144	8	5.565969E+18	5.653600E+18	5.681868E+18
118	Pr-142	8	3.106653E+17	2.301015E+17	2.103139E+17
119	Pr-143	7	6.117195E+18	6.077620E+18	6.134156E+18
120	Pr-144	7	5.597064E+18	5.681868E+18	5.710136E+18
121	Pr-144m	7	6.688209E+16	7.915040E+16	7.999844E+16
122	Pr-145	7	4.257161E+18	4.268468E+18	4.296736E+18
123	Pr-147	7	2.673022E+18	2.674153E+18	2.676980E+18
124	Nd-147	7	2.693940E+18	2.693940E+18	2.693940E+18
125	Nd-149	7	1.535518E+18	1.517992E+18	1.498204E+18
126	Nd-151	7	7.765220E+17	7.660628E+17	7.434484E+17
127	Pm-147	7	6.914353E+17	9.469780E+17	9.922068E+17
128	Pm-148	7	1.175666E+18	7.151804E+17	6.784320E+17
129	Pm-148m	7	1.758552E+17	1.438841E+17	1.450148E+17
130	Pm-149	7	2.348505E+18	2.295362E+18	2.219038E+18
131	Pm-150	7	1.885193E+16	1.778057E+16	1.520818E+16
132	Pm-151	7	7.782180E+17	7.745432E+17	7.519288E+17
133	Sm-153	7	1.823569E+18	1.713043E+18	1.597144E+18
134	Sm-155	7	1.447322E+17	1.382310E+17	1.294679E+17
135	Sm-156	7	8.915727E+16	8.593472E+16	7.971576E+16

Table II-3. BFN Core Inventory (Continued)

Isotope Number	Isotope Name	Release Group	Activity, Bq GE Uprated 35 GWD/MTU	Framatome Commercial 37 GWD/MTU	Framatome Blended LEU 37 GWD/MTU
136	Eu-154	7	4.692347E+16	3.218594E+16	3.162907E+16
137	Eu-155	7	3.293420E+16	1.344002E+16	1.275678E+16
138	Eu-156	7	5.975629E+17	7.840978E+17	6.897957E+17
139	Eu-157	7	7.997017E+16	8.028112E+16	7.123536E+16
140	Eu-158	7	3.386506E+16	3.109480E+16	2.855068E+16
141	Gd-159	7	9.078890E+17	6.689622E+17	6.417401E+17
142	W-187	6	1.594598E+16	1.583008E+16	1.540606E+16
143	Pu-238	8	1.485766E+16	1.274887E+16	4.183664E+16
144	Np-239	8	7.756739E+19	7.293144E+19	6.812588E+19
145	Pu-239	8	1.765619E+15	1.763923E+15	1.840247E+15
146	Pu-240	8	2.288295E+15	2.580868E+15	2.448009E+15
147	Pu-241	8	6.637326E+17	6.303764E+17	6.162424E+17
148	Am-241	7	8.127050E+14	8.112916E+14	8.112916E+14
149	Cm-242	7	1.819328E+17	1.840247E+17	1.648024E+17
150	Cm-244	7	8.497361E+15	7.717164E+15	6.049352E+15

** From Reference 9.*

The warning time for evacuation was estimated based on review of the accident sequences. This time is the interval between awareness of impending core melt and the release of radioactive material from the containment building. Finally, the height of release and the energy content of the released plume affect the manner in which the plume would be dispersed in the atmosphere.

E. Evacuation and Other Protective Measures

Evacuation and other protective measures (i.e., sheltering and relocation) are taken to avoid or reduce immediate exposure to the passing radioactive plume and ground contamination. Evacuation is potentially the most effective method of avoiding radiation exposure and can provide essentially total protection if completed prior to arrival of the plume.

The evacuation model does not account for actual road networks, road capacity limitations, or lateral travel possibilities (evacuation is assumed to be in a straight-line radially away from the plant).

F. Results

The results of the Level 3 consequence analysis provide projected offsite radiation doses and offsite economic costs (in 2016 dollars) as a function of accident conditions (Reference 9). This information forms part of the input data to the economic model described in Section III of this analysis. In the exposure and economic cost evaluation of each base case and each SAMA, for each plant damage state, the maximum (as determined by the mean value) dose and offsite cost from the three fuel types was selected.

III. Determination of Present Value

This section explains how the Tennessee Valley Authority (TVA) calculated the monetized value of the status quo (i.e., accident consequences without SAMA implementation). TVA also used this analysis to establish the maximum benefit that a SAMA could achieve if it eliminated all BFN risk. The following costs are included in the analysis:

1. Offsite exposure cost
2. Offsite economic cost
3. Onsite exposure cost
4. Onsite cleanup cost
5. Replacement power cost

The cost will be determined independently for both Unit 2 and Unit 3. Two real discount rates will be used in the calculations. A 7% discount rate will be used to reflect a “base case” discount rate and 3% will be used to provide analysis sensitivity to the discount rate, in accordance with Reference 10.

The sum of these costs will be used to screen out SAMAs that are not economically feasible; if the estimated cost of implementing a SAMA exceeds the maximum benefit, then it will be discarded from further analysis. Exceeding this threshold would mean that a SAMA would not have a positive net value even if it could eliminate all severe accident costs.

For the purposes of this analysis, the “present” is considered to be the year 2016. All constant dollar values from Reference 10 have been recalculated to the Year 2016 using a 3% inflation rate. Specifics are noted in the text to this section.

A. Offsite Exposure Cost

The baseline annual offsite exposure risk was converted to dollars using the United States Nuclear Regulatory Commission (USNRC) conversion factor of $2,000 per person-rem (Reference 10, Section 5.7.1.2), and discounting to present value using the USNRC standard formula (Reference 10, Section 5.7.1.3):

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

Where:

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

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

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

r = real discount rate (as fraction) = either 0.03 or 0.07/year

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

The calculated value for C using 20 years with a 3% discount rate is 15.04 and with a 7% discount rate is 10.76. Therefore, calculating the discounted monetary equivalent of accident risk involves multiplying the dose (person-rem per year) by monetary value of unit dose (1 person/rem) and by the C value (Reference 10 Section 5.7.12). Since the "present" for this analysis is the Year 2016, the future value of $2,000 at a 3% inflation rate was calculated to be $3,097, which was used in this calculation. The calculated offsite exposure cost is for each of the units is presented in Table III-1.

Table III-1. Calculated Offsite Exposure Cost for Units 2 and 3.

Real Discount Rate	Unit 2		Unit 3	
	3%	7%	3%	7%
C	15.04	10.76	15.04	10.76
Z_{pha}	$9,373	$9,373	$19,449	$19,449
W_{pha}	$140,970	$100,853	$292,513	$209,271

B. Offsite Economic Cost

The Level 3 analysis showed an annual offsite economic risk for the two units and discount rates is presented in Table III-2. Calculated values for offsite economic costs caused by severe accidents must be discounted to present value as well. This is performed in the same manner as for public health risks and uses the same C value. The resulting values are also presented in Table III-2.

Table III-2. Calculated Offsite Economic Cost for Units 2 and 3

Real Discount Rate	Unit 2		Unit 3	
	3%	7%	3%	7%
C	15.04	10.76	15.04	10.76
Sum of Annual Economic Risk	$6,500	$6,500	$13,700	$13,700
Offsite Economic Costs	$97,760	$69,940	$206,048	147,412

C. Onsite Exposure Cost

TVA evaluated occupational health using the USNRC methodology in Reference 10, Section 5.7.3, which involves separately evaluating "immediate" and long-term doses.

Immediate Dose - For the case where the plant is in operation, the equation that the USNRC recommends using (Reference 10, Sections 5.7.3 and 5.7.3.3) is:

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

Where:

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

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

F = accident frequency (events/yr)

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

S = subscript denoting status quo (current conditions)

A = subscript denoting after implementation of proposed action

r = real discount rate

t_f = years remaining until end of facility life.

The values used in the BFN analysis are:

R = \$3,097/person-rem (\$2,000 inflation at 3% to 2016 values)

r = 0.03 and 0.07

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

t_f = 20 years (license extension period)

F = 1.05E-6 for Unit 2 and 1.90E-6 for Unit 3 (total core damage frequency)

For the basis discount rate, assuming $(FD_{IO})_A$ is zero, the best estimate of the immediate dose cost is:

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

The results of the immediate dose cost calculations are presented in Table III-3.

Table III-3. Immediate Dose Cost for Units 2 and 3

Real Discount Rate	Unit 2		Unit 3	
	3%	7%	3%	7%
Core Damage Frequency (per year)	1.05E-6	1.05E-6	1.90E-6	1.90E-6
Immediate Dose Cost	\$161	\$115	\$292	\$209

<u>Long-Term Dose</u> - For the case where the plant is in operation, the USNRC equation (Reference 10, Sections 5.7.3 and 5.7.3.3) is:

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

Where:

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

m = years over which long-term doses accrue

The values used in the BFN analysis are:

R = \$3,097/person-rem (\$2,000 inflated at 3% to 2016 values)

r = 0.03 AND 0.07

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

m = “as long as 10 years”

t_f = 20 years (license extension period)

F = 1.05E-6 for Unit 2 and 1.90E-6 for Unit 3 (total core damage frequency)

For the basis discount rate, assuming $(FD_{LTO})_A$ is zero, the best estimate of the long-term dose is:

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

The results of the long-term dose cost calculations are presented in Table III-4.

Table III-4. Long-Term Dose Cost for Units 2 and 3

Real Discount Rate	Unit 2		Unit 3	
	3%	7%	3%	7%
Core Damage Frequency (per year)	1.05E-6	1.05E-6	1.90E-6	1.90E-6
Long-term Dose Cost	\$845	\$503	\$1,527	\$910

Total Occupational Exposure - Combining Equations 1 and 2 above and using the above numerical values, the total accident related on-site (occupational) exposure avoided (W_O) is presented in Table III-5.

$$W_O = W_{IO} + W_{LTO}$$

Table III-5. Total Occupational Exposure Cost for Units 2 and 3

Real Discount Rate	Unit 2		Unit 3	
	3%	7%	3%	7%
Immediate Dose Cost	$161	$115	$292	$209
Long-term Dose Cost	$845	$503	$1,527	$910
Total Occupational Exposure Cost	$1,006	$618	$1,819	$1,119

It should be noted that if the maximum exposures were used in the above calculations, there would be a negligible impact on the overall conclusions.

D. Onsite Cleanup and Decontamination Cost

The net present value (year 2001 dollars) that the USNRC provides for cleanup and decontamination for a single event is $1.1 billion, discounted over a 10-year cleanup period (Reference 10, Section 5.7.6.1). The USNRC uses the following equation in integrating the net present value over the average number of remaining service years:

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

Where:

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

r = real discount rate

t_f = years remaining until end of facility life.

The values used in the BFN analysis are:

PV_{CD} = $1.714E+9 ($1.1E+9 inflated at 3% to 2016 values)

r = 0.03 and 0.07

t_f = 20

The resulting net present value of cleanup integrated over the license renewal term is multiplied by the total core damage frequency to determine the expected value of cleanup and decontamination costs. The resulting monetary equivalent is presented in Table III-6.

Table III-6. Expected Value of Cleanup and Decontamination Costs for Units 2 and 3

Real Discount Rate	Unit 2		Unit 3	
	3%	7%	3%	7%
Net Present Value of Cleanup and Decontamination Costs	2.58+10	1.84E+10	2.58E+10	1.84E+10
Core Damage Frequency (per year)	1.05E-6	1.05E-6	1.90E-6	1.90E-6
Expected Value of Cleanup and Decontamination Costs	$27,090	$19,320	$49,020	$34,960

E. Replacement Power Cost

Long-term replacement power costs was determined following the USNRC methodology in Reference 10 Section 5.7.6.2. The net present value of replacement power for a single event, $P_{V_{RP}}$, was determined using the following equation:

$PV_{RP} = [\$1.2E + 08/r] * [1 - \exp(-rt_f)]^2$ (2001 dollars)

$PV_{RP} = [\$1.9E + 08/r] * [1 - \exp(-rt_f)]^2$ (2016 dollars)

Where:

PV_{RP} = net present value of replacement power for a single event, ($). This yields a PV_{RP} for 2016 of $2.18E+9 at 3% and $1.52+9 at 7%.

r = 0.03 and 0.07

t_f = 20 years (license renewal period)

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

$U_{RP} = [PV_{RP} /_r] * [1 - \exp(-rt_f)]^2$ (r > 5%)

$U_{RP}{}^2 = 1.9E+10$ (r =1%, 2001 dollars)

Where:

U_{RP} = net present value of replacement power over life of facility ($-year). Reference 10, Section 5.6.7.2 provides a recommended discount rate value of between 1.9E+10 at 1% and 1.2E+10 at 5%. A linear extrapolation of 1.55E+10 was made to determine the current present value (2001) of replacement power at a 3% discount rate. This value was inflated to 2016 values. This yields a U_{RP} for 2016 of $2.41E+10 for 3% and $1.23+10 for 7%.

After applying a correction factor to account for BFN's size relative to the "generic" reactor described in NUREG/BR-0184 (i.e., 1190 MWe/910 MWe), the replacement power costs are presented in Table III-7.

Table III-7. Expected Replacement Power Costs for Units 2 and 3

Real Discount Rate	Unit 2		Unit 3	
	3%	**7%**	**3%**	**7%**
Net Present Value of Replacement Power over the Life of the Facility	2.41E+10	1.23E+10	2.41E+10	1.23E+10
Correction Factor for size	1.31	1.31	1.31	1.31
Replacement Power Cost	3.16E+10	1.61E+10	3.16E+10	1.61E+10
Core Damage Frequency (F)	1.05E-6	1.05E-6	1.90E-6	1.90E-6
Replacement power costs per accident damage frequency	$33,180	$16,905	$60,9040	$30,590

F. Baseline Screening

The sum of the baseline costs is presented in Table III-8.

Table III-8. Total Costs for Units 2 and 3

Real Discount Rate	Unit 2		Unit 3	
	3%	7%	3%	7%
Monetary Value of Public Health Risk After Discounting	$140,970	$100,853	$292,513	$209,271
Offsite Economic Costs	$97,760	$69,940	$206,048	$147,412
Total Accident on-site exposure avoided	$1,006	$619	$1,819	$1,118
Expected Value of Cleanup and Decontamination Costs	$27,090	$19,320	$49,020	$34,960
Replacement Power Costs	$33,180	$16,905	$60,040	$30,590
Total	$300,006	$207,637	$609,440*	$423,351

** The most conservative value in Table III-8 is $609,440. Including the effects of restart of Unit 1 (described in Section V.HH), the maximum value for the three-unit plant is $3.6 million. This value was conservatively rounded to $10 million for initial screening of SAMAs that are not economically feasible; if the estimated cost of implementing a SAMA exceeded $10 million, it was discarded from further analysis. Exceeding this threshold means that a SAMA would not have a positive net value even if it could eliminate all severe accident costs associated with all three units.*

IV. SAMA Candidates and Screening Process

An initial list of SAMA candidates was developed from lists of Severe Accident Mitigation Alternatives for Hatch Nuclear Plant (Reference 8) and, most importantly, from the plant specific risk profile as provided by the BFN PSA (References 2 and 3) and the BFN Individual Plant Examination of External Event (IPEEE) (References 4 through 7). This initial list was then screened to remove those that met the following criteria:

- does not apply to the BFN or to BWRs in general,
- already in place at BFN, or
- Rough order of magnitude (ROM) costs exceed the screening cost savings.

This screening process will leave unique SAMA candidates that are applicable to BFN and are of potential value in averting the risk of severe accidents. A preliminary cost estimate will be prepared for each of these candidates based on previous design/procedural modifications of similar scope to focus on those that had the possibility of having a positive benefit and to eliminate those whose costs were clearly beyond the possibility of any corresponding benefit.

A more detailed estimate will be prepared for those items that appear to be cost effective.

The initial list of candidates is provided in Tables IV-1 and IV-2.

