Appendix G

NRC Staff Evaluation of Severe Accident Mitigation Alternatives for V.C. Summer Nuclear Station in Support of License Renewal Application

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G.1.0 Introduction

South Carolina Electric & Gas Company (SCE&G) submitted an assessment of SAMAs for V. C. Summer as part of the Environmental Report (ER) (SCE&G 2002). This assessment was based on the most recent V. C. Summer Probabilistic Risk Analysis (PRA) available at that time, a plant-specific offsite consequence analysis performed using the MELCOR Accident Consequence Code System 2 (MACCS2), and insights from the V. C. Summer Individual Plant Examination (IPE) (SCE&G 1993) and Individual Plant Examination of External Events (IPEEE) (SCE&G 1995). In identifying and evaluating potential SAMAs, SCE&G considered SAMA analyses performed for other operating plants which have submitted license renewal applications, as well as industry and NRC documents that discuss potential plant improvements, such as NUREG-1560 (NRC 1997a). SCE&G identified 268 potential SAMA candidates. This list was reduced to 12 unique SAMA candidates by eliminating SAMAs that were not applicable to V. C. Summer due to design differences, had already been implemented, are related to changes that would be made during the design phase of a plant rather than to an existing plant, or had high implementation costs. SCE&G assessed the costs and benefits associated with each of the potential SAMAs and concluded that none of the candidate SAMAs evaluated would be cost-beneficial for V. C. Summer.

Based on a review of the SAMA assessment, the NRC issued requests for additional information (RAI) to SCE&G by letter dated January 17, 2003 (NRC 2003a), and by fax dated April 28, 2003 (NRC 2003b). Key questions concerned: dominant risk contributors at V. C. Summer and the SAMAs that address these contributors, the impact on dose consequences if all release categories are considered rather than just large early release categories, the potential impact of uncertainties and external event initiators on the assessment results, and detailed information on several specific candidate SAMAs. SCE&G submitted additional information by letters dated March 19, 2003 and May 21, 2003 (SCE&G 2003a and 2003b). In these responses, SCE&G provided tables containing importance measures for various events and their relationship to evaluated SAMAs, results of a revised screening based on consideration of uncertainties, an assessment of risk reduction benefits for external events, and the costs and benefits associated with several lower cost alternatives. SCE&G's responses addressed the staff's concerns and reaffirmed that none of the SAMAs evaluated would be cost beneficial.

An assessment of SAMAs for V. C. Summer is presented below.

G.2.0 Estimate of Risk for V. C. Summer

SCE&G's estimates of offsite risk at V. C. Summer are summarized in Section G.2.1. The summary is followed by the staff's review of SCE&G's risk estimates in Section G.2.2.

G.2.1 SCE&G's Risk Estimates

Two distinct analyses are combined to form the basis for the risk estimates used in the SAMA analysis: (1) the V. C. Summer Level 1 and 2 PRA model, which is an updated version of the Individual Plant Examination (IPE) (SCE&G 1993), and (2) a supplemental analysis of offsite consequences and economic impacts (essentially a Level 3 PRA model) developed specifically for the SAMA analysis. The SAMA analysis is based on the most recent Level 1 and 2 PRA model available at the time of the ER, referred to as model UP3a. The scope of the V. C. Summer PRA does not include external events.

The baseline core damage frequency (CDF) for the purpose of the SAMA evaluation is approximately 5.6×10^{-5} per year, and the baseline large early release frequency (LERF) is approximately 7.0×10^{-7} per year. The CDF and LERF are based on the risk assessment for internally-initiated events. The CDF represents a sizeable change from the original IPE CDF value of 2.0×10^{-4} per year. SCE&G did not include the contribution of risk from external events within the V. C. Summer risk estimates, nor did it account for the potential risk reduction benefits associated with external events in the SAMA screening process described in the ER. It is SCE&G's position that the existing fire and IPEEE programs have already addressed potential plant improvements related to these areas (SCE&G 2002). In response to RAIs, SCE&G performed separate assessments of the impact on the results if the 95th percentile value of the internal events CDF was used in the SAMA evaluation, or if the additional risk reduction benefits in external events were included in the analysis. This is discussed further in Sections G.4.0 and G.6.2.

The breakdown of CDF by initiating event/accident type is provided in Table G-1. As shown in this table, loss of offsite power and transients (such as loss of feedwater, reactor and turbine trips, and main steam line breaks) are dominant contributors to the CDF. Bypass events (i.e., ISLOCA and SGTR) contribute less than one percent to the total internal events CDF.

The Level 2 PRA model has been updated since the IPE. SCE&G now uses a simplified LERF methodology as described in NUREG/CR-6595 (NRC 1999). The source terms are the same as those used in the IPE (SCE&G 1993). The conditional probabilities, fission product release fractions, and release characteristics associated with each release category were provided in response to an RAI (SCE&G 2003a).

Table G-1. V. C. Summer Core Damage Frequency

Initiating Event/Accident Class	CDF (Per Year)	% Contribution to CDF
Loss of Offsite Power (LOOP)	$3.9x10^{-5}$	70
Transients	$7.5x10^{-6}$	13
Special Initiators	$4.4x10^{-6}$	8
Loss-of-Coolant Accident (LOCA)	$1.7x10^{-6}$	3
Steam Generator Tube Rupture (SGTR)	$1.7x10^{-7}$	<1
Interfacing Systems LOCA (ISLOCA)	$1.8x10^{-7}$	<1
Others	$2.6x10^{-6}$	5
Total CDF (from internal events)	**$5.6x10^{-5}$**	**100**

The offsite consequences and economic impact analyses use the MACCS2 code to determine the offsite risk impacts on the surrounding environment and public. Inputs for this analysis include plant-specific and site-specific input values for core radionuclide inventory, source term and release characteristics, site meteorological data, projected population distribution (within a 80 km [50-mi] radius) for the year 2042, emergency response evacuation modeling, and economic data.

In the ER, SCE&G estimated the dose to the population within 80 km (50 mi) of the V. C. Summer site to be approximately 0.0095 person-Sv (0.95 person-rem) per year based on consideration of only those release categories that would contribute to LERF (SGTR, ISLOCA, and containment isolation failure). Late containment failures would not contribute to LERF but could still have offsite consequences. In response to a staff request, SCE&G estimated the offsite doses from late containment failures, and included this contribution in their estimate of total offsite dose. The total offsite dose is estimated to be approximately 0.01 person-Sv (1.0 person-rem) per year, with 0.0095 person-Sv (0.95 person-rem) per year from LERF-related release categories and 0.0005 person-Sv (0.05 person-rem) per year from the late release category. This total offsite dose estimate was used in the subsequent SAMA evaluation. The breakdown of the total population dose by containment release mode is summarized in Table G-2.

Table G-2. Breakdown of Population Dose by Containment Release Mode

Containment Release Mode	Population Dose (Person-Rem[a] Per Year)	% Contribution
SGTR	0.27	27
Interfacing Systems LOCAs	0.63	63
Containment isolation failure	0.05	5
Early containment failure	0	0
Late containment failure	0.05	5
Total	1.0	100

[a]One person-Rem = 0.01 person-Sv

G.2.2 Review of SCE&G's Risk Estimates

SCE&G's determination of offsite risk at V. C. Summer is based on the following three major elements of analysis:

- the Level 1 and 2 risk models that form the bases for the 1993 IPE and 1995 IPEEE submittals (SCE&G 1993 and SCE&G 1995),
- the major modifications to the IPE model that have been incorporated in the V. C. Summer PRA, and
- the MACCS2 analysis performed to translate fission product release frequencies from the Level 2 PRA model into offsite consequence measures.

