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March 19, 2003

Mr. Gregory F. Suber, Project Manager
Environmental Section
License Renewal and Environmental Impact Programs
Division of Regulatory Improvement Programs/NRR
Nuclear Regulatory Commission
MS O-12D3
1155 Rockville Pike
Rockville, MD 20852-2738

Dear Mr. Suber:

Subject: VIRGIL C. SUMMER NUCLEAR STATION
DOCKET NO. 50/395
OPERATING LICENSE NO. NPF-12
RESPONSE TO SAMA REQUEST FOR ADDITIONAL INFORMATION

Reference: Mr. Gregory F. Suber, NRC, to Mr. S. A. Byrne, VCSNS, January 17, 2003

Attached you will find responses to the request for additional information (RAI) regarding Severe Accident Mitigation Alternatives (SAMA) for the V. C. Summer Nuclear Station.

Please contact Stephen Summer at (803) 345-4252 if you have any questions.

3/19/03
Executed on

Stephen A. Byrne

SAB/ses/mbb
Attachment

c: Without attachments unless stated

N. O. Lorick
N. S. Carns
T. G. Eppink (w/attachment)
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DMS (RC-03-0043) (w/attachment)
File (821.00) (w/attachment)

Responses to Request for Additional Information (RAI) Regarding Severe Accident Mitigation Alternatives for the Virgil C. Summer Nuclear Station

SAMA RAI 1:

The SAMA analysis is based on the most recent version of the VCSNS probabilistic risk assessment (PRA) model for internal events (i.e., the UP3a model), which is a modification to the original individual plant examination (IPE) developed in 1993. Please provide the following information regarding this PRA model:

a) a summary description of the internal and external peer reviews of the level 1 and level 2 portions of this PRA;

b) a characterization of the findings of these internal and external peer reviews (if any), and the impact of any identified weaknesses on the SAMA identification and evaluation process;

c) additional information regarding the reasons for changes in core damage frequency (CDF) between the IPE model and the UP3a model. Specifically, Table F.1-2, attributes all of the changes in CDF to "model changes," while Table F.1-1 attributes some CDF reduction from plant improvements (plant improvement numbers 1 and 11). Please explain this apparent inconsistency. Also, please clarify how much of the approximate 70 percent reduction in CDF is attributed to PRA model changes and how much is attributed to actual plant improvements;

d) a breakdown of the internal event CDF and large early release frequency (LERF) by major contributors or accident classes, such as loss of offsite power (LOOP), station blackout (SBO), transients, anticipated transient without scram (ATWS), loss-of-coolant accident (LOCA), interfacing systems LOCA (ISLOCA), steam generator tube rupture (SGTR), and internal floods;

e) a breakdown of the population dose (person-rem per year within 50 miles) by containment release mode, such as SGTR, ISLOCA, containment isolation failure, early containment failure, late containment failure, and no containment failure;

f) for each containment release category (including LERF and non-LERF contributors): the associated release frequency, release magnitude (fission product release fractions), and MACCS-calculated conditional consequence measures. Please identify those release categories that are considered to contribute to LERF, and those categories to which SGTR and ISLOCA releases are assigned;

g) the definition of LERF used to distinguish a large-early release from a small-early or a large-late release; and

h) clarification of whether the reported CDF, LERF, and population dose values are per-reactor year or per-calendar year.

VCSNS Response 1a:

The independent review of the original VCSNS IPE was conducted in 1991 prior to issuance of the IPE Report. As part of this effort, four different reviews were performed.

The first two reviews focused on the Level 1 work and the containment system performance analysis. The third review consisted of an independent review of the Human Reliability Analysis (HRA) portion of the IPE and was performed by experienced human error analysts working for the Science Applications International Corporation (SAIC). The final review of the original IPE was performed by an experienced PRA analyst from SAIC and was completed to supplement the internal PRA core of expertise at VCSNS. IPE Report Section 5.2, "Independent Review Process," provides more details on these reviews. These reviews were completed and associated comments were addressed prior to issuance of the report.

In March of 2001, Westinghouse completed an independent review of the VCSNS PRA model. The purpose of this review was to ensure the PRA was ready for use in plant risk-informed activities and to help prepare for the Westinghouse Owner's Group (WOG) PRA Peer Review. The principle reviewer was the Westinghouse project manager/technical lead for the WOG PSA Peer Review program. Additional members of the Westinghouse Reliability & Risk Assessment group assisted in the review.

In August of 2002, a comprehensive review of the VCSNS PRA model was performed as part of the WOG PSA Peer Review Program. The review team consisted of two individuals from Westinghouse, PRA analysts from First Energy Nuclear Operating Co., PSEG Nuclear Co., Southern Nuclear Operating Co., and one additional industry consultant from Karl Fleming Consulting. The VCSNS PRA Team also participated in the review. The final report was issued in December 2002.

VCSNS Response 1b:

As mentioned in the response to RAI 1a, the VCSNS PRA has undergone two independent reviews since the completion of the IPE. These reviews were performed on two different versions of the PSA model. The Westinghouse review (completed in March 2001) was based on the same version of the model as the SAMA analysis, model UP3a. (The model designation UP3a is used to denote the third model update, through change "a.") The Westinghouse Owners Group (WOG) Peer Review was performed on model UP3h. This model was developed based on the UP3a model, the comments received in the March 2001 Westinghouse review, changes related to regular model maintenance, and the PRA updates performed to support the VCSNS RI-ISI effort. The impacts of the review findings on the SAMA analysis are addressed below.

Westinghouse Review

The Westinghouse review was completed in March 2001 and concluded that the technical elements of the VCSNS PRA are such that the PRA is generally suitable for plant risk-informed applications. A summary of the strengths and areas identified for improvement is provided below.

Strengths

One of the strengths identified in this review was that the VCSNS PRA is actively maintained and upgraded to better reflect plant configuration and procedural changes, and that SCE&G has pursued focused assessments of PRA capabilities (e.g., PRA vulnerabilities assessment and success criteria improvements assessment) in an effort to identify areas where the PRA could be made more realistic. It was also noted that SCE&G has taken advantage of state of the art PRA software capabilities to develop an integrated, almost "automatic" model for quantification of core damage frequency (CDF) and large early release frequency (LERF), and that this allows the use of very low quantification truncation for both CDF and LERF, so that all important modeled contributors are accounted for.

Areas of Improvement

A summary of recommended improvements is provided below, grouped by the technical element used in the review process.

Initiating Events

It was suggested that VCSNS:

- Consider using a more recent industry database for transient initiating event frequencies.
- Use Bayesian updating for initiating event data.
- Consider reviewing the intersystem LOCA accident sequence modeling and initiating event frequency calculation against the more recent guidance of NUREG/CR-5744, "Assessment of ISLOCA Risk Methodology and Application to a Westinghouse Four-Loop Ice Condenser Plant," dated March 1992.

Accident Sequences and Quantification

The reviewers suggested that VCSNS:

- improve the documentation of which fault tree gates are used to address specific event tree branch success criteria.
- expand all "success with accident management" endstates such that they are modeled to stable endpoints.
- conduct an evaluation of potential sources of uncertainty, review cutsets for each initiating event, determine the sensitivity of results to key assumptions, and determine how uncertainties and sensitivities have the potential to affect applications of the PRA.

Data and Common Cause

The reviewers recommended:

- that plant and industry operating experience be reviewed and incorporated in the PRA model.
- use of a different generic database.

- alternative means of calculating common cause failure groupings and common cause probabilities in some special initiating event scenarios.

Success Criteria

The reviewers recommended incorporating the results of recent success criteria analyses that would remove excess conservatisms.

Human Reliability Analysis

The reviewers recommended:
- improving the process used to identify and address dependencies among modeled human actions.
- improving traceability between the time windows assumed in the human error probability calculations.
- obtaining feedback from operations and training groups on various elements of the HRA model.

Large Early Release Frequency Analysis

The reviewers recommended several suggestions for improved documentation.

Maintenance and Update Process

The reviewers recommended developing a guideline to ensure that all relevant information is considered in the update process.

Impact of Westinghouse review findings on the SAMA Process

The reviewers concluded that the technical elements of the VCSNS PRA are such that the PRA is generally suitable for plant risk-informed applications.

All of the significant recommendations were addressed through the development of the UP3h version of the VCSNS PRA model with the exception of the "Data" comment relating to the use of a different generic database. While the database used in the UP3a version was considered to be a good source by the peer reviewer, it was noted that the subject database would not be included in a forthcoming revised draft ASME Standard. A new database has been developed for VCSNS, and it will be incorporated into the next data update.

The changes related to use of an alternate data source are judged to have a limited impact on the SAMA analysis and would not influence the results or conclusions of the analysis. Data collection and interpretation have improved in the last decade or so due to the implementation of the Maintenance Rule. More information is becoming available that can be used to improve the accuracy of the failure rates of components used in the PRA. However, differences will likely always exist in failure rate estimates based on the assumptions used by the analysts and on the particular sets of data implemented in a given study. These differences are within the bounds of the expected deviations in current industry PRAs.

No gross outliers in the VCSNS database were identified in either the Westinghouse or WOG PRA reviews. As such, the changes that would result from using the updated database in place of the existing database are not expected to be large. The responses to RAI 4b and 4c indicate that even a factor of 2.36 increase in the risk results would not change the conclusions of the SAMA analysis; thus, the database changes are not expected to alter the conclusions of the SAMA analysis.

As stated previously, the remaining significant recommendations from the Westinghouse review were incorporated in the UP3h model. The resulting impacts on CDF and LERF were noted to be within the normal fluctuation that occurs due to regular maintenance of the PRA model. Because of this, the findings and observations noted in the Westinghouse Peer Review are judged to have a minimal impact on the SAMA analysis.

Westinghouse Owners Group Peer Review

The VCSNS WOG Peer Review was conducted in August 2002, and the final report was issued in December 2002. The following table provides an overall assessment of the Peer Review results in terms of the grades received on each of the eleven technical elements considered by the review team.

PRA Element	Assigned Grade
Initiating Events	3©
Accident Sequences Evaluation	3
Thermal Hydraulic Analysis	3
System Analysis	3©
Data Analysis	3
Human Reliability Analysis	3©
Dependencies	3
Structural Response	3©
Quantification	3
Containment Performance	3©
Maintenance & Update	3

The report discusses "Grade 3" as follows:

> This grade extends the requirements to assure that risk significance determinations made by the PRA are adequate to support regulatory applications, when combined with deterministic insights. Therefore, a PRA with elements determined to be at Grade 3 can support physical plant changes when it is used in conjunction with other deterministic approaches that ensure that defense-in-depth is preserved.

The report also states that, a "©" designation indicates that the grade is contingent upon implementation of recommended improvements or equivalent actions."

There were three observations issued in the Peer Review Report that were noted as extremely important and necessary to ensure the technical adequacy of the PRA. One of these was in

the area of "Initiating Events," and the other two were in the "Systems Analysis" technical element. Because the final Peer Review Report was issued in December 2002, VCSNS has not yet incorporated these comments in the PRA model. However, sensitivity studies have been performed to determine their impact on the SAMA analyses. The three observations and their impact on the SAMA process are discussed below.

Initiating Events

The reviewers noted that VCSNS uses a mean point estimate for deriving the ISLOCA initiating event frequency, and recommended that a wide range of normally closed valve failure modes be considered for the event frequency.

Impact on SAMA: A sensitivity case was performed in which the ISLOCA frequency was increased by an order of magnitude. The results indicate the maximum averted cost-risk (MACR) would increase from $1.20 million to $1.55 million. While this represents a 30 percent increase in the MACR, the impact on the Phase 1 analysis is small. No additional SAMAs would be passed to the Phase 2 analysis based on the increase in MACR.

Due to the high margin in most of the Phase 2 cost benefit calculations, only a limited number of SAMAs could be impacted by this change (Phase 2 SAMAs 3 and 10). These SAMAs were examined to determine how an order of magnitude increase in the ISLOCA frequency would impact the Phase 2 results. No measurable change in the averted cost-risk was noted based on the increase in ISLOCA frequency. This is because the averted cost-risk is determined by the change in plant risk due to the affects of a given SAMA, and Phase 2 SAMAs 3 and 10 do not impact the ISLOCA sequences. Based on this, the finding has minimal impact on the SAMA analysis.

System Analysis

Two significant comments were received in the System Analysis technical element. These are addressed below.

(1) The reviewers recommended that the VCSNS diesel generator model be revised to include failure of the fuel oil transfer pumps,

Impact on SAMA:

Inclusion of the fuel oil transfer pumps in the diesel generator logic has been performed as a sensitivity analysis on the UP3H model. Results indicate a 5.9% increase in CDF and a 3.0% increase in LERF. This corresponds to an absolute change in CDF of 3.3E-06/year. Assuming a comparable change in absolute CDF would occur if the same changes were made in the UP3a model and that the increase in LERF is represented through the containment isolation failure source term (as it is not an SGTR or an ISLOCA event), the impact of this change on the UP3a model can be estimated. The corresponding increase in the maximum averted cost-risk is only $67,000. This increase in the MACR would not allow any new SAMAs to pass the Phase 1 screening process. The potential changes in the Phase 2 calculations are bounded by the response to RAI 4b and would not alter the conclusions of the Phase 2 screening.

(2) The reviewers recommended increasing the Emergency Feedwater System (EFW) mission time and documenting that Condensate Storage Tank (CST) volume is sufficient to support the EFW mission time.

Impact on SAMA:

A sensitivity study of the EFW system model has been performed to evaluate the 24-hour mission time requirement. For Station Blackout (SBO) scenarios, EFW operation is required until power is recovered and then successful Residual Heat Removal (RHR) operation is required to complete the 24-hour mission time. Alternatively, the EFW pumps could be used for the remainder of the mission time if RHR is not available. The remaining scenarios for the other initiating events have also been modified to require 24 hours of successful operation of EFW or RHR for heat removal.

The nominal CST volume has been determined to be sufficient to provide heat removal for the 24-hour mission time used in the VCSNS PRA. Realistic assumptions related to the expected volume of the CST at accident initiation support the conclusion that the CST volume is sufficient to provide heat removal for the 24 hours. No changes have been made to the model to require makeup capability for success.

