ATTACHMENT E

MICROBIOLOGICAL CORRESPONDENCE

Ameren Services

Environmental Services
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One Ameren Plaza
1901 Chouteau Avenue
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314.621.3222

April 15, 2010

Ms. Lisa Schutzenhofer
Bureau of Communicable Disease Control & Prevention
Missouri Department of Health & Senior Services
PO Box 570
Jefferson City, Missouri 65102

Ameren

SUBJECT: Callaway Unit 1 License Renewal, Request for Information on Thermophilic Microorganisms

Dear Ms. Schutzenhofer:

AmerenUE Corporation (AmerenUE) is preparing an application to the U.S. Nuclear Regulatory Commission (NRC) to renew the operating license for Callaway Unit 1 (Callaway Nuclear Plant). The current operating license for Callaway Nuclear Plant will expire on October 18, 2024. Renewing the license would provide for an additional 20 years of operation beyond this license expiration date. The NRC requires license applicants to provide "... an assessment of the impact of the proposed action [license renewal] on public health from thermophilic organisms in the affected water" (10 CFR 51.53). Organisms of concern include the enteric pathogens Salmonella and Shigella, the *Pseudomonas aeruginosa* bacterium, thermophilic Actinomycetes ("fungi"), the many species of Legionella bacteria, and pathogenic strains of the free-living Naegleria amoeba.

As part of the license renewal process, AmerenUE is consulting with your office to determine whether there is any concern about the potential occurrence of these organisms in the Missouri River in the area of the Callaway plant. By contacting you early in the application process, we hope to identify any issues that we need to address or any information that we should provide to your office to expedite the NRC consultation.

AmerenUE (formerly known as Union Electric Company) has operated Callaway Nuclear Plant since 1984. The Callaway Plant is located in Callaway County, Missouri, approximately 10 miles southeast of the town of Fulton and five miles north of the Missouri River (see attached Figure 1). The Plant employs closed-cycle cooling, with a large natural-draft cooling tower dissipating waste heat from the circulating water system. Makeup water for the cooling tower is withdrawn from the Missouri River at an intake structure located at River Mile 115.4. Cooling tower blowdown is discharged a short but sufficient distance downstream

a subsidiary of Ameren Corporation

from the intake structure to ensure that there is no recirculation of heated water (see attached Figure 2). The maximum volume of blowdown discharged to the Missouri River (approximately 11 cfs), is extremely small compared to the normal flow of the Missouri River (approximately 70,000 cfs, on average), illustrating how little impact this blowdown has on river temperatures.

Callaway Power Plant's National Pollutant Discharge Elimination System (NPDES) permit (MO-0098001), which has an effective date of February 13, 2009 requires daily monitoring of blowdown (Outfall 002) temperatures before discharge into the Missouri River. A review of Discharge Monitoring Reports submitted to Missouri DNR in the third quarter of 2007, 2008, and 2009 showed blowdown temperatures in late summer (July-August-September) ranging from 73.5° to 98°F. The highest temperatures measured over this three-year period were recorded on August 4th and 5th, 2008. Water temperatures between 73°F and 98°F are well below the optimal temperature range (122°F-140°F) for growth and reproduction of thermophilic microorganisms. And, as noted previously, the Callaway Plant's discharge (blowdown) has very little effect on ambient water temperatures.

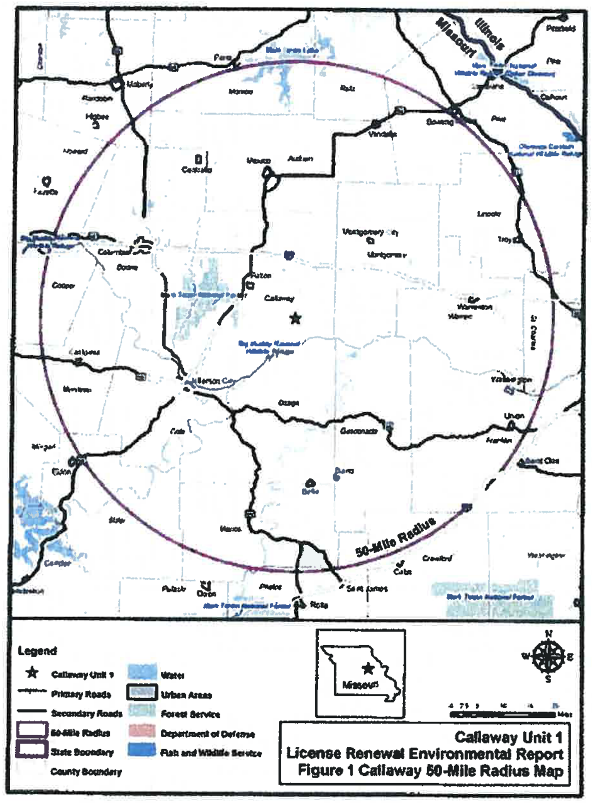
We would appreciate hearing from you by June 10, 2010, on any concerns you may have about these organisms. Please state potential public health effects over the license renewal term or your confirmation of AmerenUE's conclusion that operation of the Callaway Plant over the license renewal term would not stimulate growth of thermophilic pathogens in the Missouri River. This will enable us to meet our application preparation schedule. AmerenUE will include a copy of this letter and your response in the Environmental Report that will be submitted to the NRC as part of the Callaway license renewal application.

Please do not hesitate to contact me if you have any questions or require any additional information.

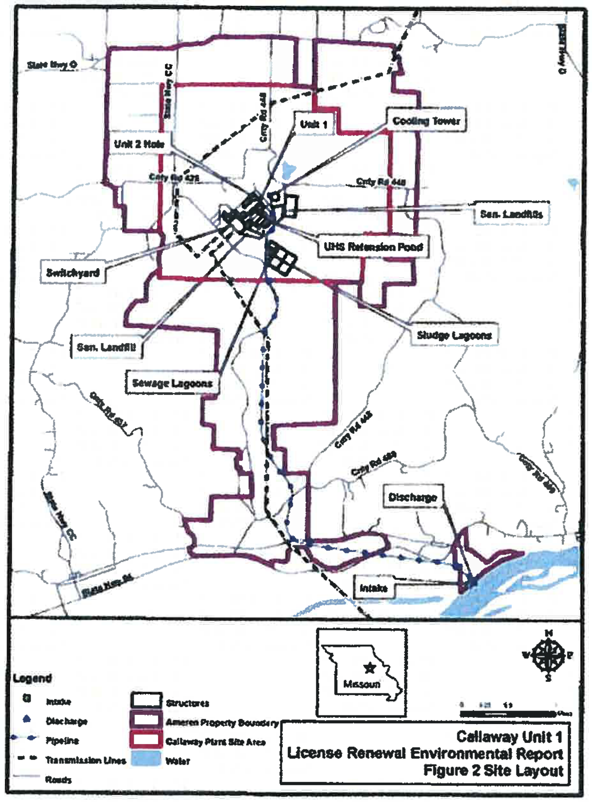
Sincerely,

Brian F. Holderness
Senior Environmental Health Physicist

Enclosure: Figure 1, Figure 2



Callaway Unit 1
License Renewal Environmental Report
Figure 1 Callaway 50-Mile Radius Map



Callaway Unit 1
License Renewal Environmental Report
Figure 2 Site Layout

bcc: Andrew Burgess (CA-460)
JCP/BFH
File WQ 3.1.1

Missouri Department of Health and Senior Services
P.O. Box 570, Jefferson City, MO 65102-0570 Phone: 573-751-6400 FAX: 573-751-6010
RELAY MISSOURI for Hearing and Speech Impaired 1-800-735-2966 VOICE 1-800-735-2466
Margaret T. Donnelly
Director

Jeremiah W. (Jay) Nixon
Governor

November 1, 2010

Mr. Brian F. Holderness
Senior Environmental Health Physicist
Ameren Services
One Ameren Plaza
1901 Chouteau Avenue
PO Box 66149
St. Louis, MO 63166-6149

Dear Mr. Holderness:

We have reviewed the "Callaway Unit 1 License Renewal, Request for Information on Thermophilic Microorganisms" dated April 15, 2010. This document states that "AmerenUE is consulting with your office (Missouri Department of Health and Senior Services) to determine whether there is any concern about the potential occurrence of these organisms in the Missouri River in the area of the Callaway plant."

In the subject heading of the letter, thermophilic microorganisms are specifically mentioned. However, within the text, other organisms are mentioned such as *Pseudomonas aeruginosa*, Legionella, and Naegleria amoeba.

It is our understanding of this letter that you would like to receive our input as to whether or not there is a potential concern that a significant number of any of these organisms may enter the Missouri River through the power plant's discharge system. This discharge system begins at the cooling tower and then travels below ground for approximately 5 miles before it discharges into the Missouri River. It is our understanding that the water temperature in the cooling tower is consistently 90° F to 100° F. The letter you sent us states that the water is between 73.5° F and 98° F when it is discharged into the Missouri River.

We agree that the temperatures of the water in the cooling tower and throughout the discharge system are not optimal for most thermophilic microorganisms. This would eliminate the likelihood of many of these organisms occurring in the system and therefore being discharged into the river. However, some Naegleria species are thermophilic. The growth range of these thermophilic amoebae is cited as being 25°C to 50°C (77°F to 122°F). The temperature range of these amoebae overlaps the temperature range of the cooling tower and discharge. Thus, the presence of these microorganisms in the system cannot be ruled out based solely on temperature.

Further, the conditions in the cooling tower and discharge are favorable for establishment and growth of other microorganisms. One organism that is known to exist in cooling towers in general is Legionella. At this time, there is no reason we know of why a microorganism, such as Legionella, could not exist in

Mr. Brian Holderness
June 21, 2010
Page 2 of 2

this system. We also do not know of anything in the system that would prevent these microorganisms from entering the Missouri River through the discharge system.

At this time, we do not have enough information to accurately make a conclusion on the wide range of microorganisms mentioned in the letter. We would be happy to review this further if you can provide additional information that would better allow us to draw a more definitive conclusion. This information may include reasons why microorganisms would not live and thrive in the cooling tower or discharge pipe and/or be present in the discharge prior to entering the river. If you have any questions, please contact Jeff Wenzel at (573) 751-6102.

Sincerely,

Cherri Baysinger, Chief
Bureau of Environmental Epidemiology

CB/JG/JW/mp

Ameren Services

Environmental Services
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One Ameren Plaza
1901 Chouteau Avenue
PO Box 66149
St. Louis, MO 63166-6149
314.621.3222

April 15, 2010

Mr. Kevin Mohammadi
Missouri Dept. of Natural Resources
Water Pollution Control Branch
P.O. Box 176
Jefferson City, Missouri 65102

Ameren

SUBJECT: Callaway Unit 1 License Renewal, Request for Information on Thermophilic Microorganisms

Dear Mr. Mohammadi:

AmerenUE Corporation (AmerenUE) is preparing an application to the U.S. Nuclear Regulatory Commission (NRC) to renew the operating license for Callaway Unit 1 (Callaway Nuclear Plant). The current operating license for Callaway Nuclear Plant will expire on October 18, 2024. Renewing the license would provide for an additional 20 years of operation beyond this license expiration date. The NRC requires license applicants to provide "...an assessment of the impact of the proposed action [license renewal] on public health from thermophilic organisms in the affected water" (10 CFR 51.53). Organisms of concern include the enteric pathogens Salmonella and Shigella, the *Pseudomonas aeruginosa* bacterium, thermophilic Actinomycetes ("fungi"), the many species of Legionella bacteria, and pathogenic strains of the free-living Naegleria amoeba.

As part of the license renewal process, AmerenUE is consulting with your office to determine whether there is any concern about the potential occurrence of these organisms in the Missouri River in the area of the Callaway plant. By contacting you early in the application process, we hope to identify any issues that we need to address or any information that we should provide to your office to expedite the NRC consultation.

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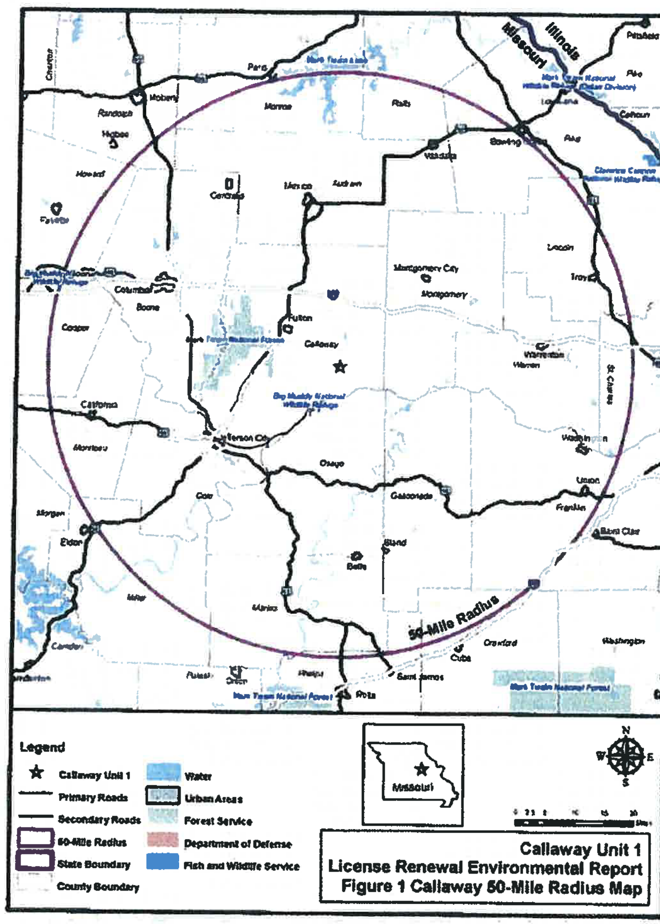
We would appreciate hearing from you by June 10, 2010, on any concerns you may have about these organisms. Please state potential public health effects over the license renewal term or your confirmation of AmerenUE's conclusion that operation of the Callaway Plant over the license renewal term would not stimulate growth of thermophilic pathogens in the Missouri River. This will enable us to meet our application preparation schedule. AmerenUE will include a copy of this letter and your response in the Environmental Report that will be submitted to the NRC as part of the Callaway license renewal application.

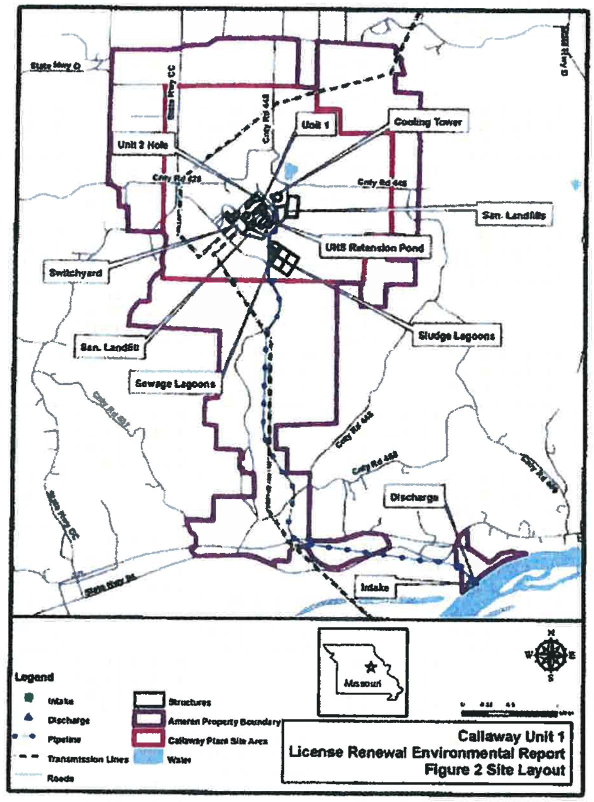
Please do not hesitate to contact me if you have any questions or require any additional information.

Sincerely,

Brian F. Holderness
Senior Environmental Health Physicist

Enclosure: Figure 1, Figure 2


Illinois
Missouri
50-Mile Radius
Legend
Callaway Unit 1
Primary Roads
Secondary Roads
50-Mile Radius
State Boundary
County Boundary
Water
Urban Areas
Forest Service
Department of Defense
Fish and Wildlife Service
Missouri
Callaway Unit 1
License Renewal Environmental Report
Figure 1 Callaway 50-Mile Radius Map


State Hwy O
State Hwy CC
Cnty Rd 448
Unit 1
Cooling Tower
Unit 2 Hole
Cnty Rd 428
Cnty Rd 448
San. Landfills
UHS Retension Pond
Switchyard
Sludge Lagoons
San. Landfill
Sewage Lagoons
Discharge
Intake
Legend
Intake
Discharge
Pipeline
Transmission Lines
Roads
Structures
Ameren Property Boundary
Callaway Plant Site Area
Water
Missouri
Callaway Unit 1
License Renewal Environmental Report
Figure 2 Site Layout

bcc: Andrew Burgess (CA-460)
JCP/BFH
File WQ 3.1.1

STATE OF MISSOURI Jeremiah W. (Jay) Nixon, Governor • Mark N. Templeton, Director
DEPARTMENT OF NATURAL RESOURCES
www.dnr.mo.gov

April 22, 2010

Mr. Brian Holderness
Senior Environmental Health Physicist
Ameren
One Ameren Plaza
1901 Chouteau Avenue, P.O. Box 66149
St. Louis, MO 63166-6149

Dear Mr. Holderness:

I am writing in response to your letter of April 15, 2010 asking if the Department of Natural Resources had any concerns about thermophilic microorganisms in the Missouri River near the Callaway Power Plant. We do.

The Department is the regulatory agency responsible for protection of water quality in Missouri and enforcement of state and federal clean water laws. We recently modified our state water quality standards (10 CSR 20-7.031) to include whole body contact recreation as a beneficial use on all of the Missouri River. We use the results of *E. coli* tests to judge whether or not there is an unacceptably high risk of waterborne disease for swimmers or others that may become fully immersed in the water, and we have *E. coli* data from several locations on the Missouri River. Data from the lower portion of the river, from Hermann to the mouth generally fails to meet our standards for whole body contact recreation, and thus is an area of concern.

However, we do not have any *E. coli* data from the portion of the river immediately downstream of the Callaway discharge, and thus do not know if this section of the river contains greater concentrations of microorganisms and thus a greater risk of waterborne disease.

While generally considered good indicators of waterborne disease risk, *E. coli* are probably not good indicators of the full range of thermophilic microorganisms, some of which are free living forms. *E. coli* are non-pathogenic enteric bacteria and are used as indicators of fecal contamination of the water and the likely presence of pathogenic enteric bacteria such as *Salmonella* and *Shigella*. The *E. coli* test does not confirm the presence of specific pathogenic enteric bacteria nor does it provide a quantitative estimate of the numbers of specific pathogenic bacteria. The *E. coli* test would likewise not be considered a good indicator of free-livings microorganisms such as *Pseudomonas aeruginosa* or *Naegleria* amoeba.

Recycled Paper

Mr. Brian Holderness
Page Two

To summarize, there are elevated levels of *E. coli* bacteria in the lower Missouri River, and there are substantial limitations on the ability of the *E. coli* test to characterize the full range of pathogenic thermophilic microorganisms that may be present in the river. Adding the possibility that the Callaway plant site and discharge may create environments more suitable for free living thermophilic microorganisms than are found in most other portions of the river, the Department cannot conclude that this section of the Missouri does not pose a significant risk of waterborne disease.

If you have any further questions, please do not hesitate to call me at (573) 751-7024 or email me at john.ford@dnr.mo.gov.

Sincerely,

WATER PROTECTION PROGRAM

John Ford, Unit Chief
Water Quality Assessment Unit

JF/lsm

ATTACHMENT F

SEVERE ACCIDENT MITIGATION ALTERNATIVES

EXECUTIVE SUMMARY

This report provides an analysis of the Severe Accident Mitigation Alternatives (SAMAs) that were identified for consideration by the Callaway Station. This analysis was conducted on a cost/benefit basis. The benefit results are contained in Section 4 of this report. Candidate SAMAs that do not have benefit evaluations have been eliminated from further consideration for any of the following reasons:

- The cost is considered excessive compared with benefits.
- The improvement is not applicable to Callaway Plant.
- The improvement has already been implemented at Callaway Plant or the intended effect of the improvement has already been achieved for Callaway Plant.

After eliminating a portion of the SAMAs for the preceding reasons, the remaining SAMAs are evaluated from a cost-benefit perspective. In general, the evaluation examines the SAMAs from a bounding analysis approach to determine whether the expected cost would exceed a conservative approximation of the actual expected benefit.

Major insights from this benefit evaluation process included the following:

- If all severe accident risk is eliminated, then the benefit in dollars over 20 years is $3,192,773.
- The largest contributors to the total benefit estimate are from onsite dose savings and onsite property costs including replacement power.
- A large number of SAMAs had already been addressed by existing plant features, modifications to improve the plant, existing procedures, or procedure changes to enhance human performance.
- Three SAMAs were identified as potentially cost-beneficial and are described in the following table.

Callaway Plant Potentially Cost Beneficial SAMAs

Callaway SAMA Number	Potential Improvement	Discussion	Additional Discussion
29	Provide capability for alternate injection via diesel-driven fire pump.	Improved injection capability.	Currently being evaluated by plant improvement program. Would use unborated water and portable pump (fire truck). Calculation of specific benefit of this SAMA was not performed since it is judged to be potentially low cost. Evaluation will consider impacts of injection of non-borated water.
160	Modifications to lessen impact of internal flooding path through Control Building dumbwaiter.	Lower impact of flood that propagates through the dumbwaiter	
162	Install a large volume Emergency Diesel Generator (EDG) fuel oil tank at an elevation greater than the EDG fuel oil day tanks.	Allows transfer of EDG fuel oil to the EDG day tanks on failure of the fuel oil transfer pumps.	

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

ACRONYMS USED IN ATTACHMENT F

AC	alternating current
AEPS	alternate emergency power system
AFW	auxiliary feedwater
AMSAC	ATWS mitigation system actuation circuitry
ASD	atmospheric steam dump
ATWS	anticipated transient without scram
BE	basic events
BOP	balance of plant
BWR	boiling water reactor
CCW	component cooling water
CDF	core damage frequency
CIF	containment isolation failure
CPI	consumer price index
CRD	control rod drive
CST	condensate storage tank
DC	direct current
EC	emergency coordinator
ECCS	emergency core cooling system
EDG	emergency diesel generator
EOP	emergency operating procedure
EPRI	electric power research institute
ESFAS	engineered safety features actuation system
ESW	essential service water
F&O	fact and observation
FIVE	fire induced vulnerability evaluation
HEP	human error probability
HFE	human failure event
HPSI	high pressure safety injection
HRA	human reliability analysis
HVAC	heating ventilation and air-conditioning system
IA	instrument air
IE	initiating event
ILRT	integrated leak rate test
IPE	individual plant examination
IPEEE	individual plant examination – external events
ISLOCA	interfacing system LOCA
LERF	large early release frequency
LOCA	loss-of-coolant accident

ACRONYMS USED IN ATTACHMENT F (CONTINUED)

LOOP	loss of off-site power
LSELS	load shedding and emergency load sequencing
MAAP	modular accident analysis program
MACCS2	MELCOR accident consequences code system, version 2
MACR	maximum averted cost-risk
MCC	motor control center
MOV	motor operated valve
MSL	mean sea level
MWe	megawatts electric
MWth	megawatts thermal
NEI	Nuclear Energy Institute
MSIV	main steam isolation valve
MSPI	mitigating systems performance index
NCP	normal charging pump
NFPA	National Fire Protection Association
NRC	U.S. Nuclear Regulatory Commission
NSAFP	non-safety auxiliary feedwater pump
OECR	off-site economic cost risk
PAG	protective action guidelines
PDS	plant damage state
PRA	probabilistic risk analysis
PORV	pressure operated relief valve
PWR	pressurized water reactor
RCP	reactor coolant pump
RHR	residual heat removal
RPV	reactor pressure vessel
RRW	risk reduction worth
RWST	refueling water storage tank
SAMA	severe accident mitigation alternative
SAMG	severe accident mitigation guidelines
SBO	station blackout
SER	safety evaluation report
SGTR	steam generator tube rupture
SI	safety injection
SLC	standby liquid control
SMA	seismic margins analysis
SPDS	safety parameter display system
SRP	standard review plan
SRV	safety relief valve

ACRONYMS USED IN ATTACHMENT F (CONTINUED)

SSC	structures, systems, and components
SW	service water
TD	turbine driven
TDAFW	turbine driven auxiliary feedwater
UHS	ultimate heat sink
UPS	uninterruptable power supply
UL	Underwriter’s Laboratories
VDC	volts direct current
WOG	Westinghouse owners group

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the analysis is to identify Severe Accident Mitigation Alternatives (SAMA) candidates at the Callaway Plant that have the potential to reduce severe accident risk and to determine whether implementation of the individual SAMA candidate would be cost beneficial. Nuclear Regulatory Commission (NRC) license renewal environmental regulations require SAMA evaluation.

1.2 REQUIREMENTS

- 10 CFR 51.53(c)(3)(ii)(L)
    - The environmental report must contain a consideration of alternatives to mitigate severe accidents "…if the staff has not previously considered severe accident mitigation alternatives for the applicant's plant in an environmental impact statement or related supplement or in an environment assessment..."
- 10 CFR 51, Subpart A, Appendix B, Table B-1, Issue 76
    - "…The probability weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to ground water, and societal and economic impacts from severe accidents are small for all plants. However, alternatives to mitigate severe accidents must be considered for all plants that have not considered such alternatives…."

2.0 METHOD

The SAMA analysis approach applied in the Callaway assessment consists of the following steps.

- Determine Severe Accident Risk

    Level 1 and 2 Probabilistic Risk Assessment (PRA) Model
    The Callaway PRA model (Section 3.1 – 3.2) was used as input to the Callaway Level 3 PRA analysis (Section 3.4).

    The PRA results include the risk from internal events, and tornado-induced loss of offsite power. Other external hazards including internal flooding and fires are not evaluated in the PRA. The risk contribution from these non-PRA, external hazards was evaluated in the Individual Plant Examination – External Events (IPEEE) [29] and is added to the risk from the internal events PRA for the SAMA evaluations.

    Level 3 PRA Analysis
    The Level 1 and 2 PRA output and site-specific meteorology, demographic, land use, and emergency response data was used as input for the Callaway Level 3 PRA (Section 3). This combined model was used to estimate the severe accident risk i.e., off-site dose and economic impacts of a severe accident.

- Determine Total Monetary Value of Severe Accident Risk / Maximum Benefit

  The NRC regulatory analysis techniques to estimate the total monetary value of the severe accident risk were used throughout this analysis. In this step these techniques were used to estimate the maximum benefit that a SAMA could achieve if it eliminated all risk i.e., the maximum benefit (Section 4).

- SAMA Identification

  In this step potential SAMA candidates (plant enhancements that reduce the likelihood of core damage and/or reduce releases from containment) were identified by Callaway Plant staff, from the PRA model, Individual Plant Examination (IPE) [28] and IPEEE recommendations, and industry documentation (Section 5). This process included consideration of the PRA importance analysis because it has been demonstrated by past SAMA analyses that SAMA candidates are not likely to prove cost-beneficial if they only mitigate the consequences of events that present a low risk to the plant.

- Preliminary Screening (Phase I SAMA Analysis)

  Because many of the SAMA candidates identified in the previous step are from the industry, it was necessary to screen out SAMA candidates that were not applicable to the Callaway design, candidates that had already been implemented or whose benefits have been achieved at the plant using other means, and candidates whose roughly estimated cost exceeded the maximum benefit. Additionally, PRA insights (specifically, importance measures) were used directly to screen SAMA candidates that did not address significant contributors to risk in this phase (Section 6).

- Final Screening (Phase II SAMA Analysis)

  In this step of the analysis the benefit of severe accident risk reduction was estimated for each of the remaining SAMA candidates and compared to an implementation cost estimate to determine net cost-benefit (Section 7). The benefit associated with each SAMA was determined by the reduction in severe accident risk from the baseline derived by modifying the plant model to represent the plant after implementing the candidate. In general, the modeling approach used was a bounding approach to first determine a bounding value of the benefit. If this benefit was determined to be smaller than the expected cost, no further modeling detail was necessary. If the benefit was found to be greater that the estimated cost, the modeling was refined to remove conservatism in the modeling and a less conservative benefit was determined for comparison with the estimated cost.

  Similarly, the initial cost estimate used in this analysis was the input from the expert panel (plant staff familiar with design, construction, operation, training and maintenance) meeting. All costs associated with a SAMA were considered, including design, engineering, safety analysis, installation, and long-term maintenance, calibrations, training, etc. If the estimated cost was found to be close to the estimated benefit, then first the benefit evaluation was refined to remove conservatism and if the estimated cost and benefit were still close, then the cost estimate was refined to assure that both the benefit calculation and the cost estimate are sufficiently accurate to justify further decision making based upon the estimates.

- Sensitivity Analysis
  The next step in the SAMA analysis process involved evaluation on the impact of changes in SAMA analysis assumptions and uncertainties on the cost-benefit analysis (Section 8).

- Identify Conclusions
  The final step involved summarizing the results and conclusions (Section 9).

3.0 SEVERE ACCIDENT RISK

The Callaway PRA models describe the results of the first two levels of the Callaway PRA. These levels are defined as follows: Level 1 determines core damage frequencies (CDFs) based on system analyses and human reliability assessments; Level 2 evaluates the impact of severe accident phenomena on radiological releases and quantifies the condition of the containment and the characteristics of the release of fission products to the environment. The Callaway models use PRA techniques to:

- Develop an understanding of severe accident behavior
- Understand the most likely severe accident consequences
- Gain a quantitative understanding of the overall probabilities of core damage and fission product releases
- Evaluate hardware and procedure changes to assess the overall probabilities of core damage and fission product releases.

The PRA was initiated in response to NRC Generic Letter 88-20 [1], which resulted in an IPE and IPEEE analysis. The current PRA model, Revision 4b, includes internal events and tornado induced loss of offsite power. Other events and initiators such as internal floods, fires, high winds, and seismic are evaluated in separate analyses and not directly combined with the internal events PRA model.

The PRA models used in this analysis to calculate severe accident risk are described in this section. The Level 1 PRA model (internal and external), the Level 2 PRA model, PRA model review history, and the Level 3 PRA model, are described in Sections 3.1, 3.2 and 3.4.

3.1 LEVEL 1 PRA MODEL

3.1.1 Internal Events

3.1.1.1 Description of Level 1 Internal Events PRA Model

The original Callaway PRA was developed to satisfy NRC's Generic Letter 88-20 requirement that each licensee perform an IPE to search for plant-specific severe accident vulnerabilities. Results of the Callaway PRA were submitted to the NRC, pursuant to this requirement, in September of 1992. The NRC Safety Evaluation Report (SER) on the Callaway IPE submittal was issued in May 1996. Since completion of the Callaway IPE (PRA), the model has been used to support numerous plant programs.