Table IV-1. Initial Screening of Generic SAMAs

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
1	Cap downstream piping of normally closed component cooling water drain and vent valves.	SAMA to reduce the frequency of a loss of component cooling event, a large portion of which was derived from catastrophic failure of one of the many single isolation valves.	N/A	N/A
2	Enhance loss of component cooling procedure to facilitate stopping reactor coolant pumps.	SAMA to reduce the potential for RCP seal damage due to pump bearing failure.	B	N/A
3	Enhance loss of component cooling procedure to present desirability of cooling down RCS prior to seal LOCA.	SAMA would reduce the potential for RCP seal failure.	B	N/A
4	Additional training on the loss of component cooling.	SAMA would potentially improve the success rate of operator actions after a loss of component cooling (to prevent RCP seal damage).	B	N/A
5	Provide hardware connections to allow another essential raw cooling water system to cool charging pump seals.	SAMA would reduce effect of loss of component cooling by providing a means to maintain the centrifugal charging pump seal injection after a loss of component cooling.	B	N/A
5A	Procedure changes to allow cross connection of motor cooling for RHRSW pumps.	SAMA would allow continued operation of both RHRSW pumps on a failure of one train of PSW.	N/A	N/A
6	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend component cooling heatup.	SAMA would increase time before the loss of component cooling (and reactor coolant pump seal failure) in the loss of essential raw cooling water sequences.	B	N/A
7	Increase CRD pump lube oil capacity.	SAMA would lengthen the time before control rod drive (CRD) pump failure due to lube oil	None	Phase II SAMA 01
8	Eliminate the RCP thermal barrier dependence on component cooling such that loss of component cooling does not result directly in core damage.	SAMA would prevent the loss of recirculation pump seal integrity after a loss of component cooling. Watts Bar Nuclear Plant IPE said that they could do this with essential raw cooling water connection to charging pump seals.	B	N/A
9	Add redundant DC Control Power for SW Pumps.	SAMA would increase reliability of SW and decrease core damage frequency due to a loss of SW. Relevant, potential concern at BFN is loss of DC-D	D	SAMA 57

Table IV-1. Initial Screening of Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
10	Create an independent RCP seal injection system, with a dedicated diesel.	SAMA would add redundancy to RCP seal cooling alternatives, reducing CDF from loss of component cooling or service water or from a station blackout event.	B	N/A
11	Use existing hydro test pump for RCP seal injection.	SAMA would provide an independent seal injection source, without the cost of a new system.	B	N/A
12	Replace ECCS pump motor with passively cooled motors.	SAMA would eliminate ECCS dependency on EECW.	None	Phase II SAMA 02
13	Install improved RCS pumps seals.	RCP seal O-ring constructed of improved materials would reduce probability of RCP seal LOCA	B	N/A
14	Install additional component cooling water pump.	SAMA would reduce probability of loss of component cooling leading to RCP seal LOC*A.*	B	N/A
15	Prevent centrifugal charging pump flow diversion from the relief valves.	If relieve valve opening causes a flow diversion large enough to prevent RCP seal injection, then the modification would reduce the frequency of the loss of RCP seal cooling.	B	N/A
16	Change procedures to isolate RCP seal letdown flow on loss of component cooling, and guidance on loss of injection during seal LOCA.	SAMA would reduce CDF from loss of seal cooling.	B	N/A
17	Implement procedures to stagger CRD pump use after a loss of service water.	SAMA would allow injection with CRD to be extended after a loss of service water.	None	Phase II SAMA 03
18	Use fire protection system pumps as a backup seal injection and high pressure make-up.	SAMA would reduce the frequency of the RCP seal LOCA and the SBO CDF.	B	N/A
19	Procedural guidance for use of cross-tied component cooling or service water pumps.	SAMA would reduce the frequency of the loss of component cooling water and service water.	None	Phase II SAMA 04
20	Procedure enhancements and operator training in support system failure sequences, with emphasis on anticipating problems and coping.	SAMA would potentially improve the success rate of operator actions subsequent to support system failures.	None	Phase II SAMA 05

Table IV-1. Initial Screening of Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
21	Improved ability to cool the residual heat removal heat exchangers	SAMA would reduce the probability of a loss of decay heat removal by implementing procedure and hardware modifications to allow manual alignment of the fire protection system or by installing a component cooling water crosstie.	None	Phase II SAMA 06
22	Provide reliable power to Control Building fans	SAMA would increase availability of control room ventilation on a loss of power.	N/A	Control Bay HVAC was not a critical function represented in the BFN models
23	Provide a redundant train of ventilation.	SAMA would increase the availability of components dependent on room cooling.	None	Phase II SAMA 07
24	Procedures for actions on loss of HVAC.	SAMA would provide for improved electrical equipment reliability upon a loss of Control Building HVAC)	C	N/A
25	Add a diesel building switchgear room high temperature alarm.	SAMA would improve diagnosis of a loss of switchgear room HVAC. Option 1: Install high temp alarm Option 2: Redundant louver and thermostat	None	Phase II SAMA 08
26	Create ability to switch fan power supply to direct current (DC) in an SBO event.	SAMA would allow continued operation in an SBO event. This SAMA was created for reactor core isolation cooling system room at Fitzpatrick Nuclear Power Plant.	N/A	N/A
27	Delay containment spray actuation after large LOCA.	SAMA would lengthen time of RWST availability.	N/A	N/A
28	Install containment spray pump header automatic throttle valves.	SAMA would extend the time over which water remains in the RWST, when full CS flow is not needed	N/A	N/A
29	Install an independent method of suppression pool cooling.	SAMA would decrease the probability of loss of containment heat removal.	D	SAMA 124
30	Develop an enhanced drywell spray system.	SAMA would provide a redundant source of water to the containment to control containment pressure, when used in conjunction with containment heat removal.	D	SAMA 46
31	Provide dedicated existing drywell spray system.	SAMA would provide a source of water to the containment to control containment pressure, when used in conjunction with containment heat removal. This would use an existing spray loop instead of developing a new spray system.	C	N/A
32	Install an unfiltered hardened containment vent.	SAMA would provide an alternate decay heat removal method for non-ATWS events, with the released fission products not being scrubbed.	C	N/A

Table IV-1. Initial Screening Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
33	Install a filtered containment vent to remove decay heat.	SAMA would provide an alternate decay heat removal method for non-ATWS events, with the released fission products being scrubbed. Option 1: Gravel Bed Filter Option 2: Multiple Venturi Scrubber	E	Cost in excess of $5M per unit
34	Install a containment vent large enough to remove ATWS decay heat.	Assuming that injection is available, this SAMA would provide alternate decay heat removal in an ATWS event.	None	Phase II SAMA 09
35	Create/enhance hydrogen recombiners with independent power supply.	SAMA would reduce hydrogen detonation at lower cost, Use either a new, independent power supply, a nonsafety-grade portable generator, existing station batteries, or existing AC/DC independent power supplies.	N/A	N/A
35A	Install hydrogen recombiners.	SAMA would provide a means to reduce the chance of hydrogen detonation.	N/A	N/A
36	Create a passive design hydrogen ignition system.	SAMA would reduce hydrogen denotation system without requiring electric power.	N/A	N/A
37	Create a large concrete crucible with heat removal potential under the basemat to contain molten core debris.	SAMA would ensure that molten core debris escaping form the vessel would be contained within the crucible. The water cooling mechanism would cool the molten core, preventing a melt-through of the basemat.	E	Cost well in excess of $10M per unit
38	Create a water-cooled rubble bed on the pedestal.	SAMA would contain molten core debris dropping on to the pedestal and would allow the debris to be cooled.	E	Cost well in excess of $10M per unit
39	Provide modification for flooding the drywell head.	SAMA would help mitigate accidents that result in the leakage through the drywell head seal.	N/A	Containment failure dominated by wet well failure or dry well shell failure other than head region (BFN IPE NUREG-1150)*
40	Enhance fire protection system and/or standby gas treatment system hardware and procedures.	SAMA would improve fission product scrubbing in severe accidents.	C	N/A
41	Create a reactor cavity flooding system.	SAMA would enhance debris coolability, reduce core concrete interaction, and provide fission product scrubbing.	C	N/A

** Reference 16*

Table IV-1. Initial Screening of Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
42	Create other options for reactor cavity flooding.	SAMA would enhance debris coolability, reduce core concrete interaction, and provide fission product scrubbing.	D	SAMA 41
43	Enhance air return fans (ice condenser plants).	SAMA would provide an independent power supply for the air return fans, reducing containment failure in SBO sequences.	N/A	N/A
44	Create a core melt source reduction system.	SAMA would provide cooling and containment of molten core debris. Refractory material would be placed underneath the reactor vessel such that a molten core falling on the material would melt and combine with the material. Subsequent spreading and heat removal from the vitrified compound would be facilitated, and concrete attack would not occur.	E	Cost well in excess of $10M per unit
45	Provide a containment inerting capability.	SAMA would prevent combustion of hydrogen and carbon monoxide gases.	C	N/A
46	Use the fire protection system as a back-up source for the containment spray system.	SAMA would provide redundant containment spray function without the cost of installing a new system.	None	Phase II SAMA 10
47	Install a secondary containment filter vent.	SAMA would filter fission products released from primary containment.	C	N/A
48	Install a passive containment spray system.	SAMA would provide redundant containment spray method without high cost.	None	Phase II SAMA 11
49	Strengthen primary/secondary containment.	SAMA would reduce the probability of containment overpressurization to failure.	E	Cost well in excess of $10M per unit
50	Increase the depth of the concrete basemat or use an alternative concrete material to ensure melt-through does not occur.	SAMA would prevent basemat melt-through.	N/A	N/A
51	Provide a reactor vessel exterior cooling system.	SAMA would provide the potential to cool a molten core before it causes vessel failure, if the lower head could be submerged in water.	E	Cost well in excess of $10M per unit
52	Construct a building to be connected to primary/secondary containment that is maintained at a vacuum.	SAMA would provide a method to depressurize containment and reduce fission product release.	E	Cost well in excess of $10M per site
53	Not Used	None	N/A	N/A

Table IV-1. Initial Screening of Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
54	Proceduralize alignment of spare diesel to shutdown board after Loss of Offsite Power and failure of the diesel normally supplying it.	SAMA would reduce the SBO frequency.	N/A	N/A
55	Not Used	None	N/A	N/A
56	Provide an additional diesel generator.	SAMA would increase the reliability and availability of onsite emergency AC power sources.	F	N/A
57	Provide additional DC battery capacity	SAMA would ensure longer batter capability during an SBO, reducing the frequency of long-term SBO sequences.	None	Phase II SAMA 12
58	Use fuel cells instead of lead-acid batteries.	SAMA would extend DC power availability in an SBO.	None	Phase II SAMA 12
59	Procedure to crosstie high pressure core spray diesel.	SAMA would improve core injection availability by providing a more reliable power supply for the high pressure core spray pumps.	N/A	N/A
60	Improve 4.16 kV bus crosstie ability.	SAMA would improve AC power reliability.	D	SAMA 132
61	Incorporate an alternate battery charging capability.	SAMA would improve DC power reliability by either cross-tying the AC buses, or installing a portable diesel-driven batter charger.	None	Phase II SAMA 13
62	Increase/improve DC bus load shedding.	SAMA would extend battery life in an SBO event.	None	Phase II SAMA 12
63	Replace existing batteries with more reliable ones.	SAMA would improve DC power reliability and thus increase available SBO recovery time.	None	Phase II SAMA 13
63A	Mod for DC Bus A reliability Loss of DC Bus A causes a loss of main condenser, prevents transfer from the main transformer to offsite power, and defeats one half of the low vessel pressure permissive for LPCI/CS injection valves.	SAMA would increase the reliability of AC power and injection capability.	N/A	Loss of DC bus does not cause plant trip at BFNP
64	Create AC power crosstie capability with other unit.	SAMA would improve AC power reliability.	C	N/A
65	Create a crosstie for diesel fuel oil.	SAMA would increase diesel fuel oil supply and thus diesel generator, reliability.	C	N/A

Table IV-1. Initial Screening of Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
66	Develop procedures to repair or replace failed 4 kV breakers.	SAMA would offer a recovery path from a failure of the breakers that perform transfer of 4.16kV non-emergency busses from unit station service transformers, leading to loss of emergency AC power.	None	Phase II SAMA 14
67	Emphasize steps in recovery of offsite power after an SBO.	SAMA would reduce human error probability during offsite power recovery.	C	N/A
68	Develop a severe weather conditions procedure.	For plants that do not already have one, this SAMA would reduce the CDF for external weather-related events.	C	N/A
69	Develop procedures for replenishing diesel fuel oil.	SAMA would allow for long-term diesel operation.	C	BFN UFSAR 8.5.3.4
70	Install gas turbine generator.	SAMA would improve onsite AC power reliability by providing a redundant and diverse emergency power system.	E	Cost greater than $10M for site
71	Not Used	None	N/A	N/A
72	Create a back-up source for diesel cooling. (Not from existing system)	This SAMA would provide a redundant and diverse source of cooling for the diesel generators which would contribute to enhanced diesel reliability.	E	Cost greater than $10M for site
73	Use Fire Protection System as a back-up source for diesel cooling.	This SAMA would provide a redundant and diverse source of cooling for the diesel generators which would contribute to enhanced diesel reliability.	None	Phase II SAMA 15
74	Provide a connection to an alternate source of offsite power.	SAMA would reduce the probability of a loss of offsite power event.	F	N/A
75	Bury offsite power lines.	SAMA could improve offsite power reliability, particularly during severe weather.	E	Cost greater than $10M for site
76	Replace anchor bolts on diesel generator oil cooler. Millstone Nuclear Power Station found a high seismic SBO risk due to failure of the diesel oil cooler anchor bolts.	For plants with a similar problem, this would reduce seismic risk. Note that these were Fairbanks Morse DGs.	D	SAMA 138

Table IV-1. Initial Screening of Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
77	Change Undervoltage (UV), Auxiliary Feedwater Actuation Signal (AFAS) Block and High Pressurizer Pressure Actuation Signals to 3-out-of-4, instead of 2-out-of-4 logic.	SAMA would reduce risk of 2/4 inverter failure.	N/A	N/A
78	Provide DC power to the 120/240 V vital AC system from the Class 1E station service battery system instead of its own battery.	SAMA would increase the reliability of the 120 VAC Bus.	N/A	N/A
79	Install a redundant spray system to depressurize the primary system during a steam generator tube rupture (SGTR).	SAMA would enhance depressurization during a SGTR.	N/A	N/A
80	Improve SGTR coping abilities.	SAMA would improve instrumentation to detect SGTR, or additional system to scrub fission product releases.	N/A	N/A
81	Add other SGTR coping abilities.	SAMA would decrease the consequences of an SGTR.	N/A	N/A
82	Increase secondary side pressure capacity such that an SGTR would not cause the relief valves to lift.	SAMA would eliminate direct release pathway for SGTR sequences.	N/A	N/A
83	Replace steam generators (SG) with a new design.	SAMA would lower the frequency of an SGTR.	N/A	N/A
84	Revise emergency operating procedures to direct that a faulted SG be isolated.	SAMA would reduce the consequences of an SGTR.	N/A	N/A
85	Direct SG flooding after a SGTR, prior to core damage.	SAMA would provide for improved scrubbing of SGTR releases.	N/A	N/A
86	Implement a maintenance practice that inspects 100% of the tubes in an SG.	SAMA would reduce the potential for an SGTR.	N/A	N/A
87	Locate RHR inside of containment.	SAMA would prevent ISLOCA out the RHR pathway.	E	Cost greater than $10M per unit
88	Not Used.	None	N/A	N/A

Table IV-1. Initial Screening of Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
89	Install additional instrumentation for ISLOCAs.	Pressure of leak monitoring instruments installed between the first two pressure isolation valves on low-pressure inject lines, RHR suction lines, and HPSI lines would decrease ISLOCA frequency.	A	N/A
90	Increase frequency for valve leak testing.	SAMA could reduce ISLOCA frequency.	A	N/A
91	Improve operator training on ISLOCA coping.	SAMA would decrease ISLOCA effects.	A	N/A
92	Install relief valves in the CC System.	SAMA would relieve pressure buildup from an RCP thermal barrier tube rupture, preventing an ISLOCA.	N/A	N/A
93	Provide leak testing of valves in ISLOCA paths. At Kewaunee Nuclear Power Plant, four MOVs isolating RHR from the RCS were not leak tested.	This SAMA would help reduce ISLOCA frequency.	A	N/A
94	Revise EOPs to improve ISLOCA identification. Salem Nuclear Power Plant had a scenario where an RHR ISLOCA could direct initial leakage back to the pressurizer relief tank, giving indication that the LOCA was inside containment.	Procedure enhancements would ensure LOCA outside containment could be identified as such.	N/A	N/A
95	Ensure all ISLOCA releases are scrubbed.	This SAMA would scrub all ISLOCA releases. One example is to plug drains in the break area so that the break point would cover with water.	A	N/A
96	Add redundant and diverse limit switches to each containment isolation valve.	Enhanced isolation valve position indication could reduce the frequency of containment isolation failure and ISLOCAs.	A	N/A
97	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	SAMA would prevent flood propagation, for a plant where internal flooding from turbine building to safeguards areas is a concern.	N/A	Doors open into turbine building. No flooding scenarios propagating from turbine building to safeguards area (BFN IPE)
98	Improve inspection of rubber expansion joints on main condenser.	SAMA would reduce the frequency of internal flooding, for a plant where internal flooding due to a failure of circulating water system expansion joints is a concern.	None	Phase II SAMA 17

