VALUE IMPACT ANALYSIS OF POTENTIAL PLANT ENHANCEMENTS FOR WATTS BAR

Revision 1

Executive Summary Only

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EXECUTIVE SUMMARY

As part of an ongoing effort to utilize and apply the Individual Plant Examination (IPE) for the Watts Bar Nuclear Plant (WBN), Tennessee Valley Authority (TVA) undertook an effort to identify potential cost effective plant enhancements. This effort was originally submitted to the NRC June 30, 1994. The report provided a summary of the systematic identification, review and evaluation of potential plant enhancements based on an updated version of the WBN IPE. As a result of the value impact assessment, TVA committed to implement two of the enhancements that were identified in the study as cost effective. In addition, one other procedural enhancement, which had not been identified as cost effective, was implemented independently for operational reasons. The purpose of this revised executive summary is to provide an update to the executive summary submitted in the original value impact evaluation which reflects the implementation of the three enhancements. A revised PRA model was developed to provide a new baseline case which reflects the enhancements to be implemented. The results of the value impact assessments of other enhancements were recalculated based on the new re-baselined result.

METHODOLOGY

The overall approach to the evaluation of potential plant enhancements is essentially unchanged from the original submittal. An overview of the process used is shown in Figure 1. The process involved the seven steps described below:

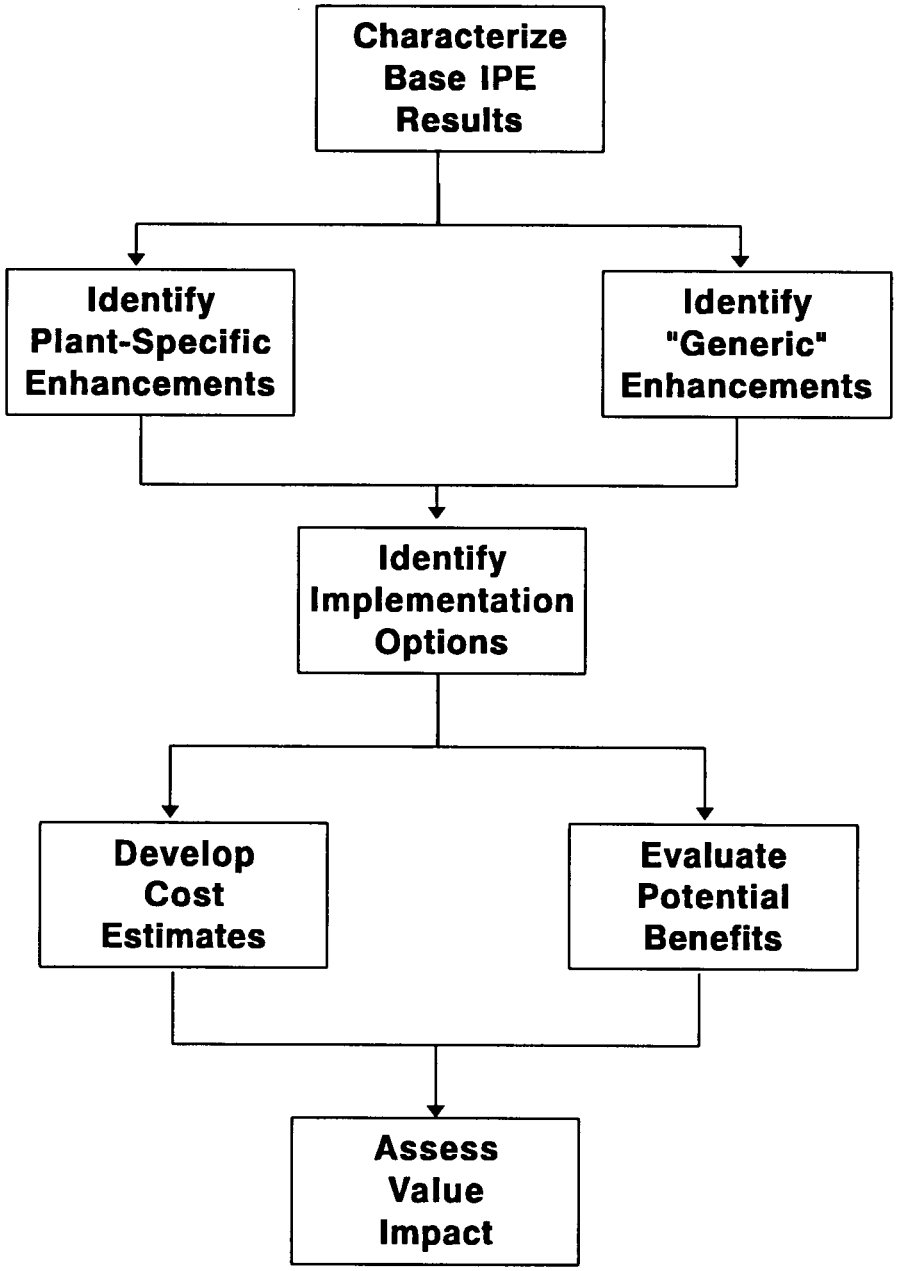
Step 1: Characterize Base IPE Results - This step involved the review of the IPE results to identify the major plant design features, procedures and functional failures which were contributors to core damage and containment failure.

Step 2: Identify Plant-Specific Enhancements - This step involved the detailed, systematic review of the IPE results to identify specific plant features which were important to risk and features which could be added to the plant design or procedures to reduce risk in light of the overall characterization of the IPE performed in Step 1. This involved the review of all split fractions and dominant sequences from the Level 1 and 2 PRA.

Step 3: Identify "Generic" Enhancements - This step involved the investigation of enhancements which were already present at other plants or had been considered as potentially cost-effective enhancements in other industry or NRC studies in light of the overall characterization of the IPE performed in Step 1. Sources reviewed include other ice condenser IPEs,

Figure 1

PROCESS FOR IDENTIFICATION & EVALUATION OF POTENTIAL PLANT ENHANCEMENTS



NUREG-1150, Supplement 2 to Generic Letter 88-20, severe accident mitigation design alternative (SAMDA) submittals by other plants, among others.

Step 4: Identify Implementation Options - This step involved the definition of specific plant enhancement options for WBN, given the overall results of the IPE and the variety of potential enhancements identified from the plant specific and generic reviews. The purpose of the step was to provide sufficient definition to the enhancement to allow cost estimation and modeling of the benefit.

Step 5: Develop Cost Estimate - This step involved the development of order of magnitude cost estimates for the various implementation options identified in Step 4. In cases where specific details of the WBN design were involved, these estimates were developed specifically by TVA for WBN. In other cases where the enhancement was general in nature, previous cost estimates (industry or NRC) were used as representative.

Step 6: Evaluate Potential Benefits - This step involved the utilization of the WBN IPE model and results to evaluate the potential risk reduction associated with each implementation option. The benefit was expressed in terms of averted off-site dose to the public (e.g., person-rem) as well as other less quantitative effects.

Step 7: Assess Value Impact - This step involved the comparison of the cost and benefits to determine whether the enhancement was potentially cost beneficial. Any enhancement which had a cost to benefit ratio of less than $1000 per person-rem was considered cost beneficial.

ENHANCEMENTS TO BE IMPLEMENTED

The original value impact assessment identified two potential plant enhancements as potentially cost effective. These two enhancements were:

I.1 - Procedure Change To Stop One Train of Sprays

This enhancement involves a change to the WBN emergency operating procedures (EOPs) to direct the stopping of one of the containment spray pumps in the event of a small loss of coolant accident (LOCA) before recirculation is required. This would reduce the rate of refueling water tank storage (RWST) depletion and substantially increase the time for operator actions following a small LOCA. This additional time would manifest itself

in a reduction in operator error rates and provide adequate time for local operator recovery actions to manually open motor operated valves (MOVs) which failed to realign.

II.1 - Procedure Change To Facilitate Cross-tie of 500kV and 161kV AC Power

The 6.9kV Shutdown Boards at Watts Bar Unit 1 are provided offsite power from the 161kV grid. Another, independent 500kV grid is connected to the WBN site, but is not currently allowed to be tied to the Unit 1 shutdown boards. A physical connection is possible, via bus cross-ties at Unit 2, but the current plant procedures do not support this crosstie. This enhancement would provide procedures and training on the crosstie of the 500kV grid to the Unit 1 shutdown boards.

In addition, for operational reasons, TVA has implemented one of the other enhancements evaluated in the original value impact assessment:

III.1 - Procedure Change To Utilize Existing Spare 6900V/480V Transformers

WBN Unit 1 has two additional spare 6900V/480V transformers which can be aligned to provide power to the 480V shutdown boards and MOV boards in the event one of the normal transformers fail. In the review of dominant split fractions from the IPE, it was identified that a procedure could be developed to assist plant operators in making the necessary bus/transformer alignments. This procedure has been developed and is in place.

The other enhancements evaluated in the original value impact assessment are evaluated in this report.

CHARACTERIZATION OF RE-BASELINED RESULTS

The original value impact assessment submitted June 30, 1994, utilizes an updated version of the IPE for Watts Bar, Unit 1. In that analysis the mean point estimate core damage frequency (CDF) for Watts Bar is 8.0×10^{-5} per reactor-year. The three enhancements have been incorporated into the dominant sequence model used in the value impact analysis in order to re-baseline the results. Tables 1, 2 and 3 provide a summary of the bases and changes made to the model. The enhancements reduce the core damage frequency to 5.8×10^{-5}/reactor-year.