The Callaway internal events CDF is calculated to be 1.66E-05/year (Table 3-1) when ISLOCA is included in the evaluation (ISLOCA is not normally calculated as an event type in the Level 1 model). The Callaway PRA was used to generate a list of basic events sorted according to their risk reduction worth (RRW) values as related to CDF. The top events in this list are those events that would provide the greatest reduction in the Callaway CDF if the failure probability were set to zero. The events were reviewed down to the 1.005 level, which corresponds to about a 0.5 percent change in the CDF given 100 percent reliability of the event. Table 3-2 documents the disposition of each basic event in the Callaway PRA with RRW values of 1.005 or greater. Basic events that do not represent failures to structures, systems, or components (SSCs) were not included in the list.

Table 3-1. Contributions to Internal Events CDF

Initiating Event Type	Contribution to Internal CDF (/year)
Small LOCA	5.93E-06
Station Blackout	4.71E-06
SGTR	2.35E-06
RCP Seal LOCA	8.63E-07
Reactor Trip	7.88E-07
All Steam Line Breaks	3.35E-07
Intermediate LOCA	3.67E-07
Anticipated Transient without Scram (ATWS)	2.04E-07
ISLOCA	1.73E-07
Loss of Feedwater	1.65E-07
Very Small LOCA	1.29E-07
Loss of CCW	1.20E-07
Loss of SW	1.15E-07
Feedwater Line Break	9.01E-08
Loss of DC Vital Bus	6.93E-08
Loss of Offsite Power	4.65E-08
PORV Fails to Reclose	4.52E-08
Large LOCA	4.21E-08
Total	1.66E-05

LOCA = loss of coolant accident; SGTR = steam generator tube rupture; RCP = reactor coolant pump; CCW = component cooling water; SW = service water; DC = direct current; PORV = power operated relief valve

Table 3-2. Level 1 Importance List Review

Basic Event Name	Basic Event Description	RRW	Associated SAMA
IE-S2	SMALL LOCA INITIATING EVENT FREQUENCY	1.554	Safety Injection SAMAs
IE-T1	LOSS OF OFFSITE POWER INITIATING EVENT FREQUENCY	1.514	Loss of Offsite Power SAMAs
OP-XHE-FO-ECLRS2	OPERATOR FAILS TO ALIGN ECCS SYSTEMS FOR COLD LEG RECIRC	1.389	SAMA 36, see note on operator action events
IE-TSG	STEAM GENERATOR TUBE RUPTURE IE FREQUENCY	1.166	SGTR SAMAs
OP-XHE-FO-SGTRDP	OPERATOR FAILS TO C/D AND DEPRESS THERCS AFTER SGTR	1.082	see note on operator action events
OP-XHE-FO-SGTRWR	OPERATOR FAILS TO C/D AND DEPRESS RCSAFTER WATER RELIEF	1.082	see note on operator action events
IE-T3	TURBINE TRIP WITH MAIN FEEDWATER AVAILABLE IE FREQ	1.07	Initiating Event
BB-PRV-CC-V455A	PRESSURIZER PORV PCV455A FAILS TO OPEN	1.053	PORV SAMAs
BB-PRV-CC-V456A	PRESSURIZER PORV PCV456A FAILS TO OPEN	1.053	PORV SAMAs
NE-DGN-DR-NE01-2	DGNS CC FTR.	1.049	Loss of Offsite Power SAMAs
AE-CKV-DF-V120-3	CHECK VALVES AEV120121,122,123 COMMON CAUSE FAIL TO OPEN	1.048	Feedwater SAMAs
EF-PSF-TM-ESWTNB	ESW TRAIN B IN TEST OR MAINTENANCE	1.045	Service Water SAMAs
OP-XHE-FO-ACRECV	OPERATOR FAILS TO RECOVER FROM A LOSSOF OFFSITE POWER	1.044	SAMA 22
EF-PSF-TM-ESWTNA	ESW TRAIN A IN TEST OR MAINTENANCE	1.043	Service Water SAMAs
FAILTORECOVER-8	PROBABILITY THAT POWER IS NOT RECOV-ERED IN 8 HOURS.	1.042	Loss of Offsite Power SAMAs
EF-MDP-DR-EFPMPS	ESW PUMPS CC FTR.	1.041	Service Water SAMAs
OP-XHE-FO-CCWRHX	OPERATOR FAILS TO INITIATE CCW FLOW TO THE RHR HXS	1.037	Cooling Water SAMAs
FAILTORECOVER-12	CONDITIONAL PROB. THAT PWR IS NOT RE-COVERED IN 12 HRS.	1.035	Loss of Offsite Power SAMAs
EF-MDP-FR-PEF01A	ESW PUMP A (PEF01A)FAILS TO RUN	1.033	Service Water SAMAs

Table 3-2. Level 1 Importance List Review (Continued)

Basic Event Name	Basic Event Description	RRW	Associated SAMA
FB-XHE-FO-FANDB	OPERATOR FAILS TO ESTABLISH RCS FEED AND BLEED	1.032	see note on operator action events
OP-XHE-FO-ECLR	OPERATOR FAILS TO ALIGN ECCS SYSTEMS FOR COLD LEG RECIRC	1.031	see note on operator action events
TORNADO-T1-EVENT	CONDITIONAL PROB. TORNADO T(1) EVENT LOSS OF AEPS	1.031	SAMA 15
EF-MDP-FR-PEF01B	ESW PUMP B (PEF01B)FAILS TO RUN	1.025	Service Water SAMAs
EG-MDP-DS-EGPMP4	ALL 4 EG PUMPS CC FTS.	1.025	Cooling Water SAMAs
IE-S1	INTERMEDIATE LOCA INITIATING EVENT FREQUENCY	1.023	Safety Injection SAMAs
IE-TMSO	MAIN STEAMLINE BREAK OUTSIDE CTMT IE FREQUENCY	1.022	Initiating Event
AL-TDP-TM-TDAFP	TDAFP IN TEST OR MAINTENANCE	1.019	AFW Related SAMAs
BB-RCA-WW-RCCAS	TWO OR MORE RCCA'S FAIL TO INSERT (MECH. CAUSES)	1.019	ATWS SAMAs
EF-DRAIN-TRAINB	ALL TRAIN B SW UNAVAIL. DUE TO DRAINAGE OF EF TRAIN B.	1.019	SW SAMAs
EG-HTX-TM-CCWHXB	CCW TRAIN B TEST/MAINT. (E.G. HX B TEST/MAINT.)	1.016	CCW SAMAs
VL-ACX-DS-GL10AB	ROOM COOLER SGL10A, B CC FTS	1.014	HVAC SAMAs
EF-MOV-CC-EFHV37	VALVE EFHV37 FAILS TO OPEN	1.013	Service Water SAMAs
IE-S3	VERY SMALL LOCA INITIATING EVNET	1.013	Initiating Event
NE-DGN-FR-NE0112	DIESEL GENERATOR NE01 FTR - 12 HR MT	1.013	Loss of Offsite Power SAMAs
NE-DGN-FR-NE0212	DIESEL GENERATOR NE02 FTR - 12 HR MT	1.013	Loss of Offsite Power SAMAs
NE-DGN-TM-NE01	DIESEL GENERATOR NE01 IN TEST OR MAINTENANCE	1.013	Loss of Offsite Power SAMAs
NE-DGN-TM-NE02	DIESEL GENERATOR NE02 IN TEST OR MAINTENANCE	1.013	Loss of Offsite Power SAMAs
IE-T2	LOSS OF MAIN FEEDWATER IE FREQUENCY	1.012	Initiating Event
NE-DGN-FS-NE01	DIESEL GENERATOR NE01 FAILS TO START	1.012	Loss of Offsite Power SAMAs
AL-TDP-FS-TDAFP	TDAFP FAILS TO START	1.011	AFW Related SAMAs

Table 3-2. Level 1 Importance List Review (Continued)

Basic Event Name	Basic Event Description	RRW	Associated SAMA
EF-MDP-FS-PEF01A	ESW PUMP A (PEF01A)FAILS TO START	1.011	Service Water SAMAs
EJ-PSF-TM-EJTRNB	RHR TRAIN B IN TEST OR MAINTENANCE	1.011	Core Cooling SAMAs
NE-DGN-FS-NE02	DIESEL GENERATOR NE02 FAILS TO START	1.011	Loss of Offsite Power SAMAs
EF-MDP-DS-EFPMPS	ESW PUMPS CC FTS	1.01	SW SAMAs
EF-MOV-CC-EFHV38	VALVE EFHV38 FAILS TO OPEN	1.01	Service Water SAMAs
OP-XHE-FO-AEPS1	OPERATOR FAILS TO ALIGN AEPS TO NB BUS IN 1 HR	1.01	Loss of Offsite Power SAMAs
VD-FAN-FR-CGD02A	UHS C.T. ELEC. ROOM SUPPLY FAN CGD02A FAILS TO RUN	1.01	HVAC SAMAs
AE-CKV-DF-V124-7	CHECK VALVES AEV124,125,126,127 COMMON CAUSE FAIL TO OPEN	1.009	SAMA 163
AEPS-ALIGN-NB02	PDG ALIGN TO NB02 (FAIL TO ALIGN PDG TO NB01)	1.009	Loss of Offsite Power SAMAs
EF-MDP-FS-PEF01B	ESW PUMP B (PEF01B)FAILS TO START	1.009	Service Water SAMAs
EF-MOV-D2-V37-38	VALVES EFHV37 & 38 COMMON CAUSE FAIL TO CLOSE (2 VALVES)	1.009	Service Water SAMAs
FAILTOMNLINSRODS	OPERATOR FAILS TO MANUALLY DRIVE RODS INTO CORE	1.009	see note on operator action events
OP-COG-FRH1	OPERATORS FAIL TO DIAGNOSE RED PATH ON HEAT SINK	1.009	see note on operator action events
VD-FAN-FR-CGD02B	UHS C.T. ELEC. ROOM SUPPLY FAN CGD02B FAILS TO RUN	1.009	HVAC SAMAs
AEPS-ALIGN-NB01	PDG ALIGN TO NB01 (FAIL TO ALIGN PDG TO NB02)	1.008	Loss of Offsite Power SAMAs
AL-XHE-FO-SBOSGL	OPERATOR FAILS TO CONTROL S//G LEVEN AFTER COMPLEX EVENT	1.008	see note on operator action events
EF-MOV-OO-EFHV59	VALVE EFHV59 FAILS TO CLOSE	1.008	Service Water SAMAs
EJ-PSF-TM-EJTRNA	RHR TRAIN A IN TEST OR MAINTENANCE	1.008	Core Cooling SAMAs
FAILTOREC-EFHV59	OPERATORS FAIL TO RECOVER (CLOSE) EFHV59	1.008	see note on operator action events
VL-ACX-FS-SGL10A	ROOM COOLER FAN SGL10A FAILS TO START	1.008	HVAC SAMAs
AL-PSF-TM-ALTRNB	AFW TRAIN B IN TEST OR MAINTENANCE	1.007	AFW Related SAMAs

Table 3-2. Level 1 Importance List Review (Continued)

Basic Event Name	Basic Event Description	RRW	Associated SAMA
BN-TNK-FC-RWSTUA	RWST UNAVAILALBE	1.007	SAMA 171
EG-MDP-DR-EGPMP4	ALL 4 EG PUMPS CC FTR.	1.007	CCW SAMAs
EJ-XHE-FO-PEJ01	OPERATOR FAILS TO START AN RHR PUMP FOR LONG TERM C/D	1.007	see note on operator action events
IE-TC	LOSS OF ALL COMPONENT COOLING WATER IE FREQUENCY	1.007	CCW SAMAs
IE-TSW	LOSS OF SERVICE WATER INITIATING EVENT	1.007	SW SAMAs
SA-ICC-AF-RWSTL1	NO RWST LOW LEVEL SIGNAL AVAILABLE (SEP GRP 1)	1.007	Core Cooling SAMAs
AE-XHE-FO-MFWFLO	FAILURE TO RE-ESTABLISH MFW FLOW DUE TO HUMAN ERRORS	1.006	see note on operator action events
BG-MDP-FR-NCP	MOTOR DRIVEN CHARGING PUMP FAILS TO RUN	1.006	ECCS SAMAs
EJ-MDP-DS-EJPMPS	RHR PUMPS CC FAIL TO START	1.006	Core Cooling SAMAs
EJ-MOV-CC-V8811A	VALVE EJHV8811A FAILS TO OPEN	1.006	Core Cooling SAMAs
IE-TFLB	FEEDLINE BREAK DOWNSTREAM OF CKVS IE FREQUENCY	1.006	Feedwater SAMAs
NF-ICC-AF-LSELSA	LOAD SHEDDER TRAIN A FAILS TO SHED LOADS	1.006	Loss of Offsite Power SAMAs
OP-XHE-FO-SGISO	OPERATOR FAILS TO ISOLATE THE FAULTED S/G FOLLOWING SGTR	1.006	see note on operator action events
SA-ICC-AF-MSLIS	NO SLIS ACTUATION SIGNAL	1.006	ATWS SAMAs
SA-ICC-AF-RWSTL4	NO RWST LOW LEVEL SIGNAL AVAILABLE (SEP GRP 4)	1.006	Core Cooling SAMAs
VL-ACX-FS-SGL10B	ROOM COOLER FAN SGL10B FAILS TO START	1.006	HVAC SAMAs
VM-BDD-CC-GMD001	DAMPER GMD001 FAILS TO OPEN	1.006	HVAC SAMAs
VM-BDD-CC-GMD004	DAMPER GMD004 FAILS TO OPEN	1.006	HVAC SAMAs
VM-EHD-CC-GMTZ1A	ELEC/HYDR OP DAMPER GMTZ01A FAILS TO OPEN	1.006	HVAC SAMAs
AL-MDP-FR-MDAFPB	MDAFPB FAILS TO RUN AFTER START	1.005	AFW Related SAMAs
AL-TDP-FR-TDAFP	TDAFP FAILS TO RUN AFTER START	1.005	AFW Related SAMAs

Table 3-2. Level 1 Importance List Review (Continued)

Basic Event Name	Basic Event Description	RRW	Associated SAMA
BM-AOV-OO-BMHV1	BLOWDOWN ISOLATION VALVE BMHV0001 FAILS TO CLOSE	1.005	AFW Related SAMAs
BM-AOV-OO-BMHV4	BLOWDOWN ISOLATION VALVE BMHV0004 FAILS TO CLOSE	1.005	AFW Related SAMAs
EJ-MOV-CC-V8811B	VALVE EJHV8811B FAILS TO OPEN	1.005	Core Cooling SAMAs
EJ-MOV-D2-8811AB	VALVES EJHV8811A & B COMMON CAUSE FAIL TO OPEN	1.005	Core Cooling SAMAs
NE-DGN-FR-NE01-2	DGN NE01 FAILS TO RUN (1 HR MISSION TIME)	1.005	Loss of Offsite Power SAMAs
NF-ICC-AF-LSELSB	LOAD SHEDDER TRAIN B FAILS TO SHED LOADS	1.005	Loss of Offsite Power SAMAs
VM-BDD-CC-GMD006	DAMPER GMD006 FAILS TO OPEN	1.005	HVAC SAMAs
VM-BDD-CC-GMD009	DAMPER GMD009 FAILS TO OPEN	1.005	HVAC SAMAs
VM-EHD-CC-GMTZ11	ELEC/HYDR OP DAMPER GMTZ11A FAILS TO OPEN	1.005	HVAC SAMAs

RCS = reactor coolant system; IE = initiating event; CC = common cause; FTR = fail to run; ESW = essential service water; ECCS = emergency core cooling system; FTS = fail to start

Note 1 – The current plant procedures and training meet current industry standards. There are no additional specific procedure improvements that could be identified that would affect the result of the human error probability (HEP) calculations. Therefore, no SAMA items were added to the plant specific list of SAMAs as a result of the human actions on the list of basic events with RRW greater than 1.005.

3.1.1.2 Level 1 PSA Model Changes Since IPE Submittal

The Callaway Level 1 internal events PRA model was developed in response to USNRC Generic Letter 88-20 [1]. The results of the internal events PRA model, developed for the IPE, were submitted to the NRC via letter ULNRC-2703, dated September 29, 1992. Following development and submittal of the results of the initial Callaway internal events PRA model, the model was revised a number of times, to maintain fidelity with the as-built, as-operated plant, to improve modeling methods, etc. Table 3-3, below, delineates the various internal events PRA model updates, the CDF resulting from each, and a high-level summary of the changes made to the internal events model. Additional detail on the various PRA model updates is provided later in this section.

Table 3-3. Callaway Internal Events PRA Update History

PRA Update	Completion Date	Selected Changes from Previous Update	Internal Events CDF (yr^{-1})
IPE	9/92	NA	5.85E-5
First Update	2/99	• Updated internal flooding analysis. • Incorporated the Normal Charging Pump. • Incorporated the swing battery chargers.	3.96E-5
Second Update	10/00	• Revised EDG mission times. • Incorporated self-assessment findings. (Self-assessment conducted in preparation for owners' group peer review.)	3.09E-5
Third Update	5/04	• Updated internal flooding analysis. • Expanded common cause failure modeling. • Incorporated plant-specific LOOP frequency. • Credited recovery of only offsite power following station blackout.	4.43E-5
Fourth Update	4/06	• Updated HRA for risk-significant HFEs. • Implemented very low quantification cutset truncation value to comply with MSPI requirements.	5.18E-5
Update 4A	11/10	• Incorporated Non-Safety Aux. Feedwater Pump. • Incorporated temporary diesel-generator modification.	2.64E-5
Update 4B	4/11	• Incorporated the Alternate Emergency Power System modification.	2.61E-5
LOOP = loss of offsite power; HRA = human reliability analysis; HFE = human failure event; MSPI = mitigating system performance index			

The various internal events PRA updates, delineated above, are described in more detail, below.

First PRA Update

The first update of the Callaway internal events PRA was completed in February 1999. The primary purpose of this revision to the internal events PRA was to factor plant physical and data changes into the PRA model, such that fidelity between the PRA model and the as-built, as operated plant was maintained. Following are noteworthy changes made to the PRA model.

- The internal flooding analysis was revised.
- Valves BGHV8357A and B, involved in the RCP seal injection function, were changed from solenoid-operated valves to motor-operated valves.
- In the RCP seal injection function, the positive displacement charging pump (PDP) was replaced with a centrifugal charging pump, i.e., the Normal Charging Pump (NCP). The NCP is not dependent on separate cooling systems. The NCP provided for additional mitigation capability following a loss of all service water or loss of all component cooling water initiating event.
- The possibility that the standby train of ESW is drained for maintenance was added to the model. In this configuration, the affected ESW heat loads cannot be cooled by non-safety service water.
- A recovery event was added for valve EFHV59.
- Logic for re-start of CCW pump train A was added to the model.
- A recovery event was added for valve EFHV52.
- A test/maintenance event was added to the model for the safety injection accumulators.
- Start logic for the emergency diesel-generator fuel oil transfer pumps was changed in the model to reflect a plant modification.
- System modeling was added to reflect a plant modification that added a swing battery charger to each train of 125 VDC power.
- System modeling was changed to require two (2) atmospheric steam dumps (ASDs), for cooldown and depressurization, as opposed to one (1) ASD.
- Certain initiating event frequencies were updated.
- Test/maintenance unavailabilities were updated.

The CDF generated via quantification of the First PRA Update was 3.96E-5 per year. The impact of the individual changes made to the PRA, above, was not determined.

Second PRA Update

The Second PRA Update was completed in October 2000. The purpose of this update was to address findings stemming from a self-assessment, which was conducted prior to a Westinghouse Owners' Group (WOG) PRA peer review. Following are noteworthy changes made to the internal events PRA in the Second PRA Update.

- Non-safety service water system models were revised to incorporate pump runout scenarios.
- LOCA initiating event frequencies were updated.
- A correction was made to the high-head ECCS system model used to quantify station blackout with power recovery.
- Emergency diesel-generator mission times were refined.
- All event tree transfer sequences were accounted for in this update. (Previously, some transfer sequences were excluded, based on their low frequencies.)

The CDF generated via quantification of the Second PRA Update was 3.09E-5 per year. The impact of the individual changes made to the PRA, above, was not determined.

Third PRA Update

The Third PRA Update was completed in May 2004. The primary purposes of this update were to maintain fidelity between the plant and PRA model, and to address a number of findings from the WOG PRA peer review. Following are noteworthy changes made to the internal events PRA in the Third PRA Update.

- The internal flooding analysis was revised.
- The feedwater isolation valve actuators were changed to system process medium actuators.
- A common cause check valve failure was added to the main feedwater fault tree.
- The system model representing failure of a pressurizer power-operated relief or safety valve to reclose following a transient was enhanced.
- The loss of all service water initiating event frequency model was revised.
- Automatic strainers were added to the normal service water system models.
- Common cause failure of the essential service water strainers was added to the system models.
- The loss of component cooling water initiating event frequency model was revised.
- Common cause modeling was expanded for rotating components.
- LOOP and other initiator frequencies were updated.
- Recovery of only offsite power was credited following a station blackout.
- Component failure rate data was updated.
- Test/maintenance unavailability data was updated.

The CDF generated via quantification of the Third PRA Update was 4.43E-5 per year. The impact of the individual changes made to the PRA, above, was not determined.

Fourth PRA Update

The Fourth PRA update was completed in April 2006. The purposes of the Fourth Update were to maintain fidelity with the plant, address additional findings from the WOG peer review and implement model enhancements in support of the MSPI. Following are noteworthy changes made to the internal events PRA in the Fourth PRA Update.

- Revised the main steam and feedwater isolation fault tree models.
- Implemented a revised HRA for risk-significant HFEs.
- Implemented very low quantification cutset truncation values to comply with MSPI requirements.

The CDF generated via quantification of the Fourth PRA Update was 5.18E-5 per year. The impact of the individual changes made to the PRA, above, was not determined.

PRA Update 4A

This PRA update was completed in November 2010. The primary motivation for this PRA update was to credit plant modifications implemented to enhance nuclear safety. Following are noteworthy changes made to the internal events PRA in Update 4A.

- Incorporated the Non-Safety Aux. Feedpump (NSAFP).
- Updated common cause failure data.
- Converted initiating event frequency values to a per reactor-year basis.
- Incorporated a temporary EDG modification.

The CDF generated via quantification of PRA Update 4A was 2.64E-5 per year. The impact of the individual changes made to the PRA, above, was not determined.

PRA Update 4B

This PRA update was completed in April 2011. The primary motivation for this PRA update was to credit the Alternate Emergency Power System (AEPS) modification. Following are noteworthy changes made to the internal events PRA in Update 4B.

- Incorporated the AEPS modification.
- The Auxiliary Feedwater fault tree was revised based on balance of plant (BOP) emergency safety features actuation system (ESFAS) attributes.

The CDF generated via quantification of PRA Update 4B was 2.61E-5 per year. The impact of the individual changes made to the PRA, above, was not determined.

3.1.2 External Events

3.1.2.1 Internal Fires Risk Analysis

For the IPEEE, Callaway used the EPRI FIVE methodology. The assumptions and screening criteria used in implementing the FIVE methodology for Callaway are discussed in the IPEEE submittal. The Callaway FIVE analysis has not been updated since the IPEEE. A fire PRA is under development to support transition of the Callaway fire protection program to NFPA 805 requirements; however, this fire model was not available for performance of the SAMA analysis. The preliminary results of the NFPA 805 fire PRA modeling show a CDF of 2.00E-5/yr. which was used in this analysis. This fire CDF is consistent with previous analysis results.

3.1.2.2 Seismic Events Risk Analysis

For the IPEEE, Callaway used the EPRI seismic margins analysis (SMA) method. This analysis was transmitted to NRC in the IPEEE submittal. The latest estimate of the Callaway seismic contribution to CDF is 5.00E-6/yr. A 2010 NRC risk assessment relating to Generic Issue 199 estimated Callaway seismic core damage frequency at approximately 2E-6/yr using 2008 USGS seismic hazard curves and a weakest link model. Comparing this to the frequency employed in the SAMA analysis, it appears that Callaway's 5E-6/yr seismic contribution to CDF is conservative relative to the NRC assessment under Generic Issue 199.

3.1.2.3 Other External Events Risk Analysis

To address potential vulnerabilities from the effects of high winds, floods, and transportation and nearby facility accidents for the IPEEE, Callaway reviewed plant-specific hazard data and its licensing basis. Callaway also determined that there were no significant changes, relative to these sources of risk, since the Operating License was issued. The only risk impact from high winds is from tornado events. This risk is estimated to be 2.50E-5/yr. Conformance to the 1975 Standard Review Plan (SRP) was also assessed. Callaway's assessment of these sources of external events risk has not been updated since the IPEEE.

The Callaway internal events PRA model does not include an analysis of internal flooding. The risk due to internal floods was analyzed in the Callaway IPE, but not included in the internal events PRA model. The IPE determined the contribution to CDF from internal flooding to be 9.14E-6/yr.

The Callaway IPEEE concluded that external flooding does not present a risk to the Callaway Plant. The Probable Maximum Flood for the Missouri River in the vicinity of the Callaway Plant is estimated to be 548 feet above mean sea level (msl). The Callaway Plant grade level is 840 feet above msl and is not impacted by river flooding on the Missouri River. Flooding due to intense local rainfall is estimated to result in local ponding to elevation 839.87 feet above msl. This is 0.13 feet below plant grade and 0.63 feet below the safety-related facilities standard plant elevation.

3.1.2.4 Treatment of External Events in the SAMA Analysis

The contributions of the external events initiators are summarized in Table 3-4:

Table 3-4. IPEEE CONTRIBUTOR SUMMARY EXTERNAL EVENT INITIATOR GROUP CDF

Contributor	CDF
High Winds	2.50E-05/yr.
Internal Flooding	9.14E-06/yr.
Fire	2.00E-05/yr.
Seismic	5.00E-06/yr.
External CDF	5.91E-05/yr.

The method chosen to account for external events contributions in the SAMA analysis is to use a multiplier on the internal events results. This is simply the ratio of total CDF (including internal and external) to only internal CDF. This ratio is called the External Events multiplier and its value is calculated as follows:

EE Multiplier = (1.66E-05+5.91E-05) / (1.66E-05) = 4.57

3.2 LEVEL 2 PSA MODEL CHANGES SINCE IPE SUBMITTAL

The full Level 2 analysis, performed for the IPE and addressed in the IPE submittal, was used, in 2000, for development of a large early release frequency (LERF) model. The driver for this effort was that LERF was the only Level 2-related metric used in most risk-informed applications. In 2002, the LERF model was updated to reflect the internal events PRA Second Update.

The Level 2 PRA model was updated in 2011. As part of the update, the model:

- includes containment bypass events, containment isolation failures, early containment failure modes, induced steam generator tube ruptures, and late containment failure modes
- applies plant damage state definitions to the Level 1 accident sequences consistent with the updated Level 2 analysis structure and incorporates a realistic, plant-specific analysis of significant containment challenges
- addresses dependencies between Level 1 and Level 2 basic events
- models the probability of RCS hot leg or surge line failure during high-pressure core damage scenarios
- determines the sequences that contribute to LERF based on source term calculations using MAAP 4.0.7
- considers whether additional credit for scrubbing of fission products may affect the significant contributors to LERF
- groups accident progression sequences into release categories based on the containment event tree end states and calculates the frequency of each release category and the release characteristics (timing and magnitude) for each release category

- Performs the LERF quantification based on requirement LE-E4 of the ASME PRA Standard.
- performs LERF calculations including uncertainty and sensitivity studies as appropriate
- reviews significant large early release accident progression sequences for reasonableness and determines if credit for repair, operation in adverse environments, or operation after containment failure may reduce LERF.

Large early release frequencies, generated with the initial and updated LERF models, are provided in Table 3-5.

Table 3-5. LERF Models and Frequencies

LERF Model	Completion Date	LERF (yr^{-1})
Initial LERF Model (used First Update Level 1 model (2/99))	10/2000	4.22E-7
Updated LERF Model (uses Second Update Level 1 model (10/00))	6/2002	4.20E-7
Updated full Level 2 Model (used 4B Level 1 model)	4/2011	2.73E-6

There were no changes to major modeling assumptions, containment event tree structure, accident progression, source term calculations or other Level 2 attributes, used in the IPE Level 2 analysis, when developing the initial and updated models.

3.2.1. Level 1 to Level 2 Interface

Plant damage states and their representative Level 1 accident scenarios provide an interface between the Level 1 and Level 2 analyses. Each Level 1 accident sequence that leads to core damage consists of a unique combination of an initiating event followed by the success or failure of various plant systems (including operator actions). Due to the large number of accident sequences created by the Level 1 PRA, the Level 1 sequences that result in core damage can be grouped into plant damage state (or accident class) bins. Each bin collects all of those sequences for which the progression of core damage, the release of fission products from the fuel, the status of the containment and its safeguards systems, and the potential for mitigating the potential radiological source terms are similar. The detailed containment event tree then analyzes each plant damage state bin as a group.

Plant damage state bins can be used as the entry states to the containment event tree quantification (similar to initiating events for the Level 1 PRA), or can be used to direct sequences onto specific containment event tree branches. The plant damage state (PDS) bins are characterized by the status of containment bypass due to SGTR or ISLOCA, the status of offsite/emergency power, reactor coolant system pressure, and the status of water in the reactor cavity.

The definition of plant damage states incorporates information from the outcome of the Level 1 analysis that is important to the determination of containment response and the release of radioactive materials into the environment.

The modeling approach for the current revision of the Level 2 PRA uses the WinNUPRA software package, which allows the incorporation of complete Level 1 results information (i.e., cutsets) into the Level 2 PRA model. This permits the somewhat artificial boundary between the Level 1 event trees and the containment event tree that exists in some Level 2 analyses to be eliminated from this analysis. Safety functions that may have been modeled in separate bridge trees can also be directly incorporated into the WinNUPRA model. That is, active systems such as containment coolers and containment spray are modeled in the Level 2 analysis alongside the Level 2 phenomenological events in order to accurately capture system dependencies such as actuation signals, electrical power, and cooling water.

Along with containment systems performance, the containment event trees (CETs) consider the influence that physical and chemical processes have on the integrity of the containment and on the release of fission products once core damage has occurred. The important physical conditions in the RCS and the containment include the pressure inside the reactor vessel at the onset of core damage, whether the reactor cavity is flooded, and the availability of cooling on the secondary side of the steam generators.