Table IV-1. Initial Screening of Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
99	Implement internal flood prevention and mitigation enhancements.	This SAMA would reduce the consequences of internal flooding.	D	SAMA 128
100	Implement internal flooding improvements such as those implemented at Fort Calhoun.	This SAMA would reduce flooding risk by preventing or mitigating: a rupture in the RCP seal cooler of the component cooling system an ISLOCA in a shutdown cooling line, an AFW flood involving the need to remove a watertight door.	N/A	N/A
101	Install a digital feedwater upgrade.	This SAMA would reduce the chance of a loss of main feedwater following a plant trip.	C	N/A
102	Perform surveillances on manual valves used for back-up AFW pump suction.	This SAMA would improve success probability for providing alternative water supply to the AFW pumps.	N/A	N/A
103	Install manual isolation valves around AFW turbine-driven steam admission valves.	This SAMA would reduce the dual turbine-driven AFW pump maintenance unavailability.	N/A	N/A
104	Install accumulators for turbine-driven AFW pump flow control valves (CVs).	This SAMA would provide control air accumulators for the turbine-driven AFW flow CVs, the motor-driven AFW pressure CVs and SG PORVs. This would eliminate the need for LOCA manual action to align nitrogen bottles for control air during a LOOP.	N/A	N/A
105	Proceduralize intermittent operation of HPCI.	SAMA would allow for extended duration of HPCI availability.	C	If RCIC is available, HPCI used in test mode to control pressure and avoid cycling.
106	Increase the reliability of safety relief valves. (Adding signals to add electrical signal to open automatically).	SAMA reduces the probability of a certain type of medium break LOCA. Hatch evaluates medium LOCA initiated by an MSIV closure transient with a failure of SRVs to open. Reducing the likelihood of the failure for SRVs to open subsequently reduces the occurrence of this medium LOCA.	C	N/A
107	Install motor-driven feedwater pump.	This would increase the availability of injection subsequent to MSIV closure.	E	Cost greater than $10M per unit
108	Procedure to instruct operators to trip unneeded RHR/CS pumps on loss of room ventilation.	SAMA increases availability of required RHR/CS pumps. Reduction in room heat load allows continued operation of required RHR/CS pumps, when room cooling is lost.	None	Phase II SAMA 18

Table IV-1. Initial Screening of Generic SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
109	Increase available NPSH for injection pumps.	SAMA increases the probability that these pumps will be available to inject coolant into the vessel by increasing the available NPSH for the injection pumps.	C	NPSH concerns are not a concern in the dominant BFN sequences. RHR has been demonstrated to operate satisfactorily at less than "minimum" NPSH. Torus water temperature leading to loss of lube oil cooling rather than NPSH, is a limiting concern for HPCI and RCIC
110	Increase the SRV reseat reliability.	SAMA addresses the risk associated with dilution of boron caused by the failure of the SRVs to reseat after SLC injection.	None	Phase II SAMA 19
111	Reduce DC dependency between high pressure injection system and ADS.	SAMA would ensure vessel depressurization and high pressure injection upon a DC failure.	None	Phase II SAMA 20
112	Modify RWCU for use as a decay heat removal system and proceduralize use.	SAMA would provide an additional source of decay heat removal.	C	N/A
113	Use of CRD for alternate boron injection.	SAMA provides an additional system to address ATWS with SLC failure or unavailability.	None	Phase II SAMA 21
114	Increase seismic ruggedness of plant components.	SAMA would increase the availability of necessary plant equipment during and after seismic events.	D	SAMA 138
115	Allow cross connection of uninterruptable compressed air supply to opposite unit.	SAMA would increase the ability to depressurize containment using the hardened vent.	N/A	N/A

**Note:*

N/A indicates that the proposed SAMA is not applicable to BFN or the BWR-4/Mark I design.

A indicates that the proposed SAMA is related to mitigation of an Intersystem LOCA (ISLOCA). ISLOCA contributes little risk for boiling water reactors, because of the lower primary pressures. Because of the low risk contribution due to ISLOCA, this SAMA has not been developed further.

B indicates that the proposed SAMA is related to RCP seal leakage. A review of NUREG-1560 (Reference 13) indicates that although RCP seal leakage is important for PWRs, recirculation pump leakage does not significantly contribute to CDF in BWRs.

C indicates that the proposed SAMA has already been installed at BFN.

D indicates that similar item is addressed under other proposed SAMAs.

E indicates that SAMA did not pass initial cost screening and was therefore not examined in detail.

F Primary cause of loss of existing, redundant hardware is due to a common cause event, which another string of hardware would not alleviate.

Table IV-2. Initial Screening of Plant Specific SAMAs

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
116	borate torus water	borate torus water to mitigate ATWS upon water injection from the torus.	None	Phase II SAMA 22
117	automate torus cooling	automate torus cooling on high torus temperature to avoid lack of torus cooling due to operator error	None	Phase II SAMA 23
117a	provide torus positive pressure relief valves	provide torus positive pressure relief valves to prevent containment overpressure failure	None	Phase II SAMA 24
117b	reduce DW head bolt pretension	reduce DW head bolt pretension to allow DW to “burp” thereby preventing catastrophic containment overpressure failure	None	Phase II SAMA 24
118	Eliminate operator action to inhibit ADS for ATWS	Mitigate failure to inhibit ADS due to operator error during ATWS conditions.	D	SAMA 116
119	Eliminate fine water level control for ATWS	Mitigate failure to control water level at TAF due to operator error for ATWS conditions.	D	SAMA 116
120	Provide redundancy for SLC	ATWS, Provide redundancy to mitigate failure of SLC due to hardware failure during ATWS conditions.	D	SAMA 116
121	automate SLC initiation	automate SLC initiation to mitigate failure of SLC due to operator error during ATWS conditions	None	Phase II SAMA 25
122	RPV replacement	replace the RPV to reduce probability of Excessive LOCA	E	Cost greater than $10M per unit
122a	RPV inspection	increase the RPV inspection frequency to reduce probability of Excessive LOCA	None	Phase II SAMA 26
123	remove DW high pressure signal from ADS logic	remove DW high pressure signal from ADS logic to mitigate loss of all HP injection coupled with failure to depressurize due to operator error	C	N/A
124	provide independent torus cooling system	mitigate failure of torus cooling due to hardware failure	None	Phase II SAMA 27
125	Eliminate operator action to initiate torus cooling	Mitigate loss of all HP injection due to hardware failure coupled with failure of torus cooling due to operator error	D	SAMA 117
126	Eliminate operator action to depressurize reactor in event of HP injection failure.	Mitigate loss of all HP injection due to operator error coupled with failure to depressurize due to operator error	D	SAMA 123
127	Provide core cooling system outside interfacing system LOCA zone of influence	Mitigate effects of interfacing system LOCA	D	SAMA 133
128	Provide core cooling system outside flood zone of influence	Mitigate effects of internal Flooding	D	SAMA 133
129	Not used	None	N/A	N/A
130	Not used	None	N/A	N/A

Table IV-2. Initial Screening of Plant Specific SAMAs (Continued)

SAMA ID Number	SAMA Title	Description of Potential Enhancement	Screening Criterion*	Reference Paragraph Number
131	Not used	None	N/A	N/A
132	Improve 4kV crosstie capability	Provide 4kV shutdown bus crosstie capability from Unit 1/2 to Unit 3.	None	Phase II SAMA 28
133	Provide HP diesel-driven pump.	Provide capability to inject river water at HP via diesel-driven pump to mitigate Station Blackout	None	Phase II SAMA 29
134	Provide additional LP core cooling system	Mitigate SORV coupled with failure of LP injection due to hardware failure	D	SAMA 133
135	Not used	None	N/A	N/A
136	Not used	None	N/A	N/A
137	Reduce fire risk	Mitigate Fire effects	K	N/A
138	Reduce earthquake risk	Mitigate Earthquake effects	G, H, I	N/A
139	Reduce HFO risk	Mitigate effects of High winds, Floods, Transportation, and Other (HFO) External Events.	J	N/A

**Note:*

N/A indicates that the proposed SAMA is not applicable to BFN or the BWR-4/Mark I design.

A indicates that the proposed SAMA is related to mitigation of an Intersystem LOCA (ISLOCA). Because of the low risk contribution due to ISLOCA, this SAMA has not been developed further.

B indicates that the proposed SAMA is related to RCP seal leakage. A review of NUREG-1560 (Reference 13) indicates that although RCP seal leakage is important for PWRs, recirculation pump leakage does not significantly contribute to CDF in BWRs.

C indicates that the proposed SAMA has already been installed at BFN.

D indicates that similar item is addressed under other proposed SAMAs.

E indicates that SAMA did not pass initial cost screening and was therefore not examined in detail.

F Primary cause of loss of existing, redundant hardware is due to a common cause event, which another string of hardware would not alleviate.

G "The outliers identified [in accordance with the Seismic Qualification Utility Group Generic Implementation Procedure criteria] for BFN Unit 3 were resolved during the Cycle 7 refueling outage that completed on March 13, 1997." "TVA considers the commitments regarding USI A-46 and the seismic portion of IPEEE to be complete for BFN Unit 3." Letter from TVA to the USNRC. R08 970411 803 (Reference 14).

H "...TVA has completed the resolution of outliers for BFN Unit 2 identified in accordance with the Seismic Qualification Utility Group (SQUG) Generic Implementation Procedure (GIP) criteria." "The outliers identified for BFN Unit 2 were resolved ... during the Cycle 9 refueling outage that completed on October 19. 1997." "TVA considers the commitments regarding USI A-46 and the seismic portion of IPEEE to be complete for BFN Unit 2." Letter from TVA to the USNRC. R08 971118 922 (Reference 15).

I "The staff's review of the licensee's action regarding outliers indicates that identified outliers have been resolved by analysis or corrective actions." "The staff has also concluded that its findings regarding the USI A-46 program do not warrant any further regulatory action under the provisions of 10 CFR 50.54(f)." Letter from the USNRC to TVA dated 3/21/2000 and attached USI A-46 SER (Reference 7).

J "These events were screened out in a manner consistent with the guidance given in NUREG-1407...." Letter from the USNRC to TVA dated 6/22/2000, and attached IPEEE SER (Reference 6).

K "No plant modifications were found to be necessary as a result of the fire IPEEE for BFN Units 2 and 3." Letter from the USNRC to TVA dated 6/22/2000, and attached IPEEE SER (Reference 6).

V. SAMA Analysis Results for BFN

A. Summary of Phase II SAMA Analysis

A summary of Phase II SAMAs is shown in Table V-1.

SAMA hardware implementation costs were first estimated in 2001 dollars and are based on costs of previous modifications judged to be similar in scope to the proposed SAMA (Reference 17). New or revised procedures were estimated to cost $50K per unit. These values were then inflated (at 3%/year) to arrive at Year 2016 estimated costs. This step is necessary to make the costs directly comparable to estimated costs averted.

Figure V-1 presents a sample table of results that summarizes the comparison of the baseline PRA results and the PRA results of each SAMA.

Baseline PRA Results

SAMA PRA Results

MAAP Case	Baseline Case	SAMA 02 Case
PIHDEP	3.65E-07	2.09E-07
PIHDEPV	2.52E-07	2.07E-07
PIHDLV	7.75E-10	4.14E-10
ENMKCTT	7.39E-08	7.08E-08
OIA	6.90E-08	8.61E-08
OIALF	2.93E-08	2.15E-08
MIALF	1.36E-07	1.37E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	3.80E-09
PID	2.88E-08	2.84E-08
NIH	295E-08	2.96E-08
Person-rem	3.03	2.36
Unit 2 Total Cost (3%)	$299,986	$235,953
Unit 2 Total Cost (7%)	$207,731	$163,200
SAMA 02 Saving (3%)	$64,033	
SAMA 02 Saving (7%)	$44,531	

Total cost for Baseline Case

Savings = Baseline case - SAMA case, e.g., $299,986 - $235,953 = $64,033

Total cost with SAMA Implemented

Figure V-1. Sample Table of Results

Table V-1. Summary of Phase II SAMA Analysis

Phase II SAMA ID No.	Phase I SAMA ID No.	SAMA Title	Result of Potential Enhancement	Estimated Cost (2001)	Estimated Cost (2016)	Phase II Disposition
1	7	Increase CRD pump lube oil capacity.	SAMA would lengthen the time before control rod drive (CRD) pump failure due to lube oil	N/A	N/A	No significant risk decrease. See Section V.B
2	12	Replace ECCS pump motor with air-cooled motors.	SAMA would eliminate ECCS dependency on ERCW.	$6M per unit	$9.3M per unit	See Section V.C
3	17	Implement procedures to stagger CRD pump use after a loss of service water.	SAMA would allow injection with CRD to be extended after a loss of service water.	$50k/unit	$78k/unit	No significant risk decrease. See Section V.D
4	19	Procedural guidance for use of cross-tied component cooling or service water pumps.	SAMA would reduce the frequency of the loss of component cooling water and service water.	$50k/unit	$78k/unit	See Section V.E
5	20	Procedure enhancements and operator training in support system failure sequences, with emphasis on anticipating problems and coping.	SAMA would potentially improve the success rate of operator actions subsequent to support system failures.	$50k/unit	$78k/unit	See Section V.F
6	21	Improved ability to cool the residual heat removal heat exchangers	SAMA would reduce the probability of a loss of decay heat removal by implementing procedure and hardware modifications to allow manual alignment of the fire protection system or by installing a component cooling water crosstie.	$1M/unit	$1.5M/unit	See Section V.G
7	23	Provide a redundant train of ventilation.	SAMA would increase the availability of components dependent on room cooling.	$6M/unit.	$9.3M per unit	See Section V.H
8	25	Add a diesel building switchgear room high temperature alarm.	SAMA would improve diagnosis of a loss of switchgear room HVAC. Option 1: Install high temp alarm Option 2: Redundant louver and thermostat	option 1: $400k per building option 2: $6M per building	Option 1: $623K per building. Option 2: $9.3M per building.	See Section V.I

Table V-1. Summary of Phase II SAMA Analysis (Continued)

Phase II SAMA ID No.	Phase I SAMA ID No.	SAMA Title	Result of Potential Enhancement	Estimated Cost (2001)	Estimated Cost (2016)	Phase II Disposition
9	34	Install a containment vent large enough to remove ATWS decay heat.	Assuming that injection is available, this SAMA would provide alternate decay heat removal in an ATWS event.	$2M/unit	$3.1M/unit	See Section V.J
10	46	Use the fire protection system as a back-up source for the containment spray system.	SAMA would provide redundant containment spray function without the cost of installing a new system.	$500k/unit	$779k/unit	See Section V.K
11	48	Install a passive containment spray system.	SAMA would provide redundant containment spray method.	$6M/unit	$9.3M/unit	See Section V.L
12	57	Provide additional DC battery capacity.	SAMA would ensure longer batter capability during an SBO, reducing the frequency of long-term SBO sequences.	$1M/plant	$1.5M/plant	See Section V.M.
	58	Use fuel cells instead of lead-acid batteries.	SAMA would extend DC power availability in an SBO.	$6M/plant	$9.3M/plant	
	62	Increase/improve DC bus load shedding.	SAMA would extend battery life in an SBO event.	$50k/plant	$78k/plant	
	9	Add redundant DC Control Power for SW pumps	SAMA would increase reliability of SW and decrease core damage frequency due to a loss of SW. Relevant potential concern at BFN is loss of DC-D	$1M/plant	$1.5M/plant	
13	61	Incorporate an alternate battery charging capability.	SAMA would improve DC power reliability by either cross-tying the AC buses, or installing a portable diesel-driven battery charger.	$1M/unit	1.5M/unit	See Section V.N
	63	Replace existing batteries with more reliable ones.	SAMA would improve DC power reliability and thus increase available SBO recovery time.	$6M/plant	$9.3M/plant	

Table V-1. Summary of Phase II SAMA Analysis (Continued)

Phase II SAMA ID No.	Phase I SAMA ID No.	SAMA Title	Result of Potential Enhancement	Estimated Cost (2001)	Estimated Cost (2016)	Phase II Disposition
14	66	Develop procedures to repair or replace failed 4 kV breakers.	SAMA would offer a recovery path from a failure of the breakers that perform transfer of 4.16kV non-emergency busses from unit station service transformers, leading to loss of emergency AC power.	$50k/unit	$78k/unit	See Section V.O
15	73	Use Fire Protection System as a back-up source for diesel cooling.	This SAMA would provide a redundant and diverse source of cooling for the diesel generators which would contribute to enhanced diesel reliability.	$1M/plant	$1.5M/plant	See Section V.P
16		This reference is reserved.				
17	98	Improve inspection of rubber expansion joints on main condenser.	SAMA would reduce the frequency of internal flooding, for a plant where internal flooding due to a failure of circulating water system expansion joints is a concern.	$100k/unit	$155k/unit	See Section V.R
18	108	Procedure to instruct operators to trip unneeded RHR/CS pumps on loss of room ventilation.	SAMA increases availability of required RHR/CS pumps. Reduction in room heat load allows continued operation of required RHR/CS pumps, when room cooling is lost.	$50k/unit	$78k/unit	See Section V.S
19	110	Increase the SRV reseat reliability.	SAMA addresses the risk associated with dilution of boron caused by the failure of the SRVs to reseat after SLC injection.	$700k/unit	$1.09M/unit	See Section V.T
20	111	Reduce DC dependency between high pressure injection system and ADS.	SAMA would ensure vessel depressurization and high pressure injection upon a DC failure.	$500k/unit	$779k/unit	See Section V.U

Table V-1. Summary of Phase II SAMA Analysis (Continued)

Phase II SAMA ID No.	Phase I SAMA ID No.	SAMA Title	Result of Potential Enhancement	Estimated Cost (2001)	Estimated Cost (2016)	Phase II Disposition
21	113	Use of CRD for alternate boron injection.	SAMA provides an additional system to address ATWS with SLC failure or unavailability.	$2M/unit	$3.1M/unit	See Section V.V
22	116	Borate torus water	Borate torus water to mitigate ATWS upon water injection from the torus.	$6M/unit	$9.3M/unit	See Section V.W
23	117	Automate torus cooling	Automate torus cooling on high torus temperature to avoid lack of torus cooling due to operator error	$400k/unit	$623k/unit	See Section V.X
24	117a	Provide torus positive pressure relief valves	Provide torus positive pressure relief valves to prevent containment overpressure failure	$700k/unit	$1.09M/unit	See Section V.Y
	177b	Reduce DW head bolt pretension	Reduce DW head bolt pretension to allow DW to “burp” thereby preventing catastrophic containment overpressure failure	$50k/unit	$78k/unit	
25	121	Automate SLC initiation	Automate SLC initiation to mitigate failure of SLC due to operator error during ATWS conditions	$400k/unit	$623k/unit	See Section V.Z
26	122a	RPV inspection	Increase the RPV inspection frequency to reduce probability of Excessive LOCA	$100k/unit	$155k/unit	See Section V.AA
27	124	Provide independent torus cooling system	Mitigate failure of torus cooling due to hardware failure	$6M/unit	$9.3M/unit	See Section V.BB
28	132	Improve 4kV crosstie capability	Provide 4kV shutdown bus crosstie capability from Unit 1/2 to Unit 3.	$5M/plant	$7.8M/plant	See Section V.CC
29	133	Provide HP diesel-driven pump.	Provide capability to inject river water at HP via diesel-driven pump to mitigate Station Blackout	$6M/unit	$9.3M/unit	See Section V.DD

B. Phase II SAMA Number 01: Increase CRD Lube Oil Capacity

This SAMA has the potential to increase the time before CRD pump failure due to failure of lube oil. The original SAMA addressed a PWR concern relating to charging pumps. The closest equivalent in BWRs are the CRD pumps.