Each of these analyses was reviewed to determine the acceptability of SCE&G's risk estimates for the SAMA analysis, as summarized below.

The staff's review of the V. C. Summer IPE is described in an NRC report dated May 8, 1997 (NRC 1997b). In that review, the staff evaluated the methodology, models, data, and assumptions used to estimate the CDF and characterize containment performance and fission product releases. The staff concluded that SCE&G's analyses met the intent of Generic Letter 88-20 (NRC 1988); that is, the IPE was of adequate quality to be used to look for design or operational vulnerabilities. The staff's review primarily focused on the licensee's ability to examine V. C. Summer for severe accident vulnerabilities and not specifically on the detailed findings or quantification estimates. Overall, the staff believed that the V. C. Summer IPE was of adequate quality to be used as a tool in searching for areas with high potential for risk reduction and to assess such risk reductions, especially when the risk models are used in conjunction with insights, such as those from risk importance, sensitivity, and uncertainty analyses. However, the staff did note that the elimination of early containment failure modes from containment failure quantification limits the use of the Level 2 analysis for systematic evaluations of the relative importance of these failure modes and the investigation of potential benefit of recovery actions on overall containment performance. The impact of this deficiency on the SAMA analysis is discussed below.

A comparison of internal events risk profiles between the IPE and the PRA used in the SAMA analysis indicates a decrease of approximately 1.4×10^{-4} per year in the total CDF (from 2.0×10^{-4} per year to 5.6×10^{-5} per year). The reduction is attributed to plant and modeling improvements that have been implemented at V. C. Summer since the IPE was submitted. A summary listing of those changes that resulted in the greatest impact on the total core damage frequency was provided in the ER and in response to an RAI (SCE&G 2003a), and include:

- Changed the cooling medium for the component cooling water (CCW) pumps and charging pumps from HVAC chilled water to CCW to eliminate chilled water dependencies,

- Developed an abnormal operating procedure for use following a loss of both trains of chilled water,

- Developed a procedure for local operation of the power-operated relief valve (PORV) dominating failure to re-establish instrument air,

- Eliminated six check valves in the emergency feedwater (EFW) system as well as incorporated associated modeling changes,

- Updated initiating event frequencies using data in NUREG/CR-5750, "Rates of Initiating Events at U.S. Nuclear Power Plants: 1987 - 1995," and updated LOOP frequency with information from EPRI TR-106306, "Loss of Off-Site Power at U.S. Nuclear Power Plants–Through 1995", and

- Updated common cause failure probability modeling and the human reliability analysis.

The CDF changes from the IPE version to the current PRA are significant. For example, an initial data and modeling update, plant modifications to change the cooling medium for the CCW pumps and charging pumps from HVAC chilled water to CCW, and plant modifications to eliminate check valves in the EFW system, collectively resulted in about a factor of two reduction in the CDF. A second data update involving the use of initiating event frequencies from NUREG/CR-5750 and EPRI TR-106306 resulted in an additional factor of two reduction. Given the magnitude of the plant and model changes, the overall reduction in CDF appears to be reasonable.

The IPE CDF value for V. C. Summer is within the range of the CDF values reported in the IPEs for other pressurized water reactors (PWRs) with large dry containments. Figure 11.6 of NUREG-1560 shows that the IPE-based total internal events CDF for three-loop Westinghouse plants ranges from $7x10^{-5}$ to $4x10^{-4}$ per year (NRC 1997a). It is recognized that other plants, in addition to V. C. Summer, have reduced the values for CDF subsequent to the IPE submittals, due to modeling and hardware changes. The current CDF results for V. C. Summer remain comparable to other plants of similar vintage and characteristics.

In the ER, SCE&G states that there would be no early containment failures at V. C. Summer, as reflected in Table 5-4. In a response to an RAI, SCE&G further supports that position by stating that the most important feature of the V. C. Summer containment with respect to fission product retention is the ability to remain intact for several tens of hours following core damage. The position that the early containment failure probability is zero is supported by a site-specific evaluation performed by Westinghouse in January 2003 which, according to SCE&G, shows that it is appropriate to assign a zero containment failure probability for direct containment heating and hydrogen burns, steam explosions and induced steam generator tube rupture. The staff did not review the Westinghouse study, which is referenced by SCE&G in its response to RAIs (SCE&G, 2003b). The staff does note, however, that SCE&G did perform a sensitivity analysis that assumed that the containment would fail early with a 10% probability for the high-pressure core melt events. This assumption is consistent with insights from severe accident assessments for large dry containments, which in general, have shown the conditional probability of early containment failure (excluding the contribution from ISLOCA, SGTR, and containment isolation failures) to be very small. The analysis yielded an increase in the maximum averted cost-risk of about $4,000. This additional averted cost-risk is small and will have a negligible impact on the SAMA conclusions, particularly since modifications to reduce early containment failure (e.g., enhancing reactor depressurization or hydrogen control capabilities) would generally involve hardware or procedure modifications with implementation costs much greater than this estimated benefit. The staff concludes that while the assumption that the early containment failure probability is zero is optimistic, the sensitivity analysis provided by SCE&G nevertheless demonstrates that inclusion of early containment failures within the risk analysis would have a negligible impact on the SAMA conclusions for V. C. Summer.

The staff considered the peer reviews performed for the V. C. Summer PRA, and the potential impact of the review findings on the SAMA evaluation. In response to an RAI (SCE&G 2003a), SCE&G described the previous reviews, the most significant of which were the Westinghouse review in March 2001 and the Westinghouse Owners Group (WOG) Peer Review of August 2002. The Westinghouse review of model UP3a concluded that the technical elements of the PRA were such that the PRA is generally suitable for plant risk-informed applications. Specific recommendations from this review were reflected in a subsequent PRA update, referred to as model UP3h, which formed the basis for the WOG Peer Review. Three observations from the

WOG Peer Review were noted as extremely important and necessary to address in order to ensure the technical adequacy of the PRA. One of these was in the area of initiating events (specifically the ISLOCA) and the other two were in the systems analysis technical element (the diesel generator model and the EFW mission times). The PRA model (UP3h) has not yet been updated to address these weaknesses in the PRA, since the WOG Peer Review Report was not issued until December 2002. However, SCE&G provided the results of sensitivity analyses in which they assessed the impact of anticipated modeling changes in these areas on the SAMA evaluations. SCE&G estimated that changes to address the WOG Peer Review comments could potentially increase the CDF by about 15% relative to PRA model UP3a, with a corresponding but smaller increase in LERF. This increase is accounted for in the consideration of averted risk for the candidate SAMAs, as described in Section G.6.2.

Given that the V. C. Summer PRA has been peer reviewed and the potential impact of the peer review findings on the SAMA evaluation has been assessed, that SCE&G satisfactorily addressed staff questions regarding the PRA, including concerns related to omission of early containment failure modes (SCE&G 2003a and 2003b), and that the CDF falls within the range of contemporary CDFs for Westinghouse three-loop plants, the staff concludes that the Level 1 and Level 2 PRA models are of sufficient quality to support the SAMA evaluation.