TABLE 1
DESCRIPTION OF CHANGES TO PRA MODEL FOR RE-BASELINING OF VALUE IMPACT ANALYSIS

ENHANCEMENT:

Provide procedure to stop one train of containment spray upon recirculation.

FUNCTIONAL BENEFIT:

Extend time to RWST depletion by stopping one of the two pumps removing inventory. Operation with one train of spray in recirculation is within the existing design basis of plant.

PRA BENEFIT:

Addresses dominant core damage sequences involving small LOCAs and failure of high pressure recirculation by providing additional time for operator alignment of high pressure recirculation and local actions, if necessary to respond to valve failures.

PRA CHANGES AND BASES:

ASSUMPTION	BASES
No credit given for additional time to establish high pressure recirculation	Conservative
MOVs which fail to change position can be locally operated manually to align recirculation	Areas where MOVs are located are accessible. All MOVs involved have manual operators. MOV failure data shows about 85% of failures could be recovered manually.
Additional time to RWST depletion allows time for auxiliary building operator to operate valves.	Time to RWST depletion extended from 20 minutes to 40 minutes. Manual operation of valve would take less than 15 minutes.
Human error rate for local manual valve operation is 0.1	Conservative screening value based on time available and simplicity of task.

TABLE 2

DESCRIPTION OF CHANGES TO PRA MODEL FOR RE-BASELINING OF VALUE IMPACT ANALYSIS

ENHANCEMENT:

Provide procedure for cross-tie of 500kV power (Unit 2) to 161kV power system at Unit 1.

FUNCTIONAL BENEFIT:

Provide alternate method of providing AC power in the event of loss of offsite power to Unit 1. The 500kV grid is independent of the 161kV grid and would provide a diverse source of power to the Unit 1 shutdown boards.

PRA BENEFIT:

Reduce contribution of Loss of Offsite Power (LOSP) sequences to core damage and public risk. Increase the probability of recovery of offsite power following a loss of offsite power.

PRA CHANGES AND BASES:

ASSUMPTION	BASES
Human error rate for alignment is 0.1.	Most of actions performed in control room. Time available - at least 1 hour Time required - less than 30 min. Operators to be trained on procedure.
Unavailability of 500kV grid is 0.1.	Based on NSAC loss of offsite power data which shows 10% of all LOSP are due to weather related events. Conservatively assumes that all weather related events fail both grids.

TABLE 3

DESCRIPTION OF CHANGES TO PRA MODEL FOR RE-BASELINING OF VALUE IMPACT ANALYSIS

ENHANCEMENT:

Provide procedure to utilize spare 6900V to 480V transformers to supply shutdown boards.

FUNCTIONAL BENEFIT:

Provide a diverse means of supplying the 480V shutdown boards in the event a normal transformer is unavailable.

PRA BENEFIT:

Reduce unavailability of 480V shutdown boards, a key contributor to core damage risk.

PRA CHANGES AND BASES:

ASSUMPTION	BASES
Existing spare transformers could be utilized to support 480V boards.	Existing installed spare hardware identified to normal transformers.
Remove preventive maintenance unavailability of transformers from split fractions.	Spare transformers would be utilized during preventive maintenance.
Procedure to align spare transformers not credited during accidents.	Conservative.

The major reductions in core damage frequency came from reductions in loss of offsite power and LOCA related event sequencies. The core damage frequency contribution from loss of offsite power is reduced by 50%, from 1.8 x 10^{-5}/yr to 9 x 10^{-6}/yr. The core damage frequency contribution from LOCAs is reduced by 37%, from 2.4 x 10^{-5}/yr to 1.5 x 10^{-5}/yr.

The following table provides a comparison of the re-baselined results to other ice condenser IPEs. In terms of overall CDF, Table 4 shows that Watts Bar Unit 1 falls within the range of values reported for other plants.

Table 4 Comparison of Ice Condenser IPE Level 1 Results

Ice Condenser Plant IPE	Mean CDF (per reactor-year)
Sequoyah 1,2 IPE	1.7×10^{-4}
Watts Bar 1 IPE Update	8.0×10^{-5}
DC Cook 1,2 IPE	6.3×10^{-5}
Re-Baselined Watts Bar 1 Result	5.8×10^{-5}
Catawba 1,2 IPE	4.3×10^{-5}

The importance of initiating events was examined by determining the contributions of core damage sequences grouped by initiating event. The ranked results are shown in Figure 2 for eight major initiating event categories.

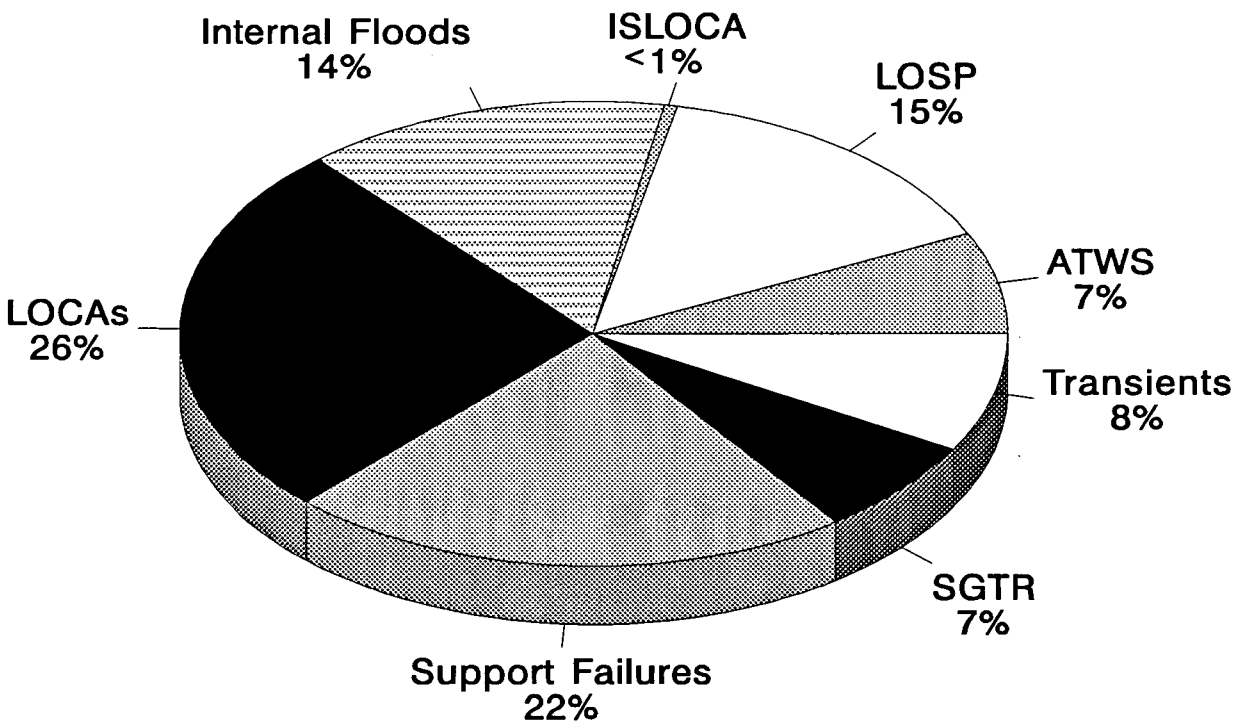
The general class of LOCAs accounts for approximately 26% of the total CDF. This class includes the following specific initiating events: small isolable LOCAs, small non-isolable LOCAs, medium LOCAs, large LOCAs, and excessive LOCAs (e.g., reactor pressure vessel failure). Sequences involving transient-induced LOCAs (e.g., stuck-open pressurizer PORV in response to a loss of main feedwater initiator) are included with the transient initiating event category. These events are primarily characterized by failure of the emergency core cooling systems (ECCS) in recirculation. These failures are due to either operator errors in aligning for recirculation or hardware failures in the recirculation systems.

The general class of support system faults accounts for approximately 22% of the total CDF. Included in this grouping are system and system train failures involving electrical power boards, component cooling water system (CCS), and essential raw cooling water (ERCW).

Figure 2

CORE DAMAGE FREQUENCY CONTRIBUTORS BY INITIATING EVENT GROUP

Re-Baselined Results



Total Mean CDF = 5.8×10^{-5}/yr

LOSP is the next largest contributor to the overall CDF. These sequences contribute approximately 15% to the total CDF. The predominant contributor to LOSP core damage sequences are unit blackout sequences with failure to recover power before core damage.

Internal floods make up approximately 14%. The most important sources of internal floods are associated with a rupture or major flow diversion in one ERCW train combined with failure of the other train. Many of these sequences are effectively a total loss of ERCW. ERCW is an important support system since it provides the ultimate heat sink for reactor coolant pump (RCP) seal cooling and ECCS pump cooling. Thus, a complete loss of ERCW results in an RCP seal LOCA with inadequate coolant makeup capability.

Transient events contribute approximately 8% to the total CDF. These events are generally characterized by subsequent support system failures which lead to a sufficient number of failures in frontline systems to lead to loss of core cooling.