The risk significance of the CRD pumps in the BFN models is modest. The risk reduction worth impact of the CRD system is approximately 6% and 3% for Unit 2 and Unit 3, respectively. In addition the contribution of lube oil failure to CRD system unavailability (BFN IPE) is approximately 0.2% of the total system unavailability.

It is therefore concluded that there is no significant risk reduction potential associated with this SAMA.

C. Phase II SAMA Number 02: Eliminate ECCS Dependency on EECW

This SAMA would replace ECCS pump motors with passively cooled motors. This would reduce the functional dependency of the RHR and Core Spray pumps on EECW.

To bound the potential impact of this SAMA, the dependency on all RHR and Core Spray pumps on EECW has been eliminated. In addition, the RHR and Core Spray top event models were reviewed. It was determined that failure of the pump coolers contributed approximately 20% to the split fractions representing the RHR pumps and the Core Spray system. All split fractions associated with the RHR pumps and Core Spray system were reduced by 20%. This has the effect of increasing the calculated availability of these pumps.

These changes necessitated changes to be made in the split fraction assignment rules in the low pressure general transient event tree (LPGTET), as well as the large and medium LOCA event trees (LLOCA and MLOCA, respectively). In addition, the split fraction adjustments were made directly to the master frequency file (which is the reference table for the split fractions used in the scenario quantification).

These changes reflect the following bounding assumption: Replacing the pump motors with passively cooled motors completely removes any dependency on EECW.

PSA Model Results

The results from this case indicates about a 18.6% reduction in Unit 2 CDF (CDF_{new}=8.5438E-7). The new end state frequencies are presented in Table V-2. For Unit 3 there is a 11.5% reduction in CDF (CDF_{new}=1.6788E-6) and the new end state frequencies are presented in Table V-3.

Table V-2. Unit 2 SAMA Number 02 Results

MAAP Case	Baseline Case	SAMA 02 Case
PIHDEP	3.65E-07	2.09E-07
PIHDEPV	2.52E-07	2.07E-07
PIHDLV	7.75E-10	4.14E-10
ENMKCTT	7.39E-08	7.08E-08
OIA	6.90E-08	8.61E-08
OIALF	2.93E-08	2.15E-08
MIALF	1.36E-07	1.37E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	3.80E-09
PID	2.88E-08	2.84E-08
NIH	2.95E-08	2.96E-08
Person-rem	3.03	2.36
Unit 2 Total Cost (3%)	$299,986	$235,953
Unit 2 Total Cost (7%)	$207,731	$163,200
SAMA 02 Saving (3%)	$64,033	
SAMA 02 Saving (7%)	$44.531	

Table V-3. Unit 3 SAMA Number 02 Results

MAAP Case	Baseline Case	SAMA 02 Case
PIHDEP	8.59E-07	6.38E-07
PIHDEPV	4.20E-07	3.71E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.42E-07
OIA	1.60E-07	2.27E-07
OIALF	1.11E-08	8.43E-09
MIALF	1.32E-07	1.33E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	1.94E-08
PID	9.67E-09	9.37E-09
NIH	3.75E-09	3.76E-09
Person-rem	6.28	5.48
Unit 3 Total Cost (3%)	$609,146	$533,518
Unit 3 Total Cost (7%)	$423,366	$370,691
SAMA 02 Saving (3%)	$75,628	
SAMA 02 Saving (7%)	$52,675	

D. Phase II SAMA Number 03: Implement Procedures to Stagger CRD Pump Use After Loss of Service Water

This SAMA originally was originally associated with the PWR concern of loss of high pressure injection following loss of service water. The CRD system at BFN can act as a source of high pressure injection and is dependent on RCW. RCW provides oil bearing cooling and thrust bearing cooling. Staggering CRD pump operation would have little benefit on loss of service water.

E. Phase II SAMA Number 04: Enhance Ability to Crosstie Service Water

Several systems at BFN provide the generic 'service water' systems support function. These systems include RCW, EECW, RHRSW, and RBCCW.

The base case models reflect the capability to realign swing RHRSW pumps to support EECW.

To bound the potential benefit of further enhancing the ability to cross tie service water systems (via hardware and procedural changes), the following assumptions were made:

1. If insufficient EECW flow occurs and the RHRSW swing pumps are available, the actions necessary to align the swing pumps for EECW service are assumed to occur with a probability of 1.

2. RBCCW is assumed to be successful if RCW is available. In other words, it is assumed that RCW is cross-tied to RBCCW.

3. The frequency of the initiator Loss of RBCCW is assumed to be zero.

To reflect these changes, top OEE, alignment of the swing RHRSW to support EECW, is assumed to be successful if the swing pumps are available. Also top RBC representing the availability of the RBCCW system is assumed to be available if RCW is available.

PSA Model Results

The results from this case indicates about a 0.9% reduction in Unit 2 CDF (CDF_{new}=1.0400E-6). The new end state frequencies are presented in Table V-4. Unit 3 there is a 1.6% reduction in CDF (CDF_{new}=1.8675E-6) and the new end state frequencies are presented in Table V-5.

Table V-4. Unit 2 SAMA Number 04 Results

MAAP Case	Baseline Case	SAMA 04 Case
PIHDEP	3.65E-07	3.63E-07
PIHDEPV	2.52E-07	2.49E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	7.33E-08
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.33E-07
PJHNSP	6.14E-08	6.13E-08
PLF	4.07E-09	3.87E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.79E-08
Person-rem	3.03	3.01
Unit 2 Total Cost (3%)	$299,986	$297,934
Unit 2 Total Cost (7%)	$207,731	$206,328
SAMA 04 Saving (3%)	$2,052	
SAMA 04 Saving (7%)	$1,403	

Table V-5. Unit 3 SAMA Number 04 Results

MAAP Case	Baseline Case	SAMA 04 Case
PIHDEP	8.59E-07	8.43E-07
PIHDEPV	4.20E-07	4.17E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.50E-07
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.26E-07
PJHNSP	1.28E-07	1.27E-07
PLF	2.11E-08	2.00E-08
PID	9.67E-09	9.67E-09
NIH	3.75E-09	3.50E-09
Person-rem	6.28	6.19
Unit 3 Total Cost (3%)	$609,146	$600,706
Unit 3 Total Cost (7%)	$423,366	$417,524
SAMA 04 Saving (3%)	$8,440	
SAMA 04 Saving (7%)	$5,842	

F. Phase II SAMA Number 05: Enhanced Recovery of Failed Support Systems

The base case models explicitly consider the recovery of key support systems. Specific recovery actions considered in one or both base case models are:

1. Alignment of RHRSW swing pumps to support EECW operation (top OEE).
2. Restoration of power at a diesel auxiliary board (top ODSB).
3. Restoration of power to support diesel room cooling (top ODSBU3).
4. Restoration of power at a 480V Reactor MOV board (top RMOV).
5. Alignment of spare battery charger (top CPREC).
6. Recovery of power at a 4-kV shutdown board (top SDREC).
7. Alignment of power to a unit board from 161-kV results in a loss of the 500-kV supply (top OUB).
8. Recovery of power at specific unit boards (UBREC).
9. Other electric power recovery actions (top OX).

To estimate a bound for the potential impact of improved procedures, each of the split fractions associated with the above top events were assumed to improve (i.e., be more reliable) by a factor of 3.

The models were then quantified with all of the above operator recovery actions simultaneously improved.

PSA Model Results

The results from this case indicates about a 0.2% reduction in Unit 2 CDF (CDF_{new}=1.0473E-6). The new end state frequencies are presented in Table V-6. For Unit 3 there is a 0.1% reduction in CDF (CDF_{new}=1.8954E-6) and the new end state frequencies are presented in Table V-7.

Table V-6. Unit 2 SAMA Number 05 Results

MAAP Case	Baseline Case	SAMA 05 Case
PIHDEP	3.65E-07	3.63E-07
PIHDEPV	2.52E-07	2.51E-07
PIHDLV	7.75E-10	7.77E-10
ENMKCTT	7.39E-08	7.39E-08
OIA	6.90E-08	6.88E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.08E-09
PID	2.88E-08	2.85E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	3.02
Unit 2 Total Cost (3%)	$299,986	$299,202
Unit 2 Total Cost (7%)	$207,731	$207,187
SAMA 05 Saving (3%)	$784	
SAMA 05 Saving (7%)	$544	

Table V-7. Unit 3 SAMA Number 05 Results

MAAP Case	Baseline Case	SAMA 05 Case
PIHDEP	8.59E-07	8.59E-07
PIHDEPV	4.20E-07	4.20E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.52E-07
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	8.69E-09
NIH	3.75E-09	3.36E-09
Person-rem	6.28	6.28
Unit 3 Total Cost (3%)	$609,146	$608,907
Unit 3 Total Cost (7%)	$423,366	$423,208
SAMA 05 Saving (3%)	$239	
SAMA 05 Saving (7%)	$158	

G. Phase II SAMA Number 06: Fire Water as Backup for RHR Heat Exchanger Cooling

To estimate the potential impact of providing a connection from the fire water system to the RHR heat exchangers, the following assumptions were made:

1. The fire water system was assumed to be capable of providing adequate cooling water flow to all Unit 2 and 3 RHR heat exchangers
2. The fire water system was assumed to have a 100% availability.
3. Any required operator actions associated with aligning the fire water system to provide flow to the RHR heat exchanger was assumed to be successfully completed in a timely manner.

To implement this bounding model, split fractions representing guaranteed success associated with the four RHRSW pumps were used. (In other words, the failure fraction for top events SW2A, SW2C, SW2B, and SW2D were set to zero.)

PSA Model Results

The results from this case indicates about a 2.6% reduction in Unit 2 CDF (CDF_{new}=1.0230E-6). The new end state frequencies are presented in Table V-8. For Unit 3 there is a 9.3% reduction in CDF (CDF_{new}=1.7201E-6) and the new end state frequencies are presented in Table V-9.

Table V-8. Unit 2 SAMA Number 06 Results

MAAP Case	Baseline Case	SAMA 6 Case
PIHDEP	3.65E-07	3.39E-07
PIHDEPV	2.52E-07	2.39E-07
PIHDLV	7.75E-10	8.01E-10
ENMKCTT	7.39E-08	7.53E-08
OIA	6.90E-08	7.81E-08
OIALF	2.93E-08	2.97E-08
MIALF	1.36E-07	1.38E-07
PJHNSP	6.14E-08	6.10E-08
PLF	4.07E-09	3.24E-09
PID	2.88E-08	2.93E-08
NIH	2.95E-08	2.99E-08
Person-rem	3.03	2.93
Unit 2 Total Cost (3%)	$299,986	$290,684
Unit 2 Total Cost (7%)	$207,731	$201,252
SAMA 06 Saving (3%)	$9,302	
SAMA 06 Saving (7%)	$6,479	

Table V-9. Unit 3 SAMA Number 06 Results

MAAP Case	Baseline Case	SAMA 6 Case
PIHDEP	8.59E-07	7.52E-07
PIHDEPV	4.20E-07	3.46E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.53E-07
OIA	1.60E-07	1.63E-07
OIALF	1.11E-08	1.13E-08
MIALF	1.32E-07	1.34E-07
PJHNSP	1.28E-07	1.26E-07
PLF	2.11E-08	2.03E-08
PID	9.67E-09	9.99E-09
NIH	3.75E-09	3.84E-09
Person-rem	6.28	5.68
Unit 3 Total Cost (3%)	$609,146	$551,355
Unit 3 Total Cost (7%)	$423,366	$383,183
SAMA 06 Saving (3%)	$57,791	
SAMA 06 Saving (7%)	$40,183	

H. Phase II SAMA Number 07: Provide a Redundant Train of Ventilation

A limited number of systems are dependent on room or area cooling at BFN. The RHR and Core Spray pumps, as modeled, require fan coolers. In addition, room cooling is required for operation of the diesel generators.

A review of the systems analyses for the RHR and Core Spray systems (BFN IPE) reveals that the contribution (including common cause) to RHR or Core Spray pump unavailability due to fan cooler failure is less than 20%.

To bound the potential impact of a redundant ventilation for the RHR and Core Spray pumps, the split fractions representing these pumps (i.e., RPA, RPB, RPC, RPD and CS) were reduced by 20%.

In addition, the top event representing recovery of diesel generator room cooling was set to guaranteed success.

This bounding modeling approach assumes that the redundant ventilation has an availability of 1.0 (i.e., an unavailability of 0.0) and is independent of any support system such as electric power.

PSA Model Results

The results from this case indicates about a 18.6% reduction in Unit 2 CDF (CDF_{new}=8.5408E-7). The new end state frequencies are presented in Table V-10. For Unit 3 there is a 11.5% reduction in CDF (CDF_{new}=1.6788E-6) and the new end state frequencies are presented in Table V-11.

Table V-10. Unit 2 SAMA Number 07 Results

MAAP Case	Baseline Case	SAMA 07 Case
PIHDEP	3.65E-07	2.08E-07
PIHDEPV	2.52E-07	2.07E-07
PIHDLV	7.75E-10	4.14E-10
ENMKCTT	7.39E-08	7.08E-08
OIA	6.90E-08	8.61E-08
OIALF	2.93E-08	2.15E-08
MIALF	1.36E-07	1.37E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	3.80E-09
PID	2.88E-08	2.84E-08
NIH	2.95E-08	2.96E-08
Person-rem	3.03	2.36
Unit 2 Total Cost (3%)	$299,986	$235,850
Unit 2 Total Cost (7%)	$207,731	$163,129
SAMA 07 Saving (3%)	$64,136	
SAMA 07 Saving (7%)	$44,602	

Table V-11. Unit 3 SAMA Number 07 Results

MAAP Case	Baseline Case	SAMA 07 Case
PIHDEP	8.59E-07	6.37E-07
PIHDEPV	4.20E-07	3.71E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.42E-07
OIA	1.60E-07	2.27E-07
OIALF	1.11E-08	8.43E-09
MIALF	1.32E-07	1.33E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	1.94E-08
PID	9.67E-09	9.38E-09
NIH	3.75E-09	3.76E-09
Person-rem	6.28	5.48
Unit 3 Total Cost (3%)	$609,146	$533,509
Unit 3 Total Cost (7%)	$423,366	$370,685
SAMA 07 Saving (3%)	$75,637	
SAMA 07 Saving (7%)	$52,681	

I. Phase II SAMA Number 08: Improve Diagnostics for Diesel Generator Room HVAC

The base case models include the consideration of recovery of a diesel aux board (top ODSB, Unit 2 and Unit 3 models) and recovery of power associated with diesel C room cooling (top ODSBU3, Unit 3).

To bound the potential impact of improved diagnostics for loss of cooling to diesel generator rooms, top events relating to diesel support recovery (ODSB and ODSBU3) were set to guaranteed success.

PSA Model Results

The results from this case indicates about a 0.03% reduction in Unit 2 CDF (CDF_{new}=1.0495E-6). The new end state frequencies are presented in Table V-12. For Unit 3 there is about a 0.04 reduction in CDF (CDF_{new}=1.8966E-6) and the new end state frequencies are presented in Table V-13.