SCE&G submitted an IPEEE in June 1995 (SCE&G 1995) in response to Supplement 4 of Generic Letter 88-20. SCE&G did not identify any fundamental weaknesses or vulnerabilities to severe accident risk in regard to the external events related to seismic, fire, or other external events. The V. C. Summer hurricane, tornado and high winds analyses show that the plant is adequately designed or procedures exist to cope with the effects of these natural events. Additionally, the V. C. Summer IPEEE demonstrated that transportation and nearby facility accidents were not considered to be significant vulnerabilities at the plant. However, a number of areas were identified for improvement in both the seismic and fire areas. In a letter dated June 14, 2000, (NRC 2000), the staff concluded that the submittal met the intent of Supplement 4 to Generic Letter 88-20, and that the licensee's IPEEE process is capable of identifying the most likely severe accidents and severe accident vulnerabilities.

The IPEEE uses a focused scope EPRI seismic margins analysis (SMA). This method is qualitative and does not provide the means to determine numerical estimates of the CDF contributions from seismic initiators. However, since V. C. Summer has a plant-level "high confidence of low probability of failure" (HCLPF) value significantly greater than its design basis, it can be qualitatively expected from the SMA that the seismic CDF is relatively low (NRC 2002). SCE&G estimated the plant's HCLPF to be greater than 0.3g peak ground acceleration, with the exception of service water pond dams that have a 0.22g HCLPF. As noted in the IPEEE SER (NRC 2000), there is no cost effective solution for increasing the seismic capacity of the service water pond dams. A number of actions were taken by SCE&G as part of the IPEEE evaluation of seismic risk. These included bolting together adjacent electrical cabinets at 17 locations throughout the plant to remove interaction concerns, providing lateral support for an isolation valve where the support was missing, and performing an analysis to show an adequate HCLPF value for a neutral grounding resistor that uses ceramic components. No additional outliers or potential areas for improvement were identified in the IPEEE.

The licensee's overall approach in the IPEEE fire analysis is similar to other fire analysis techniques, employing a graduated focus on the most important fire zones using qualitative and quantitative screening criteria. The fire zones or compartments were subjected to at least two screening stages. In the first stage, a zone was screened out if it was found to not contain any safety-related equipment. In the second stage, a CDF criterion of $1x10^{-6}$ per year was applied. Plant information gathered for Appendix R compliance was extensively used in the fire IPEEE. The licensee used the IPE model of internal events to quantify the CDF resulting from a fire initiating event. The conditional core damage probability (CCDP) was based on the equipment and systems unaffected by the fire. All fire event sequences were quantified assuming all equipment/cables in the area would fail by the fire. The CDF for each zone was obtained by multiplying the frequency of a fire in a given fire zone by the CCDP associated with that fire zone. The screening methodology applied by the licensee makes less and less conservative assumptions until a fire zone is screened out, the results do not indicate a vulnerability, or a vulnerability is identified and addressed. If applied correctly, this type of analysis will always produce a conservative result.

Using the Fire Induced Vulnerability Evaluation (FIVE) Method, the IPEEE fire CDF was estimated to be about $4x10^{-4}$ per year. In response to IPEEE RAIs, this was reduced to $8.5x10^{-5}$ per year (NRC 2002b). After the CDF was lowered to $8.5x10^{-5}$ per year, only five compartments contributed more than the screening value of $1.0x10^{-6}$; these are:

Zone Description	CDF
Control Room	$3.44x10^{-5}$
1 DA Switchgear Room	$2.44x10^{-5}$
Relay Room	$1.28x10^{-5}$
Turbine Room	$7.09x10^{-6}$
1 DB Switchgear Room	$2.75x10^{-6}$

In a response to an RAI, SCE&G discussed the potential for cost-effective hardware changes to address the five fire-related matters listed above (SCE&G, 2003a). This included consideration of the major fire contributors assumed in the analysis, and existing plant features and detection/mitigation capabilities. SCE&G concluded that no hardware modifications aimed at reducing risk were cost-effective for any of the zones. However, SCE&G, did describe several procedural and training enhancements that have been implemented to address fire-related issues.

The staff notes that additional SAMAs to reduce the fire risk contributors might be viable at V. C. Summer. However, given that the original fire CDF has already been reduced by over a factor of seven through a combination of hardware and procedure changes, that the updated fire CDF is conservative (since it is based on the IPE model which is over a factor of 3.6 greater than that of the current PRA), and that the plant meets Appendix R fire requirements, it is unlikely that further modifications would both substantially reduce risk and remain cost beneficial.

The risk associated with other external events at V. C. Summer is small. The CDFs due to high winds, floods and other events were not estimated since they were screened out using the NUREG-1407 approach.

For purposes of the SAMA evaluation, the contribution of external events to total risk would be bounded by the sensitivity assessment on internal events CDF (discussed in Section G.6.2) if: (1) the total contribution from external events is on the same order of magnitude as the contribution from internal events, and (2) there are no external event vulnerabilities that can be eliminated or mitigated by cost-effective SAMAs. As discussed above, the seismic CDF is relatively low given the high HCLPF value at V. C. Summer, and the contribution from fires is comparable to that from internal events. SCE&G has previously made modifications specifically addressing external event vulnerabilities, and further improvements are not expected to be cost effective. Furthermore, for several SAMAs that were close to being cost beneficial, SCE&G considered the additional risk reduction that might be achieved in external events. Accordingly, the staff finds SCE&G's consideration of external events to be acceptable.

The staff reviewed the process used by SCE&G to extend the containment performance (Level 2) portion of the PRA to an assessment of offsite consequences (essentially a Level 3 PRA). This included consideration of the source terms used to characterize fission product releases for the applicable containment release category and the major input assumptions used in the offsite consequence analyses. The MACCS2 code was utilized to estimate offsite consequences. Plant-specific input to the code includes the V. C. Summer reactor core radionuclide inventory, source terms for each release category, emergency evacuation modeling, site-specific meteorological data, and projected population distribution within a 80 km (50 mile) radius for the year 2042. This information is provided in Appendix F of the ER (SCE&G 2002).

In the ER, SCE&G estimated the dose consequences based on consideration of only those release categories that would contribute to LERF (SGTR, ISLOCA, and containment isolation failure). Late containment failures would not contribute to LERF but could still have offsite consequences. In response to a staff request, SCE&G estimated the offsite doses from late containment failures, and included this contribution in their estimate of total offsite dose. This total offsite dose estimate was used in the subsequent SAMA evaluation. Table 1.f-1 of the response to the RAI provides a break out of the source term by release category (SCE&G 2003a). The source terms used for the SAMA evaluation are taken from the IPE. Accordingly, the staff concludes that the assignment of release categories and source terms is acceptable for use in the SAMA analysis.

The core inventory input used in the MACCS2 was obtained from the MACCS2 User's Guide, and corresponds to the end-of-cycle values for a 3,412 MWt PWR plant. A scaling factor of 0.85 was applied to provide a representative core inventory of 2,900 MWt for V. C. Summer. Release frequencies for three sequences and release fractions were analyzed to determine the 50-mile population dose. In response to an RAI, SCE&G re-evaluated the dose after including a non-LERF sequence to account for any contribution from late releases (SCE&G 2003a). All releases were modeled as occurring at ground level. The staff questioned the non-conservatism of this assumption and requested an assessment of the impact of alternative assumptions (e.g., releases at a higher elevation). In response to the RAI, SCE&G assessed the sensitivity of the assumption by analyzing a release from the steam generator release valves with a release height as high as 22 meters. The results showed that the increase in the 50-mile population dose would be only about one percent (SCE&G 2003a). Additionally, SCE&G analyzed the sensitivity of the assumption that all releases have a thermal content the same as ambient. This was done by analyzing the releases with a heat content of 0, 3, 30, and 300 megawatts. The results showed an increase in the population dose as high as four percent. These small increases have a negligible impact on the analysis and its results.