The results based on these changes indicate a 17.9 percent increase in CDF and an 11.5 percent increase in LERF. This corresponds to an increase in the maximum averted cost-risk of about $222,000 (18.4 percent increase). While a small number of previously screened SAMAs may be retained in the Phase 1 analysis due to this increase, none would be retained further as the cost of implementation would be between $1.2 million and $1.4 million. For such a SAMA to be cost beneficial, the plant change would have to reduce the CDF by over 80 percent.

Given that the Phase 2 analysis relies on the change in CDF and LERF subcategories for the averted cost-risk calculation, this change would only impact those SAMAs that would enhance the reliability of EFW and/or RHR heat removal or provide alternate primary loop heat removal. The Phase 2 SAMAs with the potential to be impacted are 5, 10, 20, 21, and 24; however, the actual benefit is judged to be small and bounded by the analysis performed in the response to RAI 4.

Summary

The Westinghouse Peer Review comments resulted in an increase in CDF that is bounded by the normal fluctuations observed in PRA model maintenance, and the WOG Peer Review comments could potentially increase the CDF by up to 30 percent. The LERF subcategories were impacted less dramatically. The result of all these model changes in conjunction with other changes that have been implemented in the model through version UP3h would be a net increase in CDF of about 15 percent. Fluctuations such as this are comparable to those seen in regular PRA maintenance updates, and are typical in a living PRA model.

Many industry examples demonstrate that increases in one area are balanced by decreases in other areas. While these types of changes are difficult to predict, the use of the 95th percentile

PSA results as documented in the response to RAI 4 is considered to bound these types of changes. No alterations in the conclusions of the VCSNS SAMA analysis are expected based on the incorporation of the Westinghouse and WOG Peer Review comments.

VCSNS Response 1c:

Part One:

The two tables were intended to convey different information. Table F.1-1, "Summary and Status of VCSNS Improvements," was included (on Page F-6 of the Environmental Report) to provide an update on the status of plant improvements that were identified *in the original IPE process.* This table is the same as Table FE Q12-1 in the IPE RAI Response ("Request for Additional Information Regarding IPE Report Generic Letter 88-20," dated March 20, 1996) except that VCSNS has updated the status of the improvements (when applicable) and added a column that tells whether or not credit has been taken for the improvement in the PRA model. The "Impact on CDF" column of this table has not been revised from that submitted for the IPE RAI Response.

The intent of Table F.1-2, "PRA Model Changes- IPE Submittal Through Third Update 1/2000," is to show the revisions to the VCSNS PRA Model from the time the IPE was submitted through major revision 3. This table was included because VCSNS noted that the NRC had requested the information during review of SAMAs submitted by other utilities.

Revisions to the VCSNS PRA Model are controlled through the plant design calculation control process. Table F.1-2 shows changes to the model since the IPE (including the calculation number which effected the change in the model), as well as the impact of each revision on CDF and LERF. For any plant improvement to impact the CDF number, it must be modeled in the PRA, and for it to be modeled in the PRA, it has to go through the design calculation process. Therefore, the only "tie" between the two tables is that any plant improvement in Table F.1-1 that was *not* already credited in the IPE but that *is* credited in version UP3a would have been implemented under one of the design calculations listed in Table F.1-2.

Regarding the two specific items in this question, plant improvement number 11 from Table F.1-1 corresponds to Design Calculation 00300-034 (VU/CCW MOD) in Table F.1-2. Because plant improvement number 1 in Table F.1-1 was already credited in the IPE Report, there is no corresponding item in Table F.1-2.

For further clarification (and as requested during the 1/23/03 phone call between NRC and SCE&G) the below table shows the relationship between the PRA model changes in Table F.1-2 and the IPE identified improvements in Table F.1-1.

Table 1.c-1: Updated Table F.1-2 from Environmental Report

PRA MODEL CHANGES - IPE SUBMITTAL THROUGH 3RD UPDATE 1/2000

MODEL REVISION	CDF	LERF	CALC NUMBER	Date	Table F.1-1 Item No.
IPE Model	2.0E-04	N/A	IPE SUBMITTAL		N/A
Data Update	1.8E-04	N/A	DC00300-033	10/94	N/A
VU / CCW MOD	1.2E-04	N/A	DC00300-034	9/94	11
EFW CK VLV MOD, Expand IA Modeling, and Other Modeling Changes	9.6E-05	N/A	DC00300-037 DC00300-035	4/96 11/94	N/A
Conversion to Singletop Model and Removed Excess Conservatism to Singletop Model	8.4E-05	N/A	DC00300-131	4/99	N/A
Created Stand Alone LERF Model	N/A	1.7E-06	DC00300-132	7/99	N/A
Updated Common Cause Failure Probability	8.6E-05	1.1 E-06	DC00300-133	8/99	N/A
Demodulized Special Initiators	8 6E-05	1.1 E-06	DC00300-136	8/99	N/A
Human Reliability Analysis Update	1.3E-04	2.2E-06	DC00300-134	9/99	6,7, and 8
Second Data Update (Changes Primarily Due To LOCA Freq Changes, NUREG 5750 And LOSP)	5.8E-05	8.9E- 07	DC00300-135	9/99	N/A
Third Data Update, Common Cause Update And Model Corrections	5.6E-05	7.0E-07	DC00300-137	1/00	N/A

Part Two:

The information requested in this question is not available for the following reasons: (1) The CDF impact of any change to the model (whether due to a plant change or a modeling change) is measured in the calculation process relative to the CDF of the previously approved model version; the change in CDF is not "normalized" to determine its impact on the baseline IPE model, and (2) The design calculations which implement revisions to the model following plant changes may also incorporate additional "modeling" changes as well, such that the measured change in CDF is not solely due to the plant modification.

Even though the requested information is not available, one can get at least a relative idea of the CDF-impact of plant improvements by observing the change in CDF from the previously

approved model. For the two plant improvements noted in Table F.1-2, the changes in CDF are described below.

"VU/CCW MOD" represents a plant modification that changed the cooling medium for the Component Cooling Water (CCW) pumps and Charging pumps from HVAC Chilled Water to CCW. This modification resulted in a change in CDF from a base case of 1.489E-04/yr to 1.220E-04/yr, or about an 18% reduction. (It should be noted that the base case for this comparison was modified in the associated design calculation to ensure that the benefit of the modification was not overestimated. For example, the model that represents the cooling medium with CCW takes credit for operator recovery actions in the CCW system. Such recovery actions were not previously modeled for Chilled Water, so they were added to the base case model to ensure an accurate measure of the modification's benefit.)

"EFW CK VLV MOD" represents a plant modification that eliminated six check valves in the Emergency Feedwater System (EFW). The design calculation that implemented this modification also implemented other modeling changes, so an exact impact from just the deletion of the check valves is not available. However, the design calculation does document a decrease in CDF from 1.039E-04/yr to 1.006E-04/yr (~3.2%) for the valve elimination and model changes.

The "Second Data Update" represents the largest decrease in CDF due to a *modeling* change. In this revision (implemented by DC00300-135), the CDF decreased from 1.260E-04/yr to 5.759E-05/yr, or 54%. The large CDF reduction was primarily due to utilization of the updated initiating event frequencies found in NUREG/CR-5750, "Rates of Initiating Events at U.S. Nuclear Power Plants: 1987-1995," dated February 1999, as well as updating the loss of offsite power initiating event frequency with data from EPRI TR-106306, "Loss of Off-Site Power at U.S. Nuclear Power Plants-Through 1995," April 1996.

VCSNS Response 1d:

The tables below provide the requested information. All events or classes that contribute greater than or equal to 1.0% of the CDF or LERF are shown.

Table 1.d-1: Major Contributors to CDF

Major CDF Contributor	Probability / year	Percent of CDF
Loss of Offsite Power	3.94E-05	70.5%
Total Loss of CCW Special Initiator	3.86E-06	6.9%
Secondary Side Break Inside Containment	1.74E-06	3.1%
Secondary Side Break Outside Containment	1.74E-06	3.1%
Small LOCA	1.71E-06	3.0%
Loss of Main Feedwater Flow	1.64E-06	2.9%
Partial Loss of Main Feedwater	1.49E-06	2.7%
Reactor Trip	9.1E-07	1.6%
Loss of Instrument Air	5.76E-07	1.0%

Table 1.d-2: Major Contributors to LERF

Major LERF Contributor	Probability / year	Percent of LERF
Loss of Offsite Power	2.81E-07	40.1%
Interfacing System LOCA Event	1.78E-07	25.5%
Steam Generator Tube Rupture	1.18E-07	16.9%
Total Loss of CCW Special Initiator	2.87E-08	4.1%
Small LOCA	1.69E-08	2.4%
Secondary Side Break Inside Containment	1.29E-08	1.8%
Secondary Side Break Outside Containment	1.29E-08	1.8%
Loss of Main Feedwater Flow	1.17E-08	1.7%
Partial Loss of Main Feedwater Flow	1.06E-08	1.5%

VCSNS Response 1e:

The population dose-risk for the VCSNS SAMA analysis is determined based on a specific set of release categories that are used in the plant's PSA model (UP3a). The VCSNS SAMA submittal included only contributions from those release categories defined as LERF scenarios by the PSA; however, this response to the RAI also provides an estimate of the Non-LERF dose-risk. In addition, this response includes the Offsite Economic Cost-Risk (OECR) results for completeness.

Given that VCSNS implements a LERF model rather than a full Level 2 analysis, the containment release modes are limited to the following:

- Steam Generator Tube Rupture (SGTR)
- Intersystem Loss of Coolant Accident (ISLOCA)
- Containment Isolation Failure

Catastrophic containment failures that would be categorized as "early containment failure" or "late containment failure" release modes are not included in the VCSNS LERF model because VCSNS utilizes a Westinghouse large, dry containment. Those failure modes are considered to be small contributors that are dominated by the containment bypass or isolation failure events identified above. No early containment failure mode has been identified in the VCSNS IPE or PRA model; however, a source term exists for containment failure at 48 hours for long-term loss of Decay Heat Removal (DHR).

The contribution from containment failure at 48 hours has been estimated using the long-term loss of DHR scenario identified in the VCSNS IPE (TRE13IH). This source term is defined in the response to RAI 9 as "Case 2" in the LERF sensitivity analysis. The IPE estimated the frequency for this release category to be about 20 percent of the non-LERF cases.

For simplicity, 20 percent of the current PRA's CDF (1.12E-05/yr) is used here to calculate the dose-risk and OECR for this release category. The results are small compared with the LERF contribution and correspond to an increase in the maximum averted cost-risk of less than 0.1 percent.

The "no containment failure" release mode is judged to be bounded by the case for containment failure at 48 hours. Given that the 48-hour containment failure contribution is less than 0.1 percent of the maximum averted cost-risk, this contributor is judged to be negligible.

Table 1.e-1 summarizes the dose-risk results. Note that the LERF release categories were used as the sole contributors to the dose-risk in the VCSNS submittal. These release categories contribute 94.7 percent of the total dose-risk.

Table 1.e-2 summarizes the OECR results. Note that the LERF release categories were used as the sole contributors to the OECR in the VCSNS submittal. These release categories contribute 99.9 percent of the total OECR.

Table 1.e-1: Offsite Dose-risk Results

Source Term (Description)	TRE13IH (Containment Failure at 48 hours)	1-SGL16BH (SGTR)	2-ILM08BH (ISLOCA)	3-TRE13NH (Cont. Bypass)	
	Dose-Risk				Sum of Annual Risk
Population dose-risk (person-rem) 0-50 miles	5.32E-02	0 27	0.63	0.05	1.01
Population dose risk (percent) 0-50 miles	5.28	27.10	62.33	5.29	100.00
SGTR %	0.00	100.00	0.00	0.00	27.10
ISLOCA %	0.00	0.00	100.00	0.00	62.33
Containment isolation failure %	0.00	0.00	0.00	100.00	5 29
Containment failure at 48 hours	100	0.00	0.00	0.00	5.28
No containment failure	0.00	0 00	0.00	0.00	0.00

Table 1.e-2: OECR Results

Source Term (Description)	TRE13IH (Containment Failure at 48 hours)	1-SGL16BH (SGTR)	2-ILM08BH (ISLOCA)	3-TRE13NH (Cont. Bypass)	
Offsite Economic Cost-Risk					Sum of Annual Risk
Offsite Economic Cost Risk (dollars)	1.79	741.00	1994.00	4.00	2740.79
Offsite Economic Cost-Risk (percent)	0.07	27.04	72.75	0.15	100.00
SGTR %	0.00	100.00	0.00	0.00	27.04
ISLOCA %	0.00	0.00	100.00	0.00	72.75
Containment isolation failure %	0.00	0.00	0.00	100.00	0.15
Containment failure at 48 hours	100	0.00	0.00	0.00	0.07
No containment failure	0.00	0.00	0.00	0.00	0.00

VCSNS Response 1f:

Table 1.f-1 provides a summary of the Level 3 input and output for the VCSNS SAMA analysis. This table includes the following input information for each release category:

- Frequency (per year)
- VCSNS MAAP (Modular Accident Analysis Program) case identifier (for reference)
- Airborne release percent at 48 hours for each of the fission product groups provided by MAAP (in this case, Noble gases, CsI, TeO_2, SrO, MoO_2, CsOH, BaO, La_2O_3, CeO_2, Sb, Te_2, and UO_2)
- Start time of the airborne release (measured from the time of accident initiation)
- End time of the airborne release (measured from the time of accident initiation)

In addition, the row above the source term description indicates whether the release category is defined as a LERF or a Non-LERF contributor.

The Level 3 results include the dose-risk (person-rem/yr) and the offsite economic cost-risk before discounting ($/yr). The percentages of each release category composed of Steam Generator Tube Rupture and ISLOCA sequences are also provided, per request. Note that the contributions from these two initiators are completely contained within the LERF release categories SGL16BH and ILM08BH.