Table V-12. Unit 2 SAMA Number 08 Results

MAAP Case	Baseline Case	SAMA 08 Case
PIHDEP	3.65E-07	3.65E-07
PIHDEPV	2.52E-07	2.52E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	7.39E-08
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.07E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	3.03
Unit 2 Total Cost (3%)	$299,986	$299,880
Unit 2 Total Cost (7%)	$207,731	$207,658
SAMA 08 Saving (3%)	$106	
SAMA 08 Saving (7%)	$73	

Table V-13. Unit 3 SAMA Number 08 Results

MAAP Case	Baseline Case	SAMA 08 Case
PIHDEP	8.59E-07	8.59E-07
PIHDEPV	4.20E-07	4.20E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.52E-07
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	9.67E-09
NIH	3.75E-09	3.75E-09
Person-rem	6.28	6.28
Unit 3 Total Cost (3%)	$609,146	$608,956
Unit 3 Total Cost (7%)	$423,366	$423,236
SAMA 08 Saving (3%)	$190	
SAMA 08 Saving (7%)	$130	

J. Phase II SAMA Number 09: Install a Containment Vent Large Enough to Remove ATWS Decay Heat

This SAMA would provide redundancy in the ability to remove decay heat and be of sufficient size to successfully handle ATWS decay heat levels.

To estimate the potential effects of this SAMA, the event tree structure (event tree TRANCDBIN) was reviewed along with the logic rules that determine whether a sequence is assigned to core damage or "success." The relevant logic macro (AHEAT) was modified to reflect the vent (top event VNT) as a potential success path.

PSA Model Results

The results from this case indicates about a 0.9% reduction in Unit 2 CDF (CDF_{new}=1.0400E-6). The new end state frequencies are presented in Table V-14. For Unit 3 there is a 4.2% reduction in CDF (CDF_{new}=1.818E-6) and the new end state frequencies are presented in Table V-15.

Table V-14. Unit 2 SAMA Number 09 Results

MAAP Case	Baseline Case	SAMA 09 Case
PIHDEP	3.65E-07	3.65E-07
PIHDEPV	2.52E-07	2.52E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	6.41E-08
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.07E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	2.97
Unit 2 Total Cost (3%)	$299,986	$295,207
Unit 2 Total Cost (7%)	$207,731	$204,376
SAMA 09 Saving (3%)	$4,779	
SAMA 09Saving (7%)	$3,355	

Table V-15. Unit 3 SAMA Number 09 Results

MAAP Case	Baseline Case	SAMA 09 Case
PIHDEP	8.59E-07	8.59E-07
PIHDEPV	4.20E-07	4.20E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	7.30E-08
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	9.67E-09
NIH	3.75E-09	3.75E-09
Person-rem	6.28	5.84
Unit 3 Total Cost (3%)	$609,146	$570,657
Unit 3 Total Cost (7%)	$423,366	$396,348
SAMA 09 Saving (3%)	$38,489	
SAMA 09 Saving (7%)	$27,018	

K. Phase II SAMA Number 10: Fire Protection System as Backup Source for Containment Spray

This SAMA considers the use of the Fire Protection water as a backup source for Containment Spray.

To bound the potential impact of this SAMA, the analysis performed for Phase II SAMA 11 (the installation of a passive containment spray system) was used.

L. Phase II SAMA Number 11: Installation of a Passive Containment Spray System

This SAMA would result in the installation of a system capable of providing containment spray and be independent of operator actions.

To bound the potential impact of this SAMA, the top event representing the containment spray function (top event DWS) was set to "success."

PSA Model Results

The results from this case indicates about a 0.9% increase in Unit 2 CDF (CDF_{new}=1.0588E-6). The new end state frequencies are presented in Table V-16. For Unit 3 there is a 1.1% increase in CDF (CDF_{new}=1.9177E-6) and the new end state frequencies are presented in Table V-17.

Table V-16. Unit 2 SAMA Number 11 Results

MAAP Case	Baseline Case	SAMA 11 Case
PIHDEP	3.65E-07	3.67E-07
PIHDEPV	2.52E-07	2.53E-07
PIHDLV	7.75E-10	7.52E-10
ENMKCTT	7.39E-08	7.51E-08
OIA	6.90E-08	1.00E-07
OIALF	2.93E-08	3.05E-08
MIALF	1.36E-07	1.65E-07
PJHNSP	6.14E-08	6.16E-08
PLF	4.07E-09	4.14E-09
PID	2.88E-08	0.00E+00
NIH	2.95E-08	1.20E-09
Person-rem	3.03	Not meaningful
Unit 2 Total Cost (3%)	$299,986	Not meaningful
Unit 2 Total Cost (7%)	$207,731	Not meaningful
SAMA 11 Saving (3%)	Not meaningful	
SAMA 11 Saving (7%)	Not meaningful	

Table V-17. Unit 3 SAMA Number 11 Results

MAAP Case	Baseline Case	SAMA 11 Case
PIHDEP	8.59E-07	8.66E-07
PIHDEPV	4.20E-07	4.24E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.55E-07
OIA	1.60E-07	1.73E-07
OIALF	1.11E-08	1.15E-08
MIALF	1.32E-07	1.37E-07
PJHNSP	1.28E-07	1.29E-07
PLF	2.11E-08	2.16E-08
PID	9.67E-09	0.00E+00
NIH	3.75E-09	2.20E-10
Person-rem	6.28	Not meaningful
Unit 3 Total Cost (3%)	$609,146	Not meaningful
Unit 3 Total Cost (7%)	$423,366	Not meaningful
SAMA 11 Saving (3%)	Not meaningful	
SAMA 11 Saving (7%)	Not meaningful	

The core damage frequency for this SAMA should be equal to the base case evaluation. The cost of the different cases does not significantly differ from the baseline costs. The fact that the calculated core damage frequencies are slightly greater than the baseline case is attributed to model resolution limitations.

The primary impact of this SAMA is to shift release categories to more benign releases. From the data presented in Table III-8, the maximum costs averted are bounded by $300k and $610k for Units 2 and 3, respectively.

M. Phase II SAMA Number 12: Provide Additional DC Battery Capacity

This SAMA would provide additional functional battery life and be especially beneficial during a Station Blackout event.

To bound the potential impact of this SAMA, the logic associated with determining whether a sequence involves core damage or is “success” was modified. This was done by adding additional statements in the split fraction logic in the TRANCDBIN event tree (specifically for the split fraction assignment logic associated with top event NCD). Any sequence involving successful scram, no stuck open relief valves and successful operation and control of either HPCI or RCIC was considered to be successfully mitigated.

This approach involved making the bounding assumption concerning the reliability of operation of HPCI and RCIC for 24 hours. For the purposes of providing a bounding assessment of this SAMA, representing the operation of HPCI/RCIC for 24 hours with the top event representing 6 hours of operation is conservative.

PSA Model Results

The results from this case indicates about a 45.1% reduction in Unit 2 CDF (CDF_{new}=5.7609E-7). The new end state frequencies are presented in Table V-18. For Unit 3 there is a 51.1% reduction in CDF (CDF_{new}=9.2730E-7) and the new end state frequencies are presented in Table V-19.

Table V-18. Unit 2 SAMA Number 12 Results

MAAP Case	Baseline Case	SAMA 12 Case
PIHDEP	3.65E-07	2.24E-08
PIHDEPV	2.52E-07	1.68E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	7.39E-08
OIA	6.90E-08	3.67E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	5.92E-08
PLF	4.07E-09	4.07E-09
PID	2.88E-08	2.02E-08
NIH	2.95E-08	2.52E-08
Person-rem	3.03	1.44
Unit 2 Total Cost (3%)	$299,986	$145,161
Unit 2 Total Cost (7%)	$207,731	$100,069
SAMA 12 Saving (3%)	$154,825	
SAMA 12 Saving (7%)	$107,662	

Table V-19. Unit 3 SAMA Number 12 Results

MAAP Case	Baseline Case	SAMA 12 Case
PIHDEP	8.59E-07	2.57E-07
PIHDEPV	4.20E-07	1.89E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.52E-07
OIA	1.60E-07	4.81E-08
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.07E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	6.54E-09
NIH	3.75E-09	3.57E-09
Person-rem	6.28	3.01
Unit 3 Total Cost (3%)	$609,146	$289,719
Unit 3 Total Cost (7%)	$423,366	$201,195
SAMA 12 Saving (3%)	$319,427	
SAMA 12 Saving (7%)	$222,171	

N. Phase II SAMA Number 13: Improve DC Power Reliability

Two specific Phase I SAMAs focused on improving DC power reliability. Phase I SAMA 61 would incorporate additional/alternate battery charging capacity. Phase I SAMA 63 would replace station batteries with more reliable ones.

It should be noted that the PSA models already take credit for aligning the spare battery charger.

Reanalyzing the PSA models with “improved” failure probabilities assumed for the station batteries bound the potential impact of improving DC reliability. For the purposes of this analysis, it was assumed that it was possible to improve the unavailability of each of the three station batteries by a factor of 10. This is believed to be a conservative assumption.

PSA Model Results

The results from this case indicates about a 12.3% reduction in Unit 2 CDF (CDF_{new}=9.2059E-7). The new end state frequencies are presented in Table V-20. For Unit 3 there is a 3.2% reduction in CDF (CDF_{new}=1.8372E-6) and the new end state frequencies are presented in Table V-21.

Table V-20. Unit 2 SAMA Number 13 Results

MAAP Case	Baseline Case	SAMA 13 Case
PIHDEP	3.65E-07	3.67E-07
PIHDEPV	2.52E-07	1.76E-07
PIHDLV	7.75E-10	4.83E-10
ENMKCTT	7.39E-08	7.43E-08
OIA	6.90E-08	6.62E-08
OIALF	2.93E-08	2.77E-08
MIALF	1.36E-07	1.35E-07
PJHNSP	6.14E-08	6.15E-08
PLF	4.07E-09	2.97E-09
PID	2.88E-08	5.32E-09
NIH	2.95E-08	4.14E-09
Person-rem	3.03	2.78
Unit 2 Total Cost (3%)	$299,986	$273,464
Unit 2 Total Cost (7%)	$207,731	$189,607
SAMA 13 Saving (3%)	$26,522	
SAMA 13 Saving (7%)	$18,124	

Table V-21. Unit 3 SAMA Number 13 Results

MAAP Case	Baseline Case	SAMA 13 Case
PIHDEP	8.59E-07	8.61E-07
PIHDEPV	4.20E-07	3.74E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.48E-07
OIA	1.60E-07	1.58E-07
OIALF	1.11E-08	8.83E-09
MIALF	1.32E-07	1.30E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	5.70E-09
NIH	3.75E-09	2.47E-09
Person-rem	6.28	6.12
Unit 3 Total Cost (3%)	$609,146	$593,311
Unit 3 Total Cost (7%)	$423,366	$412,432
SAMA 13 Saving (3%)	$15,835	
SAMA 13 Saving (7%)	$10,934	

O. Phase II SAMA Number 14: Develop Procedures to Repair or Replace failed 4-kV Breakers

The specific concern addressed by this SAMA centers on the potential for failure to transfer 4-kV non-emergency busses from the unit station service transformers could lead to the loss of emergency AC power.

To bound the potential impact of this SAMA, the models were reanalyzed with the transfer of power at the unit board level assumed to occur without fault.

PSA Model Results

The results from this case indicates about a 0.02 % increase in Unit 2 calculated CDF (CDF_{new}=1.0500E-6). The new end state frequencies are presented in Table V-22. For Unit 3 there is a 0.01% increase in the calculated CDF (CDF_{new}=1.8971E-6) and the new end state frequencies are presented in Table V-23. These changes are due to model resolution limitations. Any costs averted would be very small.

Table V-22. Unit 2 SAMA Number 14 Results

MAAP Case	Baseline Case	SAMA 14 Case
PIHDEP	3.65E-07	3.65E-07
PIHDEPV	2.52E-07	2.52E-07
PIHDLV	7.75E-10	7.76E-10
ENMKCTT	7.39E-08	7.40E-08
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.08E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	Not meaningful
Unit 2 Total Cost (3%)	$299,986	Not meaningful
Unit 2 Total Cost (7%)	$207,731	Not meaningful
SAMA 14 Saving (3%)	Not meaningful	
SAMA 14 Saving (7%)	Not meaningful	

Table V-23. Unit 3 SAMA Number 14 Results

MAAP Case	Baseline Case	SAMA 14 Case
PIHDEP	8.59E-07	8.59E-07
PIHDEPV	4.20E-07	4.20E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.52E-07
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	9.67E-09
NIH	3.75E-09	3.75E-09
Person-rem	6.28	Not meaningful
Unit 3 Total Cost (3%)	$609,146	Not meaningful
Unit 3 Total Cost (7%)	$423,366	Not meaningful
SAMA 14 Saving (3%)	Not meaningful	
SAMA 14 Saving (7%)	Not meaningful	

P. Phase II SAMA Number 15: Redundant and Diverse Source of Cooling to the Diesel Generators

This SAMA would provide a redundant and diverse source, such as the fire protection system, of cooling water for the diesel generators.

To bound the potential impact of this SAMA, the “logical loop” linking the operation of the diesel generators and their normal cooling water source (EECW) was broken. Three assumptions were made:

1? It was assumed that the fire protection system has sufficient capacity to service all eight diesel generators.

2? It was further assumed that the fire protection system is aligned for diesel cooling in a timely manner.

3? The fire protection system is assumed to be perfectly available (i.e., its unavailability is zero) and the operators align the system (or a passive alignment scheme has been implemented) without failure.

To accomplish this model change, top OEE in the high pressure general transient event tree (HPGTET) was set to “success”. This has the effect of making the generator status macros (e.g., “NOGA” for diesel A) dependent only on the hardware status of the diesel and its associated equipment. In the large LOCA and medium LOCA event trees (LLOCA and MLOCA, respectively), the definition of the generator status macros were modified directly.

PSA Model Results

The results from this case indicates about an 18.9% reduction in Unit 2 CDF (CDF_{new}=8.5117E-7). The new end state frequencies are presented in Table V-24. For Unit 3 there is a14.3% reduction in CDF (CDF_{new}=1.6266E-6) and the new end state frequencies are presented in Table V-25.

Table V-24. Unit 2 SAMA Number 15 Results

MAAP Case	Baseline Case	SAMA 15 Case
PIHDEP	3.65E-07	2.06E-07
PIHDEPV	2.52E-07	2.15E-07
PIHDLV	7.75E-10	4.22E-10
ENMKCTT	7.39E-08	7.39E-08
OIA	6.90E-08	6.59E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.07E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	2.34
Unit 2 Total Cost (3%)	$299,986	$233,386
Unit 2 Total Cost (7%)	$207,731	$161,384
SAMA 15 Saving (3%)	$66,600	
SAMA 15 Saving (7%)	$46,347	

Table V-25. Unit 3 SAMA Number 15 Results

MAAP Case	Baseline Case	SAMA 15 Case
PIHDEP	8.59E-07	6.52E-07
PIHDEPV	4.20E-07	3.76E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.52E-07
OIA	1.60E-07	1.41E-07
OIALF	1.11E-08	1.12E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	9.72E-09
NIH	3.75E-09	3.72E-09
Person-rem	6.28	5.35
Unit 3 Total Cost (3%)	$609,146	$518,608
Unit 3 Total Cost (7%)	$423,366	$360,367
SAMA 15 Saving (3%)	$90,538	
SAMA 15 Saving (7%)	$62,999	

Q. This Section Not Used

This section is reserved.

Table V-26. This Table Reserved

MAAP Case	Baseline Case	SAMA # Case

Table V-27. This Table Reserved

MAAP Case	Baseline Case	SAMA # Case

R. Phase II SAMA Number 17: Improve Inspection of Rubber Expansion Joints on Main Condenser

This SAMA has the potential to decrease the frequency of internal flooding events impacting the turbine building.

To estimate the potential impact of improved inspection of condenser expansion joints, the basis for the turbine building flood frequencies was reviewed. Plant-specific screening of the generic flood database in support of the BFN IPE determined that 11 events were applicable to BFN. These 11 events formed the basis for the estimate of the turbine building flooding frequency in the IPE. Two of the eleven events involved failure of expansion joints (of all types). This observation supports the assumption that eliminating expansion joint failure would result in an approximate 20% reduction in the turbine building flooding frequency.

To represent the potential impact of the implementation of this SAMA, the models were reanalyzed with the initiating event flooding frequencies reduced from the base case by 20%. The new flooding frequencies for small and large turbine building floods become 1.152×10^{-2} and 1.760×10^{-3} per year, respectively.

PSA Model Results

The results from this case indicates about a 0.7% reduction in Unit 2 CDF (CDF_{new}=1.0423E-6). The new end state frequencies are presented in Table V-28. For Unit 3 there is a 0.6% reduction in CDF (CDF_{new}=1.8858E-6) and the new end state frequencies are presented in Table V-29.