Steam generator tube rupture (SGTR) events contribute approximately 7% to the total CDF. The SGTR event sequences are dominated by sequences involving failure of the plant operators to adequately control reactor coolant inventory.

Sequences without reactor trip (ATWS) contribute approximately 7%. Such sequences may lead to core damage if the initial reactor coolant system (RCS) pressure transient is not mitigated or emergency boration is not accomplished in a timely manner.

Interfacing system LOCAs make up only a very small part of the total CDF (much less than 1%). However, should they lead to core damage, these initiators are significant because of their potential for a large release path to bypass the containment.

SUMMARY OF LEVEL 2 PRA RESULTS

The WBN IPE includes a Level 2 PRA model. This model evaluates the response of the WBN containment to the challenges posed by a severe accident. A reasonable treatment of this continuum is to use a representative set of discrete release categories that span the spectrum from relatively large, early releases to ones which are much smaller, occur later, and/or over a long time period.

A more detailed definition of the Watts Bar release categories is given in Section 2. Table 4 represents a summary of these release categories in terms of general release category groups and percentage of the CDF.

Table 4. Definition and Results for General Release Category Groups

General Release Category Group	Description	Percentage of CDF Analyses*
I	Large, Early Containment Failures and Large Bypasses	2.5
II	Small, Early Containment Failures and Small Bypasses	11.9
III	Late Releases and Long-Term Releases	22.7
IV	Long-Term, Contained Releases (Containment Intact)	62.9

* Group frequency divided by CDF.

The overall contributors to containment failure are shown in Figure 3. This figure shows that nearly two thirds (63%) of the severe accident sequences end up with the containment intact. The largest contributor (12%) to containment failure is late hydrogen burns which result in a late, large failure of containment. Containment bypasses represent the next largest contributor (10%). Most of these sequences were discussed above as large early releases. The next largest contributor is late overpressurization failures (9%). These are largely due to events without containment heat removal and generally result in a late small failure of the containment. Basemat failures represent only 5% of the containment endstates. These failures are due to conditions where the core debris is inadequately cooled and core concrete interaction continues long enough for the containment basemat to be breached.

An important benchmark for a Level 2 PRA is the frequency of large, early releases. For this IPE, the frequency of large, early releases is the sum of Release Category Group I plus that fraction (0.81) of Release Category Group II that is associated with SGTR initiating events with a stuck-open secondary side relief valve. The Watts Bar frequency of large, early release is approximately 10% of the CDF, or 7.0×10^{-6} per reactor year. This frequency is low and is dominated by containment bypass results from SGTR, which accounts for approximately 4.1×10^{-6} per reactor year.

Table 5 lists the major contributors to large, early release. Included in this table is the type of event and the percentage contribution for each event.

Table 5. Major Contributors to Large, Early Release Frequency for Internal Events

Type of Event	Percent Contributions to Large, Early Release*
SGTRs (with bypass to the environment)	79
Containment Failure due to Direct Impingement	12
α-Mode Failure of Vessel/Containment	5
HPME/Hydrogen Burns at Vessel Breach	2
Hydrogen Burns/DDT before and after Vessel Breach	<1
Interfacing System LOCAs	<1

* Sum of Release Category Group I and SGTR Bypasses from Group II.

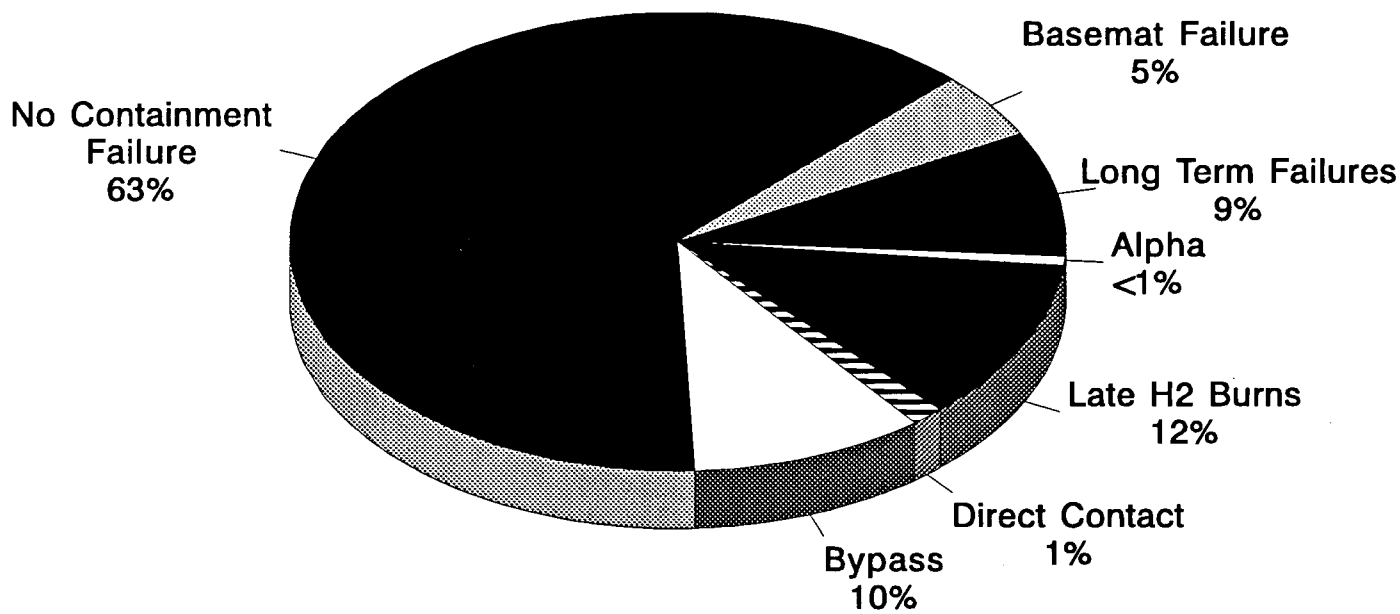
SGTR sequences contribute about 79% to the frequency of large, early releases. Containment failure due to direct impingement of debris in the containment cylinder wall in the seal table room is the second largest contributor. Steam explosions, caused by the interaction of hot fuel with water (i.e., alpha mode) is the third largest contributor. Overpressurization of the containment from hydrogen burns, detonations, and high pressure ejection of molten fuel when the pressure vessel fails contribute less than 3% to the frequency of large, early releases. Less than 1% of the large, early release is caused by interfacing systems LOCA.

SUMMARY POPULATION DOSE RESULTS

The revised Level 1 and Level 2 PRA results were applied in the simplified spreadsheet process described in the original value impact analysis in order to determine a re-baselined population dose estimate for Watts Bar. One change made to the assessment of population dose has been made in the revised value impact assessment. This involves the incorporation of expected population data for the area surrounding the Watts Bar site. The consequence analyses from NUREG-1150 that were used as a basis for the population dose estimates were performed based on 1980 population data. Over the life of the plant, the population around Watts Bar may change. Table 6 provides a summary of the estimated population data for the 50 mile radius around the plant from the Watts Bar FSAR.

Figure 3

SUMMARY OF CONTAINMENT FAILURE MODES
Based On Re-Baselined Results



Total CDF = 5.8×10^{-5}/yr

Table 6 - 50 Mile Population Data For Watts Bar

Year	50 Mile Population	% Increase Over 1980
1980*	749,455	---
1990	862,465	15.1%
1995**	899,130	20.0%
2000	935,795	24.9%
2010	992,167	32.4%
2020	1,037,702	38.5%
2030	1,052,035	40.4%
2035**	1,059,308	41.3%
2040	1,066,580	42.3%

* - Basis for Appendix C dose conversion factors
** - Interpolated value

A time weighted average of the population for the plant operating life (1995 to 2035) is 1,002,588. This yields a potential average increase in the population dose of 34%.