In this study, the RCS pressure identified in the definition of PDSs is that which occurs at the onset of core damage. Events that could influence the change in pressure after the onset of core damage but prior to vessel breach are addressed in the CETs. The two most important effects of high pressure for a Level 2 PRA are challenges to the steam generator tubes and direct containment heating. Because of this, three RCS pressure level categories are considered in the PRA: high, medium, or low. Pressure level assignment was based on the accident initiators (e.g., medium and large LOCAs result in low pressure) and the availability of feedwater (which results in pressure low enough to alleviate steam generator tube challenges, but has slightly different effects on accident progression – categorized as medium pressure). In general, either a medium/large LOCA, depressurization through the PORVs, or hot leg creep rupture is required to reach low pressure. Smaller LOCAs and transients with steam generators being fed are considered to be at medium pressure at the time of core damage. Without secondary side cooling, smaller LOCAs and transients are modeled as high pressure scenarios.

The presence of water in the reactor cavity is important to containment response because the interaction of this water with hot core debris can affect the immediate containment response at the time of vessel breach and the long-term cooling of core debris. Water in the reactor cavity at the time of vessel breach is an important issue for containment response due to its effect on hydrogen generation, the possibility of steam explosion, and quenching of debris.

Because of the way individual sequences are processed through WinNUPRA using unique house event files, sequences with a loss of offsite power or a station blackout must be identified in order to carry those house event settings through the Level 2 analysis. Identification of power status as a plant damage state parameter ensures that dependencies between the Level 1 and Level 2 analyses are properly captured.

Initiating events that bypass containment are treated separately in the Level 2 CET. As mentioned in the discussion of top events, containment bypass is identified by ISLOCA and SGTR events.

3.2.2 Plant Damage State Classifications

- Containment Bypass
  - B: Bypass
    - BI: Bypass due to ISLOCA
    - BT: Bypass due to tube rupture
- Status of Electric Power
  - O: Loss of Offsite Power
  - S: Station Blackout
- RCS Pressure
  - H: High Pressure (sequences without RCS leakage or SG cooling)
  - M: Medium Pressure (sequences without RCS leakage, but with SG cooling)
  - L: Low Pressure (sequences that depressurize due to significant RCS leakage)
- Reactor Cavity
  - W: Wet cavity (due to injection of RWST during Level 1)
  - D: Dry cavity

The PDS is therefore a two or three character code that defines the important sequence characteristics for the Level 2 analysis. The assignment of each individual Level 1 sequence is documented in Appendix B. In addition to the general PDS assignment, each PDS is supplemented with additional characters to differentiate the house event file to be used during quantification. This results in a total PDS code up to five characters in length. For example, sequence number 2 from the TAT1 Level 1 event tree, TAT1S02 is assigned to plant damage state OHDTA: O for Loss of Offsite Power, H for high pressure, D for dry reactor cavity, and TA for house settings file HSE-T1.

The Callaway PRA was used to generate a list of basic events sorted according to their RRW values as related to LERF and Large Late Release. The top events in this list are those events that would provide the greatest reduction in the Callaway LERF and Large Late Release if the failure probability were set to zero. The events were reviewed down to the 1.005 level, which corresponds to about a 0.5 percent change in the LERF/Large Late Release given 100 percent reliability of the event. Table 3-6 documents the disposition of each basic event in the Callaway PRA with RRW values of 1.005 or greater as related to LERF. Table 3-7 documents the disposition of each basic event in the Callaway PRA with RRW values of 1.005 or greater as related to Late releases. Basic events that do not represent SSC failures were not included in the list.

Table 3-6. LERF Importance Review

Basic Event Name	Basic Event Description	RRW	Associated SAMA
IE-TSG	STEAM GENERATOR TUBE RUPTURE IE FREQUENCY	6.808	SGTR SAMAs
OP-XHE-FO-SGTRDP	OPERATOR FAILS TO C/D AND DEPRESS THERCS AFTER SGTR	1.835	See note on operator action events
OP-XHE-FO-SGTRWR	OPERATOR FAILS TO C/D AND DEPRESS RCSAFTER WATER RELIEF	1.835	See note on operator action events
BB-PRV-CC-V455A	PRESSURIZER PORV PCV455A FAILS TO OPEN	1.314	SAMA 161
BB-PRV-CC-V456A	PRESSURIZER PORV PCV456A FAILS TO OPEN	1.314	SAMA 161
BI	ISLOCA CDF	1.068	ISLOCA SAMAs
OP-XHE-FO-SGISO	OPERATOR FAILS TO ISOLATE THE FAULTEDS/G FOLLOWING SGTR	1.037	See note on operator action events
IE-T1	LOSS OF OFFSITE POWER INITIATING EVENT FREQUENCY	1.034	Loss of Offsite Power SAMAs
IE-T3	TURBINE TRIP WITH MAIN FEEDWATER AVAILABLE IE FREQ	1.028	Initiating Event
AB-ARV-DF-SGPRVS	S/G PORVS ABPV01, 02, 03, & 04 COMMONCAUSE FAIL TO OPEN	1.024	SAMA 89
AB-ARV-TM-ABPV03	S/G PORV ABPV0003 ISOLATED FOR TEST/MAINTENANCE	1.024	SAMA 89
FB-XHE-FO-FANDB	OPERATOR FAILS TO ESTABLISH RCS FEED AND BLEED	1.023	SAMA 36, see note on operator action events
AE-CKV-DF-V120-3	CHECK VALVES AEV120121,122,123 COMMON CAUSE FAIL TO OPEN	1.022	SAMA 163
AB-ARV-TM-ABPV01	S/G PORV ABPV0001 ISOLATED FOR TEST/MAINTENANCE	1.02	SAMA 89
BB-RCA-WW-RCCAS	TWO (2) OR MORE RCCA's FAIL TO IN- SERT (MECH. CAUSES)	1.02	ATWS SAMAs
SA-ICC-AF-MSLIS	NO SLIS ACTUATION SIGNAL	1.016	Containment Isolation SAMAs
AB-ARV-TM-ABPV04	S/G PORV ABPV0004 ISOLATED FOR TEST/MAINTENANCE	1.015	SAMA 89
AB-PHV-OO-ABHV17	MSIV "B" (AB-HV-17) FAILS TO CLOSE ON DEMAND	1.015	SAMA 89
TORNADO-T1-EVENT	CONDITIONAL PROB. TORNADO T(1) EVENT LOSS OF AEPS	1.014	SAMA 15
BB-RLY-FT-72455	72 RELAY FAILS TO TRANSFER	1.011	SAMA 79
BB-RLY-FT-72456	72 RELAY FAILS TO TRANSFER	1.011	SAMA 79
BB-RLY-FT-AR455	AUX. RELAY FAILS TO TRANSFER	1.011	SAMA 79
BB-RLY-FT-AR456	AUX. RELAY FAILS TO TRANSFER	1.011	SAMA 79

Table 3-6. LERF Importance Review

Basic Event Name	Basic Event Description	RRW	Associated SAMA
NE-DGN-DR-NE01-2	DGNS CC FTR.	1.01	Loss of Offsite Power SAMAs
AB-ARV-CC-ABPV04	S/G PORV ASPV0004 FAILS TO OPEN	1.009	SAMA 89
VL-ACX-DS-GL10AB	ROOM COOLER SGL10A, B CC FTS	1.009	HVAC SAMAs
AB-ARV-CC-ABPV01	S/G PORV ASPV0001 FAILS TO OPEN	1.008	SAMA 89
AE-XHE-FO-MFWFLO	FAILURE TO RE-ESTABLISH MFW FLOW DUE TO HUMAN ERRORS	1.008	See note on operator action events
AL-TDP-TM-TDAFP	TDAFP IN TEST OR MAINTENANCE	1.008	AFW SAMAs
IE-TMSO	MAIN STEAMLINE BREAK OUTSIDE CTMT IE FREQUENCY	1.008	
AB-ARV-CC-ABPV03	S/G PORV ASPV0003 FAILS TO OPEN	1.007	SAMA 89
NE-DGN-FR-NE0112	DIESEL GENERATOR NE01 FTR - 12 HR MT	1.007	Loss of Offsite Power SAMAs
NE-DGN-FR-NE0212	DIESEL GENERATOR NE02 FTR - 12 HR MT	1.007	Loss of Offsite Power SAMAs
EJ-PSF-TM-EJTRNB	RHR TRAIN B IN TEST OR MAINTENANCE	1.006	Core Cooling SAMAs
OP-XHE-FO-ECA32	OPERATOR FAILS TO PERFORM C/D TO COLD S/D IAW ECA 3.2	1.006	See note on operator action events
AB-AOV-CC-ABUV34	STEAM DUMP ABUV0034 FAILS TO OPEN	1.005	SAMA 89
AB-AOV-CC-ABUV35	STEAM DUMP ABUV0035 FAILS TO OPEN	1.005	SAMA 89
AB-AOV-CC-ABUV36	STEAM DUMP ABUV0036 FAILS TO OPEN	1.005	SAMA 89
AL-XHE-FO-SBOSGL	OPERATOR FAILS TO CONTROL S//G LEVEN AFTER COMPLEX EVENT	1.005	See note on operator action events
EJ-XHE-FO-PEJ01	OPERATOR FAILS TO START AN RHR PUMP FOR LONG TERM C/D	1.005	See note on operator action events
FAILTOMNLINSRODS	OPERATOR FAILS TO MANUALLY DRIVE RODS INTO CORE	1.005	ATWS SAMAs

ISLOCA = interfacing system LOCA; S/G = steam generator

Note 1 – The current plant procedures and training meet current industry standards. There are no additional specific procedure improvements that could be identified that would affect the result of the HEP calculations. Therefore, no SAMA items were added to the plant specific list of SAMAs as a result of the human actions on the list of basic events with RRW greater than 1.005.

Table 3-7. Late Release Importance Review

Basic Event Name	Basic Event Description	RRW	Associated SAMA
IE-T1	LOSS OF OFFSITE POWER INITIATING EVENT FREQUENCY	4.51	Loss of Offsite Power SAMAs
RECSWT1	RECOVERY POWER AND SW IN 8 HRS BEFORE CORE UNCVRED	1.474	Loss of Offsite Power SAMAs
OP-XHE-FO-ACRECV	OPERATOR FAILS TO RECOVER FROM A LOSSOF OFFSITE POWER	1.14	SAMA 22, see note on operator action events
EF-PSF-TM-ESWTNB	ESW TRAIN B IN TEST OR MAINTENANCE	1.136	Cooling Water SAMAs
NE-DGN-DR-NE01-2	DGNS CC FTR.	1.133	Loss of Offsite Power SAMAs
EF-MDP-DR-EFPMPS	ESW PUMPS CC FTR.	1.129	Cooling Water SAMAs
EF-PSF-TM-ESWTNA	ESW TRAIN A IN TEST OR MAINTENANCE	1.127	Cooling Water SAMAs
FAILTORECOVER-8	PROBABILITY THAT POWER IS NOT RECOV-ERED IN 8 HOURS.	1.105	Loss of Offsite Power SAMAs
FAILTORECOVER-12	CONDITIONAL PROB. THAT PWR IS NOT RE-COVERED IN 12 HRS.	1.098	Loss of Offsite Power SAMAs
IE-T3	TURBINE TRIP WITH MAIN FEEDWATER AVAILABLE IE FREQ	1.088	Initiating Event
EF-MDP-FR-PEF01A	ESW PUMP A (PEF01A)FAILS TO RUN	1.085	Cooling Water SAMAs
FB-XHE-FO-FANDB	OPERATOR FAILS TO ESTABLISH RCS FEED AND BLEED	1.076	SAMA 36, see note on operator action events
EF-MDP-FR-PEF01B	ESW PUMP B (PEF01B) FAILS TO RUN	1.074	Cooling Water SAMAs
TORNADO-T1-EVENT	CONDITIONAL PROB. TORNADO T(1) EVENT LOSS OF TEMP EDGS	1.073	Loss of Offsite Power SAMAs
IE-S2	SMALL LOCA INITIATING EVENT FREQUENCY	1.067	Safety Injection SAMAs
AE-CKV-DF-V120-3	CHECK VALVES AEV120121,122,123 COMMON CAUSE FAIL TO OPEN	1.05	SAMA 163
BB-RCA-WW-RCCAS	TWO (2) OR MORE RCCA's FAIL TO IN- SERT (MECH. CAUSES)	1.048	ATWS SAMAs
OP-XHE-FO-ECLRS2	OPERATOR FAILS TO ALIGN ECCS SYSTEMS FOR COLD LEG RECIRC	1.042	SAMA 36, see note on operator action events
EF-DRAIN-TRAINB	ALL TRAIN B SW UN- AVAIL. DUE TO DRAINAGE OF EF TRAIN B.	1.036	Cooling Water SAMAs
NE-DGN-TM-NE02	DIESEL GEN NE02 IN TEST OR MAINTENANCE	1.034	Loss of Offsite Power SAMAs
NE-DGN-FR-NE0112	DIESEL GENERATOR NE01 FTR - 12HR MT	1.033	Loss of Offsite Power SAMAs

Table 3-7. Late Release Importance Review (Continued)

Basic Event Name	Basic Event Description	RRW	Associated SAMA
EF-MOV-CC-EFHV37	VALVE EFHV37 FAILS TO OPEN	1.032	Cooling Water SAMAs
IE-S3	VERY SMALL LOCA INITIATING EVENT FREQUENCY	1.032	Safety Injection SAMAs
NE-DGN-FR-NE0212	DIESEL GENERATOR NE02 FTR - 12HR MT	1.032	Loss of Offsite Power SAMAs
NE-DGN-TM-NE01	DIESEL GEN NE01 IN TEST OR MAINTENANCE	1.032	Loss of Offsite Power SAMAs
NE-DGN-FS-NE01	DIESEL GENERATOR NE01 FAILS TO START	1.03	Loss of Offsite Power SAMAs
NON-TORNADO-T1	CONDITIONAL PROB. T(1) EVENT NOT CAUSED BY TORNADO	1.03	Loss of Offsite Power SAMAs
VD-FAN-FR-CGD02A	UHS C.T. ELEC. ROOMSUPPLY FAN CGD02A FAILS TO RUN	1.03	HVAC SAMAs
NE-DGN-FS-NE02	DIESEL GENERATOR NE02 FAILS TO START	1.029	Loss of Offsite Power SAMAs
OP-XHE-FO-DEP1	OPERATOR FAILS TO OPEN PORV TO DEPRESSURIZE RCS	1.029	See note on operator action events
EF-MDP-DS-EFPMPS	ESW PUMPS CC FTS.	1.028	Cooling Water SAMAs
EF-MOV-CC-EFHV38	VALVE EFHV38 FAILS TO OPEN	1.028	Cooling Water SAMAs
EF-MDP-FS-PEF01A	ESW PUMP A (PEF01A)FAILS TO START	1.027	Cooling Water SAMAs
EF-MDP-FS-PEF01B	ESW PUMP B (PEF01B)FAILS TO START	1.027	Cooling Water SAMAs
EF-MOV-D2-V37-38	COMMON CAUSE FAIL.-VALVES EF-HV-37 AND38 FTC.	1.027	Cooling Water SAMAs
VD-FAN-FR-CGD02B	UHS C.T. ELEC. ROOMSUPPLY FAN CGD02B FAILS TO RUN	1.026	HVAC SAMAs
OP-XHE-FO-AEPS1	OPERATOR FAIL TO ALIGN AEPS TO NB BUS IN 1 HR	1.025	See note on operator action events
FAILTOMNLINSRODS	OPERATOR FAILS TO MANUALLY DRIVE RODSINTO CORE (RI).	1.023	ATWS SAMAs
EF-MOV-OO-EFHV59	VALVE EFHV59 FAILS TO CLOSE	1.022	Cooling Water SAMAs
FAILTOREC-EFHV59	OPERATORS FAIL TO RECOVER (CLOSE) EFHV59.	1.022	See note on operator action events
BN-TNK-FC-RWSTUA	RWST UNAVAILABLE	1.02	SAMA 171
AEPS-ALIGN-NB01	PDG ALIGN TO NB01 (FAIL TO ALIGN PDG TO NB02)	1.016	Loss of Offsite Power SAMAs
AEPS-ALIGN-NB02	PDG ALIGN TO NB02 (FAIL TO ALIGN PDG TO NB01)	1.015	Loss of Offsite Power SAMAs
AL-TDP-TM-TDAFP	TDAFP IN TEST OR MAINTENANCE	1.015	AFW SAMAs
IE-T2	LOSS OF MAIN FEEDWATER IE FREQUENCY	1.013	Feedwater SAMAs

Table 3-7. Late Release Importance Review (Continued)

Basic Event Name	Basic Event Description	RRW	Associated SAMA
NF-ICC-AF-LSELSA	LOAD SHEDDER TRAIN A FAILS TO SHED LOADS	1.013	Loss of Offsite Power SAMAs
NF-ICC-AF-LSELSB	LOAD SHEDDER TRAIN B FAILS TO SHED LOADS	1.013	Loss of Offsite Power SAMAs
VM-BDD-CC-GMD001	DAMPER GMD001 FAILS TO OPEN	1.013	HVAC SAMAs
VM-BDD-CC-GMD004	DAMPER GMD004 FAILS TO OPEN	1.013	HVAC SAMAs
VM-BDD-CC-GMD006	DAMPER GMD006 FAILS TO OPEN	1.013	HVAC SAMAs
VM-BDD-CC-GMD009	DAMPER GMD009 FAILS TO OPEN	1.013	HVAC SAMAs
VM-EHD-CC-GMTZ11	ELEC/HYDR OP DAMPER GMTZ11A FAILS TO OPEN	1.013	HVAC SAMAs
VM-EHD-CC-GMTZ1A	ELEC/HYDR OP DAMPER GMTZ01A FAILS TO OPEN	1.013	HVAC SAMAs
NE-DGN-FR-NE01-2	DGN NE02 FAILS TO RUN (1 HR MISSION TIME)	1.012	Loss of Offsite Power SAMAs
NE-DGN-FR-NE02-2	DGN NE02 FAILS TO RUN (1 HR MISSION TIME)	1.011	Loss of Offsite Power SAMAs
EF-CKV-DF-V01-04	CHECK VALVES EFV001 AND EFV004 COMMON CAUSE FAIL TO OPEN	1.009	Cooling Water SAMAs
MANLRODINSERTION	OPERATORS MANUALLY DRIVE RODS INTO THE CORE	1.009	ATWS SAMAs
VM-FAN-FS-CGM01A	DIESEL GEN SUPPLY FAN CGM01A FAILS TO START	1.009	HVAC SAMAs
VM-FAN-FS-CGM01B	DIESEL GEN SUPPLY FAN CGM01B FAILS TO START	1.009	HVAC SAMAs
AE-CKV-DF-V124-7	CHECK VALVES AEV124,125,126,127 COMMON CAUSE FAIL TO OPEN	1.008	SAMA 163
AE-XHE-FO-MFWFLO	FAILURE TO RE-ESTABLISH MFW FLOW DUE TO HUMAN ERRORS	1.008	See note on operator action events
EG-AOV-DF-TV2930	COMMON CAUSE FAILURE EG-TV-29 AND 30 TO CLOSE	1.008	Cooling Water SAMAs
EG-HTX-TM-CCWHXB	CCW TRAIN B TEST/MAINT. (E.G. HX B TEST/MAINT.)	1.008	Cooling Water SAMAs
IE-TFLB	FEEDLINE BREAK DOWNSTREAM OF CKVS IE FREQUENCY	1.008	Feedwater SAMAs
AL-TDP-FS-TDAFP	TDAFP FAILS TO START	1.007	AFW SAMAs
AL-XHE-FO-SBOSGL	OPERATOR FAILS TO CONTROL S//G LEVEN AFTER COMPLEX EVENT	1.007	See note on operator action events
IE-TSW	LOSS OF SERVICE WATER INITIATING EVENT	1.007	Service Water SAMAs
NB-BKR-CC-NB0112	BREAKER NB0112 FAILS TO OPEN	1.007	Loss of Offsite Power SAMAs

Table 3-7. Late Release Importance Review (Continued)

Basic Event Name	Basic Event Description	RRW	Associated SAMA
NE-DGN-DS-NE01-2	DGNS CC FTS.	1.007	Loss of Offsite Power SAMAs
BG-MDP-TM-CCPA	CCP A IN TEST OR MAINTENANCE	1.006	Core Cooling SAMAs
BG-MDP-TM-CCPB	CCP B IN TEST OR MAINTENANCE	1.006	Core Cooling SAMAs
EG-MDP-DS-EGPMP4	ALL 4 EG PUMPS CC FTS.	1.006	Cooling Water SAMAs
IE-TMSO	MAIN STEAMLINE BREAK OUTSIDE CTMT IE FREQUENCY	1.006	SAMA 153
NB-BKR-CC-NB0209	BREAKER NB0209 FAILS TO OPEN	1.006	Loss of Offsite Power SAMAs
VD-FAN-FS-CGD02A	UHS C.T. ELEC. ROOMSUPPLY FAN CGD02A FAILS TO START	1.006	HVAC SAMAs
IE-TDCNK01	LOSS OF VITAL DC BUS NK01 INITIATING EVENT FREQUENCY	1.005	DC Power SAMAs
OP-XHE-FO-CCWRHX	OPERATOR FAILS TO INITIATE CCW FLOW TO THE RHR HXS	1.005	See note on operator action events
OP-XHE-FO-ESW2HR	OPERATOR FAILS TO START AND ALIGN ESW 2 HR AFTER SW LOSS	1.005	See note on operator action events
VD-FAN-DR-GD02AB	FANS CGD02A,B COMMON CAUSE FTS	1.005	HVAC SAMAs
VD-FAN-FS-CGD02B	UHS C.T. ELEC. ROOMSUPPLY FAN CGD02B FAILS TO START	1.005	HVAC SAMAs
VM-FAN-DS-GMFANS	FANS CGM01A,B COMMON CAUSE FTS	1.005	HVAC SAMAs

UHS = ultimate heat sink; AEPS = alternate emergency power system; RWST = refueling water storage tank

Note 1 – The current plant procedures and training meet current industry standards. There are no additional specific procedure improvements that could be identified that would affect the result of the HEP calculations. Therefore, no SAMA items were added to the plant specific list of SAMAs as a result of the human actions on the list of basic events with RRW greater than 1.005.

3.3 MODEL REVIEW SUMMARY

Discussion of Reviews Conducted on the Callaway PRA Since the IPE

As discussed above, the Callaway internal events PRA has been updated a number of times, since the IPE, to maintain fidelity between the plant and the PRA model, and to make improvements to the model. Updates to the PRA are documented in calculation notes, revisions and addenda, which are each independently reviewed by a qualified individual.

The Callaway PRA has undergone a number of in-house, peer and other reviews since the IPE, including the following:

- A self-assessment of the PRA was conducted prior to the WOG PRA peer review.
- The WOG conducted a PRA peer review in October 2000.
- The WOG reviewed results from the Callaway PRA as part of a PRA cross-comparison performed for member plants to identify outlier PRA results prior to MSPI implementation.
- In 2006, Scientech performed a review of the Callaway PRA against the Supporting Requirements for Capability Category II of Reference 27.
- Since 2007, a number of risk-informed license amendments have been submitted to and approved by NRC for Callaway. These have included a one-time per train ESW Completion Time extension, a containment ILRT extension and a BOP ESFAS Completion Time extension. In addition, Callaway recently submitted a license amendment request for Technical Specification Initiative 5b, the Surveillance Frequency Control Program. For each of these risk-informed license amendment requests, Ameren submitted, and NRC staff reviewed, information to demonstrate technical adequacy of the Callaway PRA.

Results of the WOG Peer Review

As noted above, the WOG conducted a peer review of the Callaway internal events PRA in October 2000. This review applied a grading system to the PRA elements, as follows:

Grade 1 – supports assessment of plant vulnerabilities
Grade 2 – supports risk ranking applications
Grade 3 – supports risk significance evaluations with deterministic input
Grade 4 – provides primary basis for application.

The WOG review deemed all of the Callaway PRA elements to be Grade 3 (or contingent Grade 3), except for the HRA element, which was deemed to be Grade 2. The HRA has since been re-performed by Scientech to address the WOG peer review findings.

In addition, all but five significance-level A (expected impact to be significantly non-conservative) and B (expected impact to be non-conservative but small) Facts/Observations (F&Os) generated during the WOG peer review have been addressed in the PRA model used for the SAMA analysis. The open F&Os, and an assessment of their impact on this application, are summarized in Table 3-8.

Table 3-8. Open WOG F&Os

F&O No.	Significance Level	F&O Description	Disposition for SAMA Analysis
IE-7	B	Two ISLOCA issues: 1. ISLOCA locations are limited to only those scenarios where containment may be bypassed. 2. The ISLOCA quantification does not correlate variables for basic events using the same failure rate.	Neither of these ISLOCA issues bears negatively on the SAMA analysis. In addition, following further investigation after the WOG peer review, issue 1 was deemed by Callaway not to be valid.
ST-1	B	The ISLOCA analysis did not use current state of the art analysis to determine probability of low pressure pipe failure upon overpressure, such as the approach indicated in references such as NUREG/CR-5102 or NUREG/CR-5744.	This finding is considered to be an enhancement to the ISLOCA analysis, and does not bear negatively on the SAMA analysis.
TH-3	B	Consider preparing success criteria guidance for the PRA, to address such items as overall success criteria definition process, development of success criteria for systems, etc.	This is a documentation issue. No issues were identified with the actual success criteria utilized. Therefore, this F&O does not impact the SAMA analysis.
L2-1	A	Address containment isolation failure and internal floods in the LERF calculation.	The SAMA analysis used a newly updated Level 2 analysis. It did not use the evaluated Callaway LERF model. The newly updated Level 2 model used for the SAMA analysis included containment isolation failure. Internal flooding was considered in the SAMA analysis to be part of the external events adjustment factor.
L2-3	B	The calculation of LERF is based on containment event tree split fractions. The process simply multiplies the split fractions together, resulting in an overall LERF split fraction for each PDS. It is not obvious how the split fractions are related back to elementary phenomena or system failures.	This is a documentation issue related to the original LERF analysis. The Level 2 analysis updated and used for the SAMA analysis is an integrated model that used the containment event trees for evaluation of the Level 2 risks.
PDS = plant damage state			

3.4 LEVEL 3 PRA MODEL

The Callaway Level 3 PRA model determines off-site dose and economic impacts of severe accidents based on the Level 1 PRA results, the Level 2 PRA results, atmospheric transport, mitigating actions, dose accumulation, early and latent health effects, and economic analyses.

The MELCOR Accident Consequence Code System (MACCS2) Version 1.13 was used to perform the calculations of the off-site consequences of a severe accident. This code is documented in NUREG/CR-6613 [22], "Code Manual for MACCS2: Volumes 1 and 2."

Plant-specific release data included the time-dependent nuclide distribution of releases and release frequencies. The behavior of the population during a release (evacuation parameters) was based on plant and site-specific set points. These data were used in combination with site-specific meteorology to simulate the probability distribution of impact risks (both exposures and economic effects) to the surrounding 50-mile radius population as a result of the release accident sequences at Callaway.

The following sections describe input data for the MACCS2 analysis tool. The analyses are provided in References 24 and 25.

3.4.1 Population Distribution

The SECPOP2000 code, documented in NUREG/CR-6525 [26], is one means of calculating most input data required for a MACCS2 SITE file. SECPOP2000 can utilize 1990 or 2000 census population data, and associated county economic data. For the Callaway analysis, the SECPOP2000 code was utilized to develop initial residential population estimates for each spatial element within the 50 mile region based on year 2000 census data. Transient population data was added for spatial elements within the 10-mile radius based on the Callaway evacuation time estimate study. The population data was projected to year 2044 using county growth estimates based on Missouri Office of Administration projections for 2030 [25].

Tables 3-9 and 3-10 identify the year 2044 projected population distribution. Data choices are consistent with industry guidance provided in NEI 05-01 [19].

Table 3-9. Projected Population Distribution Within A 10-Mile Radius[1], Year 2044

Sector	0-1 mile	1-2 miles	2-3 miles	3-4 miles	4-5 miles	5-10 miles	10-mile Total
N	7	7	80	215	87	319	715
NNE	10	31	80	80	109	415	725
NE	10	7	0	26	46	75	164
ENE	10	11	0	0	0	115	136
E	10	7	0	0	122	127	266
ESE	26	7	4	17	54	166	274
SE	10	7	0	73	102	182	374
SSE	7	7	6	0	0	192	212
S	0	0	5	4	0	1049	1058
SSW	0	81	0	80	16	103	280
SW	0	0	0	0	117	2153	2270
WSW	0	0	0	0	44	867	911
W	0	208	0	0	0	922	1130
WNW	0	88	133	131	161	1348	1861
NW	0	0	1	23	7	1249	1280
NNW	0	0	42	38	11	721	812
Total	90	461	351	687	876	10003	**12468**

Source: Reference 26.

(1)Population projection for 0-10 miles includes transients and residents, population projection for 10- 50 miles includes residents only

Table 3-10. Projected Population Distribution Within A 50-Mile Radius[1], Year 2044

Sector	0-10 miles	10-20 miles	20-30 miles	30-40 miles	40-50 miles	50-mile Total
N	715	1271	7292	1424	2032	12734
NNE	725	786	2636	2126	5998	12271
NE	164	897	3790	2002	4863	11716
ENE	136	524	4025	11736	69462	85883
E	266	1848	3012	35790	47655	88571
ESE	274	3305	3047	12246	60385	79257
SE	374	824	1515	6970	10021	19704
SSE	212	451	996	7274	5779	14712
S	1058	2079	1746	3970	3254	12107
SSW	280	2463	3003	2306	3393	11445
SW	2270	2030	18012	6068	4860	33240
WSW	911	9554	66454	15257	8762	100938
W	1130	3927	10536	3602	4538	23733
WNW	1861	9482	28025	183082	5077	227527
NW	1280	15516	3821	15557	7645	43819
NNW	812	3800	10098	7414	1601	23725
Total	12468	58757	168008	316824	245325	**801382**
Source: Reference 26.						

3.4.2 Economic Data

MACCS2 requires certain site specific economic data (fraction of land devoted to farming, annual farm sales, fraction of farm sales resulting from dairy production, and property value of farm and non-farm land) for each of the 160 spatial elements. The site specific base case values are calculated using the economic data from the 2007 U.S. Department of Agriculture and from other data sources, such as the Bureau of Labor Statistics and Bureau of Economic Analysis, updated to May 2010 values using the Consumer Price Index (CPI). The calculation approach documented in NUREG/CR-6525 (SECPOP2000) was utilized to develop the regional economic data inputs, but the SECPOP2000 code was not utilized for this purpose because the embedded economic data files contain older data (i.e., 1997 U.S. Department of Agriculture).