Table V-28. Unit 2 SAMA Number 17 Results

MAAP Case	Baseline Case	SAMA 17 Case
PIHDEP	3.65E-07	3.64E-07
PIHDEPV	2.52E-07	2.50E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	7.37E-08
OIA	6.90E-08	6.82E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.34E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	3.99E-09
PID	2.88E-08	2.80E-08
NIH	2.95E-08	2.94E-08
Person-rem	3.03	3.01
Unit 2 Total Cost (3%)	$299,986	$298,379
Unit 2 Total Cost (7%)	$207,731	$206,631
SAMA 17 Saving (3%)	$1,607	
SAMA 17 Saving (7%)	$1,100	

Table V-29. Unit 3 SAMA Number 17 Results

MAAP Case	Baseline Case	SAMA 17 Case
PIHDEP	8.59E-07	8.55E-07
PIHDEPV	4.20E-07	4.18E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.51E-07
OIA	1.60E-07	1.59E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.30E-07
PJHNSP	1.28E-07	1.27E-07
PLF	2.11E-08	2.08E-08
PID	9.67E-09	9.42E-09
NIH	3.75E-09	3.73E-09
Person-rem	6.28	6.25
Unit 3 Total Cost (3%)	$609,146	$605,979
Unit 3 Total Cost (7%)	$423,366	$421,176
SAMA 17 Saving (3%)	$3,167	
SAMA 17 Saving (7%)	$2,190	

S. Phase II SAMA Number 18: Procedure to Trip Unneeded RHR/CS Pumps on Loss of Room Ventilation

This SAMA would increase the availability of RHR and/or Core Spray pumps by lessening the heat load on the room when area cooling is lost.

This SAMA has common elements to Phase II SAMAs 2 and 7. To bound the potential benefit of implementing Phase II SAMA 18, all requirements for area cooling were removed for the top events representing the RHR and CS pumps by reducing each corresponding split fraction by 20%. It has been determined earlier (see Phase II SAMAs 2 and 7) that ventilation failure contributed less than 20% to RHR and Core Spray failure.

PSA Model Results

The results from this case indicate about a 3.4% reduction in Unit 2 CDF (CDF_{new} = 1.0144E-6). The new end state frequencies are presented in Table V-30. For Unit 3 there is a 3.6% reduction in CDF (CDF_{new} = 1.8284E-6) and the new end state frequencies are presented in Table V-31.

Table V-30. Unit 2 SAMA Number 18 Results

MAAP Case	Baseline Case	SAMA 18 Case
PIHDEP	3.65E-07	3.58E-07
PIHDEPV	2.52E-07	2.39E-07
PIHDLV	7.75E-10	7.77E-10
ENMKCTT	7.39E-08	7.08E-08
OIA	6.90E-08	6.37E-08
OIALF	2.93E-08	2.15E-08
MIALF	1.36E-07	1.37E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	3.82E-09
PID	2.88E-08	2.84E-08
NIH	2.95E-08	2.96E-08
Person-rem	3.03	2.93
Unit 2 Total Cost (3%)	$299,986	$290,382
Unit 2 Total Cost (7%)	$207,731	$201,092
SAMA 19 Saving (3%)	$9,604	
SAMA 19 Saving (7%)	$6,639	

Table V-31. Unit 3 SAMA Number 18 Results

MAAP Case	Baseline Case	SAMA 18 Case
PIHDEP	8.59E-07	8.35E-07
PIHDEPV	4.20E-07	4.11E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.42E-07
OIA	1.60E-07	1.38E-07
OIALF	1.11E-08	8.43E-08
MIALF	1.32E-07	1.33E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	1.94E-08
PID	9.67E-09	9.37E-09
NIH	3.75E-09	3.78E-09
Person-rem	6.28	6.05
Unit 3 Total Cost (3%)	$609,146	$586,415
Unit 3 Total Cost (7%)	$423,366	$407,556
SAMA 19 Saving (3%)	$22,731	
SAMA 19 Saving (7%)	$15,810	

T. Phase II SAMA Number 19: Increase the SRV Reseat Reliability

This SAMA would reduce the likelihood that an SRV would fail to reseat following a successful lift.

To bound the potential impact of this SAMA, the PSA models were reanalyzed with the assumption that any valves that lift would successfully reseat. The baseline PSA models associated with initiating events involving the inadvertent lifting of relief valves were not altered in the assessment of this SAMA.

PSA Model Results

The results from this case indicates about a 5.8% reduction in Unit 2 CDF (CDF_{new}=9.8871E-7). The new end state frequencies are presented in Table V-30. For Unit 3 there is a 3.8% reduction in CDF (CDF_{new}=1.8259E-6) and the new end state frequencies are presented in Table V-31.

Table V-32. Unit 2 SAMA Number 19 Results

MAAP Case	Baseline Case	SAMA 19 Case
PIHDEP	3.65E-07	3.69E-07
PIHDEPV	2.52E-07	2.08E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	6.98E-08
OIA	6.90E-08	5.16E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.38E-07
PJHNSP	6.14E-08	6.12E-08
PLF	4.07E-09	4.12E-09
PID	2.88E-08	2.74E-08
NIH	2.95E-08	2.98E-08
Person-rem	3.03	2.84
Unit 2 Total Cost (3%)	$299,986	$281,125
Unit 2 Total Cost (7%)	$207,731	$194,638
SAMA 19 Saving (3%)	$18,861	
SAMA 19 Saving (7%)	$13,093	

Table V-33. Unit 3 SAMA Number 19 Results

MAAP Case	Baseline Case	SAMA 19 Case
PIHDEP	8.59E-07	8.68E-07
PIHDEPV	4.20E-07	3.59E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.46E-07
OIA	1.60E-07	1.45E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.34E-07
PJHNSP	1.28E-07	1.27E-07
PLF	2.11E-08	2.14E-08
PID	9.67E-09	9.54E-09
NIH	3.75E-09	3.79E-09
Person-rem	6.28	6.06
Unit 3 Total Cost (3%)	$609,146	$587,115
Unit 3 Total Cost (7%)	$423,366	$408,073
SAMA 19 Saving (3%)	$22,031	
SAMA 19 Saving (7%)	$15,293	

U. Phase II SAMA Number 20: Reduce the Dependency between the High Pressure Injection System and ADS

This SAMA would reduce the likelihood that failure of the DC power system would significantly impact redundant means of mitigating transients and small LOCAs.

To bound the potential impact of this SAMA, the PSA models were reanalyzed with the DC dependency for HPCI completely removed.

PSA Model Results

The results from this case indicates about a 1% reduction in Unit 2 CDF (CDF_{new}=1.0396E-6). The new end state frequencies are presented in Table V-32. For Unit 3 there is a 2.1% reduction in CDF (CDF_{new}=1.8579E-6) and the new end state frequencies are presented in Table V-33.

Table V-34. Unit 2 SAMA Number 20 Results

MAAP Case	Baseline Case	SAMA 20 Case
PIHDEP	3.65E-07	3.70E-07
PIHDEPV	2.52E-07	2.48E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	7.39E-08
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	1.42E-09
PID	2.88E-08	2.13E-08
NIH	2.95E-08	2.88E-08
Person-rem	3.03	3.03
Unit 2 Total Cost (3%)	$299,986	$299,709
Unit 2 Total Cost (7%)	$207,731	$207,601
SAMA 20 Saving (3%)	$277	
SAMA 20 Saving (7%)	$130	

Table V-35. Unit 3 SAMA Number 20 Results

MAAP Case	Baseline Case	SAMA 20 Case
PIHDEP	8.59E-07	8.66E-07
PIHDEPV	4.20E-07	3.84E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.52E-07
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	1.93E-08
PID	9.67E-09	2.46E-09
NIH	3.75E-09	2.96E-09
Person-rem	6.28	6.20
Unit 3 Total Cost (3%)	$609,146	$600,209
Unit 3 Total Cost (7%)	$423,366	$417,232
SAMA 20 Saving (3%)	$8,937	
SAMA 20 Saving (7%)	$6,134	

V. Phase II SAMA Number 21: Use of CRD for Alternate Boron Injection

The intent of this SAMA is to provide a second means of injecting a boron solution into the vessel in the event of an ATWS and failure of the SLC System.

The potential benefit of this SAMA was bounded by crediting operation of the CRD hydraulic system as a redundant backup to the SLC system. This was accomplished by modifying the split fraction logic rules that select the value used for top event NCD in the event tree TRANCDBIN. The top event NCD determines whether a sequence involves core damage or is successfully mitigated.

Three assumptions were made:

1. It was assumed that success of top event OSLC (the operator actions associated with initiating the SLC system) was necessary for success of the CRD system in delivering the boron solution to the reactor. Actions by the operator are assumed to be necessary to initiate boron injection via the CRD system. This assumption completely couples those actions with the actions associated with initiating the SLC system. The implication of this assumption is that the CRD system would provide redundancy for hardware failures of the SLC system.

2. It was assumed that any additional operator actions associated with initiating the CRD are represented by top event OSLC.

3. It was also assumed that any additional failure modes of the CRD system over those analyzed in the base case PSA were not significant contributors to CRD system unavailability in its postulated function of delivering boron solution to the reactor.

PSA Model Results

The results from this case indicates about a 1.5% reduction in Unit 2 CDF (CDF_{new}=1.0336E-6). The new end state frequencies are presented in Table V-34. For Unit 3 there is a 0.9% reduction in CDF (CDF_{new}=1.8811E-6) and the new end state frequencies are presented in Table V-35.

Table V-36. Unit 2 SAMA Number 21 Results

MAAP Case	Baseline Case	SAMA 21 Case
PIHDEP	3.65E-07	3.65E-07
PIHDEPV	2.52E-07	2.52E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	5.77E-08
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.07E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	2.94
Unit 2 Total Cost (3%)	$299,986	$292,089
Unit 2 Total Cost (7%)	$207,731	$202,187
SAMA 21 Saving (3%)	$7,897	
SAMA 21 Saving (7%)	$5,544	

Table V-37. Unit 3 SAMA Number 21 Results

MAAP Case	Baseline Case	SAMA 21 Case
PIHDEP	8.59E-07	8.59E-07
PIHDEPV	4.20E-07	4.20E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.36E-07
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	9.67E-09
NIH	3.75E-09	3.75E-09
Person-rem	6.28	6.19
Unit 3 Total Cost (3%)	$609,146	$601,425
Unit 3 Total Cost (7%)	$423,366	$417,948
SAMA 21 Saving (3%)	$7,721	
SAMA 21 Saving (7%)	$5,428	

W. Phase II SAMA Number 22: Borate Torus Water

The intent of this SAMA is to provide additional reactivity control by replacing the water in the torus with borated water.

No specialized model was created to provide a bounding assessment of the potential impact of this SAMA. The base case PSA models map all ATWS core damage sequences to a single endstate: ENMKCTT. To bound the potential impact of this SAMA, the frequency of this endstate was set to zero. This has the same effect as assuming that all ATWS scenarios are successfully mitigated.

This analysis does not consider any detrimental effects on plant availability and associated costs that would result with the introduction of borated water into the vessel not in response to an ATWS.

PSA Model Results

The results from this case indicates about a 7.0% reduction in Unit 2 CDF (CDF_{new}=9.7584E-7). The new end state frequencies are presented in Table V-36. For Unit 3 there is a 8.0% reduction in CDF (CDF_{new}=1.7457E-6) and the new end state frequencies are presented in Table V-37.

Table V-38. Unit 2 SAMA Number 22 Results

MAAP Case	Baseline Case	SAMA 22 Case
PIHDEP	3.65E-07	3.65E-07
PIHDEPV	2.52E-07	2.52E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	0.00E-00	0.00E+00
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.07E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	2.62
Unit 2 Total Cost (3%)	$299,986	$263,961
Unit 2 Total Cost (7%)	$207,731	$182,440
SAMA 22 Saving (3%)	$36,025	
SAMA 22 Saving (7%)	$25,291	

Table V-39. Unit 3 SAMA Number 22 Results

MAAP Case	Baseline Case	SAMA 22 Case
PIHDEP	8.59E-07	8.59E-07
PIHDEPV	4.20E-07	4.20E-07
PIHDLV	0.00+00	7.75E-10
ENMKCTT	0.00E+00	0.00E+00
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	9.67E-09
NIH	3.75E-09	3.75E-09
Person-rem	6.28	5.44
Unit 3 Total Cost (3%)	$609,146	$535,250
Unit 3 Total Cost (7%)	$423,366	$371,488
SAMA 22 Saving (3%)	$73,896	
SAMA 22 Saving (7%)	$51,878	

X. Phase II SAMA Number 23: Automate Torus Cooling

The purpose of this SAMA is to eliminate the possibility of failing to initiate torus cooling because of operator error.

To represent the potential impact of this SAMA, the operator action associated with the initiation of torus cooling was set to “guaranteed success.”

This change was implemented in the low pressure transient event tree (LPGTET), the large LOCA event tree (LLOCA) and the medium LOCA event tree (MLOCA) by setting the value (failure probability) of top event OSP (operator initiates torus cooling) to 0.

The model adopted assumes that the contribution to failure of any necessary sensors, monitors or other actuation devices does not significantly contribute to the likelihood of actuation failure.

PSA Model Results

The results from this case indicates about a 6.4% reduction in Unit 2 CDF (CDF_{new}=9.8217E-7). The new end state frequencies are presented in Table V-38. For Unit 3 there is a 9.0% reduction in CDF (CDF_{new}=1.7264E-6) and the new end state frequencies are presented in Table V-39.

Table V-40. Unit 2 SAMA Number 23 Results

MAAP Case	Baseline Case	SAMA 23 Case
PIHDEP	3.65E-07	3.51E-07
PIHDEPV	2.52E-07	1.99E-07
PIHDLV	7.75E-10	7.70E-10
ENMKCTT	7.39E-08	7.42E-08
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	2.76E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.94E-08
Person-rem	3.03	2.82
Unit 2 Total Cost (3%)	$299,986	$279,786
Unit 2 Total Cost (7%)	$207,731	$193,723
SAMA 23 Saving (3%)	$20,200	
SAMA 23 Saving (7%)	$14,008	

Table V-41. Unit 3 SAMA Number 23 Results

MAAP Case	Baseline Case	SAMA 23 Case
PIHDEP	8.59E-07	7.86E-07
PIHDEPV	4.20E-07	3.33E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.48E-07
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	1.54E-08
PID	9.67E-09	9.67E-09
NIH	3.75E-09	3.68E-09
Person-rem	6.28	5.73
Unit 3 Total Cost (3%)	$609,146	$555,650
Unit 3 Total Cost (7%)	$423,366	$386,214
SAMA 23 Saving (3%)	$53,496	
SAMA 23 Saving (7%)	$37,152	

Y. Phase II SAMA Number 24: Containment Overpressure Protection

This Phase II SAMA represents the potential impact of two specific Phase I SAMAs: 117a (Provide Torus Positive Pressure Relief Valves); and, 117b (Reduce Drywell Head Bolt Pretension).

Without the consideration of additional recovery actions, this SAMA would not alter the calculated core damage frequency, but instead changes the core damage endstate for selected sequences. The current models only consider a limited number of plant damage endstates. The only "containment failed late" endstate is "PLF." All sequences mapped to PLF were instead mapped to success; thus, bounding the potential benefit of the SAMA.

PSA Model Results

As analyzed, results from this case indicates negligible (less than 0.4%) change in the calculated Unit 2 CDF (CDF_{new} = 1.0460-06). The new end state frequencies are presented in Table V-40. For Unit 3 there is also a negligible (less than 1.1%) change in the calculated CDF (CDF_{new} = 1.8766-06) and the new end state frequencies are presented in Table V-41.

Table V-42. Unit 2 SAMA Number 24 Results

MAAP Case	Baseline Case	SAMA 24 Case
PIHDEP	3.65E-07	3.65E-07
PIHDEPV	2.52E-07	2.52E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	7.39E-08
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	0
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	3.03
Unit 2 Total Cost (3%)	$299,986	$299,775
Unit 2 Total Cost (7%)	$207,731	$207,605
SAMA 24 Saving (3%)	$211	
SAMA 24 Saving (7%)	$126	

Table V-43. Unit 3 SAMA Number 24 Results

MAAP Case	Baseline Case	SAMA 24 Case
PIHDEP	8.59E-07	8.59E-7
PIHDEPV	4.20E-07	4.20E-7
PIHDLV	0.00+00	0.00+00
ENMKCTT	1.52E-07	1.52E-7
OIA	1.60E-07	1.60E-7
OIALF	1.11E-08	1.11E-8
MIALF	1.32E-07	1.32E-7
PJHNSP	1.28E-07	1.28E-7
PLF	2.11E-08	0.00E-0
PID	9.67E-09	9.67E-9
NIH	3.75E-09	3.75E-9
Person-rem	6.28	6.27
Unit 3 Total Cost (3%)	$609,146	$607,672
Unit 3 Total Cost (7%)	$423,366	$422,449
SAMA 24 Saving (3%)	$1,474	
SAMA 24 Saving (7%)	$917	

Z. Phase II SAMA Number 25: Automate SLC Initiation

This SAMA would eliminate the failure of the SLC system to inject boron solution to the vessel due to operator error.

To represent the potential impact of this SAMA, the operator action associated with the initiation of the SLC system was set to "guaranteed success."

This change was implemented in the high pressure transient event tree (HPGTET) by setting the value (failure probability) of top event OSLC (operator initiates SLC injection) to 0.

The model adopted assumes that the contribution to failure of any necessary sensors, monitors or other actuation devices does not significantly contribute to the likelihood of actuation failure.