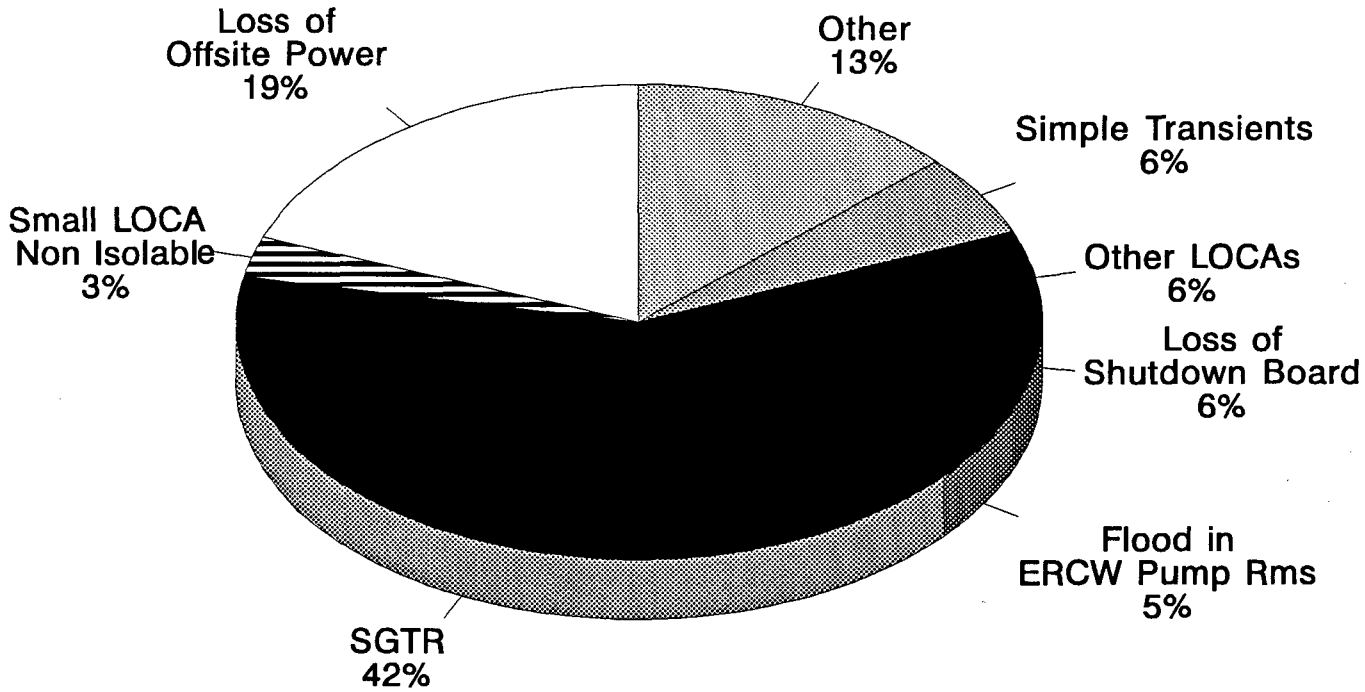
This re-baselining results in an overall annual frequency weighted dose estimate of 5.28 person-rem per year. This is equivalent to a 21% reduction from the dose utilized in the original value impact analysis (without the change in population the result would have been 3.94 person-rem per year). However, by accounting for the population growth around the site, it actually computes as a small increase over the original results. Over the anticipated 40 year plant life, this translates to a total population dose of 211 person-rem. Figure 4 shows the initiating event categories which contribute to the overall risk.

As shown in Figure 4, SGTR and loss of offsite power (LOSP) are the two dominant contributors to overall population dose. SGTR contributes approximately 42% (2.2 person-rem per year) of the total dose. Loss of offsite power contributes approximately 19% (1.0 person-rem per year). All other initiators contribute less than 5% individually and are grouped in Figure 4.

Figure 4

POPULATION DOSE CONTRIBUTORS

Initiating Event Contribution - Re-Baselined Results



Total Dose = 5.28 person-rem/year

Another characterization of the population dose contributors can be made in terms of the NUREG-1150 accident progression bins (APBs). Figure 5 provides a graphical representation of the APB contributors to dose. Containment Bypass, APB 7, is the largest contributor to population dose at approximately 58% (3.1 person-rem per year). This APB includes both bypass events and failure of containment isolation. The five APBs representing early containment failure contribute (APBs 1,2,3,4 and 9) contribute a total of approximately 23% (1.2 person-rem per year). Late containment failure (APB 5) contributes approximately 18% (0.95 person-rem per year) and basemat failures contribute approximately 1% (0.05 person-rem per year).

UNCERTAINTIES IN RESULTS

The analysis of severe accidents involves the consideration of a wide variety of factors, many of which have uncertainties associated with them. The analyses utilized in this value impact assessment utilize best estimate (mean) values for the computation of baseline risk and averted risk. A summary of some of the key sources of uncertainty are as follows:

Core Damage Assessment Uncertainties

- Initiating Event Frequencies
- Component Failure Rates
- Component Unavailabilities
- Human Error Rates

Containment Performance Assessment Uncertainties

- Severe Accident Phenomena
- Component/System Performance In Severe Accidents
- Containment Response

Consequence Assessment Uncertainties

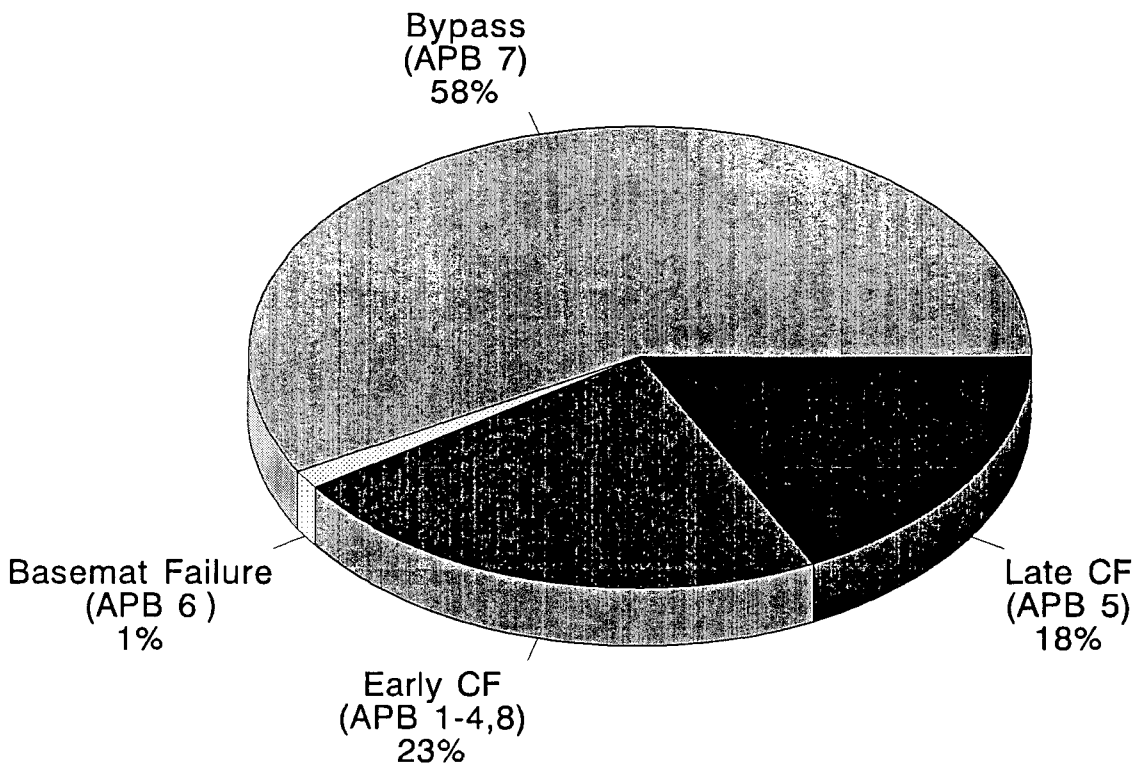
- Meteorology
- Demographics
- Transport Phenomena

The NUREG-1150 analysis of Sequoyah Unit 1, as sister plant to Watts Bar, was reviewed in order to assess the overall magnitude of uncertainties in the integrated result. Table 7 provides a summary of the uncertainty distribution results provided in NUREG/CR-4551, Volume 3 for Sequoyah. This table shows that the overall uncertainties (as expressed as a ratio from the 5th to 95th percentile values) range from a factor of 10 to over 2500. The

Figure 5

POPULATION DOSE CONTRIBUTORS

Accident Progression Bin Contribution - Re-Baselined Results



Total Dose = 5.28 person-rem/year

core damage frequency uncertainty band is the smallest and the early fatality uncertainties are the largest. The uncertainty analysis provided in the original Watts Bar IPE confirms that the Watts Bar core damage frequency is consistent, actually less, than the NUREG/CR-4551 results.

For value impact assessment, the integrated uncertainties associated with the 50 mile population dose are most important. In this case, the overall uncertainty band is approximately a factor of 50. However, as discussed above, the quantification of the dose reduction associated with the value impact assessment utilizes mean values. The difference between the mean value and the upper bound values (i.e., 95th percentile) are much smaller. Table 8 provides a summary of the same NUREG/CR-4551 data expressed as a ratio with the mean value. This table shows that, for the figures of merit considered in this analysis, the potential uncertainty in results is less than a factor of 4. Even the upper bound early fatality risk, which had the largest uncertainty band, is less than a factor of 5 from the mean value.

Therefore, the uncertainty in the risk reduction computation utilized in the value impact analysis is judged to be about a factor of 4.

QUANTITATIVE EVALUATION POTENTIAL ENHANCEMENTS

The revised value impact assessment considered, the same six general categories of enhancements as the original assessment:

- Improve Availability of ECCS Recirculation
- Improve Availability of AC Power
- Improve Ability To Cope With Loss of AC Power & Station Blackout
- Improve Ability To Cope With Loss of RCP Seal Cooling
- Improve Containment Performance
- Miscellaneous Enhancement

These specific enhancements evaluated quantitatively are listed in Table 9. Other enhancements were evaluated qualitatively or using information gleaned from the quantitative evaluation. The following provides a brief summary of the twenty-four enhancements evaluated quantitatively and the anticipated benefits of each.