Table 1.f-1: Summary of Level 3 Input and Output

Source Term Description	Non-LERF	LERF		
	Containment Failure at 48 hours	**SGTR**	**ISLOCA**	**Cont. Bypass**
Bin Frequency (per reactor year)	1.120E-05	1.180E-07	1.780E-07	4.040E-07
VCSNS Sequence Designator (From IPE Table 4.4.4-1)	TRE13IH	SGL16BH	ILM08BH	TRE13NH
Fission Product Data:				
Noble Gases				
Airborne Release % at 48 Hours	1.4	89	100	95
Start of Release (hr)	48	25	12	9
End of Release (hr)	48	25	12	48
CsI				
Airborne Release % at 48 Hours	2.00E-05	23	85	6.60E-02
Start of Release (hr)	48	25	12	9
End of Release (hr)	48	25	12	9
TeO_2				
Airborne Release % at 48 Hours	0	0.21	0.15	0
Start of Release (hr)	48	29	24	N/A
End of Release (hr)	48	48	48	N/A
SrO				
Airborne Release % at 48 Hours	1.30E-04	0.11	0.38	1.30E-04
Start of Release (hr)	48	25	12	9
End of Release (hr)	48	25	12	9
MoO_2				
Airborne Release % at 48 Hours	7.10E-03	6	13	7.10E-03
Start of Release (hr)	48	25.5	12	9
End of Release (hr)	48	25.5	12	9
CsOH				
Airborne Release % at 48 Hours	2.00E-05	20	85	6.10E-02
Start of Release (hr)	48	25	12	9
End of Release (hr)	48	25	12	9
BaO				
Airborne Release % at 48 Hours	2.10E-03	1.5	3.6	2.10E-03
Start of Release (hr)	48	25	12	9
End of Release (hr)	48	25	12	9
La_2O_3				
Airborne Release % at 48 Hours	7.00E-06	3.50E-03	5.00E-02	7.00E-06
Start of Release (hr)	48	25	12	9
End of Release (hr)	48	25	12	9

Source Term Description	Non-LERF	LERF		
	Containment Failure at 48 hours	**SGTR**	**ISLOCA**	**Cont. Bypass**
CeO2				
Airborne Release % at 48 Hours	3.60E-05	1.30E-08	7.30E-08	3.60E-05
Start of Release (hr)	48	25	12	9
End of Release (hr)	48	25	12	9
Sb				
Airborne Release % at 48 Hours	5.60E-02	35	40	5.60E-02
Start of Release (hr)	48	25	12	9
End of Release (hr)	48	25	12	9
Te_2				
Airborne Release % at 48 Hours	0	1.60E-02	3.5	0
Start of Release (hr)	48	27.5	15	N/A
End of Release (hr)	48	38	20	N/A
UO_2				
Airborne Release % at 48 Hours	0	2.60E-07	1.20E-05	0
Start of Release (hr)	48	29	15	N/A
End of Release (hr)	48	48	20	N/A
OUTPUT:				
Dose -Risk (person-rem/yr)	5.32E-02	0.27	0.63	0.05
Offsite Economic Cost-risk ($/yr)	1.79	741.00	1994.00	4.00
OTHER:				
Percent of Release Category composed of SGTR	0	100	0	0
Percent of Release Category composed of ISLOCA	0	0	100	0

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

VCSNS Response 1g:

In the VCSNS model, the contributors to LERF are made up of sequences involving: core damage with failure of containment isolation, interfacing systems loss of coolant accidents (ISLOCA), and steam generator tube ruptures. All of these sequences are considered large early releases, with no differentiation made between large or small based on the size of the failed valve and no differentiation made between late or early based on the release in relation to timing from core damage.

VCSNS Response 1h:

The VCSNS model results are calculated per reactor-year. The model input initiating event frequencies and failure rates are based on times of critical reactor operation.

SAMA RAI 2:

According to Table F.4-1 of Appendix F to the environmental report (ER), South Carolina Electric and Gas (SCE&G) evaluated 268 SAMA candidates. Of these 268 candidates, only nine were obtained from VCSNS-specific documents. As such, it is not clear that the set of SAMAs evaluated in ER addresses the major risk contributors for VCSNS. In this regard, please provide the following:

a. a description of how the dominant risk contributors at VCSNS, including dominant sequences and cut sets from the current PRA and equipment failures and operator actions identified through importance analyses, were used to identify potential plant-specific SAMAs for VCSNS. Indicate how many sequences and cut sets were considered and what percentage of the total CDF they represent;
b. a listing of equipment failures and human actions that have the greatest potential for reducing risk at VCSNS based on importance analysis and cut set screening;
c. for each dominant contributor identified in (b), provide a cross-reference to the SAMA(s) evaluated in the ER that address that contributor; and
d. a list of the subset of SAMAs (Table F.4-1, Phase 1 SAMAs) that are considered unique/specific to VCSNS other than the nine identified by References 16 and 17.

VCSNS Response 2a:

The most important means of identifying plant specific improvements for the VCSNS SAMA analysis was a review of the plant's IPE. As part of the IPE, an analysis of the VCSNS cutsets and importance rankings was performed in order to identify plant weaknesses and to suggest changes that would address the weaknesses identified. In addition to the IPE review, an informal review of the CDF based Risk Reduction Worth (RRW) rankings for the current model was performed as an update to the task performed in the IPE. These rankings were checked to determine if any vulnerabilities existed at VCSNS that were not addressed by the existing SAMA list and/or those items noted in the IPE.

The CDF based RRW listing was reviewed down to the 1.025 level. The events below this point would influence the CDF by less than 2.5% and are not considered to be likely candidates for identifying potentially cost beneficial SAMAs. It should be noted that the RRW value of 1.025 corresponds to an averted cost-risk of approximately $30,000 based on CDF reduction assuming 100% reliability of the associated event.

An evaluation of the top LERF based contributors to RRW was also performed. Of the events not already included in the CDF based list, only one event was identified with the potential to

yield an averted cost-risk of greater than $30,000. RAI response 2c provides a more detailed discussion of the importance ranking review and the results.

VCSNS Response 2b:

It is judged that the equipment failures and human errors with the greatest potential for reducing plant risk at VCSNS are represented in the Risk Reduction Worth (RRW) listings for the VCSNS PRA model used in the SAMA analysis (UP3a). An RRW value of 1.025 was used as the lower review bound for the identification of potentially important events for VCSNS. Considering that the RRW calculation assumes 100 percent reliability of a given event, the 1.025 value (for CDF based RRW) corresponds to an averted cost-risk of only $30,000. Given that the true reliability of any event is typically less than 100%, only a fraction of the $30,000 would be realized in any enhancement to the equipment or action represented by the event. Procedural enhancements and hardware changes are expected to exceed this lower bound cost and the events below the 1.025 cutoff were not explicitly considered for SAMA identification. Table 2b-1 provides a list of the VCSNS events with RRWs greater than 1.025.

The LERF based RRW factors were also reviewed to determine if there were additional equipment or operator failures that should be included in Table 2b-1, but the top contributor not identified in the CDF based RRW list (O--CNTMISOL-HE) corresponded to an averted cost-risk of less than $1,500 given 100 percent reliability. While this event has the highest LERF based Risk Reduction Worth in the VCSNS PRA (2.10), it corresponds to a small averted cost-risk due to the fact that the event only impacts the containment isolation failure source term. Containment Isolation Failure is the smallest contributor to the Level 3 results. This event was not included in Table 2b-1, as it would not yield any cost beneficial SAMAs.

The next highest event in the LERF based importance list not included in the CDF based list is the ISLOCA initiating event (%ISL). This initiator has a RRW value of 1.34 and impacts the most important source term. The corresponding averted cost-risk for this initiator is about $35,000 and is above the $30,000 cutoff that was imposed to identify events which may generate potentially cost-beneficial SAMAs. As such, it has been added to Table 2b-1. No other events have been identified in the LERF importance listing that are likely to generate cost-beneficial SAMAs.

The response to RAI 2c provides a more detailed discussion of the importance ranking review and relationships of the events to the SAMA list.

Table 2.b-1: VCSNS Contributors with the Greatest Potential for Reducing Risk

Number	Event Name	Probability	CDF Based RRW	Description
1	%LSP	3.38E-02	3.387	LOSS OF OFFSITE POWER INITIATING EVENT
2	SBO-FLAG	1.00E+00	3.189	STATION BLACKOUT SEQUENCE MARKER
3	1HR_1	3.68E-01	1.955	FAILURE TO RECOVER OFFSITE POWER WITHIN 1HR
4	AADG-----DGAFR	5.83E-02	1.531	DIESEL GENERATOR FAILS TO RUN DUE TO RANDOM FAULTS
5	ABDG-----DGBFR	5.83E-02	1.487	DIESEL GENERATOR FAILS TO RUN DUE TO RANDOM FAULTS
6	4HR_1	1.83E-01	1.387	FAILURE TO RECOVER OFFSITE POWER AT 4 HOURS GIVEN NO RECOVERY AT 1 HR
7	OAR4	3.20E-02	1.379	OPERATOR FAILS TO ALIGN HIGH PRESSURE CL RECIRC (RHR PUMP STOPPED)
8	NOSBO-FLAG	1.00E+00	1.241	NO STATION BLACKOUT SEQUENCE MARKER
9	ACP-CCF-ONSITE	2.92E-03	1.223	COMMON CAUSE FAILURE OF ON-SITE EMERGENCY POWER SOURCES
10	1HR_1-SUCCESS	6.32E-01	1.194	1HR_1 SUCCESS, POWER IS RESTORED AT 1 HOUR
11	XHR_1	3.65E-01	1.194	FAILURE TO RECOVER OFFSITE POWER AT 14 HRS GIVEN NO RECOVERY AT 1 & 4 HRS
12	DBPT----XPP8FR	3.28E-02	1.129	TD PUMP FAILS TO RUN DUE TO MECHANICAL FAILURE
13	CNU_1	3.99E-01	1.127	CORE IS UNCOVERED AT 14 HOURS (WITH RCS COOLDOWN)
14	XHR_1-SUCCESS	6.35E-01	1.127	XHR SUCCESS, POWER IS RECOVERED
15	CNU_8	2.83E-02	1.102	CORE IS UNCOVERED AT 1 HOUR (NO RCS COOLDOWN)
16	CONSLO	1.00E+00	1.097	CONSEQUENTIAL SMALL LOCA
17	EFW-CCF-ALL	3.89E-05	1.096	COMMMON CAUSE FAILURE OF EFW
18	AADG---MAINTMU	1.84E-02	1.095	DIESEL GENERATOR UNAVAILABLE DUE TO MAINTENANCE

Number	Event Name	Probability	CDF Based RRW	Description
19	ABDG---MAINTMU	1.84E-02	1.088	DIESEL GENERATOR UNAVAILABLE DUE TO MAINTENANCE
20	%LCC1	1.00E+00	1.074	TOTAL LOSS OF CCW SYSTEM SPECIAL INITIATING EVENT
21	CAPMI--XPP1AFR	1.30E-01	1.073	PUMP XPP-1A FAILS TO RUN
22	4HR_1-SUCCESS	8.17E-01	1.069	4HR_1 SUCCESS, POWER IS RESTORED AT 4 HOURS
23	OAT2	2.70E-02	1.067	OPERATOR FAILS TO TERMINATE SI GIVEN SSB
24	CNU_4	2.83E-02	1.06	CORE IS UNCOVERED AT 4 HOURS (WITH RCS COOLDOWN)
25	CBPMPP1BPP1CMU	6.94E-04	1.056	PUMPS XPP-1 C&B UNAVAIL. DUE TO MAINTENANCE (ACTION R&R)
26	DCPM----XPP8MU	1.23E-02	1.04	TURBINE-DRIVEN PUMP UNAVAILABLEDUE TO MAINTENANCE
27	OAH_1	1.10E-02	1.035	OPERATOR FAILS TO ALIGN CCW TO RHR HXs
28	OARC	1.50E-01	1.035	OPERATOR FAILS TO ALIGN & ESTABLISH CL RECIRC (CONDITIONAL)
29	%SSBO	1.80E-03	1.032	SECONDARY SIDE BREAK OUTSIDE CONTAINMENT INITIATING EVENT
30	%SSBI	1.80E-03	1.032	SECONDARY SIDE BREAK INSIDE CONTAINMENT INITIATING EVENT
31	%SLO	5.00E-04	1.031	SMALL LOCA INITIATING EVENT
32	%LMF	6.60E-01	1.03	LOSS OF MAIN FEEDWATER FLOW INITIATING EVENT
33	%PMF	6.00E-01	1.027	PARTIAL LOSS OF MAIN FEEDWATER FLOW INITIATING EVENT
34	SW_R5	7.81E-01	1.025	FAILURE TO RECOVER SW (TRAIN B SUPPORT FAILED)
35	%ISL	1.54E-06	1.342(1)	INTERFACING SYSTEMS LOCA INITIATING EVENT

(1) This Risk Reduction Worth Value is based on LERF.

VCSNS Response 2c:

Table 2C provides a correlation between the events identified in the VCSNS PSA model (UP3a) which are considered to have the greatest potential for reducing risk and the SAMAs evaluated in the Environmental Report.

The events included in Table 2C are based on the core damage frequency Risk Reduction Worth (RRW) factors. The LERF based RRW factors were also reviewed to determine if there were additional equipment or operator failures that should be included in Table 2C, but the top contributor not identified in the CDF based RRW list (O--CNTMISOL-HE) corresponded to an averted cost-risk of less than $1500 given 100 percent reliability. While this event has the highest LERF based Risk Reduction Worth in the VCSNS PRA (2.10), it corresponds to a small averted cost-risk due to the fact that the event only impacts the containment isolation failure source term. Containment Isolation Failure is the smallest contributor to the Level 3 results. This event was not included in Table 2C as it would not yield any cost beneficial SAMAs.

The next highest event in the LERF based importance list not included in the CDF based list is the ISLOCA initiating event (%ISL). This initiator has a RRW value of 1.34 and impacts the most important source term. The corresponding averted cost-risk for this initiator is about $35,000 and is above the $30,000 cutoff that was imposed to identify events which may generate potentially cost-beneficial SAMAs. As such, it has been added to Table 2C. No other events have been identified in the LERF importance listing that are likely to generate cost-beneficial SAMAs.

Table 2C is judged to include all of the dominant contributors to plant risk for VCSNS and define the correlation of those events to the SAMA list implemented in the Environmental Report submittal.