PSA Model Results

The results from this case indicates about a 2.3% reduction in Unit 2 CDF (CDF_{new}=1.0258E-6). The new end state frequencies are presented in Table V-42. For Unit 3 there is a 1.2% reduction in CDF (CDF_{new}=1.8746E-6) and the new end state frequencies are presented in Table V-43.

Table V-44. Unit 2 SAMA Number 25 Results

MAAP Case	Baseline Case	SAMA 25 Case
PIHDEP	3.65E-07	3.65E-07
PIHDEPV	2.52E-07	2.52E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	5.00E-08
OIA	6.90E-08	6.90E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.07E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	2.89
Unit 2 Total Cost (3%)	$299,986	$288,300
Unit 2 Total Cost (7%)	$207,731	$199,527
SAMA 25 Saving (3%)	$11,686	
SAMA 25 Saving (7%)	$8,204	

Table V-45. Unit 3 SAMA Number 25 Results

MAAP Case	Baseline Case	SAMA 25 Case
PIHDEP	8.59E-07	8.59E-07
PIHDEPV	4.20E-07	4.20E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.30E-07
OIA	1.60E-07	1.60E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	9.67E-09
NIH	3.75E-09	3.75E-09
Person-rem	6.28	6.16
Unit 3 Total Cost (3%)	$609,146	$598,263
Unit 3 Total Cost (7%)	$423,366	$415,729
SAMA 25 Saving (3%)	$10,883	
SAMA 25 Saving (7%)	$7,637	

AA. Phase II SAMA Number 26: Decrease Frequency of Excessive LOCA

This Phase II SAMA addressed Phase I SAMA 122a (Increase the Inspection Frequency of the Reactor Vessel).

To bound the potential impact of this SAMA, the models were reanalyzed with the initiating event frequency of “Excessive LOCA” set to 0.

PSA Model Results

The results from this case indicates about a 0.9% reduction in Unit 2 CDF (CDF_{new}=1.0404E-6). The new end state frequencies are presented in Table V-44. For Unit 3 there is about a 0.5% reduction in CDF (CDF_{new}=1.8872E-6) and the new end state frequencies are presented in Table V-45.

Table V-46. Unit 2 SAMA Number 26 Results

MAAP Case	Baseline Case	SAMA 26 Case
PIHDEP	3.65E-07	3.65E-07
PIHDEPV	2.52E-07	2.52E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	7.39E-08
OIA	6.90E-08	5.96E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.07E-09
PID	2.88E-08	2.88E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	3.00
Unit 2 Total Cost (3%)	$299,986	$297,089
Unit 2 Total Cost (7%)	$207,731	$205,720
SAMA 26 Saving (3%)	$2,897	
SAMA 26 Saving (7%)	$2,011	

Table V-47. Unit 3 SAMA Number 26 Results

MAAP Case	Baseline Case	SAMA 26 Case
PIHDEP	8.59E-07	8.59E-07
PIHDEPV	4.20E-07	4.20E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.52E-07
OIA	1.60E-07	1.51E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	2.11E-08
PID	9.67E-09	9.67E-09
NIH	3.75E-09	3.75E-09
Person-rem	6.28	6.25
Unit 3 Total Cost (3%)	$609,146	$606,075
Unit 3 Total Cost (7%)	$423,366	$421,236
SAMA 26 Saving (3%)	$3,071	
SAMA 26 Saving (7%)	$2,130	

BB. Phase II SAMA Number 27: Provide an Independent Torus Cooling System

This SAMA would mitigate the failure of torus cooling due to hardware failures.

The base case models already include consideration of the possibility of recovery of torus cooling, if failure was due to hardware unavailability. To bound the potential impact of this SAMA, the top event in the low pressure transient event tree (LPGTET), the large LOCA event tree (LLOCA) and the medium LOCA event tree (MLOCA) which represents recovery of suppression pool cooling (top SPR) was set to 'guaranteed success".

The results of the reanalysis with SPR set to guaranteed success are shown below in Tables V-46 and V-47.

PSA Model Results

The results from this case indicates a 2.9% reduction in Unit 2 CDF (CDF_{new} = 1.0196-06). The new end state frequencies are presented in Table V-46. For Unit 3 there is about a 16.0% reduction in CDF (CDF_{new} = 1.5929-06) and the new end state frequencies are presented in Table V-47.

Table V-48. Unit 2 SAMA Number 27 Results

MAAP Case	Baseline Case	SAMA 27 Case
PIHDEP	3.65E-07	3.49E-07
PIHDEPV	2.52E-07	2.49E-07
PIHDLV	7.75E-10	7.36E-10
ENMKCTT	7.39E-08	7.40E-08
OIA	6.90E-08	5.92E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.37E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	1.44E-09
PID	2.88E-08	2.87E-08
NIH	2.95E-08	2.96E-08
Person-rem	3.03	2.93
Unit 2 Total Cost (3%)	$299,986	$290,682
Unit 2 Total Cost (7%)	$207,731	$201,272
SAMA 27 Saving (3%)	$9,304	
SAMA 27 Saving (7%)	$6,459	

Table V-49. Unit 3 SAMA Number 27 Results

MAAP Case	Baseline Case	SAMA 27 Case
PIHDEP	8.59E-07	6.22E-07
PIHDEPV	4.20E-07	3.77E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.59E-07
OIA	1.60E-07	1.49E-07
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	1.23E-09
PID	9.67E-09	9.66E-09
NIH	3.75E-09	3.75E-09
Person-rem	6.28	5.30
Unit 3 Total Cost (3%)	$609,146	$513,069
Unit 3 Total Cost (7%)	$423,366	$356,625
SAMA 27 Saving (3%)	$96,077	
SAMA 27 Saving (7%)	$66,741	

CC. Phase II SAMA Number 28: Improve 4-kV Crosstie Capability

This SAMA seeks to improve the ability to crosstie emergency boards from Units 1 and 2 to Unit 3. This would be accomplished using the shutdown busses. Likewise, the ability to crosstie Unit 3 boards to support Unit 2 was considered. It is noted that the base case model already includes limited support of Unit 2 emergency busses from Unit 3.

To bound the potential impact of this SAMA, individual split fraction rules and macro-logic associated with AC power support of RHR, Core Spray, and long term operation of HPCI and RCIC were modified. It was assumed that any Unit 3 diesel could feed any Unit 1 or 2 4-kV shutdown board, and that any Units 1 or 2 diesel could feed any Unit 3 4-kV shutdown board. It was further assumed that any necessary operator actions to accomplish required breaker manipulations would be done without fail and that breaker and bus failures would not significantly contribute to failure.

PSA Model Results

The results from this case indicates about a 4.2% reduction in Unit 2 CDF (CDF_{new}=1.0053E-6). The new end state frequencies are presented in Table V-48. For Unit 3 there is a 29.3% reduction in CDF (CDF_{new}=1.3417E-6) and the new end state frequencies are presented in Table V-49.

Table V-50. Unit 2 SAMA Number 28 Results

MAAP Case	Baseline Case	SAMA 28 Case
PIHDEP	3.65E-07	3.09E-07
PIHDEPV	2.52E-07	2.33E-07
PIHDLV	7.75E-10	7.75E-10
ENMKCTT	7.39E-08	7.39E-08
OIA	6.90E-08	9.95E-08
OIALF	2.93E-08	2.93E-08
MIALF	1.36E-07	1.36E-07
PJHNSP	6.14E-08	6.14E-08
PLF	4.07E-09	4.82E-09
PID	2.88E-08	2.83E-08
NIH	2.95E-08	2.95E-08
Person-rem	3.03	2.86
Unit 2 Total Cost (3%)	$299,986	$284,458
Unit 2 Total Cost (7%)	$207,731	$196,914
SAMA 28 Saving (3%)	$15,528	
SAMA 28 Saving (7%)	$10,817	

Table V-51. Unit 3 SAMA Number 28 Results

MAAP Case	Baseline Case	SAMA 28 Case
PIHDEP	8.59E-07	5.35E-07
PIHDEPV	4.20E-07	2.55E-07
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.51E-07
OIA	1.60E-07	9.80E-08
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.32E-07
PJHNSP	1.28E-07	1.28E-07
PLF	2.11E-08	1.92E-08
PID	9.67E-09	8.43E-09
NIH	3.75E-09	3.67E-09
Person-rem	6.28	4.44
Unit 3 Total Cost (3%)	$609,146	$428,814
Unit 3 Total Cost (7%)	$423,366	$297,993
SAMA 28 Saving (3%)	$180,332	
SAMA 28 Saving (7%)	$125,373	

DD. Phase II SAMA Number 29: Provide High Pressure Diesel-Driven Pump

This SAMA would provide an additional means of mitigating a station blackout event by allowing river water to be injected into the vessel via a high pressure, diesel-driven pump.

To bound the potential impact of this SAMA, a variant of the model developed to consider Phase II SAMA 12 was used. To estimate the effect of an independent diesel driven high pressure injection source, two changes were made to the base case models. First a new logic rule was added to the TRANCDBIN event tree for top event NCD. Top event NCD determines whether a sequence is assigned to a core damage state or represents successful mitigation of the event. This new "success" rule states that if RPS is successful and if HPCI and operator control are successful, then core damage is averted. Next, the split fractions, including the one representing "guaranteed failure" of short term HPCI operation were modified. It was estimated that the unavailability of a diesel driven injection system, including start, 24-hour operation and maintenance would be on the order of 0.1. Therefore the HPCI split fractions were reduced by one order of magnitude.

PSA Model Results

The results from this case indicates about a 74.1% reduction in Unit 2 CDF (CDF_{new}=2.7173E-7). The new end state frequencies are presented in Table V-50. For Unit 3 there is a 82% reduction in CDF (CDF_{new}=3.4154E-7) and the new end state frequencies are presented in Table V-51.

Table V-52. Unit 2 SAMA Number 29 Results

MAAP Case	Baseline Case	SAMA 29 Case
PIHDEP	3.65E-07	0.00E+00
PIHDEPV	2.52E-07	5.69E-08
PIHDLV	7.75E-10	7.71E-10
ENMKCTT	7.39E-08	7.41E-08
OIA	6.90E-08	1.24E-08
OIALF	2.93E-08	2.82E-08
MIALF	1.36E-07	1.41E-08
PJHNSP	6.14E-08	6.09E-08
PLF	4.07E-09	1.75E-10
PID	2.88E-08	2.67E-09
NIH	2.95E-08	2.15E-08
Person-rem	3.03	0.92
Unit 2 Total Cost (3%)	$299,986	$86,794
Unit 2 Total Cost (7%)	$207,731	$60,314
SAMA 29 Saving (3%)	$213,192	
SAMA 29 Saving (7%)	$147,417	

Table V-53. Unit 3 SAMA Number 29 Results

MAAP Case	Baseline Case	SAMA 29 Case
PIHDEP	8.59E-07	0.00E+00
PIHDEPV	4.20E-07	5.13E-08
PIHDLV	0.00+00	0.00E+00
ENMKCTT	1.52E-07	1.56E-07
OIA	1.60E-07	1.83E-08
OIALF	1.11E-08	1.11E-08
MIALF	1.32E-07	1.38E-08
PJHNSP	1.28E-07	8.74E-08
PLF	2.11E-08	1.35E-09
PID	9.67E-09	7.40E-10
NIH	3.75E-09	1.79E-09
Person-rem	6.28	1.48
Unit 3 Total Cost (3%)	$609,146	$134,133
Unit 3 Total Cost (7%)	$423,366	$93,730
SAMA 29 Saving (3%)	$475,013	
SAMA 29 Saving (7%)	$329,636	

EE. Verification of the Model

Two RISKMAN® models were received from BFN for use in the SAMA analysis. Model U2011701 represents the base case for the operation of Unit 2 while model U3011701 represents the base case for the operation of Unit 3.

Because multiple computers were used to perform the required analyses, it was first necessary to verify that these computers would reproduce the results of the base cases. For each computer used in the SAMA analysis, models U2011701 and U3011701 were reanalyzed and the results compared to the original base case results. In all cases, the base case results were reproduced exactly.

FF. Reassignment of Core Damage Scenario End States

Models U2011701 and U3011701 characterized core damage scenarios as either 'LERF' or 'NLERF'. These characterizations are referred to as "end states". LERF scenarios are those core damage sequences that result in a "large early release" of radioactive material. The sum of the frequencies of these scenarios is the "large early release frequency." In a similar manner, core damage scenarios that do not involve a "large early release" were assigned to the 'NLERF' (no 'LERF') end state.

The LERF and NLERF end states do not sufficiently differentiate the core damage sequences to enable linkage to the conditional offsite consequence analyses. The offsite consequence analyses, and supporting MAAP analyses, utilized the end state definitions developed for the BFN Unit 2 IPE. It was therefore necessary to reassign the core damage scenarios used in the base case models to the set of end states consistent with the Level 2 (MAAP) and Level 3 (MACCS2) analyses.

The base case models with the IPE endstate binning were named U2PDSB and U3PDSB corresponding to Unit 2 and Unit 3, respectively.

Since only the assignments of end states were changed, the total calculated core damage frequency for either unit did not change.

GG. Investigation of the Impact of "Truncation Frequency" Chosen

Since the models are so large and take a significant amount of time to run, an analysis was performed to verify that the "truncation frequency" used in the U2011701 and U3011701 models would yield reasonable results. To accomplish this, several computer runs were completed. These runs included a baseline run for each unit with additional computer runs for both units with the resolved sequence frequencies truncated at 1E-13, 1E-14, and 1E-15. For Unit 2 an additional run was completed with the frequency truncated at 1E-16. The results of these runs are presented in Figures V-2 and V-3.