SCE&G used site-specific meteorological data, obtained from the plant meteorological tower, processed from hourly measurements for the 1997 calendar year as input to the MACCS2 code. Data from this year was selected because it was found to result in the largest doses based on the analysis of data from 1996 through 2000. Therefore, the staff considers use of the 1997 data in the base case to be conservative.

The population distribution the applicant used as input to the MACCS2 analysis was estimated for the year 2042, based on the NRC geographic information system (GIS) for 1990 (NRC 1997c), and the population growth rates were based on 1990 and 2000 County-level census data (USCB 2001). The staff considers the methods and assumptions for estimating population reasonable and acceptable for purposes of the SAMA evaluation.

The emergency evacuation model was modeled as a single evacuation zone extending out 16 km (10 mi) from the plant. It was assumed that 95 percent of the population would move at an average speed of approximately 0.43 meter per second (0.96 mph) with a delayed start time of 30 minutes (SCE&G 2003a). This assumption is conservative relative to the NUREG-1150 study (NRC 1990), which assumed evacuation of 99.5 percent of the population within the emergency planning zone. The evacuation assumptions and analysis are deemed reasonable and acceptable for the purposes of the SAMA evaluation.

Much of the site-specific economic data were provided from SECPOP90 (NRC 1997c) by specifying the data for each of the 22 counties surrounding the plant, to a distance of 50 miles. In addition, generic economic data that are applied to the region as a whole were revised from the MACCS2 sample problem input when better information was available. The agricultural economic data were updated using available data from the 1997 Census of Agriculture (USDA 1998). These included per diem living expenses, relocation costs, value of farm and non-farm wealth, and fraction of farm wealth from improvements (e.g., buildings).

SCE&G did not perform sensitivity analyses for the MACCS2 input parameters, such as evacuation and population assumptions. However, sensitivity analyses performed as part of previous SAMA evaluations for other plants have shown that the total benefit of the candidate SAMAs would increase by less than a factor of 2 (typically about 20 percent) due to variations in these parameters. This change is small and would not alter the outcome of the SAMA analysis. Therefore, the staff concludes that the methodology used by SCE&G to estimate the offsite consequences for V. C. Summer provides an acceptable basis from which to proceed with an assessment of risk reduction potential for candidate SAMAs. Accordingly, the staff based its assessment of offsite risk on the CDF and offsite doses reported by SCE&G.

G.3.0 Potential Plant Improvements

The process for identifying potential plant improvements, an evaluation of that process, and the improvements evaluated in detail by SCE&G are discussed in this section.

G.3.1 Process for Identifying Potential Plant Improvements

SCE&G's process for identifying potential plant improvements (SAMAs) consisted of the following elements:

- review of plant-specific improvements identified in the V.C. Summer IPE and IPEEE and subsequent PRA revisions

- review of SAMA analyses submitted in support of original licensing and license renewal activities for other operating nuclear power plants

- review of other NRC and industry documentation discussing potential plant improvements, e.g., NUREG-1560.

Based on this process, an initial set of 268 candidate SAMAs was identified, as reported in Table F.4-1 in Appendix F to the ER. In Phase 1 of the evaluation, SCE&G performed a qualitative screening of the initial list of SAMAs and eliminated SAMAs from further consideration using the following criteria:

- the SAMA is not applicable at V. C. Summer due to design differences,
- the SAMA has already been implemented at V. C. Summer,
- the SAMA is sufficiently similar to another SAMA such that they may be combined, or
- the systems/items associated with the SAMA have no significant safety benefit.

Based on this screening, 199 SAMAs were eliminated leaving 69 for further evaluation. Of the 199 SAMAs eliminated, 55 were eliminated because they were not applicable to V. C. Summer, 83 were eliminated because they already had been implemented at V. C. Summer, 56 were similar to another SAMA and were combined, and five were determined not to provide a significant safety benefit.

A preliminary cost estimate was prepared for each of the 69 remaining candidates to focus on those that had a possibility of having a net positive benefit. A screening cutoff of $1.2M (the maximum attainable benefit or MAB, corresponding to eliminating all severe accident risk) was then applied to the remaining candidates (see discussion in Section G.6.1 for a derivation of the MAB). Thirty-seven of the 69 SAMAs were eliminated because their estimated cost exceeded this MAB, leaving 32 candidate SAMAs for further evaluation in Phase 2. Of these remaining SAMAs, 20 were screened from further analysis because, based on plant-specific PRA insights, they did not provide a significant safety benefit, or because the cost of implementation would be greater than the benefits associated with implementing the SAMA. This culminated in identification of 12 candidate SAMAs.

In response to an RAI, SCE&G re-evaluated the Phase 1 SAMAs using the 95th confidence level. The screening cutoff became $2.8M. When applied, seven additional Phase 1 SAMAs were identified for further consideration. Table 4.b-1 of the response to the RAI contains the additional SAMAs and their subsequent disposition. None of the newly identified SAMAs were judged to be cost beneficial (SCE&G 2003a), as discussed in Section G.6.2.

The 12 remaining SAMAs were further evaluated and subsequently eliminated in the Phase 2 evaluation, as described in Sections G.4.0 and G.6.0 of this appendix.

G.3.2 Staff Evaluation

SCE&G's efforts to identify potential SAMAs focused primarily on areas associated with internal initiating events. The initial list of SAMAs generally addressed the accident categories that are dominant CDF contributors or issues that tend to have a large impact on a number of accident sequences at V. C. Summer.

The preliminary review of SCE&G's SAMA identification process raised some concerns regarding the completeness of the set of SAMAs identified and the inclusion of plant-specific risk contributors. The staff requested clarification regarding the portion of risk represented by the dominant risk contributors. Because a review of the importance ranking of basic events in the PRA could identify SAMAs that may not be apparent from a review of the top cut sets, the staff also questioned whether an importance analysis was used to confirm the adequacy of the SAMA identification process. In response to the RAI, SCE&G provided a tabular listing of the contributors with the greatest potential for reducing risk as demonstrated by the risk reduction worth (RRW) assigned to the event (SCE&G 2003a). SCE&G used a cutoff of 1.025, and stated that events below this point would influence the CDF by less than 2.5 percent. This equates to an averted cost-risk (benefit) of approximately $30,000. SCE&G also reviewed the LERF-based RRW events to determine if there were additional equipment failures or operator actions that should be included in the provided table. In addition, SCE&G correlated the top RRW events with the SAMAs evaluated in the ER (SCE&G 2003a). Based on these additional assessments, SCE&G concluded that the set of 268 SAMAs evaluated in the ER addresses the major contributors to CDF and LERF, and that the review of the top risk contributors does not reveal any new SAMAs.

The staff questioned SCE&G about lower cost alternatives to several of the SAMAs evaluated, including the use of: (1) portable battery chargers to supply power to the steam generator instrument panels, (2) a cross-tie to the existing non-safety station batteries, (3) a direct-drive diesel emergency feedwater pump, and (4) an automatic safety injection pump trip on low refueling water storage tank (RWST) level as an alternative to an automatic swap to recirculation (NRC 2003a). In response, SCE&G provided estimated benefits and implementation costs for each alternative (SCE&G 2003a). These are discussed further in Section G.6.2 of this appendix.