<u>**Table 2C: Correlation of High Importance Events to ER SAMA List**</u>

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
1	%LSP	3 38E-02	3.387	LOSS OF OFFSITE POWER INITIATING EVENT	The importance of the LOOP initiator can be addressed through prevention and mitigation. Many SAMAs exist for each of these means and are documented in SAMAs 90 - 129. Improvement of offsite power availability is the more difficult of the two to address, as a large component of off-site power availability is grid related. However, the industry based SAMA list already included SAMAs that address offsite power availability (refer to SAMAs 109 and 110). Also, development of severe weather procedures to address anticipation of a LOOP existed as SAMA 104. The development of procedures with an emphasis on recovery are also suggested (potentially in switchyard recovery actions) in SAMA 103. No additional

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
					SAMAs were suggested for this broad topic.
2	SBO-FLAG	1.00E+00	3.189	STATION BLACKOUT SEQUENCE MARKER	Sequence marker. This is a flag placed on sequences to aid in the quantification of the model. These potentially could be used to identify sequence importances, but the SAMA list typically covers these broad categories. No additional SAMAs were suggested.
3	1HR_1	3 68E-01	1.955	FAILURE TO RECOVER OFFSITE POWER WITHIN 1HR	As discussed for the Loss of Offsite Power initiator, enhancing recovery of offsite power is specifically addressed in SAMA 103. Also mentioned were SAMAs 109 and 110, which would reduce the Loss of Offsite Power frequency and prevent the need for recovery. Several other SAMAs exist which are focused on improving on-site AC-reliability and further reducing the need for rapid offsite power recovery. No additional, realistically beneficial SAMAs have been identified for improving "LOOP Recovery".
4	AADG-----DGAFR	5.83E-02	1.531	DIESEL GENERATOR FAILS TO RUN DUE TO RANDOM FAULTS	Failure of an emergency on-site AC source is addressed by several SAMAs in the industry based list: SAMAs 91, 106, 118, and 122 propose installing additional emergency AC generators, SAMA 95 suggests a cross-tie to the available division, SAMAs 101 and 105 address fuel oil supply, and several other SAMAs are included which deal with means to mitigate loss of AC scenarios. No additional SAMAs were suggested to address this issue.
5	ABDG-----DGBFR	5.83E-02	1.487	DIESEL GENERATOR FAILS TO RUN DUE TO RANDOM FAULTS	Failure of an emergency on-site AC source is addressed by several SAMAs in the industry based list: SAMAs 91, 106, 118, and 122 propose installing additional emergency AC generators, SAMA 95 suggests a cross-tie to the available division, SAMAs 101 and 105 address fuel oil supply, and several other SAMAs are included which deal with means to mitigate loss of AC scenarios. No additional SAMAs were suggested to address this issue.

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
6	4HR_1	1.83E-01	1.387	FAILURE TO RECOVER OFFSITE POWER AT 4 HOURS GIVEN NO RECOVERY AT 1 HR	As discussed for the Loss of Offsite Power initiator, enhancing recovery of offsite power is specifically addressed in SAMA 103. Also mentioned were SAMAs 109 and 110, which would reduce the Loss of Offsite Power frequency and prevent the need for recovery. Several other SAMAs exist which are focused on improving on-site AC-reliability and further reducing the need for rapid offsite power recovery. No additional, realistically beneficial SAMAs have been identified for improving "LOOP Recovery".
7	OAR4	3.20E-02	1.379	OPERATOR FAILS TO ALIGN HIGH PRESSURE CL RECIRC (RHR PUMP STOPPED)	SAMA 193 specifically addresses this
8	NOSBO-FLAG	1.00E+00	1.241	NO STATION BLACKOUT SEQUENCE MARKER	Sequence marker. This is a flag placed on sequences to aid in the quantification of the model. These potentially could be used to identify sequence importances, but the SAMA list typically covers these broad categories. No additional SAMAs were suggested.
9	ACP-CCF-ONSITE	2.92E-03	1.223	COMMON CAUSE FAILURE OF ON-SITE EMERGENCY POWER SOURCES	Common Cause Failure (CCF) is essentially addressed through diversity of systems. As discussed for the independent emergency diesel generator failures, SAMAs 91, 106, 118, and 122 propose installing additional emergency AC generators These generators could introduce system diversity and greatly reduce the likelihood of CCF. No additional SAMAs were suggested.

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
10	1HR_1-SUCCESS	6.32E-01	1.194	1HR_1 SUCCESS, POWER IS RESTORED AT 1 HOUR	As discussed for the Loss of Offsite Power initiator, enhancing recovery of offsite power is specifically addressed in SAMA 103. Also mentioned were SAMAs 109 and 110, which would reduce the Loss of Offsite Power frequency and prevent the need for recovery. Several other SAMAs exist which are focused on improving on-site AC-reliability and further reducing the need for rapid offsite power recovery. No additional, realistically beneficial SAMAs have been identified for improving "LOOP Recovery".
11	XHR_1	3.65E-01	1.194	FAILURE TO RECOVER OFFSITE POWER AT 14 HRS GIVEN NO RECOVERY AT 1 & 4 HRS	As discussed for the Loss of Offsite Power initiator, enhancing recovery of offsite power is specifically addressed in SAMA 103. Also mentioned were SAMAs 109 and 110, which would reduce the Loss of Offsite Power frequency and prevent the need for recovery. Several other SAMAs exist which are focused on improving on-site AC-reliability and further reducing the need for rapid offsite power recovery. No additional, realistically beneficial SAMAs have been identified for improving "LOOP Recovery".
12	DBPT----XPP8FR	3 28E-02	1.129	TD PUMP FAILS TO RUN DUE TO MECHANICAL FAILURE	One of the most important functions of the turbine driven EFW pump is to provide flow to the steam generators during an SBO. An alternate method of fulfilling this function was proposed in SAMA 170. Installation of an additional turbine driven AFW pump is a potential SAMA, but it was not included on the list due to the high cost of implementation. No other SAMAs were identified for inclusion.
13	CNU_1	3.99E-01	1.127	CORE IS UNCOVERED AT 14 HOURS (WITH RCS COOLDOWN)	CNU_* events represent the probability of core uncovery due to seal leakage when power recovery has occurred. The cooldown status of the RCS is also considered here. This event highlights the importance of power recovery, seal performance, and cooling down the RCS in an SBO. The industry based SAMA list was considered to adequately address these issues. Power recovery SAMAs are addressed in the disposition of the LOOP initiator above (%LSP), SAMA 14 addresses improving RCP seals, SAMA 3 stresses the need for RCS cooldown procedures, and several SAMAs identify means of improving seal cooling ability. It should also be noted that the values used in the CNU_* events are based on the performance of the old VCSNS RCP seals. The new, improved seals are expected to outperform the old seals; thus, these events are currently modeled conservatively in the PRA model. No additional SAMAs were suggested to address this issue.

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
14	XHR_1-SUCCESS	6.35E-01	1.127	XHR SUCCESS, POWER IS RECOVERED	As discussed for the Loss of Offsite Power initiator, enhancing recovery of offsite power is specifically addressed in SAMA 103. Also mentioned were SAMAs 109 and 110, which would reduce the Loss of Offsite Power frequency and prevent the need for recovery. Several other SAMAs exist which are focused on improving on-site AC-reliability and further reducing the need for rapid offsite power recovery. No additional, realistically beneficial SAMAs have been identified for improving "LOOP Recovery".
15	CNU_8	2.83E-02	1.102	CORE IS UNCOVERED AT 1 HOUR (NO RCS COOLDOWN)	CNU_* events represent the probability of core uncovery due to seal leakage when power recovery has occurred. The cooldown status of the RCS is also considered here. This event highlights the importance of power recovery, seal performance, and cooling down the RCS in an SBO. The industry based SAMA list was considered to adequately address these issues. Power recovery SAMAs are addressed in the disposition of the LOOP initiator above (%LSP), SAMA 14 addresses improving RCP seals, SAMA 3 stresses the need for RCS cooldown procedures, and several SAMAs identify means of improving seal cooling ability. It should also be noted that the values used in the CNU_* events are based on the performance of the old VCSNS RCP seals. The new, improved seals are expected to outperform the old seals; thus, these events are currently modeled conservatively in the PRA model. No additional SAMAs were suggested to address this issue.
16	CONSLO	1.00E+00	1.097	CONSEQUENTIAL SMALL LOCA	Consequential small LOCAs in the VCSNS model are seal LOCAs that result from loss of seal cooling during an accident scenario. The industry based SAMA list thoroughly addresses Loss of Seal Cooling issues in SAMAs 1 through 24. No additional SAMAs were suggested to address this issue.

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
17	EFW-CCF-ALL	3.89E-05	1.096	COMMMON CAUSE FAILURE OF EFW	Common Cause Failure (CCF) is essentially addressed through diversity of systems. Diversity already exists to some degree at VCSNS due to the combination of motor driven and turbine driven pumps in the system. Further diversification could be addressed through the addition of a unique AFW loop. SAMAs 168 and 176 already suggest the installation of additional motor driven pumps with the intent of increasing plant diversity. SAMAs of this scope more specifically suited to the VCSNS configuration could be suggested, but the high cost of implementation would preclude them from consideration. Thus, adding this type of SAMA was not considered to be an improvement to the list and no addition was made. In addition, SAMA 170 suggests an alternate, diverse means of performing SG make-up.
18	AADG---MAINTMU	1.84E-02	1.095	DIESEL GENERATORUNAVAILABLE DUE TO MAINTENANCE	The EDG maintenance unavailabilities are judged to be adequately monitored by the Maintenance Rule functions. No measurable benefit is considered to be attainable through further adjustment of the maintenance plan for plant equipment. No SAMAs suggested
19	ABDG---MAINTMU	1.84E-02	1.088	DIESEL GENERATOR UNAVAILABLE DUE TO MAINTENANCE	The EDG maintenance unavailabilities are judged to be adequately monitored by the Maintenance Rule functions. No measurable benefit is considered to be attainable through further adjustment of the maintenance plan for plant equipment. No SAMAs suggested.
20	%LCC1	1.00E+00	1.074	TOTAL LOSS OF CCW SYSTEM SPECIAL INITIATING EVENT	The Loss of CCW initiator can be addressed through prevention and mitigation. The most important function served by CCW is to support seal cooling (for thermal barrier cooling and seal injection via Charging Pump cooling). Many SAMAs exist in the industry based SAMA list for "Improvements Related to Seal LOCAs" and are addressed in SAMAs 1-24. No additional SAMAs were suggested for this broad topic.
21	CAPMI--XPP1AFR	1.30E-01	1.073	PUMP XPP-1A FAILS TO RUN	Loss of an individual CCW pump, like the Total Loss of CCW initiator, can be addressed through prevention and mitigation. The most important function served by CCW is to support seal cooling (for thermal barrier cooling and seal injection via Charging Pump cooling). Many SAMAs exist in the industry based SAMA list for "Improvements Related to Seal LOCAs" and are addressed in SAMAs 1-24. Given the extensive treatment of loss of CCW in the list, no additional SAMAs were identified for inclusion.

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
22	4HR_1-SUCCESS	8.17E-01	1.069	4HR_1 SUCCESS, POWER IS RESTORED AT 4 HOURS	As discussed for the Loss of Offsite Power initiator, enhancing recovery of offsite power is specifically addressed in SAMA 103. Also mentioned were SAMAs 109 and 110, which would reduce the Loss of Offsite Power frequency and prevent the need for recovery. Several other SAMAs exist which are focused on improving on-site AC-reliability and further reducing the need for rapid offsite power recovery. No additional, realistically beneficial SAMAs have been identified for improving "LOOP Recovery".
23	OAT2	2.70E-02	1.067	OPERATOR FAILS TO TERMINATE SI GIVEN SSB	A potential SAMA for reducing the risk related to overfill with HPI is the installation of a high level trip in the pressurizer; however, other factors indicate this modification may be more detrimental than beneficial. Installation of a high level trip would necessitate bypass of the trip logic for a successful bleed and feed action, which may be required for the same scenarios as OAT2. It should also be noted that the VCSNS PRA model overestimates the importance of this action. Failure of OAT2 assumes a SLOCA event through stuck open relief valve. Realistically, this LOCA could be recovered after the flow path was identified. Given that the failure to reseat probability of the safety valve is not 1.0, as it is currently modeled, the operator could terminate injection after the initial opening and close the LOCA pathway. No additional SAMA was suggested to address this issue.
24	CNU_4	2.83E-02	1.06	CORE IS UNCOVERED AT 4 HOURS (WITH RCS COOLDOWN)	CNU_* events represent the probability of core uncovery due to seal leakage when power recovery has occurred. The cooldown status of the RCS is also considered here This event highlights the importance of power recovery, seal performance, and cooling down the RCS in an SBO. The industry based SAMA list was considered to adequately address these issues. Power recovery SAMAs are addressed in the disposition of the LOOP initiator above (%LSP), SAMA 14 addresses improving RCP seals, SAMA 3 stresses the need for RCS cooldown procedures, and several SAMAs identify means of improving seal cooling ability. It should also be noted that the values used in the CNU_* events are based on the performance of the old VCSNS RCP seals. The new, improved seals are expected to outperform the old seals; thus, these events are currently modeled conservatively in the PRA model. No additional SAMAs were suggested to address this issue.

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
25	CBPMPP1BP P1CMU	6.94E-04	1.056	PUMPS XPP-1 C&B UNAVAIL. DUE TO MAINTENANCE (ACTION R&R)	The CCW pump maintenance unavailabilities are judged to be adequately monitored by the Maintenance Rule functions. No measurable benefit is considered to be attainable through further adjustment of the maintenance plan for plant equipment. No additional SAMA was suggested to address this issue.
26	DCPM---- XPP8MU	1.23E-02	1.04	TURBINE-DRIVEN PUMP UNAVAILABLEDUE TO MAINTENANCE	The EFW pump maintenance unavailabilities are judged to be adequately monitored by the Maintenance Rule functions. No measurable benefit is considered to be attainable through further adjustment of the maintenance plan for plant equipment. No additional SAMA was suggested to address this issue.
27	OAH_1	1.10E-02	1.035	OPERATOR FAILS TO ALIGN CCW TO RHR HXs	The importance of this action is primarily based on the part it plays in establishing RHR in recirculation mode. As this action is a key portion of the overall action to establish recirculation cooling, it cannot be addressed alone. Phase 2 SAMA 24 specifically addresses automation of this function. No additional SAMA was suggested to address this issue.
28	OARC	1.50E-01	1.035	OPERATOR FAILS TO ALIGN & ESTABLISH CL RECIRC (CONDITIONAL)	Phase 2 SAMA 24 specifically addresses this.
29	%SSBO	1.80E-03	1.032	SECONDARY SIDE BREAK OUTSIDE CONTAINMENT INITIATING EVENT	This initiating event is a broad category and was considered to be addressed by the industry based SAMA list. Phase 2 SAMA 28 specifically addresses steam line breaks Given the low potential averted cost-risk associated with this event (<$39k based on Level 1 and Level 2 importance measures), no hardware changes were considered to be realistically viable. Mitigation procedures are already in place for this type of accident and the benefit gained by potential improvements are small and difficult to measure with current analysis methods. No potentially beneficial SAMAs were identified that were considered enhancements to the industry based SAMA list.