TABLE 7
SUMMARY OF SEQUOYAH UNCERTAINTY DISTRIBUTIONS
BASED ON NUREG-1150 ANALYSES

EXPRESSED AS A RATIO WITH THE 5TH PERCENTILE VALUE

RISK MEASURE	5th%tile	Median	Mean	95th%tile
Core Damage	1.00	2.60	3.73	10.00
Early Fatalities	1.00	51.06	553.19	2553.19
Latent Cancer Fatalities	1.00	8.57	25.00	94.64
Population Dose (50 miles)	1.00	5.75	13.79	52.87
Population Dose (Region)	1.00	8.29	23.14	88.57
Individual Early Fatality	1.00	32.61	239.13	934.78
Individual Latent Cancer Fatalities	1.00	8.21	25.64	89.74

Based On Table 5.1-1 of NUREG/CR-4551, Vol. 3

TABLE 8
SUMMARY OF SEQUOYAH UNCERTAINTY DISTRIBUTIONS
BASED ON NUREG-1150 ANALYSES

EXPRESSED AS A RATIO WITH THE MEAN VALUE

RISK MEASURE	5th%tile	Median	Mean	95th%tile
Core Damage Frequency	0.27	0.70	1.0	2.7
Population Dose (50 mi)	0.07	0.41	1.0	3.8
Population Dose (Region)	0.04	0.36	1.0	3.8
Latent Cancer Fatalities	0.04	0.34	1.0	3.8
Early Fatalities	0.002	0.09	1.0	4.6

Based On Table 5.1-1 of NUREG/CR-4551, Vol. 3

TABLE 9

SUMMARY OF POTENTIAL ENHANCEMENTS CONSIDERED IN VALUE IMPACT ANALYSIS

ENHANCEMENT CATEGORY	IMPLEMENTATION OPTION
I - Improve Availability of ECCS Recirculation	2. Install Containment Spray Throttle Valves 3. Redesign To Delay Containment Spray Actuation 4. Install Automatic High Pressure Recirculation
II - Improve Availability of AC Power	2. Complete Fifth Emergency Diesel Generator 3. Procedure Change & Fifth Diesel (No longer applicable)
III - Improve Ability To Cope With Loss of AC Power & Station Blackout	2. Install Improved RCP Seals 3. Install Independent RCP Seal Cooling System 4. Install Accumulators For Turbine Driven AFW Pump Flow Control Valves 5. Provide DC Load Shed Analysis & Procedure 6. Provide Portable Battery Charger 7. Install AC Independent Coolant Injection System
IV - Improve Ability To Cope With Loss of RCP Seal Cooling	1. Install Improved RCP Seals 2. Install Independent RCP Seal Cooling System (w/o new EDG) 3. Modify Charging Pump Cooling From CCS To ERCW
V - Improve Containment Performance	1. Install Deliberate Ignition System 2. Install Reactor Cavity Flooding System 3. Install Filtered Containment Venting System 4. Install Core Retention Device 5. Install Containment Inerting System 6. Install Additional Containment Bypass Instrumentation 7. Install Reactor Depressurization System 8. Install Independent Containment Spray System 9. Install AC Independent Air Return Fan Power Supplies
VI - Miscellaneous	1. Install MG Set Trip Breakers In Control Room (ATWS) 2. Improve Procedures To Provide Temporary HVAC During Loss of Room Cooling

Category I - Improve Availability of ECCS Recirculation

This category of enhancements is intended to address one of the dominant contributor to the WBN IPE core damage frequency. One enhancement from this category has already been committed to be implemented, I.1 - a procedural enhancement to stop one train of sprays in recirculation. However, recirculation failures are still a sizeable contributor to overall core damage frequency and population dose. The following implementation options were identified to address this contributor to risk.

I.2 - Install Containment Spray Throttle Valves

This enhancement involves a design change to the containment spray system to provide valves to allow throttling of containment spray flow and procedures to support their use. This enhancement would result in additional time for operator recovery actions and would further reduce the susceptibility of the plant to ECCS recirculation failures. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

I.3 - Redesign To Delay Containment Spray Actuation

This enhancement involves the reanalysis and redesign of the containment spray actuation system. The current WBN design basis requires the spray system to function in the manner modeled in the IPE. However, with additional engineering analysis it is likely that the actuation of containment spray could be precluded in small LOCA events, thereby significantly extending the time before RWST depletion. This additional time would likely be sufficient to allow plant cooldown without ECCS recirculation. The re-assessment of this enhancement was performed using the re-baselined results and the same assumptions as the original analysis.

I.4 - Install Automatic High Pressure Recirculation

This enhancement would automate the alignment of ECCS recirculation to the high pressure charging and safety injection pumps. Provision of this enhancement would essentially eliminate the human errors in realignment. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

Category II - Improve Availability of AC Power

Loss of offsite power is still a sizeable contributor to core damage and population dose. One enhancement from this category has already been committed to be implemented, II.1 - a procedural enhancement to allow the cross-tie of the 500kV grid to the Unit 1 shutdown boards which are normally supplied by the 161kV grid. This category of enhancement is intended to improve the availability of AC power by providing access to alternate, diverse AC power sources not currently credited in the IPE.

II.2 - Complete Fifth Emergency Diesel Generator

The WBN emergency AC power system design provides for a fifth emergency diesel generator (EDG) which could be connected to any of the four 6.9kV shutdown boards. Currently, TVA has no plans to complete the fifth diesel. The purpose of the fifth EDG is to provide operational flexibility by providing a installed spare for EDGs which are removed from service. If completed, the fifth EDG could provide a means for ensuring all four shutdown boards are supported by an operable EDG, even while one is under going maintenance. This enhancement evaluates the benefit of the fifth EDG and considers whether the cost associated with completing it is commensurate with the benefit. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

II.3 - Procedure Change & Fifth Diesel

This enhancement is a combination of II.1 and II.2. With the commitment to provide the cross-tie procedure, this enhancement is redundant to enhancement II.2 above.

Category III - Improve Ability To Cope With Loss of AC Power & Station Blackout

This category involves those enhancements which improve the ability of the plant to cope with an extended loss of offsite power or station blackout. While the Category II enhancements involved restoration of AC power, this category involves items which would make coping with loss of AC power less likely to lead to core damage and/or containment failure. TVA has already implemented one of the enhancements considered in this category, III.1 - a procedure change to allow the use of existing spare 6900V to 480V transformers for the Unit 1 shutdown boards. This enhancement was originally identified as non-cost beneficial. However, due to operational considerations independent of the value impact assessment, TVA implemented the procedure. The following Category III enhancements have been re-assessed:

III.2 - Install Improved RCP Seals

One of the dominant contributors to the WBN core damage frequency (13%) is station blackout. Many of the station blackout sequences involve overheating and failure of the RCP O-rings seals and depletion of primary system inventory prior to restoration of AC power for makeup. Westinghouse has recently begun to provide an improved RCP O-ring material which is made of elastomers which can withstand higher temperatures and have a higher likelihood of remaining intact under conditions such as station blackout. The expert elicitation performed as part of NUREG-1150 identified that seal with the improved O-rings would be approximately four times less likely to cause significant reactor coolant loss. The re-assessment of this enhancement was performed using the re-baselined results and the same assumptions as the original analysis.

III.3 - Install Independent RCP Seal Cooling System

Another alternative to ensuring that the RCP seals remain intact and that the RCS inventory is sufficient to support secondary heat removal is to provide an alternative, AC independent RCP seal cooling system. At least two other Westinghouse plants have such a system. This enhancement involves the provision of a non-safety grade, independently powered (separate small EDG), independently cooled (non-CCS/ERCW) seal injection pump which could be manually actuated by the plant operators. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

III.4 - Install Accumulators For Turbine Driven AFW Pump Flow Control Valves

Another contributor to loss of offsite power event sequences is loss of the turbine driven AFW pump due to loss of control air to the flow control valves to the steam generators. These valves are normally provided control air by the essential control air system which is EDG backed, but introduces additional dependencies for the AFW system. In the current design, if control air is lost, the plant operators must perform a local manual action to align nitrogen bottles to the AFW flow control valves and steam generator PORVs. This enhancement considers providing control air accumulators for the turbine driven AFW flow control valves, the motor driven AFW pressure control valves and the steam generator PORVs. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

III.5 - Provide DC Load Shed Analysis & Procedure

The WBN DC power system is supported by four 125V vital batteries. In response to the Station Blackout Rule (10 CFR 50.63), it was determined that these batteries were sufficient as designed to cope for at least four hours under station blackout conditions. This enhancement involves the development of engineering analyses and procedures which would extend battery life by shedding unnecessary DC loads under station blackout conditions. The benefit of this enhancement is that it would allow operation of the turbine driven AFW pump for a longer period of time and would facilitate restoration of offsite power after 4 hours by ensuring availability of breaker control power. The re-assessment of this enhancement was performed using the re-baselined results and the similar assumptions as the original analysis. However, due to the implementation of the 500kV crosstie, the benefit of this enhancement is reduced. This is due to the fact that the 500kV crosstie effectively reduces the contribution of non-weather related losses of offsite power. With those events eliminated, the probability of recovery of offsite power is greatly reduced. Consequently, the credit for improving the likelihood of recovery of offsite power was reduced from a factor of ten to a factor of two.