In addition to these site specific values, generic economic data are utilized by MACCS2 to address costs associated with per diem living expenses (applied to owners of interdicted properties and relocated populations), relocation costs (for owners of interdicted properties), and decontamination costs. For the Callaway base case, these generic costs are based on values used in the NUREG-1150 studies (as documented in the NUREG/CR-4551 series of reports), updated to May 2010 using the CPI (Table 3-11).

Table 3-11. Generic Economic Data

Variable	Description	Callaway Value
DPRATE(1)	Property depreciation rate (per yr.)	0.20
DSRATE(2)	Investment rate of return (per yr.)	0.07
EVACST(3)	Daily cost for a person who has been evacuated ($/person-day)	$54
POPCST(3)	Population relocation cost ($/person)	$10,000
RELCST(3)	Daily cost for a person who is relocated ($/person-day)	$54
CDFRM(3)	Cost of farm decontamination for various levels of decontamination ($/hectare)(5)	$1,125 & $2,500
CDNFRM(3)	Cost of non-farm decontamination per resident person for various levels of decontamination ($/person)	$6,000 & $16,000
DLBCST(3)	Average cost of decontamination labor ($/man-year)(5)	$70,000
VALWF(4)	Value of farm wealth ($/hectare)	$6,448
VALWNF(4)	Value of non-farm wealth average in US ($/person)	$217,394

(1) NUREG/CR-4551 value.
(2) NUREG/BR-0058 value.
(3) NUREG/CR-4551 value, updated to May 2010 using the CPI.
(4) VALWF0 and VALWNF are based on the 2007 Census of Agriculture, Bureau of Labor Statistics and Bureau of Economic Analysis data, updated to May 2010 using the CPI for the counties within 50 miles.
(5) Decontamination Factors of 3 and 15 were used in the Callaway analysis, consistent with NUREG-1150 studies.

3.4.3 Nuclide Release

Core inventory represents end-of-cycle values for Callaway operating at 3565 MWth (current licensed value). The estimated core inventory reflects the current and anticipated fuel management / burnup during the license renewal period. Inventory values are provided in Table 3-12. Source term release fractions and other release data are based on plant specific MAAP simulations. Releases are modeled to occur at mid-height of the containment, consistent with NEI 05-01 guidance. Three plumes are modeled as presented in Table 3-13. The NRC has found the use of MAAP reasonable and appropriate for the purposes of SAMA analysis. Opponents in other proceedings have suggested that the source terms in NUREG-1465 should be used. However, the NUREG-1465 source term only addresses the release of radionuclides into containment. Releases into containment and releases into the environment are very different events, with significant differences in sequence progression, release pathways, and fission product deposition and removal mechanisms. Additionally, use of plant specific data (when available) is preferred to generic data. Thus, use of the NUREG-1465 source terms would be inappropriate.

Table 3-12. Callaway Core Inventory

Nuclide	Activity (Bq)	Nuclide	Activity (Bq)
Co-58	3.37E+16	Te-131m	5.15E+17
Co-60	2.58E+16	Te-132	5.08E+18
Kr-85	3.39E+16	I-131	3.58E+18
Kr-85m	9.39E+17	I-132	5.17E+18
Kr-87	1.80E+18	I-133	7.28E+18
Kr-88	2.54E+18	I-134	8.00E+18
Rb-86	7.41E+15	I-135	6.82E+18
Sr-89	3.49E+18	Xe-133	7.13E+18
Sr-90	2.66E+17	Xe-135	1.53E+18
Sr-91	4.27E+18	Cs-134	5.74E+17
Sr-92	4.63E+18	Cs-136	1.70E+17
Y-90	2.80E+17	Cs-137	3.64E+17
Y-91	4.49E+18	Ba-139	6.52E+18
Y-92	4.65E+18	Ba-140	6.32E+18
Y-93	5.37E+18	La-140	6.57E+18
Zr-95	6.06E+18	La-141	5.93E+18
Zr-97	5.99E+18	La-142	5.74E+18
Nb-95	6.09E+18	Ce-141	6.01E+18
Mo-99	6.52E+18	Ce-143	5.51E+18
Tc-99m	5.71E+18	Ce-144	4.30E+18
Ru-103	5.49E+18	Pr-143	5.39E+18
Ru-105	3.75E+18	Nd-147	2.39E+18
Ru-106	1.72E+18	Np-239	6.80E+19
Rh-105	3.41E+18	Pu-238	9.11E+15
Sb-127	3.81E+17	Pu-239	9.74E+14
Sb-129	1.14E+18	Pu-240	1.24E+15
Te-127	3.76E+17	Pu-241	4.39E+17
Te-127m	4.86E+16	Am-241	4.68E+14
Te-129	1.13E+18	Cm-242	1.43E+17
Te-129m	1.68E+17	Cm-244	9.26E+15

Table 3-13 provides a description of the release characteristics evaluated in this analysis.

Table 3-13. Callaway Source Term Release Summary

	Release Category							
	LERF-IS	**LERF-CI**	**LERF-CF**	**LERF-SG**	**LERF-ITR**	**LATE-BMT**	**LATE-COP**	**INTACT**
MAAP Case	**LERF-IS**	**LERF-CIa**	**LERF-CFa**	**LERF-SG**	**LERF-ITR**	**LATE-BMT**	**LATE-COP**	**INTACT**
Run Duration	48	48	48	48	48	96	72	48
Time after Scram when GE is declared (1)	3.1	20.9	20.9	37.9	20.9	20.5	21.0	22.4
Fission Product Group:								
1) Noble Gases								
Total Release Fraction	1.00E+00	9.00E-01	8.70E-01	9.80E-01	9.90E-01	4.80E-01	9.00E-01	2.60E-04
Total Plume 1 Release Fraction	8.60E-1	2.80E-1	4.60E-1	9.10E-1	9.00E-1	1.00E-4	4.00E-4	1.40E-5
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	1.20E-1	4.30E-1	2.80E-1	7.00E-2	5.00E-2	3.30E-1	5.90E-1	6.90E-5
Start of Plume 2 Release (hr)	4.50	28.00	32.00	42.00	23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00	40.00	45.00	30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	2.00E-2	1.90E-1	1.30E-1	0.00E+0	4.00E-2	1.50E-1	3.10E-1	1.77E-4
Start of Plume 3 Release (hr)	7.50	38.00	40.00		30.00	82.00	56.00	34.00
End of Plume 3 Release (hr)	15.00	48.00	48.00		40.00	92.00	66.00	40.00
2) CsI								
Total Release Fraction	5.00E-01	8.80E-02	1.00E-01	3.90E-01	2.70E-01	7.50E-04	2.80E-02	1.40E-05
Total Plume 1 Release Fraction	4.20E-1	2.40E-2	4.20E-2	3.70E-1	1.80E-1	4.00E-5	8.00E-3	3.40E-6
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	7.00E-2	3.20E-2	4.30E-2	2.00E-2	5.00E-2	5.80E-4	1.20E-2	9.60E-6
Start of Plume 2 Release (hr)	4.50	28.00	32.00	42.00	23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00	40.00	45.00	30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	1.00E-2	3.20E-2	1.50E-2	0.00E+0	4.00E-2	1.30E-4	8.00E-3	1.00E-6

Table 3-13. Callaway Source Term Release Summary (Continued)

	Release Category							
	LERF-IS	LERF-CI	LERF-CF	LERF-SG	LERF-ITR	LATE-BMT	LATE-COP	INTACT
MAAP Case	LERF-IS	LERF-CIa	LERF-CFa	LERF-SG	LERF-ITR	LATE-BMT	LATE-COP	INTACT
Start of Plume 3 Release (hr)	7.50	38.00	40.00		30.00	82.00	56.00	34.00
End of Plume 3 Release (hr)	15.00	48.00	48.00		40.00	92.00	66.00	40.00
3) TeO2								
Total Release Fraction	5.80E-01	5.00E-02	5.50E-02	2.00E-01	2.60E-01	7.90E-05	7.00E-03	1.40E-05
Total Plume 1 Release Fraction	4.60E-1	2.40E-2	4.60E-2	1.90E-1	1.90E-1	2.70E-5	4.50E-3	2.50E-6
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	1.10E-1	2.40E-2	6.00E-3	1.00E-2	4.00E-2	4.30E-5	1.90E-3	9.50E-6
Start of Plume 2 Release (hr)	4.50	28.00	32.00	42.00	23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00	40.00	45.00	30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	1.00E-2	2.00E-3	3.00E-3	0.00E+0	3.00E-2	9.00E-6	6.00E-4	2.00E-6
Start of Plume 3 Release (hr)	7.50	38.00	40.00		30.00	82.00	56.00	34.00
End of Plume 3 Release (hr)	15.00	48.00	48.00		40.00	92.00	66.00	40.00
4) SrO								
Total Release Fraction	4.90E-02	1.10E-03	1.10E-03	1.40E-03	2.10E-03	2.50E-05	7.90E-05	2.80E-07
Total Plume 1 Release Fraction	2.50E-2	9.70E-4	1.10E-3	1.40E-3	2.40E-4	5.00E-6	6.20E-5	2.80E-8
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	3.00E-3	1.30E-4	0.00E+0	0.00E+0	1.46E-3	1.40E-5	1.10E-5	1.92E-7
Start of Plume 2 Release (hr)	4.50	28.00			23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00			30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	2.10E-2	0.00E+0	0.00E+0	0.00E+0	4.00E-4	6.00E-6	6.00E-6	6.00E-8
Start of Plume 3 Release (hr)	7.50				30.00	82.00	56.00	34.00
End of Plume 3 Release (hr)	15.00				40.00	92.00	66.00	40.00

Table 3-13. Callaway Source Term Release Summary (Continued)

	Release Category							
	LERF-IS	LERF-CI	LERF-CF	LERF-SG	LERF-ITR	LATE-BMT	LATE-COP	INTACT
MAAP Case	**LERF-IS**	**LERF-CIa**	**LERF-CFa**	**LERF-SG**	**LERF-ITR**	**LATE-BMT**	**LATE-COP**	**INTACT**
5) MoO2								
Total Release Fraction	2.70E-02	1.80E-03	2.20E-03	5.00E-02	2.20E-02	3.70E-05	3.70E-04	2.30E-06
Total Plume 1 Release Fraction	1.90E-2	1.50E-3	1.60E-3	4.90E-2	1.90E-2	6.00E-6	1.50E-4	9.00E-7
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	6.00E-3	3.00E-4	3.00E-4	1.00E-3	3.00E-3	2.30E-5	8.00E-5	1.00E-6
Start of Plume 2 Release (hr)	4.50	28.00	32.00		23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00	40.00		30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	2.00E-3	0.00E+0	3.00E-4	0.00E+0	0.00E+0	8.00E-6	1.40E-4	4.00E-7
Start of Plume 3 Release (hr)	7.50		40.00			82.00	56.00	34.00
End of Plume 3 Release (hr)	15.00		48.00			92.00	66.00	40.00
6) CsOH								
Total Release Fraction	4.90E-01	6.70E-02	8.60E-02	1.60E-01	2.10E-01	4.30E-04	2.50E-02	1.40E-05
Total Plume 1 Release Fraction	4.20E-1	1.20E-2	4.30E-2	1.50E-1	1.20E-1	2.00E-5	5.00E-3	3.30E-6
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	6.00E-2	4.10E-2	2.30E-2	1.00E-2	2.00E-2	3.20E-4	9.00E-3	8.70E-6
Start of Plume 2 Release (hr)	4.50	28.00	32.00	42.00	23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00	40.00	45.00	30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	1.00E-2	1.40E-2	2.00E-2	0.00E+0	7.00E-2	9.00E-5	1.10E-2	2.00E-6
Start of Plume 3 Release (hr)	7.50	38.00	40.00		30.00	82.00	56.00	34.00
End of Plume 3 Release (hr)	15.00	48.00	48.00		40.00	92.00	66.00	40.00
7) BaO								
Total Release Fraction	6.50E-02	1.20E-03	1.20E-03	2.20E-02	5.80E-03	3.60E-05	2.70E-04	7.50E-07
Total Plume 1 Release Fraction	3.40E-2	1.10E-3	1.10E-3	2.20E-2	3.90E-3	5.00E-6	7.00E-5	1.90E-7

Table 3-13. Callaway Source Term Release Summary (Continued)

	Release Category							
	LERF-IS	LERF-CI	LERF-CF	LERF-SG	LERF-ITR	LATE-BMT	LATE-COP	INTACT
MAAP Case	LERF-IS	LERF-CIa	LERF-CFa	LERF-SG	LERF-ITR	LATE-BMT	LATE-COP	INTACT
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	5.00E-3	1.00E-4	0.00E+0	0.00E+0	1.50E-3	2.20E-5	1.70E-4	4.30E-7
Start of Plume 2 Release (hr)	4.50	28.00			23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00			30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	2.60E-2	0.00E+0	1.00E-4	0.00E+0	4.00E-4	9.00E-6	3.00E-5	1.30E-7
Start of Plume 3 Release (hr)	7.50		40.00		30.00	82.00	56.00	34.00
End of Plume 3 Release (hr)	15.00		48.00		40.00	92.00	66.00	40.00
8) La2O3								
Total Release Fraction	1.10E-03	1.10E-03	1.10E-03	6.80E-05	1.60E-03	4.80E-06	7.90E-05	4.30E-09
Total Plume 1 Release Fraction	1.70E-4	9.70E-4	1.10E-3	6.80E-5	2.30E-5	4.70E-6	6.20E-5	5.00E-10
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	3.00E-5	1.30E-4	0.00E+0	0.00E+0	1.34E-3	1.00E-7	1.30E-5	2.90E-9
Start of Plume 2 Release (hr)	4.50	28.00			23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00			30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	9.00E-4	0.00E+0	0.00E+0	0.00E+0	2.40E-4	0.00E+0	4.00E-6	9.00E-10
Start of Plume 3 Release (hr)	7.50				30.00		56.00	34.00
End of Plume 3 Release (hr)	15.00				40.00		66.00	40.00
9) CeO2								
Total Release Fraction	3.70E-03	1.10E-03	1.10E-03	3.60E-04	1.80E-03	4.90E-06	1.00E-04	2.80E-08
Total Plume 1 Release Fraction	1.10E-3	9.70E-4	1.10E-3	3.60E-4	9.30E-5	4.70E-6	6.00E-5	3.00E-9
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	5.00E-4	1.30E-4	0.00E+0	0.00E+0	1.36E-3	2.00E-7	2.00E-5	2.10E-8

Table 3-13. Callaway Source Term Release Summary (Continued)

	Release Category							
	LERF-IS	LERF-CI	LERF-CF	LERF-SG	LERF-ITR	LATE-BMT	LATE-COP	INTACT
MAAP Case	**LERF-IS**	**LERF-CIa**	**LERF-CFa**	**LERF-SG**	**LERF-ITR**	**LATE-BMT**	**LATE-COP**	**INTACT**
Start of Plume 2 Release (hr)	4.50	28.00			23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00			30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	2.10E-3	0.00E+0	0.00E+0	0.00E+0	3.50E-4	0.00E+0	2.00E-5	4.00E-9
Start of Plume 3 Release (hr)	7.50				30.00		56.00	34.00
End of Plume 3 Release (hr)	15.00				40.00		66.00	40.00
10) Sb (Grouped with TeO2)								
Total Release Fraction	2.60E-01	1.60E-02	1.80E-02	9.80E-02	1.50E-01	3.20E-04	2.30E-03	5.40E-06
Total Plume 1 Release Fraction	1.50E-01	1.10E-02	9.80E-03	9.70E-02	1.20E-01	2.00E-05	1.10E-03	1.10E-06
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	23.50
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	27.50
Total Plume 2 Release Fraction	2.00E-02	2.00E-03	4.20E-03	1.00E-03	2.00E-02	2.00E-04	1.00E-03	3.40E-06
Start of Plume 2 Release (hr)	4.50	28.00	32.00	42.00	23.00	72.00	46.00	27.50
End of Plume 2 Release (hr)	7.50	38.00	40.00	45.00	30.00	82.00	56.00	34.00
Total Plume 3 Release Fraction	9.00E-02	3.00E-03	4.00E-03	0.00E+00	1.00E-02	1.00E-04	2.00E-04	9.00E-07
Start of Plume 3 Release (hr)	7.50	38.00	40.00		30.00	82.00	56.00	34.00
End of Plume 3 Release (hr)	15.00	48.00	48.00		40.00	92.00	66.00	40.00
11) Te2 (Grouped with TeO2)								
Total Release Fraction	3.80E-04	1.10E-05	1.10E-05	6.00E-07	2.90E-04	3.30E-06	1.20E-05	0.00E+00
Total Plume 1 Release Fraction	0.00E+00	3.20E-06	3.70E-06	0.00E+00	0.00E+00	1.00E-07	1.70E-06	0.00E+00
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	
Total Plume 2 Release Fraction	9.00E-05	2.50E-06	3.00E-06	6.00E-07	3.20E-05	2.10E-06	6.30E-06	0.00E+00
Start of Plume 2 Release (hr)	4.50	28.00	32.00	42.00	23.00	72.00	46.00	
End of Plume 2 Release (hr)	7.50	38.00	40.00	45.00	30.00	82.00	56.00	
Total Plume 3 Release Fraction	2.90E-04	5.30E-06	4.30E-06	0.00E+00	2.58E-04	1.10E-06	4.00E-06	0.00E+00

Table 3-13. Callaway Source Term Release Summary (Continued)

	Release Category							
	LERF-IS	**LERF-CI**	**LERF-CF**	**LERF-SG**	**LERF-ITR**	**LATE-BMT**	**LATE-COP**	**INTACT**
MAAP Case	**LERF-IS**	**LERF-CIa**	**LERF-CFa**	**LERF-SG**	**LERF-ITR**	**LATE-BMT**	**LATE-COP**	**INTACT**
Start of Plume 3 Release (hr)	7.50	38.00	40.00		30.00	82.00	56.00	
End of Plume 3 Release (hr)	15.00	48.00	48.00		40.00	92.00	66.00	
12) UO2 (Grouped with CeO2)								
Total Release Fraction	6.10E-06	6.90E-10	4.60E-10	3.30E-10	3.10E-07	2.20E-09	3.00E-11	0.00E+00
Total Plume 1 Release Fraction	0.00E+00	6.10E-10	4.50E-10	0.00E+00	0.00E+00	1.00E-10	2.70E-11	0.00E+00
Start of Plume 1 Release (hr)	3.10	22.00	23.50	38.00	21.00	22.00	23.00	
End of Plume 1 Release (hr)	4.50	28.00	32.00	42.00	23.00	32.00	33.00	
Total Plume 2 Release Fraction	1.10E-06	8.00E-11	1.00E-11	3.30E-10	3.00E-08	1.70E-09	3.00E-12	0.00E+00
Start of Plume 2 Release (hr)	4.50	28.00	32.00	42.00	23.00	72.00	46.00	
End of Plume 2 Release (hr)	7.50	38.00	40.00	45.00	30.00	82.00	56.00	
Total Plume 3 Release Fraction	5.00E-06	0.00E+00	0.00E+00	0.00E+00	2.80E-07	4.00E-10	0.00E+00	0.00E+00
Start of Plume 3 Release (hr)	7.50				30.00	82.00		
End of Plume 3 Release (hr)	15.00				40.00	92.00		

3.4.4 Emergency Response

A reactor trip signal begins each evaluated accident sequence. A General Emergency is declared when plant conditions degrade to the point where it is judged that there is a credible risk to the public. Therefore, the timing of the General Emergency declaration is sequence specific and declaration ranges from 1 to 4 hours for the release sequences evaluated.

Evacuation parameters included in the file are based on the evacuation time estimate study for the Callaway Plant. Protective action parameters for the EARLY phase are based on the protective action guides (PAGs) specified in EPA-400. Data choices are consistent with guidance provided in NEI 05-01 [19]. In the modeling, 95% of the population is assumed to evacuate the 10 mile region of the emergency planning zone (EPZ) radially at an average speed of 2.14 meters/second, starting 105 minutes after the declaration of general emergency. The evacuation time estimate study presents evacuation times for normal and adverse weather conditions for an evacuation occurring in the daytime on a winter weekday. A daytime winter weekday evacuation was judged in the time estimate study to be conservative compared to other potential time periods (e.g., nighttime, summer, weekend). For the Level 3 analysis, the evacuation speed is time weighted average assuming normal weather conditions 90% of the time and adverse weather conditions 10% of the time.

Two evacuation sensitivity cases were performed. The first sensitivity case evaluated the impact of an increased delay time before evacuation begins (i.e., vehicles begin moving in the 10 mile region). For this sensitivity, the base case delay time of 105 minutes is doubled to 210 minutes. The increased delay time results in an increase in dose risk of about 2.4%. The second sensitivity case assessed the impact of evacuation speed assumptions by reducing the evacuation speed by one half, to 1.0 7 m/s (2.4 mph). The slower evacuation speed increases the dose risk by approximately 7%.

3.4.5 Meteorological Data

Each year of meteorological data consists of 8,760 weather data sets of hourly recordings of wind direction, wind speed, atmospheric stability, and accumulated precipitation Site-specific weather data was obtained from the Callaway on-site meteorological monitoring system for years 2007 through 2009. MACCS2 does not permit missing data, so bad or missing data were filled in by using interpolation, substituting data from the previous or subsequent day, or using precipitation data from the Prairie Fork Conservation area (9.5 miles NNE). The 2008 data set was found to be the most complete (<0.1% data voids) and also result in the largest economic cost risk and dose risk compared to the 2007 and 2009 data sets. Because the MACCS2 code can only process one year of meteorological data at a time, the 2008 data was conservatively selected for the base case analysis.

Studies have shown that the Gaussian plume model (ATMOS) used in MACCS2 compares well against more complex variable trajectory transport and dispersion models. NUREG/CR-6853, Molenkamp et al., Comparison of Average Transport and Dispersion Among a Gaussian, a Two-Dimensional, and a Three-Dimensional Model (Oct. 2004) compared MACCS2 with two Gaussian puff models (RASCAL and RATCHET) developed by Pacific Northwest National Laboratory, and a state-of-the-art Lagrangian particle model (LODI) developed by Lawrence Livermore National Laboratory. These models were compared using one year of hourly-observed meteorological data from many weather sites in a large domain in the Midwest, referred to as the Southern Great Plains, centered on Oklahoma and Kansas. The study found that "[n]early all the annual average ring exposures and depositions and a great majority of the arc sector values for MACCS2, RASCAL, and RATCHET are within a factor of two of the corresponding ADAPT/LODI values." Indeed, the largest observed deviation between mean results produced by MACCS2 and LODI was 58%. In comparison, the largest observed deviation between RASCAL and LODI was 61%. When averaged over a series of radial arcs out to fifty miles, MACCS2 was within plus or minus 10% of the three dimensional model. The Midwest terrain and meteorological data used in this study is very representative of Callaway. Similarly, a more recent comparison of MACCS2 against another Lagrangian puff model (CALMET, the meteorological processor in CALPUFF) using data from multiple meteorological stations showed that consideration of time and spatially variable wind fields would have less than a 4% impact on the SAMA analysis in the Pilgrim license renewal proceeding, notwithstanding the existence of a sea breeze phenomenon at that facility. Thus, MACCS2 appears well suited for estimating mean offsite consequences for use in SAMA analysis, and particularly appropriate for Callaway given the results of the Molenkamp study and the simple terrain in the vicinity of the plant.

3.5 SEVERE ACCIDENT RISK RESULTS

Using the MACCS2 code, the dose and economic costs associated with a severe accident at Callaway were calculated for each of the years for which meteorological data was gathered. This information is provided below in Table 3-14 and Table 3-15, respectively. The results for year 2008 were used since the 2008 data resulted in the highest cost/year.

Table 3-14. Dose and Cost Results by Source Term (0-50 Mile Radius from Callaway Site)

Source Term	Frequency (per yr.)	Dose (p-rem)	Dose Risk (p-rem/year)	Total Cost ($)	Cost Risk ($/yr.)
LERF-IS	1.73E-07	2.00E+06	3.46E-01	8.22E+09	1.42E+03
LERF-CI	1.66E-10	7.66E+05	1.27E-04	4.80E+09	7.96E-01
LERF-CF	1.13E-08	8.24E+05	9.27E-03	5.49E+09	6.18E+01
LERF-SG	2.33E-06	9.13E+05	2.13E+00	4.92E+09	1.15E+04
LERF-ITR	2.17E-07	1.23E+06	2.67E-01	8.01E+09	1.74E+03
LATE-BMT	2.55E-06	3.89E+04	9.92E-02	4.91E+07	1.25E+02
LATE-COP	3.19E-06	5.41E+05	1.72E+00	1.86E+09	5.92E+03
INTACT	8.08E-06	2.86E+03	2.31E-02	1.25E+06	1.01E+01
Total	1.66E-05	--	4.60E+00	--	2.08E+04
p = person					

Table 3-15. Ingestion Dose by Source Term (0-50 Mile Radius from Callaway site)

Source Term	Frequency (per yr.)	Food Dose (p-rem)	Food Dose Risk (p-rem/yr.)	Water Dose (p-rem)	Water Dose Risk (p-rem/yr.)	Ingestion Dose (p-rem)	Ingestion Dose Risk (p-rem/yr.)
LERF-IS	1.73E-07	1.43E+05	2.47E-02	1.27E+05	2.20E-02	2.70E+05	4.67E-02
LERF-CI	1.66E-10	6.38E+04	1.06E-05	1.44E+04	2.39E-06	7.82E+04	1.30E-05
LERF-CF	1.13E-08	6.55E+04	7.37E-04	1.82E+04	2.05E-04	8.37E+04	9.42E-04
LERF-SG	2.33E-06	4.61E+04	1.07E-01	3.32E+04	7.74E-02	7.93E+04	1.85E-01
LERF-ITR	2.17E-07	7.30E+04	1.58E-02	4.40E+04	9.55E-03	1.17E+05	2.54E-02
LATE-BMT	2.55E-06	2.14E+04	5.46E-02	1.01E+02	2.58E-04	2.15E+04	5.48E-02
LATE-COP	3.19E-06	6.43E+04	2.05E-01	5.17E+03	1.65E-02	6.95E+04	2.21E-01
INTACT	8.08E-06	2.21E+03	1.79E-02	3.03E+00	2.45E-05	2.21E+03	1.79E-02
Total	1.66E-05	--	4.26E-01	--	1.26E-01	--	5.52E-01
p = person							

4.0 COST OF SEVERE ACCIDENT RISK / MAXIMUM BENEFIT

Cost/benefit evaluation of SAMAs is based upon the cost of implementation of a SAMA compared to the averted onsite and offsite costs resulting from the implementation of that SAMA. The methodology used for this evaluation was based upon the NRC's guidance for the performance of cost-benefit analyses [15]. This guidance involves determining the net value for each SAMA according to the following formula:

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

Where APE = present value of averted public exposure ($)
AOC = present value of averted offsite property damage costs ($)
AOE = present value of averted occupational exposure ($)
AOSC = present value of averted onsite costs ($)
COE = cost of enhancement ($).

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

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

Present Worth

The present worth was determined by:

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

Where:

r is the discount rate = 7% (assumed throughout these analyses)
t is the duration of the license renewal = 20 years
PW is the present worth of a string of annual payments = 10.76

Dollars per rem

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

On-site Person-rem per Accident

The occupational exposure associated with severe accidents was assumed to be 23,300 person-rem/accident. This value includes a short-term component of 3,300 person-rem/accident and a long-term component of 20,000 person-rem/accident. These estimates are consistent with the "best estimate" values presented in Section 5.7.3 of Reference 15. In the cost/benefit analyses, the accident-related on-site exposures were calculated using the best estimate exposure components applied over the on-site cleanup period.

On-site Cleanup Period

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

Present Worth On-site Cleanup Cost per Accident

The estimated cleanup cost for severe accidents was assumed to be $1.5E+09/accident (undiscounted). This value was derived by the NRC in Reference 15, Section 5.7.6.1, Cleanup and Decontamination. This cost is the sum of equal annual costs over a 10-year cleanup period. At a 7% discount rate, the present value of this stream of costs is $1.1E+09.

4.1 OFF-SITE EXPOSURE COST

Accident-Related Off-Site Dose Costs

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

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

where:

- APE = monetary value of accident risk avoided due to population doses, after discounting
- R = monetary equivalent of unit dose ($/person-rem)
- F = accident frequency (events/yr)
- D_P = population dose factor (person-rems/event)
- S = status quo (current conditions)
- A = after implementation of proposed action
- r = real discount rate
- t_f = analysis period (years).

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

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

4.2 OFF-SITE ECONOMIC COST

Offsite damage was determined using the MACCS2 model developed for Callaway Plant. Costs associated with these damages were calculated using the following equation:

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

where:

- AOC = monetary value of accident risk avoided due to offsite property damage, after discounting
- F = accident frequency (events/yr)
- PD = offsite property loss factor (dollars/event)
- R = real discount rate
- tf = analysis period (years).

4.3 ON-SITE EXPOSURE COST

Methods for calculating averted costs associated with onsite accident dose costs are as follows:

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

For the case where the plant is in operation, the equations in Reference 15 can be expressed as:

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

Where:

- W_{IO} = monetary value of accident risk avoided due to immediate doses, after discounting
- R = monetary equivalent of unit dose, ($/person-rem)
- F = accident frequency (events/yr)
- D_{IO} = immediate occupational dose (person-rems/event)
- S = status quo (current conditions)
- A = after implementation of proposed action
- r = real discount rate
- t_f = analysis period (years).

The values used are:

- R = $2000/person rem
- r = .07
- D_{IO} = 3,300 person-rems /accident (best estimate)

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

For the basis discount rate, assuming F_A is zero, the <u>best estimate</u> of the limiting savings is:

$$W_{IO} = \left(F_S D_{IO_S}\right) R \frac{1-e^{-rt_f}}{r}$$
$$= 3300 * F * \$2000 * \frac{1-e^{-.07*20}}{.07}$$
$$= F * \$6{,}600{,}000 * 10.763$$
$$= F * \$0.71E + 8 \text{ , (\$).}$$

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

For the case where the plant is in operation, the equations in Reference 15 can be expressed as:

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

where:

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

m = years over which long-term doses accrue.