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
30	%SSBI	1.80E-03	1.032	SECONDARY SIDE BREAK INSIDE CONTAINMENT INITIATING EVENT	This initiating event is a broad category and was considered to be addressed by the industry based SAMA list. Phase 2 SAMA 28 specifically addresses steam line breaks. Given the low potential averted cost-risk associated with this event (<$39k based on Level 1 and Level 2 importance measures), no hardware changes were considered to be realistically viable. Mitigation procedures are already in place for this type of accident and the benefit gained by potential improvements are small and difficult to measure with current analysis methods. No potentially beneficial SAMAs were identified that were considered enhancements to the industry based SAMA list.
31	%SLO	5.00E-04	1.031	SMALL LOCA INITIATING EVENT	Many SAMAs exist in the industry-based list which address mitigation of small LOCA events. These include both enhancements to injection and depressurization methods. High pressure make-up is addressed with 179, 180, 185, 186, 198, 202, 204, 205, and 209. Depressurization enhancements are addressed in 233, 244, and 245. No additional SAMAs were suggested.
32	%LMF	6.60E-01	1.03	LOSS OF MAIN FEEDWATER FLOW INITIATING EVENT	Loss of Feedwater can be addressed through both preventive and mitigative means. Phase 1 SAMAs 159 through 177 provide examples of enhancements that could be made to improve Feedwater reliability and capability. Given loss of the primary heat sink, enhanced core cooling methods are a means to improve accident mitigation. SAMAs 178 through 209 include these types of changes. Given the low importance of this initiator, hardware changes are unlikely to be cost beneficial. Procedures and training for loss of Feedwater are already implemented at VCSNS While improvement in the training and procedure is possible, the benefits associated with such changes are expected to be small and difficult to measure. No potentially beneficial SAMAs were identified that were considered enhancements to the industry based SAMA list.

Number	Event Name	Probability	CDF Based RRW	Description	Disposition
33	%PMF	6.00E-01	1.027	PARTIAL LOSS OF MAIN FEEDWATER FLOW INITIATING EVENT	Loss of Feedwater can be addressed through both preventive and mitigative means. Phase 1 SAMAs 159 thru 177 provide examples of enhancements that could be made to improve Feedwater reliability and capability. Given loss of the primary heat sink, enhanced core cooling methods are a means to improve accident mitigation. SAMAs 178 thru 209 include these types of changes. Given the low importance of this initiator, hardware changes are unlikely to be cost beneficial. Procedures and training for loss of Feedwater are already implemented at VCSNS. While improvement in the training and procedure is possible, the benefits associated with such changes are expected to be small and difficult to measure. No potentially beneficial SAMAs were identified that were considered enhancements to the SAMA list.
34	SW_R5	7.81E-01	1.025	FAILURE TO RECOVER SW (TRAIN B SUPPORT FAILED)	The loss of SW impacts a large number of functions. In this case, recovery of service water train B after initial loss is identified as the important contributor. This event can be addressed through prevention of loss of service water and through improved recovery and/or mitigation. Some SAMAs are included in the industry-based list which directly address loss of SW. SAMA 23 proposes an additional SW pump/pump train to reduce CCF, which would improve SW recovery on an alternate loop, SAMA 10 improves SW reliability through the addition of alternate control power, SAMA 24 suggests an independent seal injection system to reduce the potential for RCP seal damage on loss of SW. Many other SAMAs indirectly address the loss of SW by proposing alternate means of supporting functions that are normally supplied by SW. These SAMAs include 2, 3, 4, 5, 6, 7, and 13. SAMA 21 suggests enhancing training on support system failure and recovery actions. No additional SAMAs were suggested.
35	%ISL	1.54E-06	1.342[1]	INTERFACING SYSTEMS LOCA INITIATING EVENT	The ISLOCA initiating event can be addressed through both preventative and mitigative means. The industry based SAMA list includes a large number of changes that meet both of these goals. SAMAs 138, 139, 140, 142, 143, 146, and 151 propose methods to reduce the ISLOCA frequency. SAMAs 141, 144, 145, 147, and 152 identify methods of mitigating an ISLOCA accident once it has occurred. This topic was considered to be thoroughly addressed in the industry based SAMA list and given the relatively low potential averted cost-risk associated with ISLOCA SAMAs, no further additions were suggested.

(1) This Risk Reduction Worth Value is based on LERF.

VCSNS Response 2d:

No plant specific SAMAs have been identified for VCSNS. Given that RAI 2d excludes the IPE based SAMAs from this response, none of those candidates have been counted as plant specific SAMAs. In addition, the response to RAI 2c demonstrated that the areas with the greatest potential for reducing plant risk at VCSNS were adequately addressed by the existing industry based SAMA list.

These entries are not considered to be unique to VCSNS as the industry has already identified the potential vulnerability and proposed a mitigative plant change.

SAMA RAI 3:

The SAMA analysis did not include an assessment of SAMAs for external events. The VCSNS individual plant examination for external events (IPEEE) study has shown that the CDF due to internal fire-initiated events is about 8.5×10^{-5} per reactor year. In addition, the risk analyses at other commercial nuclear power plants indicate that external events could be large contributors to CDF and the overall risk to the public. In this regard, the following additional information is needed:

a. NUREG-1742 ("Perspectives Gained from the IPEEE Program," Final Report, April 2002), lists the significant fire area CDFs for VCSNS (page 3-30 of Volume 2). While these fire-related CDF estimates may be conservative, they are still large relative to the VCSNS internal events CDF. For each fire area, please explain what measures were taken to further reduce risk, and explain why these CDFs cannot be further reduced in a cost effective manner,

b. NUREG-1742 lists seismic outliers and improvements for VCSNS (page 2-34 of Volume 2). Please confirm that all of the "plant improvements" that address the "anomalies & outliers" (as listed in the table) have been implemented. If not, please explain why, within the context of this SAMA study.

VCSNS Response 3a:

The final phase of the Individual Plant Examination for External Events (IPEEE) process at VCSNS consisted of reviewing those areas in the plant with the highest CDF results for potential means to reduce their fire related risks. VCSNS utilized the guidance in NEI 91-04, "Severe Accident Issue Closure Guidelines," to review the unique features of each fire zone with CDFs greater than 1.0E-06/yr to identify procedure changes or hardware changes that could reduce that zone's risk. The results of this review were submitted to the NRC by letter dated January 28, 1999, (Request for Additional Information Regarding Generic Letter 88-20), and are already included in NUREG-1742. For convenience, the results of this review are summarized in the following paragraphs.

The VCSNS IPEEE evaluation identified five fire zones with core damage frequencies greater than 1.0E-06/yr. The specific areas are: the two Emergency Safeguards Feature (ESF) switchgear rooms, the Relay Room, the Control Room, and the Turbine Building. The details of these five zones are discussed in the following paragraphs.

The risk associated with fire scenarios in the switchgear rooms (2.45E-05/yr and 2.7E-06/yr) is driven by damage to one train of ESF AC power. The risk estimates are similar whether the appropriate scenario response requires use of the Emergency Operations Procedures (EOPs) or the Fire Emergency Procedures (FEPs). This similarity demonstrates that the risk is not a result of procedural actions but rather an indication that the loss of an ESF bus for any reason leaves the plant vulnerable to a single random failure. As is the case for all areas of the plant, adequate separation between trains already exists for the ESF switchgear rooms. Therefore, a cost-effective hardware change could not be identified.

The Relay Room fire risk (1.3E-05/yr) is dominated by unsuppressed fires in cabinets that could impact safe shutdown equipment or indication (about 89% of CDF contribution). The cabinets were conservatively assumed to result in loss of one train of safe shutdown equipment because determination of circuit damage for each cabinet proved to be very time consuming. These electrical panels, which comprise the significant hazard in the Relay Room, consist of separate vertical cabinets installed side-by-side. The double wall provides an effective shield against radiant heat in the adjacent cabinets. The cables are IEEE-383 qualified, well organized, bundled and tied. Cable bundles are well separated within the cabinets and are separated from the cabinet walls by at least an inch. It is anticipated that many of the cabinet fires would be handled from the main control room (MCR) using normal EOP alternative actions and would have a CDF lower than that obtained using this conservative assumption. Additionally, the room is provided with an automatic CO2 suppression system, and the overhead cables in the room are all enclosed in conduit or closed wireways. In view of the analysis limitations and the existing "robust" Relay Room design, a cost effective hardware change could not be identified.

The MCR scenarios (3.4E-05/yr) are dominated by severe fires in the main control board panels not affecting offsite power (about 62% of CDF contribution), panels that could impact offsite power (about 21% of CDF contribution), and in the HVAC panel (about 12% of CDF contribution). Fires in the control room panels were divided into two severity classifications. The non-severe fires were those that were restricted to a single component within the target panel. All other fires were conservatively assumed to involve the entire target panel as well as the panels on either side. (This is a conservative assumption because cabinet fires are expected to be slow growing electrical fires since the cables are well organized, bundled, tied and the cable bundles are well separated within the cabinets. Manual suppression efforts are expected to begin promptly because the MCR is continuously operated and detection should occur quickly. All MCR Operators are trained members of the fire brigade.) This conservative assumption required that the event tree sequence enter FEP-4.0, "Control Room Evacuation Due to Fire," in almost all cases. The HVAC panel result is also driven by conservative modeling assumptions. Fires in this panel have the potential for stopping MCR ventilation as well as other plant ventilation systems but do not impact any safe shutdown equipment. Without MCR ventilation, the time available for suppression cannot be determined since the conditions do not match the Sandia National Laboratory cabinet fire test used as the basis for MCR suppression. This again leads to the conservative assumption that all severe fires in this

cabinet result in MCR evacuation and use of FEP-4.0. It is anticipated that most severe MCR fires would, in actuality, be mitigated using AOP-600.1 for Control Room evacuation. This procedure maintains both trains of safe shutdown equipment (whereas the FEP turns off power to one train because of the potential for hot shorts causing spurious operation of components) and would therefore have a lower Conditional Core Damage Frequency (CCDF) than FEP-4.0, but was not credited for the majority of severe fires in this evaluation. In view of these analysis limitations, a cost-effective hardware change could not be identified.

No scenario was identified in the Turbine Building (7.1E-06/yr) that requires isolation of offsite power or use of the FEPs. Non-ESF switchgear (about 38% of CDF contribution), turbine lube oil (about 23% of CDF contribution) and main turbine/generator (about 19% of CDF contribution) fires are the main contributing fire scenarios. For the non-ESF switchgear analyses, all impacted components were conservatively assumed to fail without analyzing the circuit diagrams to determine if a functional failure was possible. The turbine lube oil and main turbine/generator fire analyses are also conservative because there is no data to determine a severity factor so none was used. In view of these analysis limitations, a cost-effective hardware change could not be identified.

While the IPEEE review shows that no hardware changes were deemed feasible, several procedure and training enhancements have been made as a result of the process. Examples of these are provided below:

Procedure Enhancements

- To reinforce FEP training, the FEP steps that isolate offsite power to an ESF bus have been reorganized to ensure that power is not isolated until the emergency diesel generator is ready to load.
- A step has been added in the FEPs to check the need for shutting down the turbine driven emergency feedwater pump. This step has been added at points in the procedures where the pump start is not expected to occur, but is possible should two operators working independently reverse an intended sequence of actions.

Training Enhancements

- Operator training was enhanced by providing quantitative fire scenario analysis results showing that use of the FEPs when not appropriate actually increases plant risk. These results also provide the Senior Reactor Operator with a better basis for deciding when FEP use is appropriate.
- Fire brigade training was enhanced by developing new drill scenarios specifically for the risk significant fire zones.

VCSNS Response 3b:

Table 2.7 (page 2-34) of NUREG-1742 (Volume 2) for VCSNS identifies three (3) plant improvements which have been addressed/resolved as follows:

(1) *Bolting together adjacent electrical cabinets at 17 locations throughout the plant to remove interaction concerns*: Plant modifications for 16 of these cabinet locations were implemented during Refueling Outage (RFO) 8 (1994). The 17th panel modification was implemented during RFO 9 (1996).

(2) *Providing lateral support for the isolation valve where the support was missing*: A permanent U-Bolt lateral support in accordance with the original design was installed in 1994.

(3) *Performing analysis to show adequate High Confidence of Low Probability of Failure (HCLPF) value for the neutral grounding resistor that use ceramic components*: The identified concern was reconciled by performing a detailed review of the seismic test report for the resistors. The lowest Conservative Deterministic Failure Mechanism (CDFM) capacity HCLPF was calculated to be 0.42g based on the seismic test report, which is well above the plant review level earthquake HCLPF capacity of 0.30g.

SAMA RAI 4:

The SAMA analysis did not include an assessment of the impact that PRA uncertainties and external event risk considerations would have on the conclusions of the study. Some license renewal applicants have opted to double the estimated benefits (for internal events) to accommodate any contributions for other initiators when sound reasons exist to support such a numerical adjustment, and to incorporate additional margin in the SAMA screening criteria to address uncertainties in other parts of the analysis (e.g., an additional factor of two in comparing costs and benefits of each SAMA). Please provide the following information to address these concerns:

a. an estimate of the uncertainties associated with the calculated CDF (e.g., the mean and median CDF estimates and the 5th and 95th percentile values of the uncertainty distribution);

b. an assessment of the impact on the Phase 1 screening if risk reduction estimates are increased to account for uncertainties in the risk assessment and, the additional benefits associated with external events (if any); and

c. an assessment of the impact on the Phase 2 evaluation if risk reduction estimates are increased to account for uncertainties in the risk assessment, and the additional benefits associated with external events (if any). Please consider the uncertainties due to both the averted cost-risk and the cost of implementation to determine changes in the net value estimate for these SAMAs. (Note that some of the SAMA candidates, e.g., Phase II SAMA 3 and 7, could potentially become cost beneficial).

VCSNS Response 4a:

The following table summarizes the uncertainty inherent in the VCSNS PRA model. These values were calculated using the Latin Hypercube method in the UNCERT code. Similar values were found using the Monte Carlo method.