III.6 - Provide Portable Battery Charger

This enhancement would provide a portable, diesel driven battery charger which would assure DC power would be available under station blackout conditions. The benefit of this enhancement is similar to item III.5, except the battery life could be extended essentially indefinitely. The re-assessment of this enhancement was performed using the re-baselined results and the similar assumptions as the original analysis. However, due to the implementation of the 500kV crosstie, the benefit of this enhancement is reduced. This is due to the fact that the 500kV crosstie effectively reduces the contribution of non-weather related losses of offsite power. With those events eliminated, the probability of recovery of offsite power is greatly reduced. Consequently, the credit for improving the likelihood of recovery of offsite power was reduced from a factor of ten to a factor of two.

III.7 - Install AC Independent Coolant Injection System

This enhancement would provide an AC independent coolant injection system which could be used under station blackout conditions (as well as others) to provide feed and bleed cooling of the RCS. The system evaluated included an independent emergency diesel generator, a pump and associated controls necessary to provide adequate makeup to the RCS. The re-assessment of this

enhancement uses the re-baselined results and the same assumptions as the original analysis.

Category IV - Improve Ability To Cope With Loss of RCP Seal Cooling

The third largest contributor to the WBN Unit 1 core damage frequency involves event sequences with loss of RCP seal cooling (non-station blackout). These sequences are characterized by simultaneous loss of RCP thermal barrier cooling and loss of seal injection. This category of enhancements includes items which would either improve RCP seal performance under such conditions or prevent failure of the seals altogether.

IV.1 - Install Improved RCP Seals

As described in enhancement III.2, Westinghouse has recently developed an improved O-ring for RCP seals which has a much lower likelihood of failure under loss of cooling conditions. However, such a modification would still require the plant operators to trip the RCPs before significant overheating of the seal occurred. The current RCP seals are assumed to lead to a small LOCA under loss of cooling conditions. This results in actuation of ECCS and containment spray and a need to initiate high pressure recirculation. However, many of the systems required to support RCP seal cooling (i.e., CCS, ERCW and charging) are used in high pressure recirculation. Improved seals could prevent containment spray actuation and allow a normal plant cooldown using AFW. The quantification of benefit of this enhancement includes both station blackout and non-station blackout events such as loss of CCS or loss of ERCW. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

IV.2 - Install Independent RCP Seal Cooling System (w/o new EDG)

This enhancement is essentially identical to enhancement III.3. except it does not include one of the significant cost elements, the emergency diesel generator. Therefore, the quantified benefit of this enhancement includes only non-station blackout seal LOCAs. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

IV.3 - Modify Charging Pump Cooling From CCS To ERCW

One of the key contributors to loss of RCP seal cooling is event sequences involving loss of CCS. The CCS system provides thermal barrier cooling to the RCPs and is the primary cooling medium for the centrifugal charging pumps (CCP) which provide seal injection. Consequently, when CCS is lost, RCP seal

cooling is lost. One of the CCPs (1A-A) currently has the capability to be cooled by ERCW. This enhancement involves the provision of ERCW cooling to the other CCP. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

Category V - Improve Containment Performance

As discussed in above, the WBN Level 2 PRA identified several containment failure mechanisms as primary contributors to release from containment. These mechanisms include late hydrogen burns, late overpressurization and basemat melt through. Additionally, containment bypass, although not strictly a containment issue, was identified as a key contributor.

V.1 - Install Deliberate Ignition System

This enhancement would provide a system to promote ignition of combustible gases generated within the containment during severe accident scenarios. This enhancement will reduce the vulnerability to SBO and other scenarios in which significant amounts of hydrogen are generated. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

V.2 - Install Reactor Cavity Flooding System

This enhancement would provide a method to flood the reactor cavity region of the containment. The design of the reactor cavity in ice-condenser containments is such that the introduction of large quantities of water into the reactor cavity region and lower compartment can essentially preclude the possibility of direct contact of postulated ex-core hot debris with the containment liner and has potentially mitigating effects on corium-concrete interaction and direct containment heating. This enhancement will provide a means to inject a large quantity of water (on the order of the equivalent of two RWSTs) into the lower compartment and reactor cavity, and a capability of replenishing the water during boil-off. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

V.3 - Install Filtered Containment Venting System

This enhancement would provide the capability to vent the containment through a vent path routed to an external filter. The filtered containment vent (FCV) would mitigate challenges to containment from long-term over-pressure and

hydrogen burns by reducing the baseline containment pressure. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

V.4 - Install Core Retention Device

This enhancement would provide a core debris control (CDC) system to prevent the direct impingement of core debris onto the primary containment steel shell during a high pressure core melt ejection (HPME) event. The CDC system would prevent the molten core material from contacting the containment shell by providing a barrier between the seal table and the containment shell in the seal table room. This enhancement will reduce the vulnerability of prompt containment failure for scenarios in which HPME may occur. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

V.5 - Install Containment Inerting System

This enhancement would provide a containment inerting system (CIS) which would assure an inerted containment atmosphere to prevent the combustion of hydrogen and carbon monoxide produced during core damage scenarios. This enhancement will reduce the vulnerability of containment failure for scenarios in which the combustion of flammable gases may threaten containment integrity. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

V.6 - Install Additional Containment Bypass Instrumentation

This enhancement involves the installation of pressure-monitoring instrumentation (permanent pressure sensors) between the first two pressure isolation valves on the low-pressure injection lines, RHR suction lines, and high-pressure injection lines. The additional instrumentation would improve the ability to detect valve leakage or open valves, and would decrease the frequency of Interfacing Systems Loss of Coolant Accident (ISLOCA). This enhancement will reduce the vulnerability to ISLOCA scenarios. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

V.7 - Install Reactor Depressurization System

This enhancement would provide the capability to rapidly depressurize the reactor coolant system (RCS), thus allowing injection utilizing low-pressure systems. This would reduce the threat of direct containment heating (DCH) and induced failures of steam generator tubes and RCS piping in the event low-pressure injection systems were not available. Thermal hydraulic analysis performed for Watts Bar indicate the RCS depressurization could only be successfully achieved by a system specially designed to manually depressurize the RCS. The re-assessment of this enhancement was performed using the re-baselined results and the same assumptions as the original analysis.

V.8 - Install Independent Containment Spray System

This enhancement would provide an independent containment spray system. The spray system would cool the core debris and provide containment heat removal thus preventing over-temperature and long-term overpressure by steam. This enhancement will reduce the vulnerability to SBO and other scenarios where steam overpressure and/or quench of core debris ex-vessel is important. The re-assessment of this enhancement was performed using the re-baselined results and the same assumptions as the original analysis.

V.9 - Install AC Independent Air Return Fan Power Supplies

The containment system at Watts Bar includes two air return fans (ARFs) each having 100% capacity. The design function of each ARF is to create forced recirculation from the upper containment to the lower containment which ultimately forces the air back up through the ice condenser again. This function serves to maximize the pressure suppression capabilities of the ice condenser, and promote mixing within the containment regions to prevent the accumulation of detonable concentrations of hydrogen within the containment. This enhancement will provide the ARF functions for accident scenarios in which normal operation is not possible, e.g., Station Blackout. The re-assessment of this enhancement was performed using the re-baselined results and the same assumptions as the original analysis.

Category VI - Miscellaneous Enhancements

As part of the detailed review of the dominant contributors to core damage and containment failure, several other potential enhancements were identified.

VI.1 - Install MG Set Trip Breakers In Control Room (ATWS)

This enhancement would provide trip breakers for the MG sets in the WBN control room. In the current design, if an ATWS were to occur, the plant operators would be instructed to trip the MG sets which would require an immediate action outside the control room. This enhancement would simplify that action and decrease the risk of an ATWS event. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

VI.2 - Improve Procedures To Provide Temporary HVAC During Loss of Room Cooling

Many rooms which contain ECCS, electrical and other key support equipment require room cooling to ensure availability of components. This enhancement involves the development of procedures to cope with loss of a room cooler by providing a temporary means of room cooling. Loss of an existing room cooler could lead to overheating of equipment and subsequent failure. However, depending upon the component, conditions, and configuration, failure could be delayed significantly (i.e., an hour or more). Thus, time could be available for plant operators to provide a temporary means of room cooling until the normal cooling could be restored. The re-assessment of this enhancement uses the re-baselined results and the same assumptions as the original analysis.

VALUE IMPACT ANALYSIS

The re-assessment of value impact utilizes the same process described in the original value impact assessment. In summary, this re-assessment involved the quantification of benefits using the Level 2 PRA developed for the WBN Unit 1 IPE combined with site specific dose conversion factors to quantify the averted dose to the public which might be yielded by the proposed enhancement. The benefit assessments were generally biased in a conservative manner. That is, they were developed in a manner which identifies the maximum (or bounding) potential benefit. Specific descriptions of how the benefit of each enhancement was quantified are provided in Section 4 of the original submittal.

The quantification of the cost of each enhancement was developed either from a site specific estimate or, for the major modifications, from industry and NRC data. In general, the site specific cost estimates are biased low in order to minimize the cost-benefit ratio. In addition, efforts were made to identify simple methods for accomplishing the site specific enhancements in order to minimize costs. Specific descriptions of how the cost

cost estimates for each enhancement were quantified are provided in Section 4 of the original submittal.