The staff notes that the set of SAMAs submitted is not all inclusive, since additional, possibly even less expensive, design alternatives can always be postulated. However, the staff concludes that the benefits of any additional modifications are unlikely to exceed the benefits of the modifications evaluated and that the alternative improvements would not likely cost less than the least expensive alternatives evaluated, when the subsidiary costs associated with maintenance, procedures, and training are considered.

The staff concludes that SCE&G used a systematic and comprehensive process for identifying potential plant improvements for V. C. Summer, and that the set of potential plant improvements identified by SCE&G is reasonably comprehensive and therefore acceptable. This search included reviewing insights from the IPE and IPEEE, and plant improvements considered in previous SAMA analyses. While explicit treatment of external events in the SAMA identification process was limited, the staff recognizes that the absence of external event vulnerabilities reasonably justifies examining primarily the internal events risk results for this purpose.

G.4.0 Risk Reduction Potential of Plant Improvements

SCE&G evaluated the risk-reduction potential of the 12 Phase 2 SAMAs applicable to V. C. Summer, as well as several additional SAMAs suggested by the staff.

SCE&G used model re-quantification to determine the potential benefits. The CDF and population dose reductions were estimated using version UP3a of the V. C. Summer PRA. The changes made to the model to quantify the impact of each SAMA are detailed in Sections 5.1 through 5.11 of Appendix F to the ER (SCE&G 2002).

In response to a staff request, SCE&G further examined several SAMAs including those closest to being cost beneficial to determine the extent to which the SAMAs might reduce external event risk (SCE&G 2003b). The SAMAs considered include: Phase 2 SAMA 3, Phase 2 SAMA 10, use of a portable 120V DC generator to supply power to the steam generator level instrumentation, installation of a direct-drive diesel emergency feedwater pump, and use of the fire service water for make-up to the steam generators. This assessment included consideration of both seismic and fire risk. Based on this assessment, SCE&G concluded that although some credit may be taken for these SAMAs in external events, the benefit is more limited than in the internal events analysis. For example, power recovery in fire events may create additional difficulties not present for the initiators addressed in the internal events model. Also, the low cost alternatives would not be required to meet the rigors of a seismically-qualified component, and therefore, may not be useable following a seismic event. Nevertheless, SCE&G conservatively increased the benefit for these SAMAs by a factor of two to account for external events. Table G-3 lists the assumptions used to estimate the risk reduction for each of the 12 SAMAs and several alternatives suggested by the staff (SCE&G 2003a), the estimated risk reduction in terms of percent reduction in CDF and population dose, and the estimated total benefit (present value) of the averted risk. The estimated benefit for all SAMAs was increased by 15% to account for the resolution of peer review comments. The determination of the benefits, and the impact of uncertainties and external events is discussed in Section G.6.2.

Table G-3. SAMA Cost/Benefit Screening Analysis

Phase 2 SAMA	Assumptions	% Risk Reduction		Total Benefit ($)	
		CDF	Population Dose	Baseline	Revised[1]
2 - Add redundant DC control power for service water pumps	Reduce CDF by lowering the failure probability of the service water system. Reduce the loss of service water initiating event frequency.	0.2	~0	1,200	1,400
3 - Use existing hydro-test pump for reactor coolant pump (RCP) seal injection	Reduce CDF by providing an alternate source of seal cooling when component cooling water has failed. Add CNU_8 event to account for cold water injection shock.	9	0.5	10,300[2]	23,700[3]
9 - Refill the refueling water storage tank (RWST)	Reduce CDF during extended SBO or LOCAs which render the residual heat removal (RHR) system inoperable	2	1.5	23,800	27,400
10 - Improve the 7.2 kV bus cross-tie capability through emergency procedure and hardware change	Reduce CDF from loss of offsite power events with one failed diesel generator in combination with failure of required equipment on the remaining powered emergency bus	1	0.1	20,600	47,400[3]
11 - Install relief valves in the component cooling system	Decrease ISLOCA frequency by providing overpressure protection for the component cooling system	0.2	65.9	39,700	45,700
12 - Ensure all ISLOCA releases are scrubbed	Reduce the radionuclide release to the environment given that an ISLOCA has occurred	0.2	65.9	39,700	45,700
13 - Improved main steam isolation valve design	Impact isolation capability in accident response scenarios as well as for spurious closures that would be classified as initiating events. The failure to close probability is reduced by a factor of 10 as is the loss of condenser initiating event.	0.4	0.1	5,800	6,700

Table G-3. (contd)

Phase 2 SAMA	Assumptions	% Risk Reduction		Total Benefit ($)	
		CDF	Population Dose	Baseline	Revised[1]
20 - Replace current power-operated relief valves (PORVs) with larger ones so that only one is required for successful feed and bleed	Change success criteria for feed and bleed from two of three to one of three PORVs.	1.6	0.2	17,800	20,400
24 - Create automatic swap over to recirculation on refueling water storage tank (RWST) depletion — charging pump suction swap to RHR heat exchanger discharge	Improve the reliability of the transition to recirculation mode after depletion of the RWST. Add new logic to control the RWST and charging pump suction valves.	31	30.1	377,800	434,500
24a - Create automatic swap over to recirculation on RWST depletion — RHR suction swap to the sump from the RWST	This is a sensitivity case which assumes the operator always fails to align and establish cold leg recirculation.	9	28.2	117,800	135,400
25 - Improved low pressure system, i.e., use of the fire service system pumps for low-pressure injection to the reactor pressure vessel (RPV)	Use current RHR piping as injection path for fire pumps. Operator action to align pumps is required. Use lumped event to represent hardware and operator action.	9.3	19.9	117,500	135,100
26 - Replace old air compressors with more reliable ones	Increase reliability of the instrument air system. Reduce initiating event frequency for loss of instrument air, and the failure to start and run probabilities of the air compressors.	1.1	0.3	13,100	15,100
27 - Install motor generator (MG) set trip breakers in control room	Increase the reliability of manual RCP trip in anticipated transient without scram (ATWS). Eliminates all ATWS risk as a bounding estimate.	1.6	0.1	18,600	21,300

Table G-3. (contd)

Phase 2 SAMA	Assumptions	% Risk Reduction		Total Benefit ($)	
		CDF	**Population Dose**	**Baseline**	**Revised[1]**
	Low Cost Alternatives [not originally part of the Phase 2 SAMA process]				
A-1 - Use portable 120V DC generator to supply power to steam generator (SG) level instrumentation	Provide power to EFW instrumentation during an SBO event to aid the operators in controlling SG level after battery depletion at 4 hours.	0.2	~0	3,300	7,600[3]
A-2 - Add a cross-tie to existing non-safety station batteries	Permit successful operation of the turbine-driven EFW pump (TDEFWP) during an SBO following battery depletion.	0.2	~0	3,300	3,800
A-3 - Use direct-drive diesel emergency feedwater (EFW) pump	Provide flow to the SGs during an SBO event given the failure of the TDEFWP. The direct-drive diesel EFW pump will be available as an alternate motive source for the TDEFWP. Use independent start and run failure term for the direct-drive diesel. Use shared test and maintenance terms as failure modes for direct-drive diesel.	13.1	0.9	152,600	351,000[3]
A-4 - Create automatic safety injection pump trip on low RWST level	Prevent pump damage due air entrainment or cavitation upon a loss of suction source. Provide an addition cue for control room operators to complete alignment of recirculation mode cooling.	0.02	~0	300	350
A-5 - Use fire service water for makeup to steam generators	Provide flow to SGs during an SBO event. Secondary side depressurization has succeeded. Further SG depressurization (from 240 psig to 100 psig) is necessary to as part of the alignment of the fire service system to the SGs.	<0.1	~0	1,100	2,600[3]

[1]The reported benefit for all SAMAs includes a 15% increase to account for an expected increase in CDF when PRA peer review comments are addressed.
[2]In the ER, the benefit was estimated to be $103,000 (SCE&G 2002). In response to an RAI, the benefit was reduced to $10,300 when using more realistic assumptions (SCE&G 2003a).
[3]The reported benefit includes a 15% increase to account for an expected increase in CDF when PRA peer review comments are addressed, plus an additional factor of two increase to account for benefits from external events (SCE&G 2003b).