Table 4.a-1: VCSNS Uncertainty Analysis

Parameter	Value
Mean	5.63E-05
5%	1.87E-05
Median	4.44E-05
95%	1.32E-04
Standard Deviation	4.34E-05

VCSNS Response 4b:

The results of the Phase 1 screening process itself can be impacted by incorporating external event contributions or implementing conservative values from the PSA's uncertainty distribution. Inclusion of external events or use of the 95th percentile PSA results will increase the maximum averted cost-risk and prevent the screening of some of the higher cost modifications. However, the impact on the overall SAMA results due to the retention of the higher cost SAMAs for Phase 2 analysis is small. This is due to the fact that the benefit gleaned from the implementation of those SAMAs must be extremely large in order to be cost beneficial. The changes associated with the Phase 2 analysis are discussed in the response to RAI 4c.

The impact of uncertainty in the PSA results and the consequences of including external events contributions in the Phase 1 SAMA analysis have been examined. The maximum averted cost-risk is the primary Phase 1 criteria affected by PSA uncertainty or inclusion of external events contributions. Thus, this response focused on recalculating the maximum averted cost-risk given consideration of these factors and re-performing the Phase 1 screening process. Other factors, such as estimated costs of implementation, can impact the Phase 1 results. However, these cost estimates are generally considered to be lower end estimates due to unforeseen costs in the implementation phase and use of these estimates will more likely result in the retention of SAMAs that are not cost beneficial than in the screening of potentially important SAMAs. In some cases, lower cost alternatives may exist than those proposed in the original SAMAs. These alternatives are addressed in the response to RAI 7.

The methods and technology available to perform the external events evaluations at VCSNS have not reached the same level of maturity as those implemented in the internal events analysis. The external events analysis is primarily a screening study used to identify weaknesses based on relative risk. For areas where large uncertainties exist in event probabilities, conservative estimates are employed. The end result is one that will likely identify important components or scenarios for a given plant, but not in the production of a core damage frequency that can be compared to one that has been developed for internal events. While the VCSNS external events analysis is considered to have thoroughly evaluated plant

strengths and weaknesses, the available core damage frequencies reported in the IPEEE and its amendments are not judged to be appropriate for use in this RAI response. As a bounding estimate, external events are considered to contribute an amount equal to the internal events. Thus, the "baseline case" would be modified to develop a revised maximum averted cost-risk based on a factor of 2 increase in the CDF and Level 3 results. This revision would result in a CDF of 1.12E-04/yr, a dose-risk of 1.9 person-rem/yr, and an offsite economic cost-risk of $4,758/yr. The corresponding maximum averted cost-risk is $2.40 million.

Use of the 95th percentile PSA results yields a slightly larger result than the factor of two multiplier implemented to account for external events. As such, a review of the Phase 1 analysis using the 95th percentile PSA results is considered to bound the external events case.

The PSA uncertainty calculation, which is presented in RAI response 4a, identifies the 95th percentile CDF as 1.32E-04/yr. This is a factor of 2.36 greater than the CDF point estimate produced by the VCSNS PSA.

As the same type of uncertainty analysis was not available for the Level 2 and Level 3 results, the 95th percentile Level 3 results were estimated. The dose-risk and offsite economic cost-risk were increased by a factor of 2.36 to simulate the increase in the CDF resulting from the use of the 95th percentile results. The "95th percentile" dose-risk and offsite economic cost-risk are 2.24 person-rem/yr and $5,614/yr, respectively. The corresponding maximum averted cost-risk is $2.83 million.

The initial SAMA list has been re-examined using the revised maximum averted cost-risk to identify SAMAs that would be retained for the Phase 2 analysis. Those SAMAs that were previously screened due to costs of implementation that exceeded $1.20 million are now retained if the costs of implementation are less than $2.83 million. Table 4.b-1 identifies the additional SAMAs that would be passed to the Phase 2 analysis given the use of the 95th percentile PSA results and their Phase 2 dispositions.

As the changes made to account for external events are based on conservative estimates, use of the 95th percentile PSA results in conjunction with the external events contributions is judged to produce excessively conservative results and reduces the usefulness of the analysis. The combined effects of including external events and the 95th percentile PSA results in the SAMA analysis would allow several more high cost SAMAs to reach Phase 2. However, given the fact that highly conservative assumptions were used to allow them to pass the Phase 1 screening process, these events are not judged to be realistically cost beneficial and are not pursued further.

Table 4.b-1: Additional SAMAs Retained for Phase 2 Analysis Using 95th Percentile Results

Phase 1 SAMA ID number	SAMA title	Result of potential enhancement	Cost of Implementation	Phase 2 Disposition Given the Use of the 95th Percentile PSA Results
24	Create an independent RCP seal injection system, without dedicated diesel	This SAMA would add redundancy to RCP seal cooling alternatives, reducing the CDF from loss of CC or SW, but not SBO.	>$2.5 million	If the low end estimate of $2.5 million is assumed for the cost of implementation for this SAMA, the plant risk would have to be reduced by over 88 percent in order for the SAMA to be cost beneficial. While seal LOCA is an important contributor to the VCSNS risk profile, it is far below 88 percent. This SAMA is not cost beneficial even using the 95th percentile results and is screened from further analysis.
57	Provide a reactor vessel exterior cooling system.	This SAMA would provide the potential to cool a molten core before it causes vessel failure, if the lower head could be submerged in water.	$2.5 million	This SAMA only impacts post core damage accident mitigation; it does not play a part in accident prevention. If all Level 3 results (dose-risk and offsite economic cost-risk) are assumed to be decreased to zero based on this modification, the averted cost-risk is only $108,641, which is less than the cost of implementation. This SAMA is not cost-beneficial and is screened from further analysis.
92	Provide additional DC battery capacity.	SAMA would ensure longer battery capability during an SBO, reducing the frequency of long-term SBO sequences.	$1.88 million $84,078 for a portable generator system	The averted cost-risk associated with implementing improved DC power capability has been analyzed in the response to RAI 7. It was determined that the averted cost-risk for this enhancement is $3,300 based on the PSA quantification. If a factor of 2.36 is applied to the averted cost-risk to account for use of the 95th percentile PSA results, the averted cost-risk becomes $7,788. This amount is less than the cost of new batteries or the implementation of a portable generator system.

Phase 1 SAMA ID number	SAMA title	Result of potential enhancement	Cost of Implementation	Phase 2 Disposition Given the Use of the 95th Percentile PSA Results
93	Use fuel cells instead of lead-acid batteries.	SAMA would extend DC power availability in an SBO.	$2 million $84,078 for a portable generator system	The averted cost-risk associated with implementing improved DC power capability has been analyzed in the response to RAI 7. It was determined that the averted cost-risk for this enhancement is $3,300 based on the PSA quantification. If a factor of 2.36 is applied to the averted cost-risk to account for use of the 95th percentile PSA results, the averted cost-risk becomes $7,788. This amount is less than the cost of new batteries or the implementation of a portable generator system.
139	Install of additional instrumentation for ISLOCAs.	This SAMA would decrease ISLOCA frequency by installing pressure or leak monitoring instruments in between the first two pressure isolation valves on low-pressure inject lines, RHR suction lines, and HPSI lines.	$2.3 million	It was shown in the SAMA submittal that elimination of all ISLOCA risk resulted in an averted cost risk of $39,725 (Phase 2 SAMA numbers 11 and 12). If the 95th percentile scaling factor of 2.36 is applied to this result, the averted cost-risk becomes $93,751. This amount is less that the estimated cost of implementation and is screened from further analysis.
178	Provide the capability for diesel driven, low pressure vessel make-up	This SAMA would provide an extra water source in sequences in which the reactor is depressurized and all other injection is unavailable (e.g., FP system)	Large relative to potential averted cost-risk	The low pressure injection function is not highly important in terms of reducing risk at VCSNS. The largest RRW associated with RHR low pressure injection failure is the conditional failure to align the CCW pumps to the RHR heat exchangers given failure of the initially standby CCW train and the action to align cold leg recirculation (OARC). The RRW for this action is only 1.035 (based on CDF, 1.02 for LERF) and influences more than low pressure injection. OARC technically is an action related to the establishment of high pressure recirculation and low pressure recirculation; however, it

Phase 1 SAMA ID number	SAMA title	Result of potential enhancement	Cost of Implementation	Phase 2 Disposition Given the Use of the 95th Percentile PSA Results
				is used here to represent the LPI importance as it is the event with the largest RRW value related to the primary LPI system (RHR). Pump maintenance terms have RRW values of 1.007 or less based on CDF. The averted cost-risk associated with the installation of a diesel driven make-up system would be far less than the cost of implementation for the new system. This SAMA is screened from further analysis.
202	2.a. Passive High Pressure System	SAMA will improve prevention of core melt sequences by providing additional high pressure capability to remove decay heat through an isolation condenser type system	$1.7 million	The cost of implementation for this modification is 60 percent of the maximum averted cost risk. Given that the Risk Reduction Worth (RRW) value for the most important event related to high pressure decay heat removal (OAR4) is only 1.38, further improvements to the high pressure DHR function offers an upper bound averted cost-risk of about $800,000, using the 95th percentile results. As this is less than the cost of implementation for the SAMA, it is screened from further analysis.

VCSNS Response 4c:

This response addresses the impacts of uncertainty and the inclusion of external events contributions on the Phase 2 SAMA analysis. Table 4b-1 of RAI response 4b included the rationale for eliminating the SAMAs that were passed to Phase 2 based on the increased maximum averted cost-risk. This response focuses on addressing the Phase 2 SAMAs that were identified in the Environmental Report (ER) submittal.

As discussed in the response to RAI 4b, the 95th percentile PSA results are more limiting than the factor of two increase applied to the results to account for external events contributions. Thus, no specific case is examined to identify the impact of including the external events contributions as those effects are judged to be bounded by the 95th percentile PSA results case.

In order to perform this assessment, it was necessary to make an assumption about the 95th percentile PSA results for the Level 2 and 3 analyses. This is due to the fact that the same type

of uncertainty analysis that was performed as part of the response to RAI 4a is not available for the Level 2 and 3 models. The assumption that has been made is that the 95th percentile results for the Level 2 and 3 models can be represented by increasing the base dose-risk and offsite economic cost-risk in proportion to the Level 1 results.

The PSA uncertainty calculation, which is presented in RAI response 4a, identifies the 95th percentile CDF as 1.32E-04/yr. This is a factor of 2.36 greater than the CDF point estimate produced by the VCSNS PSA. As discussed in the response to RAI 4b, the 95th percentile dose-risk and offsite economic cost-risk are 2.24 person-rem/yr and $5,614/yr, respectively. The corresponding maximum averted cost-risk is $2.83 million. The factor of 2.36 is also assumed to propagate through the results for the model runs performed for the Phase 2 detailed calculations. This means that the averted cost-risks for each case will be increased by the same factor.

Table 4.c-1 provides a summary of the impact of using the 95th percentile PSA results in the detailed cost benefit calculations that were performed for the ER submittal. The initial results indicate that Phase 2 SAMAs 3 and 10 are cost beneficial when the 95th percentile PSA results are used. However, review of the assumptions used in the ER submittal to estimate the impact of these SAMAs shows them to be highly optimistic. When a more realistic assessment of the risk reduction offered by the SAMAs is applied, the associated averted cost-risks decrease and the SAMAs are no longer cost-beneficial. These two SAMAs are discussed in more detail below.

Phase 2 SAMA 3, Use Existing Hydro-Test Pump for RCP Seal Injection:

The use of the hydrostatic test pump has the potential to reduce the core damage frequency by providing an alternate source of seal cooling when CCW has failed. Table 4.c-1 shows that this SAMA becomes cost beneficial if the averted cost-risk is scaled to account for the use of the 95th percentile results; however, the original estimate of the benefit for this SAMA was highly overestimated. A more realistic model of the pump shows that the benefit of this plant change is extremely limited.

The evaluation in the ER implemented a lumped event for the use of the hydro pump at a failure rate of 1.0E-03. This event did not account for power dependencies and was optimistic in the value assigned to its reliability. If a 480V AC emergency power dependency is added and the failure probability of the event is increased to a more realistic 5.0E-02, the benefit of this SAMA decreases slightly. It should be noted that a non-ESF 480V AC bus powers the hydro test pump, but as the PRA model does not include this power source, a surrogate has been used. The estimated benefit of this SAMA is increased slightly by this substitution.

A more important consideration for this plant change is related to the time required to align the alternate cooling method. The plant model already includes credit for use of the demineralized water system to provide alternate cooling to the charging pumps on loss of CCW; however, the credit for this cooling method is limited due to the potential of a consequential seal LOCA. While the alternate cooling method is being aligned, the RCP seals will heat up and may fail during the alignment time. There is also the consideration that cold water injection may shock the seals on initiation and cause a failure. The CNU_8 event accounts for this phenomenon.

Once this event is added to the hydro test pump model, the benefit is greatly reduced and yields an averted cost risk of $10,300. If the 2.36 scaling factor for the 95th percentile results is applied, the averted cost risk is only $24,308 and the SAMA is not cost beneficial.

It should be noted that if the CNU_8 event was considered to be inappropriate for use in this case, it would likewise be inappropriate for the other alternate cooling methods as the alignment times are judged to be comparable. Given that the hydrostatic test pump would not be available in an SBO, the primary benefit from this plant change would be realized in loss of CCW events. As the demineralized water, chilled water, and fire water alignments to cool the charging pumps also affect these scenarios, it is logical that the use of the hydrostatic test pump for seal cooling would not provide a large benefit. The small reduction in risk for this SAMA would be derived from the sequences in which CCW is lost in conjunction with the charging pumps. This SAMA is screened from further analysis.

Phase 2 SAMA 10, Improve 7.2kV Bus Cross-tie Ability:

The averted cost-risk for this SAMA was shown to be only $20,630 in the ER submittal. Use of the 95th percentile results yields an averted cost-risk of $48,687, which is close to the upper end of the estimate provided for the cost of implementation. However, the original cost of implementation does not consider the resources required to modify the controls in the main control room or to perform the engineering analysis required to support this change. Given these additional costs and the fact that the 95th percentile PSA results were used to generate the averted cost-risk of $48,687, this SAMA is not considered to be cost beneficial.