The results of the value impact analysis are presented in Table 10 in terms of the cost of the enhancement option (in 1994 dollars), the maximum benefit calculated (in person-rem over the life of the plant) and the cost benefit ratio (in $ per person-rem). It is generally accepted that cost to benefit ratios which are less than $1000 per person-rem should be considered cost-effective, unless unquantifiable factors indicate a strong reason to not perform the enhancement. Cost to benefit ratios in excess of $1000 per person-rem are generally considered non-cost beneficial.

Even when considering the time averaged population, all of the enhancements have cost to benefit ratios in excess of $7,500 per person-rem. This exceeds the upper bound uncertainty estimates of a factor of 3.8 by approximately a factor of two.

QUALITATIVE EVALUATION OF OTHER ENHANCEMENTS

As part of the identification and review of potential enhancements, a number of potential plant changes were considered and evaluated qualitatively. Some of these are identified in Appendix B of the value impact assessment, others were screened out without being documented. As part of discussions with the NRC staff, several potential enhancements which were evaluated qualitatively have been questioned. The purpose of this section is to provide a summary of the qualitative evaluation of the enhancements known to be of interest to the NRC staff. The following have been identified:

- Enhancements To Reduce The Risk From Steam Generator Tube Rupture Events
- Provision of Alternate Power To Igniters From An Existing Onsite Source
- Use of Existing Plant Hardware for RCS Depressurization
- Use of Fire Water For Containment Spray or Steam Generator Makeup
- Use of A Hydro Pump As A Backup For RCP Seal Injection/Cooling

The following paragraphs provide a summary of the qualitative evaluations performed on these enhancements.

TABLE 10
SUMMARY OF REVISED VALUE IMPACT RESULTS

ENHANCEMENT CATEGORY	IMPLEMENTATION OPTION	COST ($)	MAXIMUM RISK REDUCTION[1] (Person-rem)	BENEFIT RATIO ($/person-rem)
Base-Case	I.1 Procedure Change to Stop One Train of Sprays and II.1 Procedure Change to Facilitate Cross-Tie of 500kV and 161kV AC Power and III.1 Procedure Change to Utilize Existing Spare 6900/480V Transformers	$75,600	57.19	$1,322
I. Improve Availability of ECCS Recirculation	2. Install Containment Spray Throttle Valves	>$200,000[2]	1.10	>$181,818
	3. Redesign to Delay Containment Spray Actuation	$406,470	1.10	$369,518
	4. Install Automatic High Pressure Recirculation	$2,100,000	<1.10	>$1,909,090
II. Improve Availability of AC Power	2. Complete Fifth Emergency Diesel Generator	$431,300	4.86	$88,745
	3. Procedure Change and Fifth Diesel Generator (Included in Item II.2)	NA		
III. Improve Ability to Cope with Loss of AC Power and Station Blackout	2. Install Improved RCP Seals	$162,800	8.47	$19,221
	3. Install Independent RCP Seal Cooling System	$3,500,000	9.54	$366,876
	4. Install Accumulators for Turbine Driven AFW Pump Flow Control Valves and S/G PORVs	$324,600	22.26	$14,582
	5. Provide DC Load Shed Analysis and Procedure	$113,200	13.84	$8,179
	6. Provide Portable Battery Charger	$107,100	13.84	$7,738
	7. Install AC Independent Coolant Injection System	$3,500,000	89.67	$39,032

NOTES:
(1) Based on 40 year plant life.
(2) No specific cost estimate developed for these enhancements. However, due to the nature of the design changes involved a reasonable lower bound cost estimate of $200,000 was assumed.

Table 10 (Cont.)
SUMMARY OF VALUE IMPACT RESULTS (Cont.)

ENHANCEMENT CATEGORY	IMPLEMENTATION OPTION	COST ($)	MAXIMUM RISK REDUCTION[1] (Person-rem)	BENEFIT RATIO ($/person-rem)
IV. Improve Ability to Cope with Loss of RCP Seal Cooling	1. Install Improved RCP Seals	$162,800	8.47	$19,221
	2. Install Independent RCP Seal Cooling System (w/o new DG)	$2,400,000	10.71	$224,089
	3. Modify Charging Pump Cooling from CCS to ERCW	$295,200	18.67	$15,811
V. Improve Containment Performance	1. Install Deliberate Ignition System	$6,100,000	18.84	$323,779
	2. Install Reactor Cavity Flooding System	$8,750,000	89.67	$97,579
	3. Install Filtered Containment Venting System	$20,000,000	89.67	$223,038
	4. Install Core Retention Device	$44,500,000	61.47	$723,989
	5. Install Containment Inerting System	$10,900,000	18.84	$578,556
	6. Install Additional Containment Bypass Instrumentation	$2,300,000	0.86	$2,674,419
	7. Install Reactor Depressurization System	$4,600,000	19.48	$236,140
	8. Install Independent Containment Spray System	$5,800,000	61.47	$94,354
	9. Install AC Independent Air Return Fan Power Supplies	$1,000,000	18.84	$53,079
VI. Miscellaneous	1. Install MG Set Trip Breakers in Control Room (ATWS)	$142,500	2.76	$51,630
	2. Improve Procedures to Provide Temporary HVAC During Loss of Room Cooling	$25,200	0.39	$64,615

Enhancements To Reduce The Risk From Steam Generator Tube Rupture Events - Steam generator tube rupture events are a substantial contributor to the total population dose used in the value impact analyses (~42%). However, the sequences which dominate (approximately 90%) the steam generator tube rupture core damage events involve the failure of human actions. The human error probabilities for these actions were quantified using the same methods used for other actions in the IPE. The actions involved are well trained, have adequate instrumentation and involve relatively long periods of time. The overall human error rates for these sequences are low (< 1E-4), but, due to the hardware design of the plant, they constitute the dominant failure causes for SGTR events at Watts Bar. As part of the effort to identify enhancements, the human reliability analyses for the key human actions in these scenarios were reviewed and no significant plant specific weaknesses were identified. Therefore, only expensive hardware changes could be identified. Given the existing low risk from SGTR (<90 person-rem over the life of the plant), and the high cost of physical modifications to eliminate the human errors, no enhancements were identified.

Provision of Alternate Power To Igniters From An Existing Onsite Source - Enhancement V.1 considers the provision of a deliberate ignition system. This system would provide the maximum benefit in reducing containment failures due to hydrogen. The calculated maximum benefit associated with this enhancement is 18.8 person-rem based on the re-baselined results. Thus, even accounting for 95th percentile uncertainties, this kind of an enhancement has a maximum value of $71,500 ($1,000 per person-rem * 3.8 upper bound to mean ratio). This exceeds the cost of any modifications to the 1E electrical system to provide backup power to the igniters.

Furthermore, based on NRC sponsored containment analyses summarized in NUREG/CR-5586, it was concluded that any enhancement to utilize an existing onsite source to provide alternate power to the igniters which did not also provide power to the air return fans could result in the ignition of detonable concentrations of hydrogen in the ice condenser. This could have potentially adverse risk impacts.

Use of Existing Plant Hardware for RCS Depressurization - A procedural option for depressurizing the RCS with existing hardware was considered. However, thermal hydraulic analyses found that the existing pressurizer PORVs and head vents could not to depressurize the RCS for the severe accident scenarios considered. MAAP 3.0B calculations were performed to assess the impact of opening one or two pressurizer PORVs in loss of feedwater type sequences at Watts Bar.

These calculations found that there are several effects o£ opening the PORVs. While the RCS pressure is reduced, the combined effect of accumulator

discharge and debris water interactions in the lower plenum make it difficult to reach a pressure sufficiently low to prevent debris dispersal from the reactor cavity. Moreover, depressurization is calculated to prevent induced rupture of one of the hot legs, which is predicted to occur in cases where the PORVs are not opened due to efficient transfer of heat from the core to the hot legs via natural circulation. Rupture of the hot legs would create a rather large opening, which should be sufficient to eliminate DCH concerns. More important, it appears likely that induced rupture will allow low pressure injection to initiate, which could prevent vessel failure altogether. This has been noted in NUREG 1150 and many IPEs.

Based on these analyses, it was concluded that the existing hardware does not support the depressurization of the RCS as a prevention or mitigation alternative.

Use of Fire Water For Containment Spray or Steam Generator Makeup - Watts Bar has four high pressure fire pumps (~150 psig discharge pressure). The plant design provides a connection between the fire system and the auxiliary feedwater system for makeup to the steam generators. This connection was not credited in the IPE nor in the value impact assessment due to the small contribution from loss of feedwater events and the time required to make connections. Timeline analyses found that the fire connection would only support very long term events (i.e., where alternate makeup would not be required for several hours). Thus events with loss of auxiliary feedwater early would not be recovered with this capability. In long term events, such as a long term station blackout, the fire connection could be effective. However, the only significant contributor to this class of sequences is station blackout. In these sequences, the restoration of feedwater with firewater would be of limited benefit due to the loss of RCS inventory through RCP seal leakage. That is, even if feedwater was supplied by the fire water system, core damage would not be avoided due to loss of RCS inventory. A bounding estimate of the benefit was made assuming that all sequences with an EDG available were recovered. This bounding estimate found the maximum averted dose to be less than <10 person-rem. Other design changes to provide a diesel fire pump or reduce the time align the system could be envisioned, but similar computations of bounding risk found less than 20 person-rem could be avoided. This type of risk reduction does not support the large cost of new equipment and physical plant modifications.