The staff has reviewed SCE&G's bases for calculating the risk reduction for the various plant improvements and concludes that the rationale and assumptions for estimating risk reduction are reasonable and, for the above reasons, are generally conservative (i.e., the estimated risk reduction is higher than what would actually be realized). Accordingly, the staff based its estimates of averted risk for the various SAMAs on SCE&G's risk reduction estimates.

G.5.0 Cost Impacts of Candidate Plant Improvements

SCE&G estimated the costs of implementing the 12 SAMAs which were not initially screened out. The cost estimates conservatively did not include the cost of replacement power during any extended outages that might be needed to implement the modifications. Estimates that were taken from prior SAMA analyses were not adjusted to present-day dollars. For many of the SAMAs considered, the cost estimates were significantly greater than the benefits calculated such that a detailed evaluation was not necessary and a specific dollar value was not reported. Cost estimates were provided for the following SAMAs:

SAMA	Description	Cost Estimate ($)
3	Use existing hydro-test pump for RCP seal injection	150K - 170K
10	Improve 7.2 kV bus cross-tie capability	>50K
24	Create automatic swap over to recirculation on RWST depletion	1.2M
25	Install additional diesel-driven fire pump to provide low-pressure injection to the RPV from the RWST through existing RHR piping	565K
A-1	Use portable 120V DC generator to supply power to steam generator level instrumentation	84K
A-2	Add a cross-tie to existing non-safety station batteries	59K
A-3	Add direct-drive diesel EFW pump	800K
A-4	Create automatic safety injection pump trip on low RWST level	750K
A-5	Use fire service water for makeup to steam generators	28K

The staff reviewed the bases for the applicant's cost estimates. For certain improvements, the staff also compared the cost estimates (presented in Table F.6-1 of Appendix F to the ER) to estimates developed elsewhere for similar improvements, including estimates developed as part of other licensees' analyses of SAMAs for operating reactors and advanced light-water reactors. A majority of the SAMAs were eliminated from further consideration on the basis that the expected implementation cost would be much greater than the estimated risk reduction benefit. This is reasonable for the SAMAs considered given the relatively small estimated benefit for the SAMAs (a maximum benefit of about $378K based on the analyses contained in the ER), and the large implementation costs typically associated with major hardware changes and hardware changes that impact safety-related systems. In previous SAMA evaluations the implementation costs for such hardware changes were generally estimated to be $1 million or more.

The staff notes that the cost to implement a direct-drive diesel EFW pump at another plant was estimated to be about $200K. SCE&G estimated the cost of the modification to be about $800K based on the following: $200K for design, $200K for evaluations, $100K for materials, $200K for implementation, $30K for training, and $80K for documentation and closeout (SCE&G 2003c). To verify the validity of the $800K cost, the staff reviewed the costs for similar modifications evaluated in other plants' SAMA analyses as summarized below:

- $460K for installation of a safety-related SW pump (Calvert Cliffs)

- $300K - $600K to provide capability for diesel-driven, low pressure vessel makeup (adding a line from the firewater header, a post indicator valve in the yard and safety-related double isolation valves to the connection with the LHSI) (Surry)

- >$890K to replace two of the four safety injection pumps with diesel pumps (Turkey Point). Assuming that one pump would be half of this cost, the value would be >$445K.

- >$2M to install a motor-driven feedwater pump (Peach Bottom)

- $480K to install a suppression pool jockey pump (Peach Bottom).

Although SCE&G's cost estimate is significantly greater than $200K, it does not appear to be unreasonable relative to the cost estimates for similar modifications. The staff concludes that the cost estimates provided by SCE&G are sufficient and appropriate for use in the SAMA evaluation.

G.6.0 Cost-Benefit Comparison

SCE&G's cost-benefit analysis and the staff's review are described in the following sections.

G.6.1 SCE&G Evaluation

The methodology used by SCE&G was based primarily on NRC's guidance for performing cost-benefit analysis, i.e., NUREG/BR-0184, *Regulatory Analysis Technical Evaluation Handbook* (NRC 1997d). The guidance involves determining the net value for each SAMA according to the following formula:

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

where,

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

If the net value of a SAMA is negative, the cost of implementing the SAMA is larger than the benefit associated with the SAMA and it is not considered cost beneficial. SCE&G's derivation of each of the associated costs is summarized below.

<u>Averted Public Exposure (APE) Costs</u>

The APE costs were calculated using the following formula:

APE = Annual reduction in public exposure (Δperson-rem/year)
x monetary equivalent of unit dose ($2,000 per person-rem)
x present value conversion factor (10.76 based on a 20-year period with a 7-percent discount rate).

As stated in NUREG/BR-0184 (NRC 1997d), it is important to note that the monetary value of the public health risk after discounting does not represent the expected reduction in public health risk due to a single accident. Rather, it is the present value of a stream of potential losses extending over the renewal period for the facility. Thus, it reflects the expected annual loss due to a single accident, the possibility that such an accident could occur at any time over the renewal period, and the effect of discounting these potential future losses to present value. For the purposes of initial screening, SCE&G calculated an APE of approximately $20,500 for the 20-year license renewal period, which assumes elimination of all severe accidents.

Averted Offsite Property Damage Costs (AOC)

The AOCs were calculated using the following formula:

AOC = Annual CDF reduction
x offsite economic costs associated with a severe accident (on a per-event basis)
x present value conversion factor.

For the purposes of initial screening which assumes all severe accidents are eliminated, SCE&G calculated an annual offsite economic risk of about $2,700 based on the Level 3 risk analysis. This results in a discounted value of approximately $29,500 for the 20-year license renewal period.

Averted Occupational Exposure (AOE) Costs

The AOE costs were calculated using the following formula:

AOE = Annual CDF reduction
x occupational exposure per core damage event
x monetary equivalent of unit dose
x present value conversion factor.

SCE&G derived the values for averted occupational exposure from information provided in Section 5.7.3 of the regulatory analysis handbook (NRC 1997d). Best estimate values provided for immediate occupational dose (3300 person-rem) and long-term occupational dose (20,000 person-rem over a 10-year cleanup period) were used. The present value of these doses was calculated using the equations provided in the handbook in conjunction with a monetary equivalent of unit dose of $2,000 per person-rem, a real discount rate of 7-percent, and a time period of 20 years to represent the license renewal period. For the purposes of initial screening, which assumes all severe accidents are eliminated, SCE&G calculated an AOE of approximately $21,300 for the 20-year license renewal period.

Averted Onsite Costs (AOSC)

Averted onsite costs (AOSC) include averted cleanup and decontamination costs and averted power replacement costs. Repair and refurbishment costs are considered for recoverable accidents only and not for severe accidents. SCE&G derived the values for AOSC based on information provided in Section 5.7.6 of the regulatory analysis handbook (NRC 1997d).