Summary:

The result of using the 95th percentile PSA results (or including External Events contributions) does not impact the results of the SAMA analysis. New, high cost SAMAs were retained from the Phase 1 analysis as a result of the higher maximum averted cost-risk, but these high cost items had relatively low averted cost-risks associated with their implementation. None were identified as potentially cost beneficial. Those SAMAs that were analyzed in the Phase 2 analysis in the ER were re-examined. Use of the 95th percentile PSA results in conjunction with the original estimates of the SAMAs' impacts on the model resulted in the classification of two SAMAs as cost beneficial (Phase 2 SAMAs 3 and 10). However, SAMAs 3 and 10 were ultimately shown not to be cost beneficial when more realistic estimates of their benefits and costs of implementation were used.

Table 4.c-1: Initial Disposition of the Original Phase 2 SAMAs Given the Use of the 95th Percentile PSA Results

Phase 2 SAMA ID	Averted Cost- Risk (Baseline)	Averted Cost-Risk using the 95th Percentile PSA Results	Cost of Implementation	Net Value	Cost Beneficial Based on ER Submittal Assumptions?
2	$1,249	$2,948	Not Required	Large Negative	No
3	$103,093	$243,299	$150,000 to $170,000	$93,299 to $73,299	Yes*
9	$23,818	$56,210	Not Required	Large Negative	No
10	$20,630	$48,687	$25,000 to 50,000	$23,687 to -$1313	Yes*
11/12	$39,725	$93,751	Not Required	Large Negative	No
13	$5,788	$13,660	Not Required	Large Negative	No
20	$17,766	$41,928	Not Required	Large Negative	No
24	$377,828	$891,674	$1,225,000	-$333,326	No
24a	$117,758	$277,909	$1,225,000	-$947091	No
25	$117,510	$277,324	$565,000	-$287,676	No
26	$13,147	$31,027	Not Required	Large Negative	No
27	$18,556	$43,792	Not Required	Large Negative	No

* As discussed in the text to this RAI response, these items were found not to be cost beneficial when more realistic assumptions related to the SAMA's implementation were used in place of the conservative estimates included in the ER submittal.

SAMA RAI 5:

Please provide the following information concerning the MACCS analyses:

a. for the evacuation input, discuss any assumptions used for delayed start after declaration of an emergency and sheltering;

b. for meteorology input, clarify the source from which the annual data sets were obtained, e.g., the plant meteorological tower;

c. the MACCS analysis assumes all releases occur at ground-level and have a thermal content that is the same as ambient. These assumptions could be non-conservative when estimating offsite consequences. Please provide an assessment of the impact that alternative assumptions might have on the estimated offsite consequences (doses to the population within 50 miles) and the conclusions of the SAMA evaluation; and

d. please provide additional discussion to clarify what is meant by the following sentence in Section F.2.2, page F-14, "Each VCSNS category corresponded with a single release

duration (either puff or continuous); MACCS2 categories Te and Ce required multiple releases."

VCSNS Response 5a:

All evacuees were assumed to begin evacuation 30 minutes after the declaration of an emergency. The evacuation speed of 0.43 meter per second was conservatively chosen as the minimum implied speed (evacuation distance/ evacuation time) from any evacuation zone assuming adverse weather conditions.

VCSNS Response 5b:

The annual data sets were obtained from the plant meteorological tower.

VCSNS Response 5c:

Of those sequences analyzed using MACCS2 (Melcor Accident Consequences Code System), only sequence SGL16BH is expected to be a non-ground level release. This release would be from the steam generator (SG) relief valves, with a release height as high as 22 meters. If the release from this sequence were at 22 meters above grade, the increase in dose risk (over that of a ground-level release) from this sequence would only be 1 percent.

The sensitivity of the assumption that all releases have a thermal content the same as ambient was investigated by comparing the 50-mile population dose risk that would result if all of the analyzed sequences were released with a heat content (above ambient) of 0, 3, 30, and 300 megawatts. It was found that the risk is relatively insensitive to this assumption. The dose risk for heat contents of release of 3, 30, and 300 megawatts (relative to ambient) increases by 1 percent, 4 percent, and -1 percent, respectively.

Given that the contributions to the VCSNS maximum averted cost-risk from the dose-risk and offsite economic cost-risk are only about 4 percent of the base case, these perturbations have a minimal effect on the Phase 1 analysis and would not influence the results of the evaluation. The dose-risk and offsite economic cost are also minimal contributors to the Phase 2 averted cost-risk calculations and the potential changes that may be introduced by the adjustments identified in this sensitivity are negligible.

VCSNS Response 5d:

For some of the sequences, Te is released as both TeO_2 and Te_2. These releases occur at different times and at different rates. Accordingly, Te was modeled as a "multiple release," i.e., in two segments. The release of UO_2 was conservatively represented by the MACCS2 category containing Ce (and Pu). The UO_2 release (release fractions of 10^{-7} or less) was at a different time and rate than the CeO_2 release for some of the sequences; Ce was, therefore, also modeled as two release segments. Note that these release categories together contribute only 3 percent of the total population dose risk.

SAMA RAI 6:

In the Phase 2 assessment (Section F.5), the benefits associated with reducing population dose are reported in terms of percent reduction in LERF. Please provide this estimated benefit in terms of percent reduction in person-rem dose for each of the SAMAs that are quantitatively assessed.

VCSNS Response 6:

The SAMA Phase 2 cost benefit analysis required the calculation of the change in dose-risk (person-rem/yr) for each SAMA identified; however, these changes were not reported in the Environmental Report (ER) submittal. The changes in dose-risk corresponding to each of the Phase 2 SAMAs are provided in Tables 6-1. While not specifically requested in this RAI, Table 6-2 provides the changes Offsite Economic Cost-Risk for each Phase 2 SAMA for completeness.

Table 6-1: Population dose, 0-50 mile (risk in person-rem)

Phase 2 SAMA #	SGL16BH (SGTR)	ILM08BH (ISLOCA)	TRE13NH (Cont. Failure)	**Total**	Percent Reduction
Baseline	2.73E-01	6.28E-01	5.33E-02	**9.54E-01**	0.0%
SAMA 2	2.73E-01	6.28E-01	5.33E-02	**9.54E-01**	0.0%
SAMA 3	2.73E-01	6.28E-01	4.84E-02	**9.49E-01**	0.5%
SAMA 9	2.72E-01	6.16E-01	5.22E-02	**9.40E-01**	1.5%
SAMA 10	2.72E-01	6.28E-01	5.24E-02	**9.53E-01**	0.1%
SAMA 11/12	2.73E-01	0.00E+00	5.33E-02	**3.26E-01**	65.9%
SAMA 13	2.72E-01	6.28E-01	5.31E-02	**9.54E-01**	0.1%
SAMA 20	2.72E-01	6.28E-01	5.25E-02	**9.53E-01**	0.2%
SAMA 24	2.56E-01	3.74E-01	3.68E-02	**6.67E-01**	30.1%
SAMA 24a	2.62E-01	3.74E-01	4.87E-02	**6.85E-01**	28.2%
SAMA 25	2.72E-01	4.44E-01	4.78E-02	**7.64E-01**	19.9%
SAMA 26	2.69E-01	6.30E-01	5.27E-02	**9.52E-01**	0.3%
SAMA 27	2.73E-01	6.28E-01	5.25E-02	**9.53E-01**	0.1%

Table 6-2: Offsite Economic Cost-Risk, 0-50 miles (risk in $)

Phase 2 SAMA #	SGL16BH (SGTR)	ILM08BH (ISLOCA)	TRE13NH (Cont. Failure)	Total	Percent Reduction
Baseline	$741.04	$1,993.60	$4.02	**$2,738.66**	0.0%
SAMA 2	$740.85	$1,993.60	$4.02	**$2,738.47**	0.0%
SAMA 3	$741.04	$1,993.60	$3.65	**$2,738.29**	0.0%
SAMA 9	$740.10	$1,953.28	$3.94	**$2,697.32**	1.5%
SAMA 10	$740.41	$1,993.60	$3.95	**$2,737.96**	0.0%
SAMA 11/12	$740.85	$0.00	$4.02	**$744.87**	72.8%
SAMA 13	$740.35	$1,993.60	$4.00	**$2,737.95**	0.0%
SAMA 20	$739.16	$1,993.60	$3.96	**$2,736.72**	0.1%
SAMA 24	$697.08	$1,187.20	$2.77	**$1,887.05**	31.1%
SAMA 24a	$712.78	$1,187.20	$3.67	**$1,903.65**	30.5%
SAMA 25	$739.78	$1,408.96	$3.60	**$2,152.35**	21.4%
SAMA 26	$731.62	$1,998.08	$3.98	**$2,733.68**	0.2%
SAMA 27	$741.00	$1,994.00	$3.95	**$2,738.95**	0.0%

SAMA RAI 7:

For certain SAMAs considered in the ER, there may be lower-cost alternatives that could achieve much of the risk reduction at a lower cost. In this regard, please provide the following:

a. for the subset of plant-specific SAMAs identified in RAI 2d and for the Phase 2 SAMAs, discuss whether any lower-cost alternatives to those considered in the ER would be viable and potentially cost-beneficial;

b. SAMAs 92 and 93 address added DC capability with costs estimated as being greater than $1.88M, thus, eliminating them from further consideration. Please provide the averted-risk benefit from these SAMAs, and address whether less costly alternatives to the SAMAs suggested might make these alternatives viable. Specifically, consider and provide estimated costs and benefits for diesel-driven battery chargers, and cross-connects to the existing non-safety station batteries as two potential alternatives'

c. a plant has recently installed a direct-drive diesel to power an auxiliary feed water (AFW) pump for under $200K. Please provide the averted-risk benefit of supplemental AFW capability at Summer, and an assessment of whether such a SAMA could be a cost-beneficial alternative to a motor-driven pump (Phase 1 SAMA 176); and

d. please provide an assessment of the costs and benefits of an automatic safety injection pump trip on low refueling water storage tank level as an alternative to fully automating the switch-over from injection to recirculation (Phase 2 SAMA 24).

VCSNS Response 7a:

Given that the plant specific changes identified in the IPE are excluded from consideration in the response to RAI 2d and that the VCSNS PSA insights did not identify any potential plant changes that were not already accounted for on the industry based SAMA list, there are no plant specific SAMAs to address here.

The VCSNS Phase 2 SAMAs were reviewed in order to identify viable, low cost alternatives to those proposed in the Environmental Report. No such changes or modifications were found.

VCSNS Response 7b:

SAMAs 92 and 93 were screened in the Phase 1 analysis of the ER as the estimated costs of implementation for improved batteries and fuel cells were greater than the VCSNS maximum averted cost-risk. Given the consideration of the lower cost alternatives presented in RAI 7b to improve DC capability, a re-examination of this SAMA is warranted.

The original plant change suggested replacement or modification of the VCSNS safety-related batteries (or the use of fuel cells) to increase the DC capacity in an SBO. As indicated in RAI 7b, there are other means of increasing the plant's DC capacity for lower costs. Specifically, a portable AC diesel or gas powered charger that can be connected to the plant's battery chargers in an SBO would provide DC power for a potentially unlimited duration. Compared with the increase in DC battery life afforded by the battery upgrade, the portable charger is more desirable. While this alternative is an improvement over the original SAMA, 480V AC generators with the power output to supply the DC chargers are still on the order of $11,000 each. Based on an industry example, 120V AC generators have been proposed to supply the steam generator instrumentation buses with power in an SBO. This contingency would provide a more limited benefit for a reduced hardware expenditure.

Cross-tie to the non-ESF station batteries was also suggested as a potential low cost alternative for improving DC capability. This modification has also been evaluated.

The primary benefit for these SAMAs is the ability to successfully operate the turbine driven EFW pump in an SBO after battery depletion. The VCSNS PRA model already credits operator action to control the turbine driven EFW pump following battery depletion (OAEFC); thus, this modification is represented by changing the action's failure probability from 4.1E-03 to 0.0.

The potential benefit of powering the instrumentation busses with a portable DC generator (or by means of a battery cross-connect) has been modeled by the addition of an alternate DC source (DC-CHARGER, 5.0E-02) that is credited in the same way as the current ESF batteries. The exception is that the portable generator (or battery cross-tie) can't prevent a loss of DC power initiating event.

Given that a safety-related emergency diesel generator has a combined start/run failure probability of 6.0E-02, it was considered appropriate to apply a similar reliability to the portable generator. A lumped system failure of 5.0E-02 was applied to the charger to account for

hardware and operator failures. The reduced failure rate compared with the EDGs conservatively shows slightly more benefit than using the EDG failure rate.

120V DC Generators

The cost of procuring and implementing the use of portable 120V DC generators to supply power to the steam generator instrumentation panels is $84,078.

Incorporation of the portable generator into the model resulted in a reduction in CDF of about 0.2 percent (CDF_{new}=5.584E-05/yr). The changes in the dose-risk and offsite economic cost - risk (OECR) for this SAMA are presented in Table 7.b-1:

Table 7.b-1: Dose-Risk and OECR Results Summary

Source Term Description	LERF		
	SGTR	ISLOCA	Cont. Bypass
Bin Frequency (per reactor year)	1.180E-07	1.780E-07	4.028E-07
VCSNS Sequence Designator (From IPE Table 4.4.4-1)	SGL16BH	ILM08BH	TRE13NH
OUTPUT:			
Dose -Risk (person-rem/yr)	0.27	0.63	0.05
Offsite Economic Cost-risk ($/yr)	741.00	1994.00	4.00

These results correspond to an averted cost-risk of $3,295. Given that the cost of implementation of this plant modification is $84,078, the net value is -$80,783. Based on the SAMA cost-benefit methodology, this plant change is not cost-beneficial.

Cross-tie to Non-ESF Station Batteries

Given that the averted cost-risk for this SAMA was developed using model changes that simulate the benefits of a successful cross-tie to the non-ESF 125V DC station batteries, it can also be used in the calculation of the net value for the cross-tie modification. The cost of implementation for the battery cross-tie has been developed separately as it differs from the portable generator estimate. The cost of the cross-tie modification is $59,117.

The net value for this SAMA is calculated as -$55,822, which demonstrates that this SAMA is not cost beneficial based on the SAMA methodology. Additionally, the non-ESF batteries are only rated for four hours and are not expected to provide a significant increase in DC availability. Load shed of the non-ESF batteries could be performed, but the decision to initiate the load shed would not be made until it was clear that the action was needed for core cooling, as non-ESF DC is required to prevent damage to the turbine generator. The actual benefit of the cross-tie is considered to be much more limited than this analysis demonstrates and it is suggested that it be eliminated from further consideration based on the limitations of non-ESF battery life.