The values used are:

R = $2000/person rem
r = .07
D_{LTO} = 20,000 person-rem /accident (best estimate)
m = “as long as 10 years”

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

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

$$W_{LTO} = \left(F_S D_{LTO_S}\right) R * \frac{1-e^{-rt_f}}{r} * \frac{1-e^{-rm}}{rm}$$
$$= \left(F_S 20000\right) \$2000 * \frac{1-e^{-.07*20}}{.07} * \frac{1-e^{-.07*10}}{.07*10}$$
$$= F_S * \$40{,}000{,}000 * 10.763 * 0.719$$
$$= F_S * \$3.10E + 8 \text{ , (\$).}$$

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

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

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

4.4 ON-SITE ECONOMIC COST

Methods for calculation of averted costs associated with accident-related on-site property damage are as follows:

Cleanup/Decontamination

Reference 15 assumes a total cleanup/decontamination cost of $1.5E+9 as a reasonable estimate and this same value was adopted for these analyses. Considering a 10-year cleanup period, the present value of this cost is:

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

Where

- PV_{CD} = present value of the cost of cleanup/decontamination
- C_{CD} = total cost of the cleanup/decontamination effort
- m = cleanup period
- r = discount rate

Based upon the values previously assumed:

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

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

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

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

Based upon the values previously assumed:

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

$$U_{CD} = \$1.161E+10$$

Replacement Power Costs

Replacement power costs, U_{RP}, are an additional contributor to onsite costs. These are calculated in accordance with NUREG/BR-0184, Section 5.6.7.2.[1] Since replacement power will be needed for that time period following a severe accident, for the remainder of the expected generating plant life, long-term power replacement calculations have been used. The calculations are based on the 910 MWe reference plant, and are appropriately scaled for the 1236 MWe Callaway Plant. The present value of replacement power is calculated as follows:

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

$$PV_{RP} = \left(\frac{\left(\$1.2E+8\right)\dfrac{(Ratepwr)}{(910MWe)}}{r} \right)\left(1-e^{-rt_f}\right)^2$$

Where
PV$_{RP}$ = Present value of the cost of replacement power for a single event.
t_f = Analysis period (years).
r = Discount rate.
Ratepwr = Rated power of the unit

The $1.2E+8 value has no intrinsic meaning but is a substitute for a string of non-constant replacement power costs that occur over the lifetime of a "generic" reactor after an event (from Reference 15). This equation was developed per NUREG/BR-0184 for discount rates between 5% and 10% only.

For discount rates between 1% and 5%, Reference 15 indicates that a linear interpolation is appropriate between present values of $1.2E+9 at 5% and $1.6E+9 at 1%. So for discount rates in this range the following equation was used to perform this linear interpolation.

$$PV_{RP} = \left\{ \left(\$1.6E+9\right) - \left(\frac{\left[\left(\$1.6E+9\right) - \left(\$1.2E+9\right)\right]}{\left[5\% - 1\%\right]} * \left[r_s - 1\% \right] \right) \right\} * \left\{ \frac{Ratepwr}{910MWe} \right\}$$

Where
r_s = Discount rate (small), between 1% and 5%.
Ratepwr = Rated power of the unit

To account for the entire lifetime of the facility, U$_{RP}$ was then calculated from PV$_{RP}$, as follows:

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

Where
U$_{RP}$ = Present value of the cost of replacement power over the life of the facility.

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

$$U_{RP} = \left\{ \left(\$1.9E+10\right) - \left(\frac{\left[\left(\$1.9E+10\right) - \left(\$1.2E+10\right)\right]}{\left[5\% - 1\%\right]} * \left[r_s - 1\% \right] \right) \right\} * \left\{ \frac{Ratepwr}{910MWe} \right\}$$

Where
r_s = Discount rate (small), between 1% and 5%.
Ratepwr = Rated power of the unit

c) Repair and Refurbishment

It is assumed that the plant would not be repaired/refurbished. Therefore, there is no contribution to averted onsite costs from this source.

d) Total Onsite Property Damage Costs

The net present value of averted onsite damage costs is, therefore:

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

Where F = Annual frequency of the event.

4.5 TOTAL COST OF SEVERE ACCIDENT RISK / MAXIMUM BENEFIT

Cost/benefit evaluation of the maximum benefit is baseline risk of the plant converted dollars by summing the contributors to cost.

Maximum Benefit Value = (APE + AOC + AOE + AOSC)

where APE = present value of averted public exposure ($),
AOC = present value of averted offsite property damage costs ($),
AOE = present value of averted occupational exposure ($),
AOSC = present value of averted onsite costs ($)

For Callaway Plant, based on the internal events PRA this value is $698,101 as shown in Table 4-1.

Table 4-1. Contributions to Maximum Averted Cost Risk

Parameter	Present Dollar Value ($)
Averted Public Exposure	$98,930
Averted offsite costs	$223,382
Averted occupational exposure	$6300
Averted onsite costs	$369,549
Total (Maximum Averted Cost Risk – MACR)	$698,161

This internal events MACR is multiplied by 4.57 to account for external event and internal flooding contributions not included in the internal events PRA (Section 3.1.2.4). The resulting modified MACR is $3,192,773. This value was used for the SAMA screening and sensitivity analyses.

5.0 SAMA IDENTIFICATION

A list of SAMA candidates was developed by reviewing the major contributors to CDF and population dose based on the plant-specific risk assessment and the standard pressurized water reactor (PWR) list of enhancements from Reference 19 (NEI 05-01). Other recent license renewal applications (including Wolf Creek) were also reviewed to identify any applicable SAMA items for consideration. This section discusses the SAMA selection process and its results.

5.1 PRA IMPORTANCE

The top core damage sequences and the components/systems having the greatest potential for risk reduction were examined to determine whether additional SAMAs could be identified from these sources.

Use of Importance Measures

RRW of the basic events in the baseline model was used to identify those basic events that could have a significant potential for reducing risk. Basic Events with RRW >1.02 were identified as the most important. The basic events were reviewed to ensure that each basic event on the importance lists is covered by an existing SAMA item or added to the list if not.

5.2 PLANT IPE

The Callaway Plant PRA identified no potential vulnerabilities. However, a number of plant modifications and procedure changes to reduce risk were identified. The Callaway Plant potential enhancements are listed in Table 5-1.

5.3 PLANT IPEEE

Potential improvements to reduce seismic risk and risk from other external events were evaluated in the Callaway Plant IPEEE. These items are included in Table 5-1.

5.4 INDUSTRY SAMA CANDIDATES

The generic PWR enhancement list from Table 14 of Reference 19 was included in the list of Phase I SAMA candidates to assure adequate consideration of potential enhancements identified by other industry studies.

5.5 PLANT STAFF INPUT TO SAMA CANDIDATES

The Callaway plant staff provided plant specific items that were included in the evaluation. These are identified in the list of SAMA candidates by their source.

5.6 LIST OF PHASE I SAMA CANDIDATES

Table 5-1 provides the combined list of potential SAMA candidates considered in the Callaway Plant SAMA analysis. From this table it can be seen that 171 SAMA candidates were identified for consideration.

Table 5-1. List of SAMA Candidates.

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
1	Provide additional DC battery capacity.	Extended DC power availability during an SBO station blackout (SBO).	AC/DC	1
2	Replace lead-acid batteries with fuel cells.	Extended DC power availability during an SBO.	AC/DC	1
3	Add additional battery charger or portable, diesel-driven battery charger to existing DC system.	Improved availability of DC power system.	AC/DC	1
4	Improve DC bus load shedding.	Extended DC power availability during an SBO.	AC/DC	1
5	Provide DC bus cross-ties.	Improved availability of DC power system.	AC/DC	1
6	Provide additional DC power to the 120/240V vital AC system.	Increased availability of the 120 V vital AC bus.	AC/DC	1
7	Add an automatic feature to transfer the 120V vital AC bus from normal to standby power.	Increased availability of the 120 V vital AC bus.	AC/DC	1
8	Increase training on response to loss of two 120V AC buses which causes inadvertent actuation signals.	Improved chances of successful response to loss of two 120V AC buses.	AC/DC	1
9	Provide an additional diesel generator.	Increased availability of on-site emergency AC power.	AC/DC	1
10	Revise procedure to allow bypass of diesel generator trips.	Extended diesel generator operation.	AC/DC	1
11	Improve 4.16-kV bus cross-tie ability.	Increased availability of on-site AC power.	AC/DC	1
12	Create AC power cross-tie capability with other unit (multi-unit site)	Increased availability of on-site AC power.	AC/DC	1
13	Install an additional, buried off-site power source.	Reduced probability of loss of off-site power.	AC/DC	1
14	Install a gas turbine generator.	Increased availability of on-site AC power.	AC/DC	1
15	Install tornado protection on gas turbine generator.	Increased availability of on-site AC power.	AC/DC	1
16	Improve uninterruptible power supplies.	Increased availability of power supplies supporting front-line equipment.	AC/DC	1
17	Create a cross-tie for diesel fuel oil (multi-unit site).	Increased diesel generator availability.	AC/DC	1
18	Develop procedures for replenishing diesel fuel oil.	Increased diesel generator availability.	AC/DC	1
19	Use fire water system as a backup source for diesel cooling.	Increased diesel generator availability.	AC/DC	1
20	Add a new backup source of diesel cooling.	Increased diesel generator availability.	AC/DC	1
21	Develop procedures to repair or replace failed 4 KV breakers.	Increased probability of recovery from failure of breakers that transfer 4.16 kV non-emergency buses from unit station service transformers.	AC/DC	1
22	In training, emphasize steps in recovery of off-site power after an SBO.	Reduced human error probability during off-site power recovery.	AC/DC	1
23	Develop a severe weather conditions procedure.	Improved off-site power recovery following external weather-related events.	AC/DC	1
24	Bury off-site power lines.	Improved off-site power reliability during severe weather.	AC/DC	1
25	Install an independent active or passive high pressure injection system.	Improved prevention of core melt sequences.	Core Cooling	1

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
26	Provide an additional high pressure injection pump with independent diesel.	Reduced frequency of core melt from small LOCA and SBO sequences.	Core Cooling	1
27	Revise procedure to allow operators to inhibit automatic vessel depressurization in non-ATWS scenarios.	Extended HPCI and RCIC operation.	Core Cooling	1
28	Add a diverse low pressure injection system.	Improved injection capability.	Core Cooling	1
29	Provide capability for alternate injection via diesel-driven fire pump.	Improved injection capability.	Core Cooling	1
30	Improve ECCS suction strainers.	Enhanced reliability of ECCS suction.	Core Cooling	1
31	Add the ability to manually align emergency core cooling system recirculation.	Enhanced reliability of ECCS suction.	Core Cooling	1
32	Add the ability to automatically align emergency core cooling system to recirculation mode upon refueling water storage tank depletion.	Enhanced reliability of ECCS suction.	Core Cooling	1
33	Provide hardware and procedure to refill the reactor water storage tank once it reaches a specified low level.	Extended reactor water storage tank capacity in the event of a steam generator tube rupture (or other LOCAs challenging RWST capacity).	Core Cooling	1
34	Provide an in-containment reactor water storage tank.	Continuous source of water to the safety injection pumps during a LOCA event, since water released from a breach of the primary system collects in the in-containment reactor water storage tank, and thereby eliminates the need to realign the safety injection pumps for long-term post-LOCA recirculation.	Core Cooling	1
35	Throttle low pressure injection pumps earlier in medium or large-break LOCAs to maintain reactor water storage tank inventory.	Extended reactor water storage tank capacity.	Core Cooling	1
36	Emphasize timely recirculation alignment in operator training.	Reduced human error probability associated with recirculation failure.	Core Cooling	1
37	Upgrade the chemical and volume control system to mitigate small LOCAs.	For a plant like the Westinghouse AP600, where the chemical and volume control system cannot mitigate a small LOCA, an upgrade would decrease the frequency of core damage.	Core Cooling	1
38	Change the in-containment reactor water storage tank suction from four check valves to two check and two air-operated valves.	Reduced common mode failure of injection paths.	Core Cooling	1
39	Replace two of the four electric safety injection pumps with diesel-powered pumps.	Reduced common cause failure of the safety injection system. This SAMA was originally intended for the Westinghouse-CE System 80+, which has four trains of safety injection. However, the intent of this SAMA is to provide diversity within the high- and l	Core Cooling	1

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
40	Provide capability for remote, manual operation of secondary side pilot-operated relief valves in a station blackout.	Improved chance of successful operation during station blackout events in which high area temperatures may be encountered (no ventilation to main steam areas).	Core Cooling	1
41	Create a reactor coolant depressurization system.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	Core Cooling	1
42	Make procedure changes for reactor coolant system depressurization.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	Core Cooling	1
43	Add redundant DC control power for SW pumps.	Increased availability of SW.	Cooling Water	1
44	Replace ECCS pump motors with air-cooled motors.	Elimination of ECCS dependency on component cooling system.	Cooling Water	1
45	Enhance procedural guidance for use of cross-tied component cooling or service water pumps.	Reduced frequency of loss of component cooling water and service water.	Cooling Water	1
46	Add a service water pump.	Increased availability of cooling water.	Cooling Water	1
47	Enhance the screen wash system.	Reduced potential for loss of SW due to clogging of screens.	Cooling Water	1
48	Cap downstream piping of normally closed component cooling water drain and vent valves.	Reduced frequency of loss of component cooling water initiating events, some of which can be attributed to catastrophic failure of one of the many single isolation valves.	Cooling Water	1
49	Enhance loss of component cooling water (or loss of service water) procedures to facilitate stopping the reactor coolant pumps.	Reduced potential for reactor coolant pump seal damage due to pump bearing failure.	Cooling Water	1
50	Enhance loss of component cooling water procedure to underscore the desirability of cooling down the reactor coolant system prior to seal LOCA.	Reduced probability of reactor coolant pump seal failure.	Cooling Water	1
51	Additional training on loss of component cooling water.	Improved success of operator actions after a loss of component cooling water.	Cooling Water	1
52	Provide hardware connections to allow another essential raw cooling water system to cool charging pump seals.	Reduced effect of loss of component cooling water by providing a means to maintain the charging pump seal injection following a loss of normal cooling water.	Cooling Water	1
53	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend the component cooling water heat-up time.	Increased time before loss of component cooling water (and reactor coolant pump seal failure) during loss of essential raw cooling water sequences.	Cooling Water	1
54	Increase charging pump lube oil capacity.	Increased time before charging pump failure due to lube oil overheating in loss of cooling water sequences.	Cooling Water	1

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
55	Install an independent reactor coolant pump seal injection system, with dedicated diesel.	Reduced frequency of core damage from loss of component cooling water, service water, or station blackout.	Cooling Water	1
56	Install an independent reactor coolant pump seal injection system, without dedicated diesel.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout.	Cooling Water	1
57	Use existing hydro test pump for reactor coolant pump seal injection.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout, unless an alternate power source is used.	Cooling Water	1
58	Install improved reactor coolant pump seals.	Reduced likelihood of reactor coolant pump seal LOCA.	Cooling Water	1
59	Install an additional component cooling water pump.	Reduced likelihood of loss of component cooling water leading to a reactor coolant pump seal LOCA.	Cooling Water	1
60	Prevent makeup pump flow diversion through the relief valves.	Reduced frequency of loss of reactor coolant pump seal cooling if spurious high pressure injection relief valve opening creates a flow diversion large enough to prevent reactor coolant pump seal injection.	Cooling Water	1
61	Change procedures to isolate reactor coolant pump seal return flow on loss of component cooling water, and provide (or enhance) guidance on loss of injection during seal LOCA.	Reduced frequency of core damage due to loss of seal cooling.	Cooling Water	1
62	Implement procedures to stagger high pressure safety injection pump use after a loss of service water.	Extended high pressure injection prior to overheating following a loss of service water.	Cooling Water	1
63	Use fire prevention system pumps as a backup seal injection and high pressure makeup source.	Reduced frequency of reactor coolant pump seal LOCA.	Cooling Water	1
64	Implement procedure and hardware modifications to allow manual alignment of the fire water system to the component cooling water system, or install a component cooling water header cross-tie.	Improved ability to cool residual heat removal heat exchangers.	Cooling Water	1
65	Install a digital feed water upgrade.	Reduced chance of loss of main feed water following a plant trip.	Feedwater/ Condensate	1
66	Create ability for emergency connection of existing or new water sources to feedwater and condensate systems.	Increased availability of feedwater.	Feedwater/ Condensate	1
67	Install an independent diesel for the condensate storage tank makeup pumps.	Extended inventory in CST during an SBO.	Feedwater/ Condensate	1
68	Add a motor-driven feedwater pump.	Increased availability of feedwater.	Feedwater/ Condensate	1
69	Install manual isolation valves around auxiliary feedwater turbine-driven steam admission valves.	Reduced dual turbine-driven pump maintenance unavailability.	Feedwater/ Condensate	1

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
70	Install accumulators for turbine-driven auxiliary feedwater pump flow control valves.	Eliminates the need for local manual action to align nitrogen bottles for control air following a loss of off-site power.	Feedwater/ Condensate	1
71	Install a new condensate storage tank (auxiliary feedwater storage tank).	Increased availability of the auxiliary feedwater system.	Feedwater/ Condensate	1
72	Modify the turbine-driven auxiliary feedwater pump to be self-cooled.	Improved success probability during a station blackout.	Feedwater/ Condensate	1
73	Proceduralize local manual operation of auxiliary feedwater system when control power is lost.	Extended auxiliary feedwater availability during a station blackout. Also provides a success path should auxiliary feedwater control power be lost in non-station blackout sequences.	Feedwater/ Condensate	1
74	Provide hookup for portable generators to power the turbine-driven auxiliary feedwater pump after station batteries are depleted.	Extended auxiliary feedwater availability.	Feedwater/ Condensate	1
75	Use fire water system as a backup for steam generator inventory.	Increased availability of steam generator water supply.	Feedwater/ Condensate	1
76	Change failure position of condenser makeup valve if the condenser makeup valve fails open on loss of air or power.	Allows greater inventory for the auxiliary feedwater pumps by preventing condensate storage tank flow diversion to the condenser.	Feedwater/ Condensate	1
77	Provide a passive, secondary-side heat-rejection loop consisting of a condenser and heat sink.	Reduced potential for core damage due to loss-of-feedwater events.	Feedwater/ Condensate	1
78	Modify the startup feedwater pump so that it can be used as a backup to the emergency feedwater system, including during a station blackout scenario.	Increased reliability of decay heat removal.	Feedwater/ Condensate	1
79	Replace existing pilot-operated relief valves with larger ones, such that only one is required for successful feed and bleed.	Increased probability of successful feed and bleed.	Feedwater/ Condensate	1
80	Provide a redundant train or means of ventilation.	Increased availability of components dependent on room cooling.	HVAC	1
81	Add a diesel building high temperature alarm or redundant louver and thermostat.	Improved diagnosis of a loss of diesel building HVAC.	HVAC	1
82	Stage backup fans in switchgear rooms.	Increased availability of ventilation in the event of a loss of switchgear ventilation.	HVAC	1
83	Add a switchgear room high temperature alarm.	Improved diagnosis of a loss of switchgear HVAC.	HVAC	1
84	Create ability to switch emergency feedwater room fan power supply to station batteries in a station blackout.	Continued fan operation in a station blackout.	HVAC	1
85	Provide cross-unit connection of uninterruptible compressed air supply.	Increased ability to vent containment using the hardened vent.	IA/Nitrogen	1
86	Modify procedure to provide ability to align diesel power to more air compressors.	Increased availability of instrument air after a LOOP.	IA/Nitrogen	1

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
87	Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft driven fans.	Elimination of instrument air system dependence on service water cooling.	IA/Nitrogen	1
88	Install nitrogen bottles as backup gas supply for safety relief valves.	Extended SRV operation time.	IA/Nitrogen	1
89	Improve SRV and MSIV pneumatic components.	Improved availability of SRVs and MSIVs.	IA/Nitrogen	1
90	Create a reactor cavity flooding system.	Enhanced debris cool ability, reduced core concrete interaction, and increased fission product scrubbing.	Containment Phenomena	1
91	Install a passive containment spray system.	Improved containment spray capability.	Containment Phenomena	1
92	Use the fire water system as a backup source for the containment spray system.	Improved containment spray capability.	Containment Phenomena	1
93	Install an unfiltered, hardened containment vent.	Increased decay heat removal capability for non-ATWS events, without scrubbing released fission products.	Containment Phenomena	1
94	Install a filtered containment vent to remove decay heat. Option 1: Gravel Bed Filter; Option 2: Multiple Venturi Scrubber	Increased decay heat removal capability for non-ATWS events, with scrubbing of released fission products.	Containment Phenomena	1
95	Enhance fire protection system and standby gas treatment system hardware and procedures.	Improved fission product scrubbing in severe accidents.	Containment Phenomena	1
96	Provide post-accident containment inerting capability.	Reduced likelihood of hydrogen and carbon monoxide gas combustion.	Containment Phenomena	1
97	Create a large concrete crucible with heat removal potential to contain molten core debris.	Increased cooling and containment of molten core debris. Molten core debris escaping from the vessel is contained within the crucible and a water cooling mechanism cools the molten core in the crucible, preventing melt-through of the base mat.	Containment Phenomena	1
98	Create a core melt source reduction system.	Increased 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.	Containment Phenomena	1
99	Strengthen primary/secondary containment (e.g., add ribbing to containment shell).	Reduced probability of containment over-pressurization.	Containment Phenomena	1
100	Increase depth of the concrete base mat or use an alternate concrete material to ensure melt-through does not occur.	Reduced probability of base mat melt-through.	Containment Phenomena	1
101	Provide a reactor vessel exterior cooling system.	Increased potential to cool a molten core before it causes vessel failure, by submerging the lower head in water.	Containment Phenomena	1

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
102	Construct a building to be connected to primary/secondary containment and maintained at a vacuum.	Reduced probability of containment over-pressurization.	Containment Phenomena	1
103	Institute simulator training for severe accident scenarios.	Improved arrest of core melt progress and prevention of containment failure.	Containment Phenomena	1
104	Improve leak detection procedures.	Increased piping surveillance to identify leaks prior to complete failure. Improved leak detection would reduce LOCA frequency.	Containment Phenomena	1
105	Delay containment spray actuation after a large LOCA.	Extended reactor water storage tank availability.	Containment Phenomena	1
106	Install automatic containment spray pump header throttle valves.	Extended time over which water remains in the reactor water storage tank, when full containment spray flow is not needed.	Containment Phenomena	1
107	Install a redundant containment spray system.	Increased containment heat removal ability.	Containment Phenomena	1
108	Install an independent power supply to the hydrogen control system using either new batteries, a non-safety grade portable generator, existing station batteries, or existing AC/DC independent power supplies, such as the security system diesel.	Reduced hydrogen detonation potential.	Containment Phenomena	1
109	Install a passive hydrogen control system.	Reduced hydrogen detonation potential.	Containment Phenomena	1
110	Erect a barrier that would provide enhanced protection of the containment walls (shell) from ejected core debris following a core melt scenario at high pressure.	Reduced probability of containment failure.	Containment Phenomena	1
111	Install additional pressure or leak monitoring instruments for detection of ISLOCAs.	Reduced ISLOCA frequency.	Containment Bypass	1
112	Add redundant and diverse limit switches to each containment isolation valve.	Reduced frequency of containment isolation failure and ISLOCAs.	Containment Bypass	1
113	Increase leak testing of valves in ISLOCA paths.	Reduced ISLOCA frequency.	Containment Bypass	1
114	Install self-actuating containment isolation valves.	Reduced frequency of isolation failure.	Containment Bypass	1
115	Locate residual heat removal (RHR) inside containment	Reduced frequency of ISLOCA outside containment.	Containment Bypass	1
116	Ensure ISLOCA releases are scrubbed. One method is to plug drains in potential break areas so that break point will be covered with water.	Scrubbed ISLOCA releases.	Containment Bypass	1

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
117	Revise EOPs to improve ISLOCA identification.	Increased likelihood that LOCAs outside containment are identified as such. A plant had a scenario in which an RHR ISLOCA could direct initial leakage back to the pressurizer relief tank, giving indication that the LOCA was inside containment.	Containment Bypass	1
118	Improve operator training on ISLOCA coping.	Decreased ISLOCA consequences.	Containment Bypass	1
119	Institute a maintenance practice to perform a 100% inspection of steam generator tubes during each refueling outage.	Reduced frequency of steam generator tube ruptures.	Containment Bypass	1
120	Replace steam generators with a new design.	Reduced frequency of steam generator tube ruptures.	Containment Bypass	1
121	Increase the pressure capacity of the secondary side so that a steam generator tube rupture would not cause the relief valves to lift.	Eliminates release pathway to the environment following a steam generator tube rupture.	Containment Bypass	1
122	Install a redundant spray system to depressurize the primary system during a steam generator tube rupture	Enhanced depressurization capabilities during steam generator tube rupture.	Containment Bypass	1
123	Proceduralize use of pressurizer vent valves during steam generator tube rupture sequences.	Backup method to using pressurizer sprays to reduce primary system pressure following a steam generator tube rupture.	Containment Bypass	1
124	Provide improved instrumentation to detect steam generator tube ruptures, such as Nitrogen-16 monitors).	Improved mitigation of steam generator tube ruptures.	Containment Bypass	1
125	Route the discharge from the main steam safety valves through a structure where a water spray would condense the steam and remove most of the fission products.	Reduced consequences of a steam generator tube rupture.	Containment Bypass	1
126	Install a highly reliable (closed loop) steam generator shell-side heat removal system that relies on natural circulation and stored water sources	Reduced consequences of a steam generator tube rupture.	Containment Bypass	1
127	Revise emergency operating procedures to direct isolation of a faulted steam generator.	Reduced consequences of a steam generator tube rupture.	Containment Bypass	1
128	Direct steam generator flooding after a steam generator tube rupture, prior to core damage.	Improved scrubbing of steam generator tube rupture releases.	Containment Bypass	1
129	Vent main steam safety valves in containment.	Reduced consequences of a steam generator tube rupture.	Containment Bypass	1
130	Add an independent boron injection system.	Improved availability of boron injection during ATWS.	ATWS	1
131	Add a system of relief valves to prevent equipment damage from pressure spikes during an ATWS.	Improved equipment availability after an ATWS.	ATWS	1
132	Provide an additional control system for rod insertion (e.g., AMSAC).	Improved redundancy and reduced ATWS frequency.	ATWS	1
133	Install an ATWS sized filtered containment vent to remove decay heat.	Increased ability to remove reactor heat from ATWS events.	ATWS	1

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
134	Revise procedure to bypass MSIV isolation in turbine trip ATWS scenarios.	Affords operators more time to perform actions. Discharge of a substantial fraction of steam to the main condenser (i.e., as opposed to into the primary containment) affords the operator more time to perform actions (e.g., SLC injection, lower water level, depressurize RPV) than if the main condenser was unavailable, resulting in lower human error probabilities.	ATWS	1
135	Revise procedure to allow override of low pressure core injection during an ATWS event.	Allows immediate control of low pressure core injection. On failure of high pressure core injection and condensate, some plants direct reactor depressurization followed by five minutes of automatic low pressure core injection.	ATWS	1
136	Install motor generator set trip breakers in control room.	Reduced frequency of core damage due to an ATWS.	ATWS	1
137	Provide capability to remove power from the bus powering the control rods.	Decreased time required to insert control rods if the reactor trip breakers fail (during a loss of feedwater ATWS which has rapid pressure excursion).	ATWS	1
138	Improve inspection of rubber expansion joints on main condenser.	Reduced frequency of internal flooding due to failure of circulating water system expansion joints.	Internal Flooding	1
139	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	Prevents flood propagation.	Internal Flooding	1
140	Increase seismic ruggedness of plant components.	Increased availability of necessary plant equipment during and after seismic events.	Seismic Risk	1
141	Provide additional restraints for CO2 tanks.	Increased availability of fire protection given a seismic event.	Seismic Risk	1
142	Replace mercury switches in fire protection system.	Decreased probability of spurious fire suppression system actuation.	Fire Risk	1
143	Upgrade fire compartment barriers.	Decreased consequences of a fire.	Fire Risk	1
144	Install additional transfer and isolation switches.	Reduced number of spurious actuations during a fire.	Fire Risk	1
145	Enhance fire brigade awareness.	Decreased consequences of a fire.	Fire Risk	1
146	Enhance control of combustibles and ignition sources.	Decreased fire frequency and consequences.	Fire Risk	1
147	Install digital large break LOCA protection system.	Reduced probability of a large break LOCA (a leak before break).	Other	1
148	Enhance procedures to mitigate large break LOCA.	Reduced consequences of a large break LOCA.	Other	1
149	Install computer aided instrumentation system to assist the operator in assessing post-accident plant status.	Improved prevention of core melt sequences by making operator actions more reliable.	Other	1
150	Improve maintenance procedures.	Improved prevention of core melt sequences by increasing reliability of important equipment.	Other	1
151	Increase training and operating experience feedback to improve operator response.	Improved likelihood of success of operator actions taken in response to abnormal conditions.	Other	1

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
152	Develop procedures for transportation and nearby facility accidents.	Reduced consequences of transportation and nearby facility accidents.	Other	1
153	Install secondary side guard pipes up to the main steam isolation valves.	Prevents secondary side depressurization should a steam line break occur upstream of the main steam isolation valves. Also guards against or prevents consequential multiple steam generator tube ruptures following a main steam line break event.	Other	1
154	Mount or anchor the MCCs to the respective building walls.	Reduces failure probability of MCCs during an earthquake	IPEEE - Seismic	B
155	Install shear pins (or strength bolts) in the AFW pumps.	Takes up the shear load on the pump and/or driver during an earthquake.	IPEEE - Seismic	B
156	Mount all fire extinguishers within their UL Standard required drop height and remove hand-held fire extinguishers from Containment during normal operation.	Reduces the potential for the fire extinguishers to fall during an earthquake and potentially fracturing upon impact with the floor or another object.	IPEEE - Seismic	B
157	Identify and remove unsecured equipment near areas that contain relays that actuate, so area is kept clear.	Ensures direct access to areas such as Load Shedding and Emergency Load Sequencing (LSELS) and Engineered Safety Feature Actuation System (ESFAS) cabinets. Unsecured equipment (e.g., carts, filing cabinets, and test equipment) in these areas could result	IPEEE – Seismic	B
158	Properly position chain hoists that facilitate maintenance on pumps within pump rooms and institute a training program to ensure that the hoists are properly positioned when not in use.	Improper positioning of hoists reduces the availability due to moving during an earthquake and having chainfalls impacting pump oil bubblers or other soft targets resulting in failure of the pumps.	IPEEE – Seismic	B
159	Secure floor grating to prevent damage to sensing lines due to differential building motion.	Prevent sensing lines that pass through the grating from being damaged.	IPEEE – Seismic	B
160	Modifications to lessen impact of internal flooding path through Control Building dumbwaiter.	Lower impact of flood that propagates through the dumbwaiter	Internal Flooding	D
161	Improvements to PORV performance that will lower the probability of failure to open.	Decrease in risk due to PORV failing to open.	Core Cooling	E
162	Install a large volume EDG fuel oil tank at an elevation greater than the EDG fuel oil day tanks.	Allows transfer of EDF fuel oil to the EDG day tanks on failure of the fuel oil transfer pumps.	AC/DC	C
163	Improve feedwater check valve reliability to reduce probability of failure to open.	Lower risk due to failures in which feedwater check valves fail to open and allow feeding of the steam generators.	Cooling Water	E
164	Provide the capability to power the normal service water pumps from AEPS.	Provide backup to ESW in conditions with power only available from AEPS.	Cooling Water	D

Table 5-1. List of SAMA Candidates (Continued).