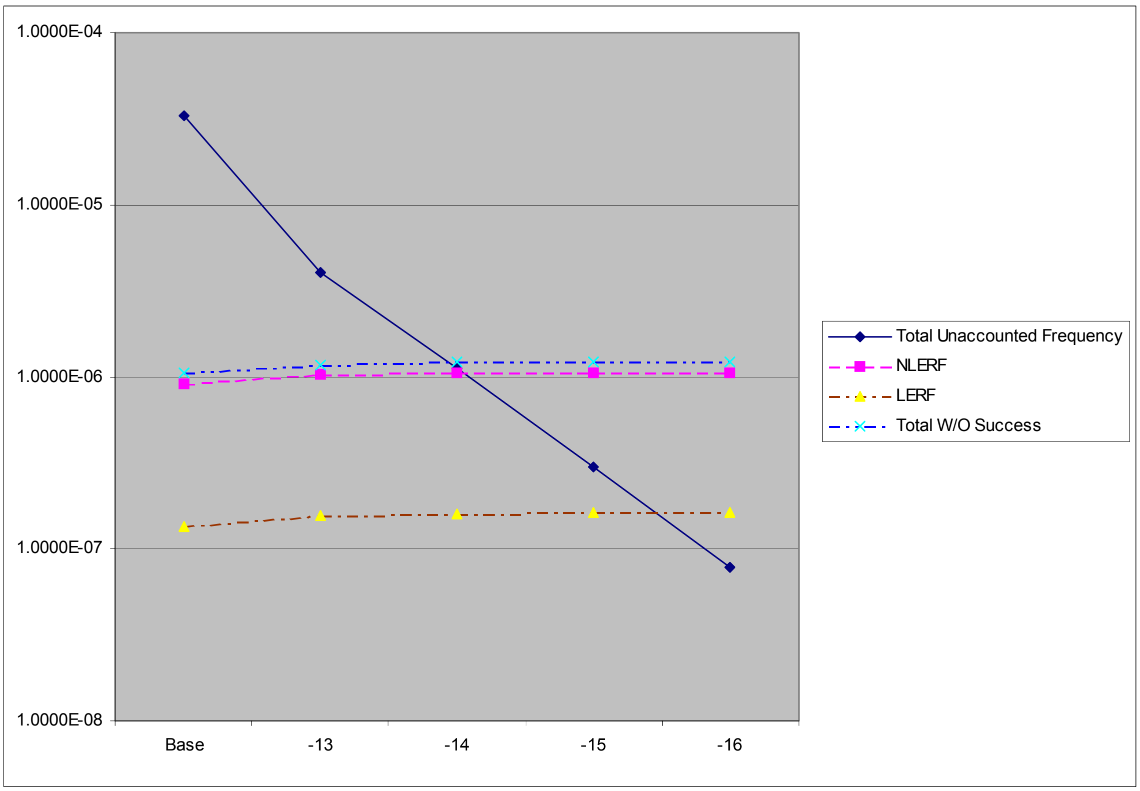

Figure V-2. Results of the Truncation Frequency Verification for Unit 2

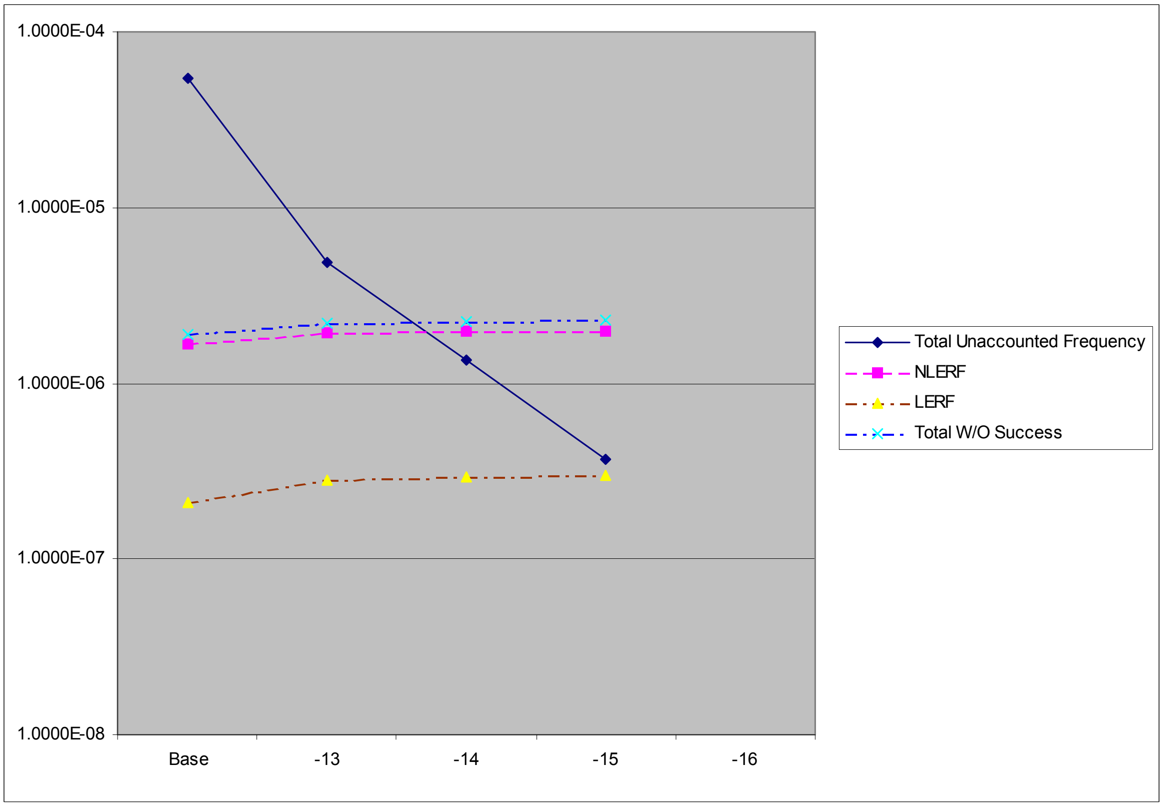

Figure V-3. Results of the Truncation Frequency Verification for Unit 3

As can be seen in Figures V-2 and V-3, there is very little change of the values for LERF and NLERF at truncation frequencies below 1E-13. Based on these results the SAMA computer runs were truncated at 1E-13.

HH. Extrapolation to Operation of All Three Units Operating at EPV Power Level

Browns Ferry Nuclear plant is comprised of three individual units that share certain systems and buildings. In the consideration of the cost/benefit measures of potential SAMAs, therefore, it is important to consider how multiple unit events may impact the evaluation.

As discussed in the BFN Multi Unit PRA, selected initiators, have the potential to result in core damage in both Unit 2 and Unit 3. SBO is an example of a class of scenarios with this potential. The cost of such scenarios, in the unlikely event that they were to occur, would likely be equal to or less than the cost associated with two independent core damage events. It is therefore concluded that considering post accident costs as the sum of Unit 2 and Unit 3 costs unit basis is appropriate and conservative for such initiators.

Implementation costs are considered on a per plant basis for specific SAMAs. One example would be replacement of the station batteries. The cost/benefits comparison for these specific SAMAs are then made on a plant basis.

Up to this point the detailed evaluations of the individual SAMAs have utilized the PSAs that are current and available. These PSAs address the operation of Units 2 and 3 operating at 105% of their original licensed power level. Both PSAs assume that Unit 1 is in extended layup and not operating.

The analysis now addresses how the conclusions of the SAMA cost/benefit analysis are potentially impacted if operation of all three units under EPUP conditions is considered.

The operation of unit 1 would increase the calculated core damage frequency of Units 2 and 3. The units share certain equipment (e.g., diesel generators, RHR Service Water and Emergency Equipment Cooling Water) resulting, in selected scenarios, in decreased availability of equipment to a particular unit. Success criteria for selected systems are also impacted.

The Multiple Unit PSA (reference 18) performed in 1995 provides some insight into the potential affect of multiple unit operation. That study provides a basis for the comparison of the core damage frequency of Unit 2 with both other units operating with the IPE results. The IPE assumed that only Unit 2 was operational. The observation is made in the Multiple Unit PSA that the mean core damage frequency of Unit 2 is a factor of 4 greater with all three units operating compared to only Unit 2 operating. For the purpose of the SAMA screening analysis, it is assumed that the baseline core damage frequencies for Unit 1 and Unit 2 are equal with a mean value 4 times the currently calculated Unit 2 core damage frequency mean. This is felt to be a conservative assumption.

Because Unit 1 is more closely associated with Unit 2 than it is with Unit 3, it is expected that the return to service will have a larger impact on Unit 2 that it will on Unit 3. Units 1 and 2 share the electrical system in a more intimate manner than do Units 1 and 3. In addition, RHR System interunit cross connections are possible between Units 1 and 2, as well as Units 2 and 3, but not directly between Units 1 and 3. It is assumed that the maximum impact on the calculated core damage frequency of Unit 3 will be a factor of 2 over the currently calculated value.

If we further assume that the potential economic savings of the individual SAMAs scale by the same factor as the baseline PSA core damage frequency results, then the preceding analyses can be revisited to identify individual SAMAs that warrant further attention. This assumption is felt to be conservative since ATWS scenarios (which have relatively severe offsite impacts) would be “increased” in frequency in the scaled model but, in fact, not appreciably increased in frequency due to the restart of Unit 1.

II. Uncertainty

An important consideration in any PSA involves the evaluation of uncertainty and its potential impact on the information provided to support management decisions. The uncertainty in the total core damage frequency was calculated for both base case models. The results are shown in Table V-52.

Table V-54. Core Damage Uncertainty

	Unit 2	Unit 3
Mean value	1.0498E-6	1.9866E-6
5th percentile	2.4458E-7	3.1794E-7
50th percentile	7.2170E-7	1.1919E-6
95th percentile	2.8152E-6	5.6597E-6

Note that the ratio of the 95th percentile to the mean is 2.7 and 2.8 for Units 2 and 3, respectively. The values in Table V-52 reflect the uncertainty in the data distributions used in the analysis. Each of the Phase II SAMA evaluations were reviewed to determine if a factor of 3 would alter the decision to screen any of them

VI. SAMA Analysis Results

A. SAMA Analysis Results for BFNP

A summary comparison of estimate costs and costs averted is shown in Table VI-1 for the Phase II SAMAs.

It should be noted that additional engineering analyses is warranted to further consider those SAMAs identified as cost effective via this analysis. The analysis documented here is bounding in nature. In addition, as noted in the text, potential negative impacts associated with the SAMAs were not considered.

B. SAMA Analysis Results from Previous Submittals

A review of previously approved and submitted SAMA analyses was performed to determine the potential scope of changes that would reasonably be expected to be applicable to this analysis. The following paragraphs are quoted from the conclusion of each referenced SAMA analysis.

Calvert Cliffs (approved) – "BGE identified and committed to pursue one enhancement in accordance with the CCNPP modification process. This involves the installation of a watertight door between the service water pump room and the adjacent fan room to reduce the likelihood of core damage from internal flooding events. BGE also committed to further evaluate the adequacy of CCNPP procedures regarding response to internal floods following resolution of the hardware flooding enhancement. BGE concluded that no additional mitigation alternatives are cost-beneficial and warrant implementation at CCNPP."

Oconee (approved) – "Because the environmental impacts of potential severe accidents are of small significance and because additional measures to reduce such impacts would not be justified from a public risk perspective, Duke concludes that no additional severe accident mitigation alternative measures beyond those already implemented during the current term license would be warranted for Oconee."

Hatch (in review by the USNRC) – "None of the SAMAs analyzed would be being[sic] justified on a cost-benefit basis."

Arkansas Nuclear One Unit 1 (approved by the USNRC) – "As a result of this reassessment, the "marginally" cost-beneficial SAMA 129 became more cost-beneficial. All other SAMA candidates retained negative net values. SAMA 129 involves improvements in training and awareness associated with operator actions required to swapover from the injection phase to low-pressure recirculation during a large LOCA. This SAMA does not relate to adequately managing the effects of aging during the period of extended operation and based on further information provided by Entergy, appears to be adequately addressed within the current operations training cycle. Therefore, no further action is necessary as part of license renewal pursuant to 10 CFR Part 54."

Table VI-1. Evaluation of Phase II SAMAs

Phase II SAMA ID No.	Phase I SAMA ID No.	SAMA Title	Estimated Cost (2016)	Maximum Cost Avoidance (Base Case)	Screening Cost Avoidance for Impact of Uncertainty	Screening Cost Avoidance for Impact of Three-Unit Operation	Screening Cost Avoidance for Impact of both Uncertainty and Three-Unit Operation	Cost Effective?
1	7	Increase CRD pump lube oil capacity.	N/A	N/A	N/A	N/A	N/A	N
2	12	Replace ECCS pump motor with air-cooled motors.	$9.3M/unit	$76k/unit	$228k/unit	$256k/plant	$768k/unit	N
3	17	Implement procedures to stagger CRD pump use after a loss of service water.	$78k/unit	N/A	N/A	N/A	N/A	N
4	19	Procedural guidance for use of cross-tied component cooling or service water pumps.	$78k/unit	$8k/unit	$24k/unit	$17k/unit	$51k/unit	N
5	20	Procedure enhancements and operator training in support system failure sequences, with emphasis on anticipating problems and coping.	$78k/unit	$1k/unit	$3k/unit	$3k/unit	$9k/unit	N
6	21	Improved ability to cool the residual heat removal heat exchangers	$1.5M/unit	$58k/unit	$174k/unit	$115k/unit	$347k/unit	N
7	23	Provide a redundant train of ventilation.	$9.3M/unit	$75k/unit	$225k/unit	$256k/unit	$770k/unit	N
8	25	Add a diesel building switchgear room high temperature alarm.	Option 1: $623k per building Option 2: $9.3M per building	$0.2k/unit	$0.6/unit	$0.4/unit	$1k/unit	N
9	34	Install a containment vent large enough to remove ATWS decay heat.	$3.1M/unit	$38k/unit	$114k/unit	$77k/unit	$231k/unit	N

Table VI-2. Evaluation of Phase II SAMAs

Phase II SAMA ID No.	Phase I SAMA ID No.	SAMA Title	Estimated Cost (2016)	Maximum Cost Avoidance (Base Case)	Screening Cost Avoidance for Impact of Uncertainty	Screening Cost Avoidance for Impact of Three-Unit Operation	Screening Cost Avoidance for Impact of both Uncertainty and Three-Unit Operation	Cost Effective?
10	46	Use the fire protection system as a back-up source for the containment spray system.	$779k/unit	N/A	N/A	N/A	N/A	N
11	48	Install a passive containment spray system.	$9.3M/unit	N/A	N/A	N/A	N/A	N
12	57	Provide additional DC battery capacity.	$1.5M/plant	$474k/plant	$1.4M/plant	$1.9M/plant	$5.6M/plant	*Y(1)
	58	Use fuel cells instead of lead-acid batteries.	$9.3M/plant					N
	62	Increase/improve DC bus load shedding.	$78k/plant					Y
13	61	Incorporate an alternate battery charging capability.	1.5M/unit	$27k/unit	$81k/unit	$106k/unit	$318k/unit	N
	63	Replace existing batteries with more reliable ones.	$9.3M/plant	aa				N
14	66	Develop procedures to repair or replace failed 4 kV breakers.	$78k/unit	N/A	N/A	N/A	N/A	N
15	73	Use Fire Protection System as a back-up source for diesel cooling.	$1.5M/plant	$157k/plant	$471k/plant	$713k/plant	$2.1M/plant	*Y(2)

** Note: Y(1) Potentially cost-beneficial for three-unit operation.*
Y(2) Potentially cost-beneficial for three-unit operation when uncertainty is considered.

Table VI-3. Evaluation of Phase II SAMAs

Phase II SAMA ID No.	Phase I SAMA ID No.	SAMA Title	Estimated Cost (2016)	Maximum Cost Avoidance (Base Case)	Screening Cost Avoidance for Impact of Uncertainty	Screening Cost Avoidance for Impact of Three-Unit Operation	Screening Cost Avoidance for Impact of both Uncertainty and Three-Unit Operation	Cost Effective?
17	98	Improve inspection of rubber expansion joints on main condenser.	$155k/unit	$3k/unit	$9k/unit	6.4k/unit	$19k/unit	N
18	108	Procedure to instruct operators to trip unneeded RHR/CS pumps on loss of room ventilation.	$78k/unit	$23k/unit	$69k/unit	$45k/unit	$136k/unit	*Y(2)
19	110	Increase the SRV reseat reliability.	$1.09M/unit	$22k/unit	$66k/unit	$75k/unit	$226k/unit	N
20	111	Reduce DC dependency between high pressure injection system and ADS.	$779k/unit	$9k/unit	$27k/unit	$18k/unit	$54k/unit	N
21	113	Use of CRD for alternate boron injection.	$3.1M/unit	$8k/unit	$24k/unit	$32k/unit	$95k/unit	N
22	116	borate torus water	$9.3M/unit	$74k/unit	$222k/unit	$148k/unit	$443k/unit	N
23	117	automate torus cooling	$623k/unit	$53k/unit	$159k/unit	$107k/unit	$321k/unit	N
24	117a	provide torus positive pressure relief valves	$1.09M/unit	$1k/unit	$3k/unit	$3k/unit	$9k/unit	N
	117b	reduce DW head bolt pretension	$78k/unit					N
25	121	automate SLC initiation	$623k/unit	$12k/unit	$36k/unit	$46k/unit	$140k/unit	N
26	122a	RPV inspection	$155k/unit	$3k/unit	$9k/unit	$12k/unit	$35k/unit	N
27	124	provide independent torus cooling system	$9.3M/unit	$96k/unit	$288k/unit	$192k/unit	$576k/unit	N
28	132	Improve 4kV crosstie capability	$7.8M/plant	$196k/plant	$588k/plant	$484k/plant	$1.4M/plant	N
29	133	provide HP diesel-driven pump.	$9.3M/unit	$475k/unit	$1.4M/unit	$950k/unit	$2.9M/unit	N

** Note: Y(1) Potentially cost-beneficial for three-unit operation.*
Y(2) Potentially cost-beneficial for three-unit operation when unit uncertainty is considered.

VII. References

1. Reserved.

2. Browns Ferry Nuclear Plant Probabilistic Safety Assessment, Unit 2 Summary Report, R0.

3. Browns Ferry Nuclear Plant Probabilistic Safety Assessment, Unit 3 Summary Report, R0.

4. Letter from TVA to the USNRC, Browns Ferry Nuclear Plant (BFN) – Generic letter (GL) 88-20, Supplement 4, Individual Plant Examination of External Events (IPEEE) for Sever Accident Vulnerabilities – Partial Submittal of Report. RIMS R08 950724 976.

5. Letter from TVA to the USNRC, Browns Ferry Nuclear Plant (BFN) – Units 1, 2, and 3 – Final Response to Request for Additional Information Regarding Browns Ferry Nuclear Plant Individual Plant Examination for External Events (IPEEE) (TAC Nos. M83595, M83596, M83597). RIMS R08 990129 770.

6. Letter from the USNRC to TVA, Browns Ferry Units 1, 2, and 3, Individual Plant Examination of External Events (IPEEE) and Related Generic Safety Issues. Issuance of Staff Evaluation (TAC Nos. M83595, M83596, M83597). 6/22/2000.

7. Letter from the USNRC to TVA, Browns Ferry, Units 1, 2, and 3 RE: Completion of Licensing Action for Generic Letter 87-02 (TAC Nos. M83595, M83596, M83597). 3/21/2000.

8. Edwin I. Hatch Nuclear Plant, Application for License Renewal, Environmental Report, Appendix D, Attachment F. February 2000.

9. TVA calculation CN-BFN-MEB-MDN0-999-2001-0011, R0.

10. Regulatory Analysis Technical Evaluation Handbook, NUREG/BR-0184.

11. TVA calculation CN-BFN-MEB-MDN0-999-2001-0016, Revision 0

12. Browns Ferry Nuclear Plant, Unit 2 Probabilistic Risk Assessment Individual Plant Examination, September 1992.

13. NUREG-1560, “Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance,” Volume 2, NRC, December 1987.

14. Letter from TVA to USNRC, RO8 970411 803.

15. Letter from TVA to USNRC, RO8 971118 922.

16. NUREG-1150, “Severe Accident Rises: An assessment for Five U.S. Nuclear

Power Plants," U.S. Nuclear Regulatory Commission, Washington, D.C., June 1989.

17. Tennessee Valley Authority, "BFN Completed Capital Projects," RIMS B44 010824 001.

18. PLG, "Browns Ferry Multi-Unit Probabilistic Risk Assessment," prepared for Tennessee Valley Authority, PLG-1045, January 1995.