SCE&G divided this cost element into two parts – the Onsite Cleanup and Decontamination Cost, also commonly referred to as averted cleanup and decontamination costs, and the replacement power cost.

Averted cleanup and decontamination costs (ACC) were calculated using the following formula:

ACC = Annual CDF reduction
x present value of cleanup costs per core damage event
x present value conversion factor.

The total cost of cleanup and decontamination subsequent to a severe accident is estimated in the regulatory analysis handbook to be $\$1.5 \times 10^9$ (undiscounted). This value was converted to present costs over a 10-year cleanup period and integrated over the term of the proposed license extension. For the purposes of initial screening, which assumes all severe accidents are eliminated, SCE&G calculated an ACC of approximately $663,000 for the 20-year license renewal period.

Long-term replacement power costs (RPC) were calculated using the following formula:

RPC = Annual CDF reduction
x present value of replacement power for a single event
x factor to account for remaining service years for which replacement power is required
x reactor power scaling factor

SCE&G based its calculations on the value of 966 MWe. Therefore, SCE&G applied a power scaling factor of 966 MWe/910 MWe to determine the replacement power costs. For the purposes of initial screening, which assumes all severe accidents are eliminated, SCE&G calculated an RPC of approximately $469,000 for the 20-year license renewal period.

Using the above equations, SCE&G estimated the total present dollar value equivalent associated with completely eliminating severe accidents at V. C. Summer to be about $1.2M.

<u>SCE&G's Results</u>

If the implementation costs were greater than the maximum attainable benefit (MAB) of $1.2M, then the SAMA was screened from further consideration. Thirty-seven of the 69 SAMAs surviving the Phase 1 screening were eliminated from further consideration in this way. Twenty additional SAMAs were eliminated because, based on plant-specific PRA insights, they did not provide a significant safety benefit, or because the cost of implementation would be greater than the benefits associated with implementing the SAMA, leaving 12 for final analysis. A more refined look at the costs and benefits was performed for the remaining 12 SAMAs, plus several alternative SAMAs identified by the staff. The cost-benefit results for these SAMAs are presented in Table G-3. As a result, all SAMAs that were evaluated were eliminated because the cost was expected to exceed the estimated benefit.

SCE&G performed sensitivity analyses to evaluate the impact of parameter choices on the analysis results (SCE&G 2002, 2003a). The sensitivity analyses included the calculation of candidate SAMA benefits using a 3-percent real discount rate as recommended in NUREG/BR-0184 (NRC 1997d). This sensitivity case resulted in less than a factor of 1.2 increase in the benefit calculation. Additionally, SCE&G considered the impact on results if the 95th percentile value of the CDF were utilized in the cost-benefit analysis instead of the mean CDF. This analysis resulted in about a factor of 2.3 increase in the benefit calculation. These analyses did not change SCE&G's conclusion that none of the candidate SAMAs would be cost beneficial.

G.6.2 Staff Evaluation

The cost-benefit analysis performed by SCE&G was based primarily on NUREG/BR-0184 (NRC 1997d) and was executed consistent with that guidance.

In response to an RAI, SCE&G considered the uncertainties associated with the calculated CDF (Table G-4). If the 95th percentile values of the CDF were utilized in the cost-benefit analysis instead of the mean CDF value cited above, the estimated benefits of the SAMAs would increase by about a factor of 2.3. SCE&G revisited the set of SAMAs screened out in Phase 1 of the evaluation and identified seven additional SAMAs that could be cost-beneficial using the 95th percentile value of the CDF. In Table 4.b-1 of the response to the RAI, SCE&G discusses the cost of implementation and the benefit for each of these additional SAMAs (SCE&G 2003a). The averted cost-risk (benefit) was estimated by utilizing RRWs or the averted cost-risk for similar SAMAs, and then scaling this value by a factor of 2.3 in order to account for the 95th percentile PRA results. All seven SAMAs were found to have implementation costs greater than their averted cost-risk (benefit), and thus, were eliminated from further consideration. The staff reviewed the information provided by the applicant in response to this RAI and agrees with the conclusion that none of the newly identified Phase 2 SAMAs would be cost beneficial.

Table G-4. Uncertainty in the calculated CDF for V. C. Summer

Percentile	CDF (per year)
5th	1.87×10^{-5}
median	4.44×10^{-5}
mean	5.63×10^{-5}
95th	1.32×10^{-4}

SCE&G revisited the cost-benefit analyses for the 12 Phase 2 SAMAs and found that when the 95^{th} confidence level is used, SAMAs 3 and 10 potentially become cost beneficial (SCE&G 2003a). These SAMA were further evaluated and dispositioned as summarized below:

SAMA 3 involves use of the existing hydro-test pump for RCP seal injection. This would reduce the CDF by providing an alternate source of cooling when CCW has failed. A benefit of $103K was initially calculated for this SAMA based on internal events, as described in Response 4c to the RAI. In their RAI response (SCE&G 2003a), SCE&G noted that the evaluation used a lumped event in the model which did not account for power dependencies, and assumed an optimistic reliability value (a failure probability of 0.001). Additionally, the benefit estimate did not consider that the RCP seals may heat up and fail while the alternate cooling method is being aligned, or could fail as a result of thermal shock when cold water is eventually reintroduced. When power dependencies and thermal effects are included in the model, the benefit of this SAMA is reduced to about $10K. The staff agrees that these modeling considerations are valid and that the benefits associated with this SAMA would be small, given that it derives from low probability sequences in which CCW is lost in conjunction with the charging pumps. This benefit was subsequently increased by 15% to account for an expected increase in CDF when PRA peer review comments are addressed, plus an additional factor of two to account for benefits from external events, resulting in a total benefit of about $24K. Using the 95^{th} percentile CDF for internal events, the benefit would also be about $24K. SCE&G estimated the cost of implementation to be approximately $150K to $170K. Accordingly, this SAMA is not cost-beneficial.

SAMA 10 involves improvements to the 7.2 kV bus cross-tie via the development of emergency procedures that contain step-by-step instructions for performing the cross-tie. An averted cost-risk (benefit) of $20.6K was initially calculated for this SAMA based on internal events, as described in response 4c to the RAI (SCE&G 2003a). The estimated benefit was subsequently increased by 15% to account for an expected increase in CDF when PRA peer review comments are addressed, plus an additional factor of two to account for benefits from external events, resulting in a total benefit of about $48K (SCE&G 2003b). Using the 95^{th} percentile results in conjunction with the internal events CDF, the benefit would also be about $48K (SCE&G 2003a). In the ER, SCE&G estimated the cost of implementation to be approximately $25,000 to $50,000. However, in their RAI response (SCE&G 2003a), SCE&G noted that this SAMA would require modification to controls in the main control room. Costs associated with this aspect were not considered in the original cost estimate provided, nor were costs associated with the engineering analysis needed to support the modification. When these additional costs factors are included, the implementation costs would be substantially greater than $50K. Accordingly, this SAMA is not cost-beneficial.