Callaway SAMA Number	Potential Improvement	Discussion	Focus of SAMA	Source
165	Purchase or manufacture a "gagging device" that could be used to close a stuck open steam generator relief valve for a SGTR event prior to core damage.	Reduce the amount of radioactive material release to the atmosphere in a SGTR event with core damage.	SGTR	C
166	Installation of high temperature qualified RCP seal O-rings.	Lower potential for RCP seal leakage.	RCP Seal LOCA	A
167	Addition of procedural guidance to re-establish normal service water should essential service water fail.	Provide back-up pumps for UHS cooling.	Cooling Water	A
168	Addition of procedural guidance for running charging and safety injection pumps without component cooling water	Allow use of pumps following loss of component cooling water.	Cooling Water	A
169	Addition of procedural guidance to verify RHR pump room cooling at switchover to ECCS recirculation phase.	Verifying that support system for RHR pumps is in service to allow continued operation of RHR pumps.	HVAC	A
170	Modifications to add controls in the main control room to allow remote operation of nearby diesel generator farm and alignment/connection to the plant vital electrical busses.	Faster ability to provide power to the plant electrical busses from the offsite diesel generator farm.	AC Power	C
171	Increase the size of the RWST or otherwise improve the availability of the RWST	Ensure a supply of makeup water is available from the RWST.	Core Cooling	E

Note 1: The source references are:
- 1 NEI 05-01 (Reference 19)
- A IPE (Reference 28)
- B IPEEE (Reference 29)
- C Recent industry SAMA submittals (Wolf Creek, South Texas, Diablo Canyon, Seabrook)
- D Expert panel convened to review SAMA analysis
- E PRA importance list review

6.0 PHASE I ANALYSIS

A preliminary screening of the complete list of SAMA candidates was performed to limit the number of SAMAs for which detailed analysis in Phase II was necessary. The screening criteria used in the Phase I analysis are described below.

- Screening Criterion A - Not Applicable: If a SAMA candidate did not apply to the Callaway Unit 1 plant design, it was not retained.
- Screening Criterion B - Already Implemented or Intent Met: If a SAMA candidate had already been implemented at the Callaway Plant or its intended benefit already achieved by other means, it was not retained.
- Screening Criterion C - Combined: If a SAMA candidate was similar in nature and could be combined with another SAMA candidate to develop a more comprehensive or plant-specific SAMA candidate, only the combined SAMA candidate was retained.
- Screening Criterion D - Excessive Implementation Cost: If a SAMA required extensive changes that will obviously exceed the maximum benefit (Section 4.5), even without an implementation cost estimate, it was not retained.
- Screening Criterion E - Very Low Benefit: If a SAMA from an industry document was related to a non-risk significant system for which change in reliability is known to have negligible impact on the risk profile, it was not retained. (No SAMAs were screened using this criterion.)

Table 6-1 presents the list of Phase I SAMA candidates and provides the disposition of each candidate along with the applicable screening criterion associated with each candidate. Those candidates that have not been screened by application of these criteria are evaluated further in the Phase II analysis (Section 7). It can be seen from this table that 107 SAMAs were screened from the analysis during Phase 1 and that 64 SAMAs passed into the next phase of the analysis.

Table 6-1. Callaway Plant Phase I SAMA Analysis

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
12	Create AC power cross-tie capability with other unit (multi-unit site)	Increased availability of on-site AC power.	Yes	A - Not Applicable	Callaway is a single unit site.
17	Create a cross-tie for diesel fuel oil (multi-unit site).	Increased diesel generator availability.	Yes	A - Not Applicable	Callaway is a single unit site.
27	Revise procedure to allow operators to inhibit automatic vessel depressurization in non-ATWS scenarios.	Extended HPCI and RCIC operation.	Yes	A - Not Applicable	BWR item.
34	Provide an in-containment reactor water storage tank.	Continuous source of water to the safety injection pumps during a LOCA event, since water released from a breach of the primary system collects in the in-containment reactor water storage tank, and thereby eliminates the need to realign the safety injection pumps for long-term post-LOCA recirculation.	Yes	A - Not Applicable	Not applicable for existing designs. Insufficient room inside primary containment.
35	Throttle low pressure injection pumps earlier in medium or large-break LOCAs to maintain reactor water storage tank inventory.	Extended reactor water storage tank capacity.	Yes	A - Not Applicable	Per the Callaway safety analysis, this is an undesirable action. The Callaway safety analysis and design calls for injection of the RWST to inside the containment as soon as possible.
38	Change the in-containment reactor water storage tank suction from four check valves to two check and two air-operated valves.	Reduced common mode failure of injection paths.	Yes	A - Not Applicable	Callaway does not have an in-containment RWST with this valve arrangement.
47	Enhance the screen wash system.	Reduced potential for loss of SW due to clogging of screens.	Yes	A - Not Applicable	Plant uses Ultimate Heat Sink pond for cooling. UHS sized for 30 days without make-up. River intake is only used for make-up to the UHS.
52	Provide hardware connections to allow another essential raw cooling water system to cool charging pump seals.	Reduced effect of loss of component cooling water by providing a means to maintain the charging pump seal injection following a loss of normal cooling water.	Yes	A - Not Applicable	Charging pump seals do not require external cooling, they are cooled by the process fluid.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
57	Use existing hydro test pump for reactor coolant pump seal injection.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout, unless an alternate power source is used.	Yes	A - Not Applicable	Callaway does not have a permanently installed hydro test pump. Timing considerations prevent credit for hookup of temporary pump.
63	Use fire prevention system pumps as a backup seal injection and high pressure makeup source.	Reduced frequency of reactor coolant pump seal LOCA.	Yes	A - Not Applicable	Existing fire protection system pumps do not have sufficient discharge head to use as high pressure makeup source.
69	Install manual isolation valves around auxiliary feedwater turbine-driven steam admission valves.	Reduced dual turbine-driven pump maintenance unavailability.	Yes	A - Not Applicable	Callaway does not have dual turbine AFW pump.
85	Provide cross-unit connection of uninterruptible compressed air supply.	Increased ability to vent containment using the hardened vent.	Yes	A - Not Applicable	N/A, single unit.
95	Enhance fire protection system and standby gas treatment system hardware and procedures.	Improved fission product scrubbing in severe accidents.	Yes	A - Not Applicable	Standby gas treatment system is BWR item.
105	Delay containment spray actuation after a large LOCA.	Extended reactor water storage tank availability.	Yes	A - Not Applicable	Per the Callaway safety analysis, this is an undesirable action. The Callaway safety analysis and design calls for injection of the RWST to inside the containment as soon as possible.
106	Install automatic containment spray pump header throttle valves.	Extended time over which water remains in the reactor water storage tank, when full containment spray flow is not needed.	Yes	A - Not Applicable	Per the Callaway safety analysis, this is an undesirable action. The Callaway safety analysis and design calls for injection of the RWST to inside the containment as soon as possible.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
134	Revise procedure to bypass MSIV isolation in turbine trip ATWS scenarios.	Affords operators more time to perform actions. Discharge of a substantial fraction of steam to the main condenser (i.e., as opposed to into the primary containment) affords the operator more time to perform actions (e.g., SLC injection, lower water level, depressurize RPV) than if the main condenser was unavailable, resulting in lower human error probabilities.	Yes	A - Not Applicable	Specific to BWRs.
135	Revise procedure to allow override of low pressure core injection during an ATWS event.	Allows immediate control of low pressure core injection. On failure of high pressure core injection and condensate, some plants direct reactor depressurization followed by five minutes of automatic low pressure core injection.	Yes	A - Not Applicable	Based on description, this is a BWR item.
138	Improve inspection of rubber expansion joints on main condenser.	Reduced frequency of internal flooding due to failure of circulating water system expansion joints.	Yes	A - Not Applicable	No risk significant flooding sources identified in the turbine building.
139	Modify swing direction of doors separating turbine building basement from areas containing safeguards equipment.	Prevents flood propagation.	Yes	A - Not Applicable	Flooding analysis did not indicate any flooding issues related to the direction of door swing.
142	Replace mercury switches in fire protection system.	Decreased probability of spurious fire suppression system actuation.	Yes	A - Not Applicable	No mercury switches in the fire protection system.
143	Upgrade fire compartment barriers.	Decreased consequences of a fire.	Yes	A - Not Applicable	Fire analysis did not identify any issues related to fire barriers. NFPA 805 Fire Protection Program is in progress, any issues identified by that project will be handled by the NFPA 805 program.
152	Develop procedures for transportation and nearby facility accidents.	Reduced consequences of transportation and nearby facility accidents.	Yes	A - Not Applicable	IPEEE determined that there are no transportation routes or nearby facilities that could cause concern.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
165	Purchase or manufacture a "gagging device" that could be used to close a stuck open steam generator relief valve for a SGTR event prior to core damage.	Reduce the amount of radioactive material release to the atmosphere in a SGTR event with core damage.	Yes	A - Not Applicable	Callaway does not have the ability to isolate the steam generator from the RCS loop. The amount of force required to close a stuck open atmospheric steam dump valve would likely not be successful and would result in further damage to the valve.
3	Add additional battery charger or portable, diesel-driven battery charger to existing DC system.	Improved availability of DC power system.	Yes	B - Intent Met	Current configuration is two spare battery chargers for the instrument buses. The spare can carry one bus. One feeds A/B, the other feeds C/D trains. Also Emergency Coordinator Supplemental Guidelines, Attachment N, "Temporary Power to NK Swing Charger
4	Improve DC bus load shedding.	Extended DC power availability during an SBO.	Yes	B - Intent Met	DC load shedding is conducted.
6	Provide additional DC power to the 120/240V vital AC system.	Increased availability of the 120 V vital AC bus.	Yes	B - Intent Met	Procedures in place to provide temporary power to DC Chargers which can power vital AC system.
7	Add an automatic feature to transfer the 120V vital AC bus from normal to standby power.	Increased availability of the 120 V vital AC bus.	Yes	B - Intent Met	On loss of DC or inverter, the UPS static switch automatically transfers to AC power through a constant voltage transformer. An additional backup AC source is available, but must be closed manually.
8	Increase training on response to loss of two 120V AC buses which causes inadvertent actuation signals.	Improved chances of successful response to loss of two 120V AC buses.	Yes	B - Intent Met	Typical response training in place.
9	Provide an additional diesel generator.	Increased availability of on-site emergency AC power.	Yes	B - Intent Met	Alternate Emergency Power System installed.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
10	Revise procedure to allow bypass of diesel generator trips.	Extended diesel generator operation.	Yes	B - Intent Met	Bypass of non-vital diesel generator trips were in original design for Callaway.
13	Install an additional, buried off-site power source.	Reduced probability of loss of off-site power.	Yes	B - Intent Met	AEPS installed with buried power lines.
14	Install a gas turbine generator.	Increased availability of on-site AC power.	Yes	B - Intent Met	Alternate Emergency Power System installed.
16	Improve uninterruptible power supplies.	Increased availability of power supplies supporting front-line equipment.	Yes	B - Intent Met	Replaced to add static switch and upgrade to newer design.
18	Develop procedures for replenishing diesel fuel oil.	Increased diesel generator availability.	Yes	B - Intent Met	EOP Addenda direct ordering fuel oil.
19	Use fire water system as a backup source for diesel cooling.	Increased diesel generator availability.	Yes	B - Intent Met	Procedures exist for cooling EDG with fire water.
20	Add a new backup source of diesel cooling.	Increased diesel generator availability.	Yes	B - Intent Met	Procedure exists for backup diesel cooling.
21	Develop procedures to repair or replace failed 4 KV breakers.	Increased probability of recovery from failure of breakers that transfer 4.16 kV non-emergency buses from unit station service transformers.	Yes	B - Intent Met	Spares exist and procedures exist.
22	In training, emphasize steps in recovery of off-site power after an SBO.	Reduced human error probability during off-site power recovery.	Yes	B - Intent Met	Recovery stressed in training.
23	Develop a severe weather conditions procedure.	Improved off-site power recovery following external weather-related events.	Yes	B - Intent Met	Severe weather condition procedure in place.
30	Improve ECCS suction strainers.	Enhanced reliability of ECCS suction.	Yes	B - Intent Met	Callaway has implemented a containment sump modification that now uses state-of-the-art strainers to address the industry's concerns on blockage from debris. This modification occurred over two outages in 2007 and 2008.
31	Add the ability to manually align emergency core cooling system recirculation.	Enhanced reliability of ECCS suction.	Yes	B - Intent Met	Current alignment capabilities are half and half (manual/automatic).

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
32	Add the ability to automatically align emergency core cooling system to recirculation mode upon refueling water storage tank depletion.	Enhanced reliability of ECCS suction.	Yes	B - Intent Met	Current alignment capabilities are half and half (manual/automatic).
33	Provide hardware and procedure to refill the reactor water storage tank once it reaches a specified low level.	Extended reactor water storage tank capacity in the event of a steam generator tube rupture (or other LOCAs challenging RWST capacity).	Yes	B - Intent Met	Addressed in SAMGs and the EC Supplemental Guideline.
36	Emphasize timely recirculation alignment in operator training.	Reduced human error probability associated with recirculation failure.	Yes	B - Intent Met	Current alignment capabilities are half and half (manual/automatic). Swap to recirculation is stressed in operator training.
37	Upgrade the chemical and volume control system to mitigate small LOCAs.	For a plant like the Westinghouse AP600, where the chemical and volume control system cannot mitigate a small LOCA, an upgrade would decrease the frequency of core damage.	Yes	B - Intent Met	CVCS system is capable of mitigating small LOCA.
40	Provide capability for remote, manual operation of secondary side pilot-operated relief valves in a station blackout.	Improved chance of successful operation during station blackout events in which high area temperatures may be encountered (no ventilation to main stream areas).	Yes	B - Intent Met	Remote Operation of Atmospheric Steam Dumps (ASDs) is possible. Equipment Operators trained and Operator Aid posted.
42	Make procedure changes for reactor coolant system depressurization.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	Yes	B - Intent Met	Multiple depressurization methods are in place.
44	Replace ECCS pump motors with air-cooled motors.	Elimination of ECCS dependency on component cooling system.	Yes	B - Intent Met	Current ECCS pump motors are air-cooled. Additionally the plant OTN procedures allow for alternate trains to supply cooling.
45	Enhance procedural guidance for use of cross-tied component cooling or service water pumps.	Reduced frequency of loss of component cooling water and service water.	Yes	B - Intent Met	Can use service water as backup to ESW.
48	Cap downstream piping of normally closed component cooling water drain and vent valves.	Reduced frequency of loss of component cooling water initiating events, some of which can be attributed to catastrophic failure of one of the many single isolation valves.	Yes	B - Intent Met	Vents & drains capped.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
49	Enhance loss of component cooling water (or loss of service water) procedures to facilitate stopping the reactor coolant pumps.	Reduced potential for reactor coolant pump seal damage due to pump bearing failure.	Yes	B - Intent Met	CCW is cooled by ESW. Currently authorized to run 10 minutes.
50	Enhance loss of component cooling water procedure to underscore the desirability of cooling down the reactor coolant system prior to seal LOCA.	Reduced probability of reactor coolant pump seal failure.	Yes	B - Intent Met	Procedures include direction to cool down to minimize impact of RCP seal LOCA.
51	Additional training on loss of component cooling water.	Improved success of operator actions after a loss of component cooling water.	Yes	B - Intent Met	Training is conducted for Loss of CCW.
53	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend the component cooling water heat-up time.	Increased time before loss of component cooling water (and reactor coolant pump seal failure) during loss of essential raw cooling water sequences.	Yes	B - Intent Met	Most non-safety loads have been removed from the system. Non-safety loop is automatically isolated on safety injection signal.
60	Prevent makeup pump flow diversion through the relief valves.	Reduced frequency of loss of reactor coolant pump seal cooling if spurious high pressure injection relief valve opening creates a flow diversion large enough to prevent reactor coolant pump seal injection.	Yes	B - Intent Met	Current configuration does not have a relief valve.
61	Change procedures to isolate reactor coolant pump seal return flow on loss of component cooling water, and provide (or enhance) guidance on loss of injection during seal LOCA.	Reduced frequency of core damage due to loss of seal cooling.	Yes	B - Intent Met	Procedure exist
62	Implement procedures to stagger high pressure safety injection pump use after a loss of service water.	Extended high pressure injection prior to overheating following a loss of service water.	Yes	B - Intent Met	Procedure currently in place to stagger use of HPSI.
66	Create ability for emergency connection of existing or new water sources to feedwater and condensate systems.	Increased availability of feedwater.	Yes	B - Intent Met	Procedures exist.
67	Install an independent diesel for the condensate storage tank makeup pumps.	Extended inventory in CST during an SBO.	Yes	B - Intent Met	Procedures do exist for make-up to CST from fire water and for supplying fire water directly to the TDAFW pump.
68	Add a motor-driven feedwater pump.	Increased availability of feedwater.	Yes	B - Intent Met	Non-Safety Auxiliary Feedwater Pump installed.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
70	Install accumulators for turbine-driven auxiliary feedwater pump flow control valves.	Eliminates the need for local manual action to align nitrogen bottles for control air following a loss of off-site power.	Yes	B - Intent Met	Currently have nitrogen accumulators.
72	Modify the turbine-driven auxiliary feedwater pump to be self-cooled.	Improved success probability during a station blackout.	Yes	B - Intent Met	Turbine-driven auxiliary feedwater pump is self-cooled.
73	Proceduralize local manual operation of auxiliary feedwater system when control power is lost.	Extended auxiliary feedwater availability during a station blackout. Also provides a success path should auxiliary feedwater control power be lost in non-station blackout sequences.	Yes	B - Intent Met	Procedures exist.
74	Provide hookup for portable generators to power the turbine-driven auxiliary feedwater pump after station batteries are depleted.	Extended auxiliary feedwater availability.	Yes	B - Intent Met	Procedures exist, hardware on site.
75	Use fire water system as a backup for steam generator inventory.	Increased availability of steam generator water supply.	Yes	B - Intent Met	Equipment staged at CST for makeup. See operator aids. Procedural guidance exists.
76	Change failure position of condenser makeup valve if the condenser makeup valve fails open on loss of air or power.	Allows greater inventory for the auxiliary feedwater pumps by preventing condensate storage tank flow diversion to the condenser.	Yes	B - Intent Met	Valve currently fails closed.
78	Modify the startup feedwater pump so that it can be used as a backup to the emergency feedwater system, including during a station blackout scenario.	Increased reliability of decay heat removal.	Yes	B - Intent Met	Non-Safety Auxiliary Feedwater Pump gets power from Alternate Emergency Power System.
81	Add a diesel building high temperature alarm or redundant louver and thermostat.	Improved diagnosis of a loss of diesel building HVAC.	Yes	B - Intent Met	Computer points for monitoring diesel room temperatures.
82	Stage backup fans in switchgear rooms.	Increased availability of ventilation in the event of a loss of switchgear ventilation.	Yes	B - Intent Met	Procedures include instructions for opening doors to provide alternate cooling capability.
83	Add a switchgear room high temperature alarm.	Improved diagnosis of a loss of switchgear HVAC.	Yes	B - Intent Met	Plant Process Computer has alarming computer points for switchgear room temperature.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
84	Create ability to switch emergency feedwater room fan power supply to station batteries in a station blackout.	Continued fan operation in a station blackout.	Yes	B - Intent Met	Procedure currently in place to switch fan power supply.
86	Modify procedure to provide ability to align diesel power to more air compressors.	Increased availability of instrument air after a LOOP.	Yes	B - Intent Met	Currently have 3 air compressors (service air). A/B compressors are powered off the emergency buses (cooled from essential service lines). Compressors are initially load shed, but procedure direct operators to override and place compressor in service.
88	Install nitrogen bottles as backup gas supply for safety relief valves.	Extended SRV operation time.	Yes	B - Intent Met	Current configuration includes nitrogen bottles as backup gas supply.
89	Improve SRV and MSIV pneumatic components.	Improved availability of SRVs and MSIVs.	Yes	B - Intent Met	MSIV actuators changed to process fluid actuated. Modification installed to relocate Atmospheric Steam Dump valve controllers.
90	Create a reactor cavity flooding system.	Enhanced debris cool ability, reduced core concrete interaction, and increased fission product scrubbing.	Yes	B - Intent Met	Procedures exist
92	Use the fire water system as a backup source for the containment spray system.	Improved containment spray capability.	Yes	B - Intent Met	Procedures exist
101	Provide a reactor vessel exterior cooling system.	Increased potential to cool a molten core before it causes vessel failure, by submerging the lower head in water.	Yes	B - Intent Met	Procedures exist.
103	Institute simulator training for severe accident scenarios.	Improved arrest of core melt progress and prevention of containment failure.	Yes	B - Intent Met	Operators are trained on the SAMG that the operators must implement.
117	Revise EOPs to improve ISLOCA identification.	Increased likelihood that LOCAs outside containment are identified as such. A plant had a scenario in which an RHR ISLOCA could direct initial leakage back to the pressurizer relief tank, giving indication that the LOCA was inside containment.	Yes	B - Intent Met	Current EOPs address ISLOCA identification.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
118	Improve operator training on ISLOCA coping.	Decreased ISLOCA consequences.	Yes	B - Intent Met	Current procedure training addresses ISLOCA identification.
120	Replace steam generators with a new design.	Reduced frequency of steam generator tube ruptures.	Yes	B - Intent Met	Replaced during the fall of 2005 (newer design) which consist of 72,000 sq. ft. per generator.
123	Proceduralize use of pressurizer vent valves during steam generator tube rupture sequences.	Backup method to using pressurizer sprays to reduce primary system pressure following a steam generator tube rupture.	Yes	B - Intent Met	Procedure currently in place.
124	Provide improved instrumentation to detect steam generator tube ruptures, such as Nitrogen-16 monitors).	Improved mitigation of steam generator tube ruptures.	Yes	B - Intent Met	Modification installed to improve operation of N16 detectors.
127	Revise emergency operating procedures to direct isolation of a faulted steam generator.	Reduced consequences of a steam generator tube rupture.	Yes	B - Intent Met	EOP currently in place.
128	Direct steam generator flooding after a steam generator tube rupture, prior to core damage.	Improved scrubbing of steam generator tube rupture releases.	Yes	B - Intent Met	Procedures direct that steam generator level be maintained above the tubes.
132	Provide an additional control system for rod insertion (e.g., AMSAC).	Improved redundancy and reduced ATWS frequency.	Yes	B - Intent Met	Currently have AMSAC.
137	Provide capability to remove power from the bus powering the control rods.	Decreased time required to insert control rods if the reactor trip breakers fail (during a loss of feedwater ATWS which has rapid pressure excursion).	Yes	B - Intent Met	Response procedure in place.
144	Install additional transfer and isolation switches.	Reduced number of spurious actuations during a fire.	Yes	B - Intent Met	Items are identified and are being implemented as part of the 805 process. Examples include fuse and alternate feed line modifications to prevent the loss of the 4160 V buses.
145	Enhance fire brigade awareness.	Decreased consequences of a fire.	Yes	B - Intent Met	Most recent inspections and evaluations did not identify any weaknesses in this area.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
146	Enhance control of combustibles and ignition sources.	Decreased fire frequency and consequences.	Yes	B - Intent Met	Procedure in place. NFPA-805 project will evaluate the needs for any additional controls.
148	Enhance procedures to mitigate large break LOCA.	Reduced consequences of a large break LOCA.	Yes	B - Intent Met	Existing procedures meet current guidelines issued by the Owner's Group.
149	Install computer aided instrumentation system to assist the operator in assessing post-accident plant status.	Improved prevention of core melt sequences by making operator actions more reliable.	Yes	B - Intent Met	Currently have SPDS in place.
150	Improve maintenance procedures.	Improved prevention of core melt sequences by increasing reliability of important equipment.	Yes	B - Intent Met	Current procedures are in line with industry guidelines and practices.
151	Increase training and operating experience feedback to improve operator response.	Improved likelihood of success of operator actions taken in response to abnormal conditions.	Yes	B - Intent Met	Current training program meets industry standards and practices.
154	Mount or anchor the MCCs to the respective building walls.	Reduces failure probability of MCCs during an earthquake	Yes	B - Intent Met	Identified in the IPEEE and successfully implemented.
155	Install shear pins (or strength bolts) in the AFW pumps.	Takes up the shear load on the pump and/or driver during an earthquake.	Yes	B - Intent Met	Identified in the IPEEE and successfully implemented.
156	Mount all fire extinguishers within their UL Standard required drop height and remove hand-held fire extinguishers from Containment during normal operation.	Reduces the potential for the fire extinguishers to fall during an earthquake and potentially fracturing upon impact with the floor or another object.	Yes	B - Intent Met	Identified in the IPEEE and successfully implemented.
157	Identify and remove unsecured equipment near areas that contain relays that actuate, so area is kept clear.	Ensures direct access to areas such as Load Shedding and Emergency Load Sequencing (LSELS) and Engineered Safety Feature Actuation System (ESFAS) cabinets. Unsecured equipment (e.g., carts, filing cabinets, and test equipment) in these areas could result	Yes	B - Intent Met	Identified in the IPEEE and successfully implemented.
158	Properly position chain hoists that facilitate maintenance on pumps within pump rooms and institute a training program to ensure that the hoists are properly positioned when not in use.	Improper positioning of hoists reduces the availability due to moving during an earthquake and having chainfalls impacting pump oil bubblers or other soft targets resulting in failure of the pumps.	Yes	B - Intent Met	Identified in the IPEEE and successfully implemented.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
159	Secure floor grating to prevent damage to sensing lines due to differential building motion.	Prevent sensing lines that pass through the grating from being damaged.	Yes	B - Intent Met	Identified in the IPEEE and successfully implemented.
166	Installation of high temperature qualified RCP seal O-rings.	Lower potential for RCP seal leakage.	Yes	B - Intent Met	High temperature O-Rings installed.
167	Addition of procedural guidance to re-establish normal service water should essential service water fail.	Provide back-up pumps for UHS cooling.	Yes	B - Intent Met	Procedures in place.
168	Addition of procedural guidance for running charging and safety injection pumps without component cooling water	Allow use of pumps following loss of component cooling water.	Yes	B - Intent Met	Procedures in place.
169	Addition of procedural guidance to verify RHR pump room cooling at switchover to ECCS recirculation phase.	Verifying that support system for RHR pumps is in service to allow continued operation of RHR pumps.	Yes	B - Intent Met	Procedures in place.
170	Modifications to add controls in the main control room to allow remote operation of nearby diesel generator farm and alignment/connection to the plant vital electrical busses.	Faster ability to provide power to the plant electrical busses from the offsite diesel generator farm.	Yes	B - Intent Met	AEPS diesel generators automatically start upon loss of offsite power to the local electrical co-op distribution system. The controls for the breakers to connect to the Callaway distribution system are in the main control room.
140	Increase seismic ruggedness of plant components.	Increased availability of necessary plant equipment during and after seismic events.	Yes	C - Combined	Individual seismic issues identified in the IPEEE are included as SAMA items 154, 155, 156, 157, 158, and 159.
141	Provide additional restraints for CO2 tanks.	Increased availability of fire protection given a seismic event.	Yes	C - Combined	Individual seismic issues identified in the IPEEE are included as SAMA items 154, 155, 156, 157, 158, and 159.
1	Provide additional DC battery capacity.	Extended DC power availability during an SBO.	No		Original battery capacity is 4 hrs. No additional battery capacity has been added. Evaluate in Phase II.
2	Replace lead-acid batteries with fuel cells.	Extended DC power availability during an SBO.	No		Plant currently uses batteries rather than fuel cells. Evaluate in Phase II.