In addition to the above justification for this alternative SAMA, the question of whether the batteries could be physically cross-connected in a suitable time frame is debatable. During the scenario to which the cross-connect applies, all available maintenance personnel would be

involved in efforts to restore power to the ESF busses, and the proposal would require use of manual hoists to transport the required cable to the tie-in locations. When the cost of additional manpower (full time employment) is added to the estimate to *ensure* that the cross-connect is implemented in a timely manner, the cost of this alternative exceeds the benefit by greater than two million dollars.

Sensitivity Case for Portable DC Generator: OAEFC = 1.0E-01 as the Baseline Model

A pivotal factor in the evaluation of this SAMA is the human error probability (HEP) estimated for the operation of the turbine driven pump after battery depletion. Industry examples span the range of possible values from 1.0 to essentially 0.0. The VCSNS failure probability of 4.1E-03 for this action is relatively low. An alternate calculation assuming less credit for this action is considered warranted given the importance of the HEP.

The baseline case has been adjusted so that the nominal value for this action is 1.0E-01 rather than 4.1E-03. Given this assumption, the baseline CDF is 5.83E-05/yr, which is a 4.2 percent increase over the original baseline case. The dose-risk for the revised baseline is presented in Table 7.b-2 along with the results for the portable generator case. Table 7.b-3 provides similar results for the OECR.

Table 7.b-2: Population dose, 0-50 mile (risk in person-rem)

Phase 2 SAMA #	SGL16BH (SGTR)	ILM08BH (ISLOCA)	TRE13NH (Cont. Failure)	Total	Percent Reduction
Sensitivity Baseline	2.726E-01	6.298E-01	5.544E-02	**9.578E-01**	N/A
RAI 7b SAMA	2.726E-01	6.283E-01	5.320E-02	**9.541E-01**	0.4%

Table 7.b-3: Total economic costs, 0-50 miles (risk in $)

Phase 2 SAMA #	SGL16BH (SGTR)	ILM08BH (ISLOCA)	TRE13NH (Cont. Failure)	Total	Percent Reduction
Sensitivity Baseline	7.410E+02	1.998E+03	4.179E+00	**2.743E+03**	N/A
RAI 7b SAMA	7.410E+02	1.994E+03	4.010E+00	**2.739E+03**	0.2%

Use of the revised baseline for this SAMA yields an averted cost-risk of $50,924 for implementation of the portable 120V DC generator modification. The corresponding net value is -$33,154. Because of the negative net value, even when operator action OAEFC is increased, this modification is not cost beneficial based on the SAMA methodology.

Additionally, (as in the case of the battery cross-connect proposal), implementation of this alternative SAMA would require redirecting the electrical maintenance priority from efforts to restore either onsite or offsite power to the ESF busses. When the need to hire additional maintenance personnel is factored into the estimate to ensure that such redirection does not occur, the cost of the portable generator proposal exceeds the benefit by an even larger amount than noted above.

VCSNS Response 7c:

RAI 7c proposes the use of a direct drive diesel EFW pump as a low cost alternative for improving EFW capability at VCSNS. The direct drive diesel EFW pump primarily has the potential of improving the reliability of SBO scenarios in which the turbine driven EFW pump fails. This response describes the analysis performed to evaluate the potential cost-benefit associated with implementing this plant change.

It has been determined that implementation of the direct drive diesel EFW pump can be modeled in the VCSNS PRA by assuming it will be available as an alternate motive source for the turbine driven EFW pump (TDEFWP). This assumption implies that the diesel motor can be connected to the current TDEFWP with a drive shaft when the steam driven turbine has failed. Pump modifications required to accommodate this connection are assumed to be included in the $200,000 estimate for the cost of implementation. This type modification is considered here as it is judged to be less resource intensive than cutting into the current EFW system piping and altering it to incorporate a new pump and injection path.

The types of failures averted by this enhancement include failures of the TDEFWP's steam supply as well start and run failures for the TDEFWP. It is assumed that the original values for the TDEFWP's start and run failures are all associated with the turbine and not the pump itself; hence, an independent "start and run" failure term is used for the direct drive diesel. The same total start and run failure probability is used for the direct drive diesel as is used for the TDEFWP (3.9E-02). The test and maintenance terms are assumed to be shared and are included as failure modes for the direct drive diesel.

An operator action to align the direct drive system has also been added to the model. The failure probability assumed for this alignment action is 5.0E-02.

Incorporation of the direct drive AFW pump into the model resulted in a reduction in CDF of about 13.1 percent (CDF_{new}=4.86E-05/yr). The changes in the dose-risk and offsite economic cost -risk (OECR) are presented in Tables 7.c-1 and 7.c-2.

Table 7.c-1: Population dose, 0-50 mile (risk in person-rem)

Phase 2 SAMA #	SGL16BH (SGTR)	ILM08BH (ISLOCA)	TRE13NH (Cont. Failure)	Total	Percent Reduction
Baseline	2.73E-01	6.28E-01	5.33E-02	**9.54E-01**	N/A
7c	2.71E-01	6.28E-01	4.63E-02	**9.46E-01**	0.9%

Table 7.c-2: Total economic costs, 0-50 miles (risk in $)

Phase 2 SAMA #	SGL16BH (SGTR)	ILM08BH (ISLOCA)	TRE13NH (Cont. Failure)	Total	Percent Reduction
Baseline	$741.04	$1,993.60	$4.02	**$2,738.66**	N/A
7c	$737.27	$1,993.60	$3.49	**$2,734.36**	0.2%

These results correspond to an averted cost-risk of $152,639. Given that the cost of implementation of this plant modification has been estimated to be $200,000, the net value is -$47,361. Based on the cost-benefit methodology applied in the SAMA evaluation, this plant change is not cost-beneficial and is screened from further consideration.

VCSNS Response 7d:

Automatic swap to recirculation mode has been shown to provide a relatively large averted cost-risk for VCSNS; however, due to the modification's large cost of implementation, it has been demonstrated this change is not cost beneficial. RAI 7d suggests that it may be possible to gain most of the benefit related to the automatic swap function with a less comprehensive plant change. The proposed change is the installation of a "low Refueling Water Storage Tank (RWST) level" trip for the Safety Injection (SI) pumps. This SAMA has the potential reduce plant risk in at least two ways. The first is that the low level trip would prevent pump damage due to air entrainment and/or cavitation on loss of the suction source. The second is that the pump trip would serve as an additional cue for control room operators to complete the alignment of recirculation mode cooling.

Given that an alarm on low RWST level already exists, the benefit of an additional alarm due to pump trip is judged to be small. However, there may be a difference in the way operators respond to low RWST level alarms and pump trip alarms. No reduction in credit was assumed due to alarm response dependence in this evaluation.

Cavitation on low RWST level is not explicitly modeled as a failure mode in the VCSNS PRA (cavitation is implicitly considered by requiring sump swapover as a success path for

recirculation), but a surrogate means of addressing this failure mode exists in the model. This same surrogate can be used to assume credit for the additional alarm signal from the SI pump trip. This SAMA can be modeled by setting the operator action to swap to cold leg recirculation (OAR1) to zero. This accounts for a completely reliable pump trip and a completely reliable understanding of the need to complete the swap to recirculation mode. It also conservatively reduces the failure probability of closing the RWST suction valve to zero.

OAR1 is the action to initiate the recirculation mode for a large Loss of Coolant Accident (LOCA) in the VCSNS PRA model. The large LOCA is the most relevant initiating event for this SAMA because the Residual Heat Removal (RHR) pumps will initially be running for injection to the Reactor Coolant System (RCS) and because the rapid decrease in RWST level will likely necessitate the need for the use of recirculation mode. For other recirculation mode initiation actions (OAR2 AND OARC), the RHR pumps are assumed to be in standby prior to recirculation mode alignment and would not require a manual trip.

Currently, Emergency Operations Procedures provide guidance for the operators to manually stop all pumps drawing suction from the RWST (Reactor Building Spray, RHR, and Charging Pumps) upon receipt of the 6 percent "RWST Empty" alarm.

The estimated cost to implement a change where the operators would not have to manually trip the pumps upon receipt of the "RWST Empty" alarm (including hardware, labor, and support documentation updates) is approximately $750,000, minimum, in 2003 dollars.

Installation of the automatic pump trip function corresponds to a reduction in CDF of about 0.02 percent (CDF_{new}=5.594E-05/yr) and a 0.02 percent reduction in the containment isolation failure frequency (CI_{new}=4.035E-07/yr). These changes yield no measurable decrease in the Level 3 results. The averted cost-risk for this SAMA is only $296. As the cost of implementation of the pump trip logic is far greater than the averted cost-risk, this SAMA is not a cost beneficial enhancement.

SAMA RAI 8:

Referring to Table F.1-1, Plant Improvement No. 10, it is noted that this improvement would reduce CDF due to SBO events, yet was never implemented. Please discuss whether this improvement was considered in the SAMA study and, if not, why?

VCSNS Response 8:

The subject plant improvement (which involves modifying the Component Cooling Water (CCW) system such that Fire Service Water can be aligned to provide cooling for the Reactor Coolant Pump thermal barrier heat exchangers) was abandoned during the IPE process. The issue of RCP seal cooling during SBO conditions was determined to be an industry concern and it was judged that the issue would be best addressed by working through the Westinghouse Owners Group. In the VCSNS IPE Staff Evaluation Report, the NRC acknowledged the decision to abandon this improvement.

From a SAMA review standpoint, other plant changes were already included in the industry based list that addressed similar seal cooling issues. The averted cost risk for a modification that would provide an equivalent benefit to Plant Improvement 10 was determined to be $103,930 (Phase 2 SAMA 3). When Plant Improvement 10 was evaluated in 1993 for the IPE process, the cost estimate to provide the engineering instruction package (alone) exceeded this amount. Given the cost of the engineering instruction package and the additional costs related to hardware procurement, labor, procedure adaptation, and other miscellaneous items, the proposed modification was excluded from further review.

Additionally, it should be noted that when this SAMA was reevaluated in the response to RAI 4c, the averted cost risk was shown to be limited to $10,300, making the modification even less cost beneficial.

SAMA RAI 9:

In Section F.7.1, a LERF sensitivity assessment is described. For completeness, please provide the source terms used (release fractions for each radionuclide, release categories, release timing, etc.) and the corresponding population doses for both Cases 1 and 2.

VCSNS Response 9:

The LERF sensitivity analysis included two cases related to estimating the potential contribution of the non-LERF release categories for VCSNS. Case 1 was judged to provide a highly conservative bounding estimate by using the non-Large Early Release Frequency with the LERF source term for containment bypass (TRE13NH) at a 48-hour release time (to simulate late containment failure). Case 2 implemented a source term for containment failure at 48 hours (TRE13IH) at the expected late containment failure frequency, which is about 20 percent of the CDF. Case 2 is judged to be a more realistic estimate of the non-LERF contribution.

An error was identified in the LERF sensitivity calculation presented in the ER. For LERF sensitivity Case 1, the non-LERF was reported as 4.42E-05/yr rather than 5.52E-05/yr. The result was that the dose-risk and offsite economic cost-risk (OECR) for this sensitivity were lower than intended. The dose-risk and OECR were recalculated using the appropriate frequency and the results indicate an increase in maximum averted cost-risk of about 13 percent over the baseline cases. This is approximately 3 percent larger than what was estimated in the ER. Given that the results for the revised Case 1 sensitivity are consistent with the real discount rate sensitivity presented in the ER, the same conclusion is reached: inclusion of non-LERF contributions would not alter the conclusions of the SAMA analysis for VCSNS.

Table 9-1 provides the Case 1 and Case 2 source term summaries, as requested.

Table 9-1: LERF Sensitivity Source Term Summary

	Release Category[1]	
Sequence Designator and Source Term Description	**TRE13NH (Case 1, Cont. Iso. Failure)**	**TRE13IH (Case 2, Containment Failure at 48 hours)**
Bin Frequency	5.520E-05	1.120E-05
Fission Product Data:		
1) Noble		
Airborne Release % at 48 Hours	95	1.4
Start of Release (hr)	48	48
End of Release (hr)	48	48
2) CsI		
Airborne Release % at 48 Hours	6.60E-02	2.00E-05
Start of Release (hr)	48	48
End of Release (hr)	48	48
3) TeO2		
Airborne Release % at 48 Hours	0	0
Start of Release (hr)	N/A	48
End of Release (hr)	N/A	48
4) SrO		
Airborne Release % at 48 Hours	1.30E-04	1.30E-04
Start of Release (hr)	48	48
End of Release (hr)	48	48
5) MoO2		
Airborne Release % at 48 Hours	7.10E-03	7.10E-03
Start of Release (hr)	48	48
End of Release (hr)	48	48
6) CsOH		
Airborne Release % at 48 Hours	6.10E-02	2.00E-05
Start of Release (hr)	48	48
End of Release (hr)	48	48
7) BaO		
Airborne Release % at 48 Hours	2.10E-03	2.10E-03
Start of Release (hr)	48	48
End of Release (hr)	48	48
8) La2O3		
Airborne Release % at 48 Hours	7.00E-06	7.00E-06
Start of Release (hr)	48	48
End of Release (hr)	48	48

	Release Category(1)	
Sequence Designator and Source Term Description	**TRE13NH (Case 1, Cont. Iso. Failure)**	**TRE13IH (Case 2, Containment Failure at 48 hours)**
9) CeO2		
Airborne Release % at 48 Hours	3.60E-05	3.60E-05
Start of Release (hr)	48	48
End of Release (hr)	48	48
10) Sb		
Airborne Release % at 48 Hours	5.60E-02	5.60E-02
Start of Release (hr)	48	48
End of Release (hr)	48	48
11) Te2		
Airborne Release % at 48 Hours	0	0
Start of Release (hr)	N/A	48
End of Release (hr)	N/A	48
12) UO2		
Airborne Release % at 48 Hours	0	0
Start of Release (hr)	N/A	48
End of Release (hr)	N/A	48
OUTPUT:		
Dose -Risk (person-rem/yr)	7.40	5.30E-02
Offsite Economic Cost-risk ($/yr)	477.00	1.79

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