The staff questioned SCE&G about lower cost alternatives to several of the SAMAs evaluated, including the use of: (1) a portable 120V DC generator to supply power to the steam generator instrument panels, (2) a cross-tie to the existing non-safety station batteries, (3) a direct-drive diesel emergency feedwater pump, and (4) an automatic safety injection pump trip on low RWST level as an alternative to an automatic swap to recirculation (NRC 2003a). In response, SCE&G provided estimated benefits and implementation costs for each alternative. Based on these estimates, none of these alternatives appear cost beneficial. Specifically, SCE&G estimated that the portable 120V DC generator alternative would have a benefit of $7.6K (including impact of external events) and an implementation cost of $84K (SCE&G 2003a, 2003b). The cross-tie to the existing non-safety station batteries would have a benefit of $3300 and an implementation cost of $59K. The direct-drive emergency feedwater pump would have a benefit of $351K (including impact of external events) and a revised implementation cost of $800K (SCE&G 2003a, 2003b). The fourth alternative would have a benefit of $300 which is far less than the estimated implementation cost of $750K (SCE&G 2003a). SCE&G determined that none of the alternative SAMAs suggested in the RAI would be cost beneficial.

For the portable120V DC generator alternative, a key factor in the evaluation is the human error probability associated with the operation of the turbine driven EFW pump after battery depletion. SCE&G assumed a value of 0.0041 in the baseline analysis, and provided supporting justification for this value in response to RAIs (SCE&G 2003a and 2003b). The rationale includes consideration of the long time period available for operator and technical support center staff to achieve specified steam generator levels prior to battery depletion, the relatively minor adjustments to feed rates that would be necessary following battery depletion, and the available procedures and local indications associated with the necessary human actions. Although it is SCE&G's position that the value of 0.0041 is appropriate, they provided a sensitivity case in which the baseline human error probability for operation of the turbine driven EFW was increased to a nominal value of 0.1. Given this assumption, the benefit increases to about $51K. If a factor of two is added to account for benefits from external events, as was done for the baseline case, the benefit would become $102K. When compared to the implementation cost of $84K, this SAMA appears to be cost beneficial. However, as noted in Section G.4.0, the benefit of this SAMA in external events would be limited by factors such as equipment operability after a seismic event. The staff concludes that given more realistic assumptions regarding risk reduction achievable in external events, and a somewhat lower nominal human error probability that might be justified based on the rationale provided by SCE&G, this SAMA would not be cost beneficial.

SCE&G estimated the benefit of the direct-drive diesel EFW pump to be $153K. The staff, noting that the estimated cost to implement this modification at another plant was about $200K, issued a supplmental RAI regarding the estimated benefits. In response to the supplemental RAI, SCE&G provided a revised risk reduction estimate of about $350K, which included both a 15% increase to account for the resolution of peer review comments and a factor of two increase to account for additional benefits that might be achieved in external events. However, SCE&G also estimated the plant-specific cost to implement this modification to be about $800K for V. C. Summer. The cost estimates are discussed further in Section G.5.0. Based on the revised cost and benefit estimates, the staff finds that the applicant's assessment is reasonable, and concludes that this SAMA is not cost-beneficial.

In addition, the staff requested a cost-benefit assessment for using the fire protection system as a backup for maintaining steam generator inventory. This alternative was estimated to have a benefit of $2.6K (including impact of external events) and an implementation cost of $28K, and would therefore not be cost beneficial (SCE&G 2003b).

SCE&G also performed a sensitivity analysis that addressed variations in discount rate. The use of a three-percent real discount rate (rather than seven percent used in the baseline) results in an increase in the maximum attainable benefit of approximately 13 percent. The results of the sensitivity study are bounded by the uncertainty assessment described above, which considered an increase of a factor of 2.3.

The staff concludes that the costs of all of the SAMAs assessed would be higher than the associated benefits. This conclusion is supported by sensitivity analysis and upheld despite a number of additional uncertainties and non-quantifiable factors in the calculations, summarized as follows:

- Uncertainty in the internal events CDF was not initially included in the calculations, which employed best-estimate values to determine the benefits. The 95th percentile CDF for internal events is approximately 2.3 times the mean value. Even upon considering the benefits at the 95th percentile value, no SAMAs were judged to be cost-beneficial. Therefore, the staff does not expect the consideration of CDF uncertainty to alter the conclusions of the analysis.

- External events were similarly not included in the V. C. Summer risk profile. However, given that the expected external events contribution to CDF is calculated in a conservative fashion and is expected to be on the same order of magnitude as the internal events contribution to CDF, a factor of two increase in the maximum attainable benefits to account for the external events should be conservative. In response to an RAI, SCE&G re-evaluated several SAMAs that were closest to being cost beneficial by increasing the benefits by 15% to account for PRA peer review comments, plus an additional factor of two to account for external events. This equates to a factor of 2.3 which is the same as the factor considered in the uncertainty assessment. As a result, none of the evaluated SAMAs were cost beneficial. Therefore, the staff concludes that a more detailed assessment would not yield any new SAMAs.

- The staff finds the risk reduction and cost estimates to be reasonable, and generally conservative. As such, uncertainty in the costs of any of the contemplated SAMAs would not likely have the effect of making them cost beneficial.

G.7.0 Conclusions

SCE&G compiled a list of 268 SAMA candidates using the SAMA analyses as submitted in support of licensing activities for other nuclear power plants, NRC and industry documents discussing potential plant improvements, and the plant-specific insights from the V. C. Summer IPE, IPEEE, and current PRA model. A qualitative screening removed SAMA candidates that (1) were not applicable at V. C. Summer due to design differences, (2) were sufficiently similar to another SAMA such that they could be combined, (3) had already been implemented at V. C. Summer, or (4) did not provide a significant safety benefit. A total of 199 SAMA candidates were eliminated based on the above criteria, leaving 69 SAMA candidates for further evaluation.

Using guidance in NUREG/BR-0184 (NRC 1997d), the current PRA model, and a Level 3 analysis developed specifically for SAMA evaluation, a maximum attainable benefit of about $1.2M was calculated, representing the total present dollar value equivalent associated with completely eliminating severe accidents at V. C. Summer. Thirty-seven of the 69 SAMAs were eliminated from further evaluation because their implementation costs were greater than this maximum attainable benefit. An additional 20 SAMAs were eliminated because, based on plant-specific PRA insights, they did not provide a significant safety benefit, or because the cost of implementation would be greater than the benefits associated with implementing the SAMA. For the remaining 12 SAMA candidates and several additional alternatives identified by the staff, more detailed conceptual design and cost estimates were developed as shown in Table G-3. The cost-benefit analyses showed that none of the candidate SAMAs were cost-beneficial.

The staff reviewed the SCE&G analysis and concluded that the methods used and the implementation of those methods were sound. The treatment of SAMA benefits and costs, the generally large negative net benefits, and the small baseline risks support the general conclusion that the SAMA evaluations performed by SCE&G are reasonable and sufficient for the license renewal submittal. The unavailability of a seismic and fire PRA model precluded a quantitative evaluation of SAMAs specifically aimed at reducing risk of these initiators; however, improvements have been realized as a result of the IPEEE process at V. C. Summer that would minimize the likelihood of identifying further cost-beneficial enhancements in these areas. To assess the potential impact of uncertainties in the analysis or the inclusion of additional benefits in external events, SCE&G applied a factor of two multiplier to the estimated benefits based on internally-initiated events, and confirmed that even when considering the increase in the benefits, none of the SAMAs become cost beneficial.

Based on its review of the SCE&G SAMA assessment and as explained above, the staff finds that none of the candidate SAMAs are cost beneficial. This is based on conservative treatment of costs and benefits. This conclusion is consistent with the low residual level of risk indicated in the V. C. Summer PRA and the fact that V. C. Summer has already implemented plant improvements identified from the IPE and IPEEE processes.

G.8.0 References

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