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
5	Provide DC bus cross-ties.	Improved availability of DC power system.	No		No existing capability for DC bus cross-ties. Evaluate in Phase II.
11	Improve 4.16-kV bus cross-tie ability.	Increased availability of on-site AC power.	No		Evaluate during Phase II
15	Install tornado protection on gas turbine generator.	Increased availability of on-site AC power.	No		No gas turbine currently installed. No tornado protection for Alternate Emergency Power System diesel generators. Evaluate in Phase II.
24	Bury off-site power lines.	Improved off-site power reliability during severe weather.	No		Evaluate during Phase II
25	Install an independent active or passive high pressure injection system.	Improved prevention of core melt sequences.	No		Evaluate during Phase II
26	Provide an additional high pressure injection pump with independent diesel.	Reduced frequency of core melt from small LOCA and SBO sequences.	No		Evaluate during Phase II
28	Add a diverse low pressure injection system.	Improved injection capability.	No		Evaluate during Phase II
29	Provide capability for alternate injection via diesel-driven fire pump.	Improved injection capability.	No		Currently being evaluated by plant improvement program. Would use unborated water and portable pump (fire truck). Calculation of specific benefit of this SAMA was not performed since it is judged to be potentially low cost. Evaluation will consider impacts of injection of non-borated water.
39	Replace two of the four electric safety injection pumps with diesel-powered pumps.	Reduced common cause failure of the safety injection system. This SAMA was originally intended for the Westinghouse-CE System 80+, which has four trains of safety injection. However, the intent of this SAMA is to provide diversity within the high- and l	No		Evaluate during Phase II

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
41	Create a reactor coolant depressurization system.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	No		Evaluate during Phase II
43	Add redundant DC control power for SW pumps.	Increased availability of SW.	No		Evaluate during Phase II
46	Add a service water pump.	Increased availability of cooling water.	No		Evaluate during Phase II
54	Increase charging pump lube oil capacity.	Increased time before charging pump failure due to lube oil overheating in loss of cooling water sequences.	No		Evaluate during Phase II
55	Install an independent reactor coolant pump seal injection system, with dedicated diesel.	Reduced frequency of core damage from loss of component cooling water, service water, or station blackout.	No		Evaluate during Phase II
56	Install an independent reactor coolant pump seal injection system, without dedicated diesel.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout.	No		Evaluate during Phase II
58	Install improved reactor coolant pump seals.	Reduced likelihood of reactor coolant pump seal LOCA.	No		Evaluate in Phase II.
59	Install an additional component cooling water pump.	Reduced likelihood of loss of component cooling water leading to a reactor coolant pump seal LOCA.	No		Evaluate during Phase II
64	Implement procedure and hardware modifications to allow manual alignment of the fire water system to the component cooling water system, or install a component cooling water header cross-tie.	Improved ability to cool residual heat removal heat exchangers.	No		Evaluate during Phase II
65	Install a digital feed water upgrade.	Reduced chance of loss of main feed water following a plant trip.	No		Evaluate in Phase II.
71	Install a new condensate storage tank (auxiliary feedwater storage tank).	Increased availability of the auxiliary feedwater system.	No		Evaluate during Phase II
77	Provide a passive, secondary-side heat-rejection loop consisting of a condenser and heat sink.	Reduced potential for core damage due to loss-of-feedwater events.	No		Evaluate during Phase II
79	Replace existing pilot-operated relief valves with larger ones, such that only one is required for successful feed and bleed.	Increased probability of successful feed and bleed.	No		Evaluate during Phase II

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
80	Provide a redundant train or means of ventilation.	Increased availability of components dependent on room cooling.	No		Evaluate during Phase II
87	Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft driven fans.	Elimination of instrument air system dependence on service water cooling.	No		Air compressors currently cooled by ESW. Evaluate in Phase II.
91	Install a passive containment spray system.	Improved containment spray capability.	No		Evaluate during Phase II
93	Install an unfiltered, hardened containment vent.	Increased decay heat removal capability for non-ATWS events, without scrubbing released fission products.	No		Evaluate during Phase II
94	Install a filtered containment vent to remove decay heat. Option 1: Gravel Bed Filter; Option 2: Multiple Venturi Scrubber	Increased decay heat removal capability for non-ATWS events, with scrubbing of released fission products.	No		Evaluate during Phase II
96	Provide post-accident containment inerting capability.	Reduced likelihood of hydrogen and carbon monoxide gas combustion.	No		Evaluate during Phase II
97	Create a large concrete crucible with heat removal potential to contain molten core debris.	Increased cooling and containment of molten core debris. Molten core debris escaping from the vessel is contained within the crucible and a water cooling mechanism cools the molten core in the crucible, preventing melt-through of the base mat.	No		Evaluate during Phase II
98	Create a core melt source reduction system.	Increased 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.	No		Evaluate during Phase II
99	Strengthen primary/secondary containment (e.g., add ribbing to containment shell).	Reduced probability of containment over-pressurization.	No		Evaluate during Phase II
100	Increase depth of the concrete base mat or use an alternate concrete material to ensure melt-through does not occur.	Reduced probability of base mat melt-through.	No		Evaluate during Phase II

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
102	Construct a building to be connected to primary/secondary containment and maintained at a vacuum.	Reduced probability of containment over-pressurization.	No		Evaluate during Phase II
104	Improve leak detection procedures.	Increased piping surveillance to identify leaks prior to complete failure. Improved leak detection would reduce LOCA frequency.	No		Evaluate during Phase II
107	Install a redundant containment spray system.	Increased containment heat removal ability.	No		Evaluate during Phase II
108	Install an independent power supply to the hydrogen control system using either new batteries, a non-safety grade portable generator, existing station batteries, or existing AC/DC independent power supplies, such as the security system diesel.	Reduced hydrogen detonation potential.	No		Evaluate during Phase II
109	Install a passive hydrogen control system.	Reduced hydrogen detonation potential.	No		Evaluate during Phase II
110	Erect a barrier that would provide enhanced protection of the containment walls (shell) from ejected core debris following a core melt scenario at high pressure.	Reduced probability of containment failure.	No		Evaluate during Phase II
111	Install additional pressure or leak monitoring instruments for detection of ISLOCAs.	Reduced ISLOCA frequency.	No		Evaluate during Phase II
112	Add redundant and diverse limit switches to each containment isolation valve.	Reduced frequency of containment isolation failure and ISLOCAs.	No		Evaluate during Phase II
113	Increase leak testing of valves in ISLOCA paths.	Reduced ISLOCA frequency.	No		Evaluate during Phase II
114	Install self-actuating containment isolation valves.	Reduced frequency of isolation failure.	No		Evaluate during Phase II
115	Locate residual heat removal (RHR) inside containment	Reduced frequency of ISLOCA outside containment.	No		Evaluate during Phase II

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
116	Ensure ISLOCA releases are scrubbed. One method is to plug drains in potential break areas so that break point will be covered with water.	Scrubbed ISLOCA releases.	No		Evaluate during Phase II
119	Institute a maintenance practice to perform a 100% inspection of steam generator tubes during each refueling outage.	Reduced frequency of steam generator tube ruptures.	No		Current frequency of inspection of SG tubes is 100% inspection every third outage. Evaluate during Phase II
121	Increase the pressure capacity of the secondary side so that a steam generator tube rupture would not cause the relief valves to lift.	Eliminates release pathway to the environment following a steam generator tube rupture.	No		Evaluate during Phase II
122	Install a redundant spray system to depressurize the primary system during a steam generator tube rupture	Enhanced depressurization capabilities during steam generator tube rupture.	No		Evaluate during Phase II
125	Route the discharge from the main steam safety valves through a structure where a water spray would condense the steam and remove most of the fission products.	Reduced consequences of a steam generator tube rupture.	No		Evaluate during Phase II
126	Install a highly reliable (closed loop) steam generator shell-side heat removal system that relies on natural circulation and stored water sources	Reduced consequences of a steam generator tube rupture.	No		Evaluate during Phase II
129	Vent main steam safety valves in containment.	Reduced consequences of a steam generator tube rupture.	No		Evaluate during Phase II
130	Add an independent boron injection system.	Improved availability of boron injection during ATWS.	No		Evaluate during Phase II
131	Add a system of relief valves to prevent equipment damage from pressure spikes during an ATWS.	Improved equipment availability after an ATWS.	No		Evaluate during Phase II
133	Install an ATWS sized filtered containment vent to remove decay heat.	Increased ability to remove reactor heat from ATWS events.	No		Evaluate during Phase II

Table 6-1. Callaway Plant Phase I SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	Screened Out Ph 1?	Screening Criterion	Phase I Disposition
136	Install motor generator set trip breakers in control room.	Reduced frequency of core damage due to an ATWS.	No		Evaluate in Phase II.
147	Install digital large break LOCA protection system.	Reduced probability of a large break LOCA (a leak before break).	No		Evaluate during Phase II
153	Install secondary side guard pipes up to the main steam isolation valves.	Prevents secondary side depressurization should a steam line break occur upstream of the main steam isolation valves. Also guards against or prevents consequential multiple steam generator tube ruptures following a main steam line break event.	No		Evaluate during Phase II
160	Modifications to lessen impact of internal flooding path through Control Building dumbwaiter.	Lower impact of flood that propagates through the dumbwaiter	No		Evaluate in Phase II
161	Improvements to PORV performance that will lower the probability of failure to open.	Decrease in risk due to PORV failing to open.	No		Evaluate in Phase II.
162	Install a large volume EDG fuel oil tank at an elevation greater than the EDG fuel oil day tanks.	Allows transfer of EDF fuel oil to the EDG day tanks on failure of the fuel oil transfer pumps.	No		Evaluate in Phase II.
163	Improve feedwater check valve reliability to reduce probability of failure to open.	Lower risk due to failures in which feedwater check valves fail to open and allow feeding of the steam generators.	No		Valves replaced with new type, but are still significant risk contributor. Evaluate in Phase II.
164	Provide the capability to power the normal service water pumps from AEPS.	Provide backup to ESW in conditions with power only available from AEPS.	No		Evaluate in Phase II.
171	Increase the size of the RWST or otherwise improve the availability of the RWST	Ensure a supply of makeup water is available from the RWST.	No		Evaluate in Phase II.

7.0 PHASE II SAMA ANALYSIS

A cost-benefit analysis was performed on each of the SAMA candidates remaining after the Phase I screening. The benefit of a SAMA candidate is the difference between the baseline cost of severe accident risk (maximum benefit from Section 4.5) and the cost of severe accident risk with the SAMA implemented (Section 7.1). The cost figure used is the estimated cost to implement the specific SAMA. If the estimated cost of implementation exceeds the benefit of implementation, the SAMA is not cost-beneficial.

7.1 SAMA BENEFIT

7.1.1 Severe Accident Risk with SAMA Implemented

Bounding analyses were used to determine the change in risk following implementation of SAMA candidates or groups of similar SAMA candidates. For each analysis case, the Level 1 internal events or Level 2 PRA models were altered to conservatively consider implementation of the SAMA candidate(s). Then, severe accident risk measures were calculated using the same procedure used for the baseline case described in Section 3. The changes made to the PRA models for each analysis case are described in the annex, Section 11.

“Bounding analyses” are exemplified by the following:

LBLOCA

This analysis case was used to evaluate the change in plant risk profile that would be achieved if a digital large break LOCA protection system was installed. Although the proposed change would not completely eliminate the potential for a large break LOCA, a bounding benefit was estimated by removing the large break LOCA initiating event. This analysis case was used to model the benefit of SAMAs that deal with mitigation of large LOCA events.

DCPWR

This analysis case was used to evaluate plant modifications that would increase the availability of Class 1E DC power (e.g., increased battery capacity or the installation of a diesel-powered generator that would effectively increase battery capacity). Although the proposed SAMAs would not completely eliminate the potential failure, a bounding benefit was estimated by removing the battery discharge events and battery failure events. This analysis case was used to model the benefit of SAMAs that deal with mitigation of station blackout events regarding extending the availability of DC power.

The severe accident risk measures were obtained for each analysis case by modifying the baseline model in a simple manner to capture the effect of implementation of the SAMA in a bounding manner. Bounding analyses are very conservative and result in overestimation of the benefit of the candidate analyzed. However, if this bounding assessment yields a benefit that is smaller than the cost of implementation, then the effort involved in refining the PRA modeling approach for the SAMA would be unnecessary because it would only yield a lower benefit result. If the benefit is greater than the cost when modeled in this bounding approach, it is necessary to refine the PRA model of the SAMA to remove the excess conservatism. As a result of this modeling approach, models representing the Phase II SAMAs will not all be at the same level of detail and if any are implemented, the PRA result after implementation of the final installed design will differ from the screening-type analyses done during this evaluation.

7.1.2 Cost of Severe Accident Risk with SAMA Implemented

Using the risk measures determined as described in Section 7.1.1, severe accident impacts in four areas (offsite exposure cost, off-site economic cost, on-site exposure cost, and on-site economic cost) were calculated using the same procedure used for the baseline case described in Section 4. As in Section 4.5, the severe accident impacts were summed to estimate the total cost of severe accident risk with the SAMA implemented.

7.1.3 SAMA Benefit Calculation

The respective SAMA benefit was calculated by subtracting the total cost of severe accident risk with the SAMA implemented from the baseline cost of severe accident risk (maximum benefit from Section 4.5). The estimated benefit for each SAMA candidate is listed in Table 7-1. The calculation of the benefit is performed using an Excel spreadsheet.

7.2 COST OF SAMA IMPLEMENTATION

The final step in the evaluation of the SAMAs is estimating the cost of implementation for comparison with the benefit. For the purpose of this analysis the Callaway staff has estimated that the cost of making a change to a procedure and for conducting the necessary training on a procedure change is expected to exceed $15,000. Similarly, the minimum cost associated with development and implementation of an integrated hardware modification package (including post-implementation costs, e.g. training) is expected to exceed $100,000. These values were used for initial comparison with the benefit of SAMAs.

The benefits resulting from the bounding estimates presented in the benefit analysis are in some cases rather low. In those cases for which the benefits are so low that it is obvious that the implementation costs would exceed the benefit, a detailed cost estimate was not warranted. Plant staff judgment is applied in assessing whether the benefit approaches the expected implementation costs in many cases.

Plant staff judgment was obtained from an independent, expert panel consisting of senior staff members from the PRA group, the design group, operations and license renewal. This panel reviewed the benefit calculation results and, based upon their experience with developing and implementing modifications at the plant, judged whether a modification could be made to the plant that would be cost beneficial in comparison with the calculated benefit. The purpose of this approach was to minimize the effort expended on detailed cost estimation. The cost estimations provided by the expert panel are included in Table 7-1 along with the conclusions reached for each SAMA evaluated for cost/benefit.

The results of the sensitivity analyses are presented in Section 8. The sensitivity analyses did not identify any cost-benefit conclusions affected by uncertainties.

Table 7-1. Callaway Plant 1 Phase II SAMA Analysis

Callaway SAMA Number	Potential Improvement	Discussion	% Red. In CDF	% Red. In OS Dose	SAMA Case	SAMA Case Description	Benefit	Cost	Cost Basis	Evaluation	Basis for Evaluation
1	Provide additional DC battery capacity.	Extended DC power availability during an SBO.	0.30%	0.00%	DC01	TDAFW no DC Dependency	$1K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
2	Replace lead-acid batteries with fuel cells.	Extended DC power availability during an SBO.	12.17%	10.87%	NOSBO	No Station Blackout Events	$360K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
5	Provide DC bus cross-ties.	Improved availability of DC power system.	0.30%	0.00%	DC01	TDAFW no DC Dependency	$1K	>$199K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
11	Improve 4.16-kV bus cross-tie ability.	Increased availability of on-site AC power.	12.17%	10.87%	NOSBO	No Station Blackout Events	$360K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit. Cost for implementation includes analysis, material to be purchased and prestaged, development of procedures, and training of personnel on implementation.,
15	Install tornado protection on gas turbine generator.	Increased availability of on-site AC power.	2.65%	4.35%	LOSP1	No tornado related LOSP	$91K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
24	Bury off-site power lines.	Improved off-site power reliability during severe weather.	40.66%	41.30%	NOLOSP	Eliminate all Loss of Offsite Power Events	$1.2M	>$3M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit. Previous SAMA submittals have estimated approximately $1M per mile.
25	Install an independent active or passive high pressure injection system.	Improved prevention of core melt sequences.	2.77%	0.00%	LOCA12	No failures of the charging or SI pumps	$48K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
26	Provide an additional high pressure injection pump with independent diesel.	Reduced frequency of core melt from small LOCA and SBO sequences.	2.77%	0.00%	LOCA12	No failures of the charging or SI pumps	$48K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
28	Add a diverse low pressure injection system.	Improved injection capability.	3.19%	2.17%	LOCA03	No failure of low pressure injection	$65K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
29	Provide capability for alternate injection via diesel-driven fire pump.	Improved injection capability.								Potentially Cost-Beneficial	SAMA is judged to be low cost, but analysis is needed to determine impacts of injection of non-borated water to RCS. Expert Panel judged this SAMA to be potentially cost-beneficial without determining an actual benefit or cost.

Table 7-1. Callaway Plant 1 Phase II SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	% Red. In CDF	% Red. In OS Dose	SAMA Case	SAMA Case Description	Benefit	Cost	Cost Basis	Evaluation	Basis for Evaluation
39	Replace two of the four electric safety injection pumps with diesel-powered pumps.	Reduced common cause failure of the safety injection system. This SAMA was originally intended for the Westinghouse-CE System 80+, which has four trains of safety injection. However, the intent of this SAMA is to provide diversity within the high- and l	2.77%	0.00%	LOCA12	No failures of the charging or SI pumps	$748K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
41	Create a reactor coolant depressurization system.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	0.78%	0.00%	DEPRESS	No failures of depressurization	$12K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
43	Add redundant DC control power for SW pumps.	Increased availability of SW.	0.30%	0.00%	SW01	Service Water Pumps not dependent on DC Power	$1K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
46	Add a service water pump.	Increased availability of cooling water.	12.35%	21.74%	SW02	No failures of ESW pumps	$464K	>$5M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
54	Increase charging pump lube oil capacity.	Increased time before charging pump failure due to lube oil overheating in loss of cooling water sequences.	0.48%	0.00%	CHG01	Charging pumps not dependent on cooling water.	$4K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
55	Install an independent reactor coolant pump seal injection system, with dedicated diesel.	Reduced frequency of core damage from loss of component cooling water, service water, or station blackout.	5.54%	0.00%	RCPLOCA	No RCP Seal LOCAs	$94K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit. Previous investigation into installing such a system concluded that operators did not have sufficient time to place the system in service prior to seal damage.
56	Install an independent reactor coolant pump seal injection system, without dedicated diesel.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout.	5.54%	0.00%	RCPLOCA	No RCP Seal LOCAs	$94K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
58	Install improved reactor coolant pump seals.	Reduced likelihood of reactor coolant pump seal LOCA.	5.54%	0.00%	RCPLOCA	No RCP Seal LOCAs	$94K	>$3M		Not Cost-Beneficial	Cost will exceed benefit.
59	Install an additional component cooling water pump.	Reduced likelihood of loss of component cooling water leading to a reactor coolant pump seal LOCA.	3.61%	0.00%	CCW01	No failures of the CCW Pumps	$59K	>$1M	Cost will exceed benefit	Not Cost-Beneficial	Cost will exceed benefit.

Table 7-1. Callaway Plant 1 Phase II SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	% Red. In CDF	% Red. In OS Dose	SAMA Case	SAMA Case Description	Benefit	Cost	Cost Basis	Evaluation	Basis for Evaluation
64	Implement procedure and hardware modifications to allow manual alignment of the fire water system to the component cooling water system, or install a component cooling water header cross-tie.	Improved ability to cool residual heat removal heat exchangers.	3.61%	0.00%	CCW01	No failures of the CCW Pumps	$59K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
65	Install a digital feed water upgrade.	Reduced chance of loss of main feed water following a plant trip.	1.57%	0.00%	FW01	No loss of Feedwater Events	$29K	$19M	Callaway Modification Costs	Not Cost-Beneficial	Cost will exceed benefit.
71	Install a new condensate storage tank (auxiliary feedwater storage tank).	Increased availability of the auxiliary feedwater system.	1.14%	0.00%	CST01	CST does not deplete	$18K	>$2.5M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
77	Provide a passive, secondary-side heat-rejection loop consisting of a condenser and heat sink.	Reduced potential for core damage due to loss-of-feedwater events.	1.57%	0.00%	FW01	No loss of Feedwater Events	$29K	$>1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
79	Replace existing pilot-operated relief valves with larger ones, such that only one is required for successful feed and bleed.	Increased probability of successful feed and bleed.	3.43%	2.17%	FB01	Only one PORV required for Feed & Bleed	$79K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
80	Provide a redundant train or means of ventilation.	Increased availability of components dependent on room cooling.	6.08%	4.35%	HVAC	No dependencies on HVAC	$156K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
87	Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft driven fans.	Elimination of instrument air system dependence on service water cooling.	0.36%	0.00%	INSTAIR	Eliminate all instrument air failures	$2K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
91	Install a passive containment spray system.	Improved containment spray capability.	19.52%	36.96%	CONT01	No failures due to containment overpressure	$1.2M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
93	Install an unfiltered, hardened containment vent.	Increased decay heat removal capability for non-ATWS events, without scrubbing released fission products.	19.52%	36.96%	CONT01	No failures due to containment overpressure	$1.2M	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
94	Install a filtered containment vent to remove decay heat. Option 1: Gravel Bed Filter; Option 2: Multiple Venturi Scrubber	Increased decay heat removal capability for non-ATWS events, with scrubbing of released fission products.	19.52%	36.96%	CONT01	No failures due to containment overpressure	$1.2M	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
96	Provide post-accident containment inerting capability.	Reduced likelihood of hydrogen and carbon monoxide gas combustion.	0.48%	0.00%	H2BURN	No hydrogen burns/explosions	$10K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.

Table 7-1. Callaway Plant 1 Phase II SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	% Red. In CDF	% Red. In OS Dose	SAMA Case	SAMA Case Description	Benefit	Cost	Cost Basis	Evaluation	Basis for Evaluation
97	Create a large concrete crucible with heat removal potential to contain molten core debris.	Increased cooling and containment of molten core debris. Molten core debris escaping from the vessel is contained within the crucible and a water cooling mechanism cools the molten core in the crucible, preventing melt-through of the base mat.			MAB			>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
98	Create a core melt source reduction system.	Increased 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.			MAB			>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
99	Strengthen primary/secondary containment (e.g., add ribbing to containment shell).	Reduced probability of containment over-pressurization.	19.52%	36.96%	CONT01	No failures due to containment overpressure	$1.2M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
100	Increase depth of the concrete base mat or use an alternate concrete material to ensure melt-through does not occur.	Reduced probability of base mat melt-through.			MAB			>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
102	Construct a building to be connected to primary/secondary containment and maintained at a vacuum.	Reduced probability of containment over-pressurization.	19.52%	36.96%	CONT01	No failures due to containment overpressure	$1.2M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
104	Improve leak detection procedures.	Increased piping surveillance to identify leaks prior to complete failure. Improved leak detection would reduce LOCA frequency.	39.34%	2.17%	LOCA05	No piping system LOCAs	$689K	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
107	Install a redundant containment spray system.	Increased containment heat removal ability.	19.52%	36.96%	CONT01	No failures due to containment overpressure	$1.2M	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.

Table 7-1. Callaway Plant 1 Phase II SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	% Red. In CDF	% Red. In OS Dose	SAMA Case	SAMA Case Description	Benefit	Cost	Cost Basis	Evaluation	Basis for Evaluation
108	Install an independent power supply to the hydrogen control system using either new batteries, a non-safety grade portable generator, existing station batteries, or existing AC/DC independent power supplies, such as the security system diesel.	Reduced hydrogen detonation potential.	0.48%	0.00%	H2BURN	No hydrogen burns/explosions	$10K	>$100K	Expert Panel	Not Cost-Beneficial	
109	Install a passive hydrogen control system.	Reduced hydrogen detonation potential.	0.48%	0.00%	H2BURN	No hydrogen burns/explosions	$10K	>$100M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
110	Erect a barrier that would provide enhanced protection of the containment walls (shell) from ejected core debris following a core melt scenario at high pressure.	Reduced probability of containment failure.			MAB			>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
111	Install additional pressure or leak monitoring instruments for detection of ISLOCAs.	Reduced ISLOCA frequency.	1.33%	8.70%	ISLOCA	No ISLOCA events	$123K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
112	Add redundant and diverse limit switches to each containment isolation valve.	Reduced frequency of containment isolation failure and ISLOCAs.	0.30%	0.00%	CONT02	No failures of containment isolation	$1K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
113	Increase leak testing of valves in ISLOCA paths.	Reduced ISLOCA frequency.	1.33%	8.70%	ISLOCA	No ISLOCA events	$123K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
114	Install self-actuating containment isolation valves.	Reduced frequency of isolation failure.	0.30%	0.00%	CONT02	No failures of containment isolation	$1K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
115	Locate residual heat removal (RHR) inside containment	Reduced frequency of ISLOCA outside containment.	1.33%	8.70%	ISLOCA	No ISLOCA events	$123K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
116	Ensure ISLOCA releases are scrubbed. One method is to plug drains in potential break areas so that break point will be covered with water.	Scrubbed ISLOCA releases.	1.33%	8.70%	ISLOCA	No ISLOCA events	$123K	>$1M	Expert Panel	Not Cost-Beneficial	Cost would exceed benefit. Current plant design requires drains to be open. Analysis and license changes required to implement are included in the cost estimate.
119	Institute a maintenance practice to perform a 100% inspection of steam generator tubes during each refueling outage.	Reduced frequency of steam generator tube ruptures.	15.66%	52.17%	NOSGTR	No SGTR Events	$1.2M	>$3M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
121	Increase the pressure capacity of the secondary side so that a steam generator tube rupture would not cause the relief valves to lift.	Eliminates release pathway to the environment following a steam generator tube rupture.	15.66%	52.17%	NOSGTR	No SGTR Events	$1.2M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
122	Install a redundant spray system to depressurize the primary system during a steam generator tube rupture	Enhanced depressurization capabilities during steam generator tube rupture.	15.66%	52.17%	NOSGTR	No SGTR Events	$1.2M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.

Table 7-1. Callaway Plant 1 Phase II SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	% Red. In CDF	% Red. In OS Dose	SAMA Case	SAMA Case Description	Benefit	Cost	Cost Basis	Evaluation	Basis for Evaluation
125	Route the discharge from the main steam safety valves through a structure where a water spray would condense the steam and remove most of the fission products.	Reduced consequences of a steam generator tube rupture.	15.66%	52.17%	NOSGTR	No SGTR Events	$1.2M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
126	Install a highly reliable (closed loop) steam generator shell-side heat removal system that relies on natural circulation and stored water sources	Reduced consequences of a steam generator tube rupture.	15.66%	52.17%	NOSGTR	No SGTR Events	$1.2M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
129	Vent main steam safety valves in containment.	Reduced consequences of a steam generator tube rupture.	15.66%	52.17%	NOSGTR	No SGTR Events	$1.2M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit. Current containment design does not support this modification. Modifications to containment and associated analysis are included in the cost estimate.
130	Add an independent boron injection system.	Improved availability of boron injection during ATWS.	2.41%	2.17%	NOATWS	Eliminate all ATWS	$63K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
131	Add a system of relief valves to prevent equipment damage from pressure spikes during an ATWS.	Improved equipment availability after an ATWS.	2.41%	2.17%	NOATWS	Eliminate all ATWS	$63K	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
133	Install an ATWS sized filtered containment vent to remove decay heat.	Increased ability to remove reactor heat from ATWS events.	2.41%	2.17%	NOATWS	Eliminate all ATWS	$63K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit
136	Install motor generator set trip breakers in control room.	Reduced frequency of core damage due to an ATWS.	2.41%	2.17%	NOATWS	Eliminate all ATWS	$53K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
147	Install digital large break LOCA protection system.	Reduced probability of a large break LOCA (a leak before break).	39.34%	2.17%	LOCA05	No piping system LOCAs	$689K	>$5M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
153	Install secondary side guard pipes up to the main steam isolation valves.	Prevents secondary side depressurization should a steam line break occur upstream of the main steam isolation valves. Also guards against or prevents consequential multiple steam generator tube ruptures following a main steam line break event.	2.53%	0.00%	NOSLB	No Steam Line Breaks	$51K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.

Table 7-1. Callaway Plant 1 Phase II SAMA Analysis (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	% Red. In CDF	% Red. In OS Dose	SAMA Case	SAMA Case Description	Benefit	Cost	Cost Basis	Evaluation	Basis for Evaluation
160	Modifications to lessen impact of internal flooding path through Control Building dumbwaiter.	Lower impact of flood that propagates through the dumbwaiter						<$50K	Expert Panel	Potentially Cost-Beneficial	Relatively minor modifications to door opening could result in lower flow to the dumbwaiter. Specific benefit could not be calculated but SAMA item is judged to be low cost and therefore potentially cost beneficial.
161	Improvements to PORV performance that will lower the probability of failure to open.	Decrease in risk due to PORV failing to open.			PORV	PORVs do not fail to open	$18K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
162	Install a large volume EDG fuel oil tank at an elevation greater than the EDG fuel oil day tanks.	Allows transfer of EDF fuel oil to the EDG day tanks on failure of the fuel oil transfer pumps.			EDGFUEL	No EDG fuel pump failures	$124K	$150K	Wolf Creek	Potentially Cost-Beneficial	Wolf Creek estimated cost of $150K is less than the potential benefit.
163	Improve feedwater check valve reliability to reduce probability of failure to open.	Lower risk due to failures in which feedwater check valves fail to open and allow feeding of the steam generators.			FW02	Feedwater Check Valves do not fail to open	$127K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
164	Provide the capability to power the normal service water pumps from AEPS.	Provide backup to ESW in conditions with power only available from AEPS.			SW03	AEPS power to SW pumps	$191K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
171	Increase the size of the RWST or otherwise improve the availability of the RWST	Ensure a supply of makeup water is available from the RWST.			LOCA04	RWST does not deplete	$13K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.

OS = off site

8.0 SENSITIVITY ANALYSES

The purpose of performing sensitivity analyses is to examine the impact of analysis assumptions on the results of the SAMA evaluation. This section identifies several sensitivities that can be considered in SAMA analysis (Reference 19, NEI 05-01) and discusses the sensitivity as is applies to Callaway Plant and the impact of the sensitivity on the results of the Phase II SAMA analysis at Callaway.

Unless it was otherwise noted, it is assumed in these sensitivity analyses that sufficient margin existed in the maximum benefit estimation that the Phase I screening would not have to be repeated in the sensitivity analyses.

8.1 PLANT MODIFICATIONS

There are no plant modifications that are currently pending that would be expected to impact the results of this SAMA evaluation.

8.2 UNCERTAINTY

Since the inputs to PRA cannot be known with complete certainty, there is possibility that the actual plant risk is greater than the point estimate values used in the evaluation of the SAMA described in the previous sections. To consider this uncertainty, a sensitivity analysis was performed in which an uncertainty factor was applied to the frequencies calculated by the PRA and the subsequent benefits were calculated based upon the point estimate risk values multiplied by this uncertainty factor. The uncertainty factor applied is the ratio of the 95th percentile value of the CDF from the PRA uncertainty analysis to the mean value of the CDF. For Callaway the 95th percentile value of the CDF is 3.50E-5/yr; therefore, uncertainty factor is 2.11. Table 8-1 provides the benefit results from each of the sensitivities for each of the SAMA cases evaluated.

8.3 PEER REVIEW FACTS/OBSERVATIONS

The model used in this SAMA analysis includes the resolution of the Facts-and-Observations (F&Os) identified during the PRA Peer Review. Therefore, no specific sensitivities were performed related to this issue.

8.4 EVACUATION SPEED

Two evacuation sensitivity cases were performed to determine the impact of evacuation assumptions. The Callaway base case assumes a delay time of 105 minutes prior to evacuation to address public notification, trip time home after notification, and trip preparation time (e.g., loading vehicles) and an average evacuation speed of 2.14 meters/sec (4.8 mph). Both values are based on data provided in the Callaway Evacuation Time Estimate study.

Two evacuation sensitivity cases were evaluated. The first sensitivity case evaluates the impact of an increased delay time before evacuation begins (i.e., vehicles begin moving in the 10 mile region). For this sensitivity, the base case delay time of 105 minutes is doubled to 210 minutes. The increased delay time results in an increase in dose risk of about 2.4%. An increase in dose risk is generally expected because more individuals would be expected be exposed to the release due to their later departure (i.e., they failed to out run the release).

The second sensitivity case assesses the impact of evacuation speed assumptions by reducing the evacuation speed by one half, to 1.07 m/s (2.4 mph). The slower evacuation speed increases the dose risk by approximately 7%. An increase in dose risk is generally expected because individuals will tend to be subject to the plumes for a longer period of time when traveling slower. For either evacuation speed, the plumes can be viewed as tending to blow over the evacuees (average wind speed of 7 mph) as the evacuees progress through traffic.

8.5 REAL DISCOUNT RATE

Calculation of severe accident impacts in the Callaway SAMA analysis was performed using a “real discount rate” of 7% (0.07/year) as recommended in Reference 15, NUREG/BR-0184. Use of both a 7% and 3% real discount rate in regulatory analysis is specified in Office of Management Budget (OMB) guidance (Reference 20) and in NUREG/BR-0058 (Reference 21). Therefore, a sensitivity analysis was performed using a 3% real discount rate.

In this sensitivity analysis, the real discount rate in the Level 3 PRA model was changed to 3% from 7% and the Phase II analysis was re-performed with the lower interest rate. The analysis was also performed at a “realistic” discount rate of 8.3%.

The results of this sensitivity analysis are presented in Table 8-1. This sensitivity analysis does not affect any decisions made regarding the SAMAs.

8.6 ANALYSIS PERIOD

As described in Section 4, calculation of severe accident impacts involves an analysis period term, t_f, which could have been defined as either the period of extended operation (20 years), or the years remaining until the end of facility life (from the time of the SAMA analysis to the end of the period of extended operation) (33 years).

The value used for this term was the period of extended operation (20 years). This sensitivity analysis was performed using the period from the time of the SAMA analysis to the end of the period of extended operation to determine if SAMAs would be potentially cost-beneficial if performed immediately.

In this sensitivity analysis, the analysis period in the calculation of severe accident risk was modified to 33 years and the Phase II analysis was re-performed with the revised analysis period. The cost of additional years of maintenance, surveillance, calibrations, and training were included appropriately in the cost estimates for SAMAs in this Phase II analysis.

The results of this sensitivity analysis are presented in Table 8-1. This sensitivity analysis does not affect any decisions made regarding the SAMAs.

Table 8-1. Callaway Plant Sensitivity Evaluation

Callaway SAMA Number	Potential Improvement	Discussion	SAMA Case	Benefit	Benefit at 3% Disc Rate	Benefit at Realistic Disc Rate	Benefit at 33yrs	Benefit at 95% CDF	Cost	Cost Basis	Evaluation	Basis for Evaluation
1	Provide additional DC battery capacity.	Extended DC power availability during an SBO.	DC01	$1K	$1K	$1K	$1K	$1K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
2	Replace lead-acid batteries with fuel cells.	Extended DC power availability during an SBO.	NOSBO	$360K	$588K	$325K	$512K	$761K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
5	Provide DC bus cross-ties.	Improved availability of DC power system.	DC01	$1K	$1K	$1K	$1K	$1K	>$199K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
11	Improve 4.16-kV bus cross-tie ability.	Increased availability of on-site AC power.	NOSBO	$360K	$588K	$325K	$512K	$761K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit. Cost for implementation includes analysis, material to be purchased and prestaged, development of procedures, and training of personnel on implementation.,
15	Install tornado protection on gas turbine generator.	Increased availability of on-site AC power.	LOSP1	$91K	$144K	$82K	$125K	$192K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
24	Bury off-site power lines.	Improved off-site power reliability during severe weather.	NOLOSP	$1.2M	$2.0M	$1.1M	$1.7M	$2.6M	>$3M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit. Previous SAMA submittals have estimated approximately $1M per mile.
25	Install an independent active or passive high pressure injection system.	Improved prevention of core melt sequences.	LOCA12	$48K	$85K	$44K	$75	$102	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
26	Provide an additional high pressure injection pump with independent diesel.	Reduced frequency of core melt from small LOCA and SBO sequences.	LOCA12	$48K	$85K	$44K	$75	$102	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
28	Add a diverse low pressure injection system.	Improved injection capability.	LOCA03	$65K	$111K	$58K	$97K	$137K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
29	Provide capability for alternate injection via diesel-driven fire pump.	Improved injection capability.									Potentially Cost-Beneficial	SAMA is judged to be low cost, but analysis is needed to determine impacts of injection of non-borated water to RCS. Expert Panel judged this SAMA to be potentially cost-beneficial without determining an actual benefit or cost.

Table 8-1. Callaway Plant Sensitivity Evaluation (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	SAMA Case	Benefit	Benefit at 3% Disc Rate	Benefit at Realistic Disc Rate	Benefit at 33yrs	Benefit at 95% CDF	Cost	Cost Basis	Evaluation	Basis for Evaluation
39	Replace two of the four electric safety injection pumps with diesel-powered pumps.	Reduced common cause failure of the safety injection system. This SAMA was originally intended for the Westinghouse-CE System 80+, which has four trains of safety injection. However, the intent of this SAMA is to provide diversity within the high- and l	LOCA12	$48K	$85K	$44K	$75	$102	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
41	Create a reactor coolant depressurization system.	Allows low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure.	DEPRESS	$12K	$20K	$11K	$17K	$25K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
43	Add redundant DC control power for SW pumps.	Increased availability of SW.	SW01	$1K	$2K	$1K	$2K	$3K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
46	Add a service water pump.	Increased availability of cooling water.	SW02	$464K	$734K	$419K	$637K	$980K	>$5M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
54	Increase charging pump lube oil capacity.	Increased time before charging pump failure due to lube oil overheating in loss of cooling water sequences.	CHG01	$4K	$7K	$4K	$6K	$9K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
55	Install an independent reactor coolant pump seal injection system, with dedicated diesel.	Reduced frequency of core damage from loss of component cooling water, service water, or station blackout.	RCPLOCA	$94K	$168K	$85K	$148K	$198K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit. Previous investigation into installing such a system concluded that operators did not have sufficient time to place the system in service prior to seal damage.
56	Install an independent reactor coolant pump seal injection system, without dedicated diesel.	Reduced frequency of core damage from loss of component cooling water or service water, but not a station blackout.	RCPLOCA	$94K	$168K	$85K	$148K	$198K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
58	Install improved reactor coolant pump seals.	Reduced likelihood of reactor coolant pump seal LOCA.	RCPLOCA	$94K	$168K	$85K	$148K	$198K	>$3M		Not Cost-Beneficial	Cost will exceed benefit.
59	Install an additional component cooling water pump.	Reduced likelihood of loss of component cooling water leading to a reactor coolant pump seal LOCA.	CCW01	$59K	$106K	$53K	$93K	$124K	>$1M	Cost will exceed benefit	Not Cost-Beneficial	Cost will exceed benefit.
64	Implement procedure and hardware modifications to allow manual alignment of the fire water system to the component cooling water system, or install a component cooling water header cross-tie.	Improved ability to cool residual heat removal heat exchangers.	CCW01	$59K	$106K	$53K	$93K	$124K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
65	Install a digital feed water upgrade.	Reduced chance of loss of main feed water following a plant trip.	FW01	$29K	$50K	$27K	$44K	$62K	$19M	Callaway Modification Costs	Not Cost-Beneficial	Cost will exceed benefit.

Table 8-1. Callaway Plant Sensitivity Evaluation (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	SAMA Case	Benefit	Benefit at 3% Disc Rate	Benefit at Realistic Disc Rate	Benefit at 33yrs	Benefit at 95% CDF	Cost	Cost Basis	Evaluation	Basis for Evaluation
71	Install a new condensate storage tank (auxiliary feedwater storage tank).	Increased availability of the auxiliary feedwater system.	CST01	$18K	$32K	$16K	$28K	$39K	>$2.5M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
77	Provide a passive, secondary-side heat-rejection loop consisting of a condenser and heat sink.	Reduced potential for core damage due to loss-of-feedwater events.	FW01	$29K	$50K	$27K	$44K	$62K	$>1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
79	Replace existing pilot-operated relief valves with larger ones, such that only one is required for successful feed and bleed.	Increased probability of successful feed and bleed.	FB01	$79K	$133K	$72K	$117K	$168K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
80	Provide a redundant train or means of ventilation.	Increased availability of components dependent on room cooling.	HVAC	$156K	$259K	$141K	$227K	$331K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
87	Replace service and instrument air compressors with more reliable compressors which have self-contained air cooling by shaft driven fans.	Elimination of instrument air system dependence on service water cooling.	INSTAIR	$2K	$3K	$2K	$$2K	$4K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
91	Install a passive containment spray system.	Improved containment spray capability.	CONT01	$1.2M	$1.2M	$717K	$1.1M	$1.7M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
93	Install an unfiltered, hardened containment vent.	Increased decay heat removal capability for non-ATWS events, without scrubbing released fission products.	CONT01	$1.2M	$1.2M	$717K	$1.1M	$1.7M	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
94	Install a filtered containment vent to remove decay heat. Option 1: Gravel Bed Filter; Option 2: Multiple Venturi Scrubber	Increased decay heat removal capability for non-ATWS events, with scrubbing of released fission products.	CONT01	$1.2M	$1.2M	$717K	$1.1M	$1.7M	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
96	Provide post-accident containment inerting capability.	Reduced likelihood of hydrogen and carbon monoxide gas combustion.	H2BURN	$10K	$15K	$9K	$13K	$20K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
97	Create a large concrete crucible with heat removal potential to contain molten core debris.	Increased cooling and containment of molten core debris. Molten core debris escaping from the vessel is contained within the crucible and a water cooling mechanism cools the molten core in the crucible, preventing melt-through of the base mat.	MAB						>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
98	Create a core melt source reduction system.	Increased 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.	MAB						>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.

Table 8-1. Callaway Plant Sensitivity Evaluation (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	SAMA Case	Benefit	Benefit at 3% Disc Rate	Benefit at Realistic Disc Rate	Benefit at 33yrs	Benefit at 95% CDF	Cost	Cost Basis	Evaluation	Basis for Evaluation
99	Strengthen primary/secondary containment (e.g., add ribbing to containment shell).	Reduced probability of containment over-pressurization.	CONT01	$1.2M	$1.2M	$717K	$1.1M	$1.7M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
100	Increase depth of the concrete base mat or use an alternate concrete material to ensure melt-through does not occur.	Reduced probability of base mat melt-through.	MAB						>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
102	Construct a building to be connected to primary/secondary containment and maintained at a vacuum.	Reduced probability of containment over-pressurization.	CONT01	$1.2M	$1.2M	$717K	$1.1M	$1.7M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
104	Improve leak detection procedures.	Increased piping surveillance to identify leaks prior to complete failure. Improved leak detection would reduce LOCA frequency.	LOCA05	$685K	$1.2M	$620K	$1.1M	$1.5M	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
107	Install a redundant containment spray system.	Increased containment heat removal ability.	CONT01	$1.2M	$1.2M	$717K	$1.1M	$1.7M	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
108	Install an independent power supply to the hydrogen control system using either new batteries, a non-safety grade portable generator, existing station batteries, or existing AC/DC independent power supplies, such as the security system diesel.	Reduced hydrogen detonation potential.	H2BURN	$10K	$15K	$9K	$13K	$20K	>$100K	Expert Panel	Not Cost-Beneficial	
109	Install a passive hydrogen control system.	Reduced hydrogen detonation potential.	H2BURN	$10K	$15K	$9K	$13K	$20K	>$100M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
110	Erect a barrier that would provide enhanced protection of the containment walls (shell) from ejected core debris following a core melt scenario at high pressure.	Reduced probability of containment failure.	MAB						>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
111	Install additional pressure or leak monitoring instruments for detection of ISLOCAs.	Reduced ISLOCA frequency.	ISLOCA	$123K	$179K	$111K	$154K	$259K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
112	Add redundant and diverse limit switches to each containment isolation valve.	Reduced frequency of containment isolation failure and ISLOCAs.	CONT02	$1K	$1K	$1K	$1K	$2K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
113	Increase leak testing of valves in ISLOCA paths.	Reduced ISLOCA frequency.	ISLOCA	$123K	$179K	$111K	$154K	$259K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
114	Install self-actuating containment isolation valves.	Reduced frequency of isolation failure.	CONT02	$1K	$1K	$1K	$1K	$2K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
115	Locate residual heat removal (RHR) inside containment	Reduced frequency of ISLOCA outside containment.	ISLOCA	$123K	$179K	$111K	$154K	$259K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
116	Ensure ISLOCA releases are scrubbed. One method is to plug drains in potential break areas so that break point will be covered with water.	Scrubbed ISLOCA releases.	ISLOCA	$123K	$179K	$111K	$154K	$259K	>$1M	Expert Panel	Not Cost-Beneficial	Cost would exceed benefit. Current plant design requires drains to be open. Analysis and license changes required to implement are included in the cost estimate.

Table 8-1. Callaway Plant Sensitivity Evaluation (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	SAMA Case	Benefit	Benefit at 3% Disc Rate	Benefit at Realistic Disc Rate	Benefit at 33yrs	Benefit at 95% CDF	Cost	Cost Basis	Evaluation	Basis for Evaluation
119	Institute a maintenance practice to perform a 100% inspection of steam generator tubes during each refueling outage.	Reduced frequency of steam generator tube ruptures.	NOSGTR	$1.2M	$1.7M	$1.0M	$1.5M	$2.4M	>$3M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
121	Increase the pressure capacity of the secondary side so that a steam generator tube rupture would not cause the relief valves to lift.	Eliminates release pathway to the environment following a steam generator tube rupture.	NOSGTR	$1.2M	$1.7M	$1.0M	$1.5M	$2.4M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
122	Install a redundant spray system to depressurize the primary system during a steam generator tube rupture	Enhanced depressurization capabilities during steam generator tube rupture.	NOSGTR	$1.2M	$1.7M	$1.0M	$1.5M	$2.4M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
125	Route the discharge from the main steam safety valves through a structure where a water spray would condense the steam and remove most of the fission products.	Reduced consequences of a steam generator tube rupture.	NOSGTR	$1.2M	$1.7M	$1.0M	$1.5M	$2.4M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
126	Install a highly reliable (closed loop) steam generator shell-side heat removal system that relies on natural circulation and stored water sources	Reduced consequences of a steam generator tube rupture.	NOSGTR	$1.2M	$1.7M	$1.0M	$1.5M	$2.4M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
129	Vent main steam safety valves in containment.	Reduced consequences of a steam generator tube rupture.	NOSGTR	$1.2M	$1.7M	$1.0M	$1.5M	$2.4M	>$10M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit. Current containment design does not support this modification. Modifications to containment and associated analysis are included in the cost estimate.
130	Add an independent boron injection system.	Improved availability of boron injection during ATWS.	NOATWS	$63K	$104K	$57K	$90K	$134K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
131	Add a system of relief valves to prevent equipment damage from pressure spikes during an ATWS.	Improved equipment availability after an ATWS.	NOATWS	$63K	$104K	$57K	$90K	$134K	>$2M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
133	Install an ATWS sized filtered containment vent to remove decay heat.	Increased ability to remove reactor heat from ATWS events.	NOATWS	$63K	$104K	$57K	$90K	$134K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit
136	Install motor generator set trip breakers in control room.	Reduced frequency of core damage due to an ATWS.	NOATWS	$63K	$104K	$57K	$90K	$134K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
147	Install digital large break LOCA protection system.	Reduced probability of a large break LOCA (a leak before break).	LOCA05	$689K	$1.2M	$620K	$1.1M	$1.5M	>$5M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
153	Install secondary side guard pipes up to the main steam isolation valves.	Prevents secondary side depressurization should a steam line break occur upstream of the main steam isolation valves. Also guards against or prevents consequential multiple steam generator tube ruptures following a main steam line break event.	NOSLB	$51K	$87K	$46K	$77K	$108K	>$1M	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.

Table 8-1. Callaway Plant Sensitivity Evaluation (Continued)

Callaway SAMA Number	Potential Improvement	Discussion	SAMA Case	Benefit	Benefit at 3% Disc Rate	Benefit at Realistic Disc Rate	Benefit at 33yrs	Benefit at 95% CDF	Cost	Cost Basis	Evaluation	Basis for Evaluation
160	Modifications to lessen impact of internal flooding path through Control Building dumbwaiter.	Lower impact of flood that propagates through the dumbwaiter							<$50K	Expert Panel	Potentially Cost-Beneficial	Relatively minor modifications to door opening could result in lower flow to the dumbwaiter. Specific benefit could not be calculated but SAMA item is judged to be low cost and therefore potentially cost beneficial.
161	Improvements to PORV performance that will lower the probability of failure to open.	Decrease in risk due to PORV failing to open.	PORV	$18K	$32K	$16K	$28K	$39K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
162	Install a large volume EDG fuel oil tank at an elevation greater than the EDG fuel oil day tanks.	Allows transfer of EDF fuel oil to the EDG day tanks on failure of the fuel oil transfer pumps.	EDGFUEL	$124K	$131K	$113K	$156K	$263K	$150K	Wolf Creek	Potentially Cost-Beneficial	Wolf Creek estimated cost of $150K is less than the potential benefit.
163	Improve feedwater check valve reliability to reduce probability of failure to open.	Lower risk due to failures in which feedwater check valves fail to open and allow feeding of the steam generators.	FW02	$127K	$218K	$115K	$191K	$270K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
164	Provide the capability to power the normal service water pumps from AEPS.	Provide backup to ESW in conditions with power only available from AEPS.	SW03	$1191K	$307K	$172K	$267K	$403K	>$500K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.
171	Increase the size of the RWST or otherwise improve the availability of the RWST	Ensure a supply of makeup water is available from the RWST.	LOCA04	$13K	$23K	$12K	$20K	$27K	>$100K	Expert Panel	Not Cost-Beneficial	Cost will exceed benefit.

9.0 CONCLUSIONS

As a result of this analysis, the SAMAs identified in Table 9-1 have been identified as potentially cost beneficial. Since these potential improvements could result in a reduction in public risk, these SAMAs will be entered into the Callaway long-range plan development process for further consideration.

Table 9-1. Callaway Plant Potentially Cost Beneficial SAMAs

Callaway SAMA Number	Potential Improvement	Discussion	Additional Discussion
29	Provide capability for alternate injection via diesel-driven fire pump.	Improved injection capability.	Currently being evaluated by plant improvement program. Would use unborated water and portable pump (fire truck). Calculation of specific benefit of this SAMA was not performed since it is judged to be potentially low cost. Evaluation will consider impacts of injection of non-borated water.
160	Modifications to lessen impact of internal flooding path through Control Building dumbwaiter.	Lower impact of flood that propagates through the dumbwaiter	
162	Install a large volume EDG fuel oil tank at an elevation greater than the EDG fuel oil day tanks.	Allows transfer of EDG fuel oil to the EDG day tanks on failure of the fuel oil transfer pumps.	

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29. Docket Number 50-483, Callaway Plant Response to Generic Letter 88-20, Supplemental No.4, Individual Plant Examination of External Events (IPEEE), June 1995.

11.0 ANNEX – PRA RUNS FOR SELECTED SAMA CASES

This annex describes each of the SAMA evaluation cases. An evaluation case is an evaluation of plant risk using a plant PRA model that considers implementation of the evaluated SAMA. The case-specific plant configuration is defined as the plant in its baseline configuration with the model modified to represent the plant after the implementation of a particular SAMA. As indicated in the main report, these model changes were performed in a manner expected to bound the change in risk that would actually be expected if the SAMA were implemented. This approach was taken because the actual designs for the SAMAs have not been developed.

Each analysis case is described in the following pages. Each case description contains a description of the physical change that the case represents along with a description of the SAMAs that are being evaluated by this specific case.

The PDS frequencies calculated as a result of the PRA model quantification for each SAMA case is presented in Table 11-1.

NOATWS

This case is used to determine the benefit of eliminating all Anticipated Transient Without Scram (ATWS) events. For the purposes of the analysis, a single bounding analysis was performed which assumed that ATWS events do not occur.

NOSGTR

This case is used to determine the benefit of eliminating all Steam Generator Tube Rupture (SGTR) events. This allows evaluation of various possible improvements that could reduce the risk associated with SGTR events. For the purposes of this analysis, a single bounding analysis was performed which assumed that SGTR events do not occur.

INSTAIR

This case is used to determine the benefit of replacing the air compressors. For the purposes of the analysis, a single bounding condition was performed, which assumed the station air systems do not fail.

NOLOSP

This case is used to determine the benefit of eliminating all Loss of Offsite Power (LOSP) events, both as the initiating event and subsequent to a different initiating event. This allows evaluation of various possible improvements that could reduce the risk associated with LOSP events. For the purposes of the analysis, a single bounding analysis was performed which assumed that LOSP events do not occur.

CCW01

This case is used to determine the benefit of improvement to the CCW system by assuming that CCW pumps do not fail.

FW01

Eliminate loss of feedwater initiating events. This case is used to determine the benefit of improvements to the feedwater and feedwater control systems.

NOSLB

This case is used to determine the benefit of installing secondary side guard pipes to the Main Steam Isolation Valves (MSIVs). This would prevent secondary side depressurization should a Steam Line Break (SLB) occur upstream of the MSIVs. For the purposes of the analysis, a single bounding analysis was performed which assumed that no SLB inside containment events occur.

CHG01

Assume the charging pumps are not dependent on cooling water. This case is used to determine the benefit of removing the charging pumps dependency on cooling water.

SW01

Assume the service water pumps are not dependent on DC power. This case is used to determine the benefit of enhancing the DC control power to the service water pumps.

NOSBO

This case is used to determine the benefit of eliminating all Station Blackout (SBO) events. This allows evaluation of possible improvements related to SBO sequences. For the purpose of the analysis, a single bounding analysis is performed that assumes the emergency AC power supplies do not fail.

LOCA05

Assume that piping system LOCAs do not occur. This case is used to determine the benefit of eliminating all LOCA events related to piping failure (no change to non-piping failure is considered).

NOSLOCA

Assume small LOCA events do not occur. This case is used to determine the benefit of eliminating all small LOCA events.

H2BURN

Assume hydrogen burns and detonations do not occur. This case is used to determine the benefit of eliminating all hydrogen ignition and burns.

RCPLOCA

This case is used to determine the benefit of eliminating all Reactor Coolant Pump (RCP) seal loss of coolant accident (LOCA) events. This allows evaluation of various possible improvements that could reduce the risk associated with RCP seal LOCA and other small LOCA events.

LOCA02

This case is used to determine the benefit of no failures of high pressure injection/recirculation systems. This allows evaluation of various possible improvements that could reduce the risk associated with high pressure injection/recirculation failures.

LOCA12

This case is used to determine the benefit of no failures of high pressure injection/recirculation pumps. This allows evaluation of various possible improvements that could reduce the risk associated with high pressure injection/recirculation pump failures.

CONT02

Eliminate all containment isolation failures.

LOCA04

Assume RWST does not run out of water.

CONT01

Eliminate all containment overpressure failures.

LOCA03

This case is used to determine the benefit of no failures of low pressure injection/recirculation pumps. This allows evaluation of various possible improvements that could reduce the risk associated with low pressure injection/recirculation pump failures.

SW02

This case is used to determine the benefit of no failures service water pumps.

DC01

Eliminates the TDAFW pump dependency on DC power.

CCW02

Sets all CCW pumps and SW pumps to 0.0 to evaluate the benefit of backup cooling water supplies.

ISLOCA

Eliminate all intra-system LOCA failures.

LOSP1

Used to evaluate the benefit of providing tornado protection for the AEPS diesel generators.

DEPRESS

Evaluate additional means of depressurization by making depressurization always successful.

LOCA06

Assume that Large LOCAs do not occur. This case is used to determine the benefit of eliminating all risk due to Large LOCA events.

HVAC

Eliminates various HVAC dependencies.

FB01

Used to evaluate modifying the PORVs such that only one PORV is required for Feed and Bleed.

PORV

Used to evaluate improvements that lower the probability of PORVs failing to open.

EDGFUEL

Used to evaluate the addition of a gravity feed EDG fuel oil tank.

FW02

Used to evaluate improvements that lower the probability of feedwater check valves failing to open.

SW03

Used to evaluate adding the ability to power the normal service water pumps from the AEPS.

HVAC02

Used to evaluate adding additional UHS cooling tower electrical room HVAC.

Table 11-1. Callaway Plant Release Category Frequency Results Obtained From SAMA Cases

RELEASE CATEGORY	BASE	NOATWS	INSTAIR	NOLOSP	NOSLOCA	CCW01	FW01	NOSGTR	NOSLB	CHG01
LERF-IS	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07
LERF-CI	1.658E-10	1.411E-10	1.658E-10	1.422E-10	6.210E-11	1.567E-10	1.658E-10	1.658E-10	1.610E-10	1.658E-10
LERF-CF	1.125E-08	1.103E-08	1.124E-08	7.372E-09	5.378E-09	1.071E-08	1.115E-08	1.125E-08	1.116E-08	1.123E-08
LERF-SG	2.331E-06	2.306E-06	2.330E-06	2.331E-06	2.331E-06	2.331E-06	2.331E-06	0.000E+00	2.331E-06	2.331E-06
LERF-ITR	2.170E-07	1.845E-07	2.167E-07	1.309E-07	2.072E-07	2.170E-07	2.052E-07	0.000E+00	1.936E-07	2.169E-07
LATE-BMT	2.551E-06	2.268E-06	2.547E-06	1.254E-07	2.029E-06	2.507E-06	2.448E-06	2.551E-06	2.515E-06	2.467E-06
LATE-COP	3.185E-06	3.185E-06	3.185E-06	1.796E-08	3.170E-06	3.185E-06	3.185E-06	3.185E-06	3.185E-06	3.185E-06
SERF	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
INTACT	8.080E-06	8.075E-06	8.080E-06	7.065E-06	2.553E-06	7.573E-06	7.983E-06	8.080E-06	7.773E-06	8.137E-06
TOTAL	1.655E-05	1.620E-05	1.654E-05	9.851E-06	1.047E-05	1.600E-05	1.634E-05	1.400E-05	1.618E-05	1.652E-05

Table 11-1. Callaway Plant Release Category Frequency Results Obtained From SAMA Cases (Continued)

RELEASE CATEGORY	SW01	NOSBO	LOCA05	H2BURN	RCPLOCA	LOCA 12	CONT02	LOCA04	LOCA03	CONT01
LERF-IS	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07
LERF-CI	1.658E-10	1.658E-10	6.210E-11	1.658E-10	1.567E-10	1.658E-10	0.000E+00	1.658E-10	1.658E-10	1.658E-10
LERF-CF	1.124E-08	1.030E-08	5.018E-09	4.102E-12	1.048E-08	1.099E-08	1.125E-08	1.114E-08	1.089E-08	1.125E-08
LERF-SG	2.331E-06	2.329E-06	2.331E-06	2.331E-06	2.331E-06	2.331E-06	2.331E-06	2.331E-06	2.298E-06	2.331E-06
LERF-ITR	2.170E-07	1.443E-07	2.072E-07	2.170E-07	2.170E-07	2.165E-07	2.170E-07	2.170E-07	2.169E-07	2.170E-07
LATE-BMT	2.553E-06	1.611E-06	2.009E-06	2.551E-06	2.475E-06	1.893E-06	2.551E-06	2.441E-06	2.007E-06	2.551E-06
LATE-COP	3.181E-06	2.426E-06	3.170E-06	3.170E-06	3.173E-06	3.182E-06	3.185E-06	3.185E-06	3.185E-06	0.000E+00
SERF	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
INTACT	8.080E-06	7.883E-06	2.170E-06	8.080E-06	7.301E-06	8.329E-06	8.080E-06	8.080E-06	8.180E-06	8.080E-06
TOTAL	1.655E-05	1.458E-05	1.007E-05	1.652E-05	1.568E-05	1.614E-05	1.655E-05	1.644E-05	1.607E-05	1.336E-05

Table 11-1. Callaway Plant Release Category Frequency Results Obtained From SAMA Cases (Continued)

RELEASE CATEGORY	BREAKER	DC01	SW02	CCW02	CST01	ISLOCA	LOSP1	DEPRESS	LOCA06	HVAC
LERF-IS	1.730E-07	1.730E-07	1.730E-07	1.730E-07	1.730E-07	0.000E+00	1.730E-07	1.730E-07	1.730E-07	1.730E-07
LERF-CI	1.666E-10	1.658E-10	1.514E-10	1.422E-10	1.650E-10	1.658E-10	1.666E-10	1.658E-10	1.658E-10	1.658E-10
LERF-CF	1.129E-08	1.124E-08	9.548E-09	8.906E-09	1.112E-08	1.125E-08	1.113E-08	1.122E-08	1.109E-08	1.099E-08
LERF-SG	2.328E-06	2.331E-06	2.331E-06	2.331E-06	2.331E-06	2.331E-06	2.331E-06	2.331E-06	2.331E-06	2.329E-06
LERF-ITR	2.093E-07	2.170E-07	2.110E-07	2.108E-07	2.169E-07	2.170E-07	1.814E-07	2.160E-07	2.169E-07	1.944E-07
LATE-BMT	2.047E-06	2.551E-06	2.417E-06	1.864E-06	2.022E-06	2.551E-06	2.039E-06	2.508E-06	2.020E-06	1.657E-06
LATE-COP	3.210E-06	3.185E-06	1.455E-06	1.455E-06	3.185E-06	3.185E-06	2.991E-06	3.166E-06	3.185E-06	2.917E-06
SERF	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
INTACT	8.180E-06	8.080E-06	7.951E-06	7.836E-06	8.471E-06	8.080E-06	8.431E-06	8.069E-06	8.431E-06	8.312E-06
TOTAL	1.616E-05	1.655E-05	1.455E-05	1.388E-05	1.641E-05	1.638E-05	1.616E-05	1.647E-05	1.637E-05	1.559E-05

Table 11-1. Callaway Plant Release Category Frequency Results Obtained From SAMA Cases (Continued)

RELEASE CATEGORY	FB01	PORV	EDGFUEL	FW02	SW03	HVAC02
LERF-IS	1.730E-07	1.730E-07	1.730E-10	1.730E-07	1.730E-07	1.730E-07
LERF-CI	1.658E-10	1.658E-10	1.658E-10	1.658E-10	1.514E-10	1.658E-10
LERF-CF	1.094E-08	1.112E-08	1.124E-08	1.047E-08	1.031E-08	1.096E-08
LERF-SG	2.326E-06	2.331E-06	2.331E-06	2.324E-06	2.331E-06	2.331E-06
LERF-ITR	1.796E-07	2.169E-07	2.169E-07	1.659E-07	2.141E-07	2.169E-07
LATE-BMT	2.006E-06	2.022E-06	2.544E-06	1.983E-06	2.428E-06	1.990E-06
LATE-COP	3.185E-06	3.185E-06	3.182E-06	3.185E-06	2.557E-06	2.823E-06
SERF	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
INTACT	8.146E-06	8.471E-06	8.078E-06	7.796E-06	7.907E-06	8.461E-06
TOTAL	1.603E-05	1.641E-05	1.636E-05	1.564E-05	1.562E-05	1.601E-05