Use of the fire water pumps for containment spray would require a plant modification. Based on the re-baselined results, about 9% of the CDF involves late containment overpressure failures. This is equivalent to 5.2×10^{-6}/year or 40% of the late containment failures. Based on the overall contribution of late containment failures to total population dose of 38 person-rem, a bounding estimate of the maximum possible benefit is 15.2 person-rem. Therefore, the maximum cost which could be justified to meet this benefit is $15,200 to

$58,000, based on mean ($1,000 per person-rem) and upper bound estimates ($1,000 per person-rem * 3.8 upper bound to mean ratio), respectively. This justifiable cost range is much less than the cost of this type of modification.

Use of A Hydro Pump As A Backup For RCP Seal Injection/Cooling - RCP seal LOCAs due to loss of RCP seal cooling contribute approximately 16% to the total re-baselined core damage frequency. One enhancement suggested by the NRC staff is to use a hydro test pump as a backup. Watts Bar does not currently have a hydro pump dedicated to this function. One could be procured and connections provided from a borated water source and to the RCP seal injection path. However, to provide a potential for success, additional plant modification would be required to assure a source of power was available for the hydro pump to avoid early RCP seal failures.

Based on the re-baselined results, an upper bound estimate of the potential benefit of such a modification was found to be less than 15.7 person-rem. This assumes that the existing fire water connection and the hydro pump were successful in preventing all station blackout core damage events where power is available and the hydro pump alone was sufficient for a backup seal cooling system for loss of seal cooling sequences. Therefore, the maximum cost which could be justified to meet this benefit is $15,700 to $60,000, based on mean ($1,000 per person-rem) and upper bound estimates ($1,000 per person-rem * 3.8 upper bound to mean ratio), respectively. If a portable diesel were procured to provide power to the hydro pump and a fire pump, the maximum benefit would increase to 25.0 person-rem. Therefore, the maximum cost which could be justified to meet this benefit is $25,000 to $95,000, based on mean ($1,000 per person-rem) and upper bound estimates ($1,000 per person-rem * 3.8 upper bound to mean ratio), respectively. In either case, the cost associated with the physical modification of ECCS systems and 1E electric systems would exceed the mean and upper bound benefits computed.

CONCLUSIONS

A comprehensive, systematic effort to identify potentially cost beneficial plant enhancement for Watts Bar Unit 1 was completed. As a result, two potential plant enhancements were identified for implementation. In addition, one other enhancement was implemented for other reasons. This updated summary provides a re-assessment of the value impact of other enhancements, utilizing re-baselined risk profile which credits these enhancements. All the enhancements evaluated were found to be non-cost beneficial. It is concluded that there are no additional cost effective design enhancements for severe accident mitigation.

WATTS BAR NUCLEAR PLANT UNIT 1

SEVERE ACCIDENT MITIGATION DESIGN ALTERNATIVE

CHAPTER 4 TABLES FOR
AVERTED OFFSITE DOSE ENHANCEMENT CASE

TABLE 4-3c

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - REDESIGN TO DELAY CONTAINMENT SPRAY

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.29E-01	25.14	25.14	0.00
2	3.14E-07	2.95E-07	7.66E-02	7.20E-02	3.06	2.88	0.19
3	1.14E-06	1.14E-06	4.87E-01	4.87E-01	19.48	19.48	0.00
4	3.10E-08	3.10E-08	1.41E-02	1.41E-02	0.56	0.56	0.00
5	1.03E-05	1.01E-05	9.48E-01	9.34E-01	37.92	37.36	0.56
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.00
7	5.56E-06	5.55E-06	3.04E+00	3.03E+00	121.67	121.35	0.32
8	3.10E-05	2.88E-05	8.29E-03	7.70E-03	0.33	0.31	0.02
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	4.32E-06	8.43E-04	6.75E-04	0.03	0.03	0.01
TOTAL	5.77E-05	5.42E-05	5.28E+00	5.26E+00	211.34	210.25	1.10

TABLE 4-6c

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - COMPLETE FIFTH EMERGENCY DIESEL GENERATOR

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.22E-06	6.29E-01	6.23E-01	25.14	24.91	0.24
2	3.14E-07	3.08E-07	7.66E-02	7.53E-02	3.06	3.01	0.05
3	1.14E-06	1.07E-06	4.87E-01	4.55E-01	19.48	18.19	1.29
4	3.10E-08	2.93E-08	1.41E-02	1.33E-02	0.56	0.53	0.03
5	1.03E-05	9.91E-06	9.48E-01	9.12E-01	37.92	36.48	1.44
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.00
7	5.56E-06	5.48E-06	3.04E+00	3.00E+00	121.67	119.87	1.80
8	3.10E-05	3.05E-05	8.29E-03	8.15E-03	0.33	0.33	0.01
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	5.40E-06	8.43E-04	8.43E-04	0.03	0.03	0.00
TOTAL	5.77E-05	5.66E-05	5.28E+00	5.16E+00	211.34	206.49	4.86

TABLE 4-10c

CALCULATION OF AVERTED OFFSITE DOSE ENHANCEMENT CASE - INSTALL IMPROVED RCP SEALS

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.28E-01	25.14	25.11	0.03
2	3.14E-07	2.60E-07	7.66E-02	6.35E-02	3.06	2.54	0.52
3	1.14E-06	1.13E-06	4.87E-01	4.82E-01	19.48	19.30	0.18
4	3.10E-08	3.07E-08	1.41E-02	1.39E-02	0.56	0.56	0.00
5	1.03E-05	8.54E-06	9.48E-01	7.86E-01	37.92	31.42	6.49
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.00
7	5.56E-06	5.51E-06	3.04E+00	3.01E+00	121.67	120.49	1.18
8	3.10E-05	2.60E-05	8.29E-03	6.97E-03	0.33	0.28	0.05
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	5.38E-06	8.43E-04	8.39E-04	0.03	0.03	0.00
TOTAL	5.77E-05	5.08E-05	5.28E+00	5.07E+00	211.34	202.87	8.47

TABLE 4-11c

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - INSTALL INDEPENDENT RCP SEAL COOLING SYSTEM

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.28E-01	25.14	25.11	0.04
2	3.14E-07	2.53E-07	7.66E-02	6.18E-02	3.06	2.47	0.59
3	1.14E-06	1.13E-06	4.87E-01	4.82E-01	19.48	19.27	0.21
4	3.10E-08	3.07E-08	1.41E-02	1.39E-02	0.56	0.56	0.01
5	1.03E-05	8.32E-06	9.48E-01	7.65E-01	37.92	30.61	7.31
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.00
7	5.56E-06	5.50E-06	3.04E+00	3.01E+00	121.67	120.34	1.33
8	3.10E-05	2.54E-05	8.29E-03	6.80E-03	0.33	0.27	0.06
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	5.38E-06	8.43E-04	8.39E-04	0.03	0.03	0.00
TOTAL	5.77E-05	5.00E-05	5.28E+00	5.05E+00	211.34	201.80	9.54

TABLE 4-13c

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - PROVIDE ACCUMULATORS FOR TURBINE DRIVEN AFW PUMP

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.22E-06	6.29E-01	6.22E-01	25.14	24.89	0.25
2	3.14E-07	2.49E-07	7.66E-02	6.09E-02	3.06	2.43	0.63
3	1.14E-06	1.03E-06	4.87E-01	4.39E-01	19.48	17.58	1.90
4	3.10E-08	3.09E-08	1.41E-02	1.40E-02	0.56	0.56	0.00
5	1.03E-05	8.20E-06	9.48E-01	7.55E-01	37.92	30.20	7.72
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.00
7	5.56E-06	5.03E-06	3.04E+00	2.75E+00	121.67	109.98	11.69
8	3.10E-05	2.48E-05	8.29E-03	6.64E-03	0.33	0.27	0.07
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	5.32E-06	8.43E-04	8.30E-04	0.03	0.03	0.00
TOTAL	5.77E-05	4.86E-05	5.28E+00	4.73E+00	211.34	189.09	22.26

TABLE 4-14c

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - INSTALL DC SHEDDING ANALYSIS AND PROCEDURE

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.19E-06	6.29E-01	6.09E-01	25.14	24.35	0.79
2	3.14E-07	3.04E-07	7.66E-02	7.41E-02	3.06	2.96	0.10
3	1.14E-06	8.17E-07	4.87E-01	3.49E-01	19.48	13.96	5.52
4	3.10E-08	2.73E-08	1.41E-02	1.24E-02	0.56	0.50	0.07
5	1.03E-05	9.04E-06	9.48E-01	8.32E-01	37.92	33.26	4.66
6	2.74E-06	2.75E-06	7.85E-02	7.90E-02	3.14	3.16	-0.02
7	5.56E-06	5.44E-06	3.04E+00	2.97E+00	121.67	118.96	2.72
8	3.10E-05	3.01E-05	8.29E-03	8.05E-03	0.33	0.32	0.01
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	5.40E-06	8.43E-04	8.43E-04	0.03	0.03	-0.00
TOTAL	5.77E-05	5.50E-05	5.28E+00	4.94E+00	211.34	197.51	13.84

TABLE 4-16c

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - INSTALL INDEPENDENT RCP SEAL COOLING SYSTEM (W/O NEW EDG)

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.29E-01	25.14	25.14	0.00
2	3.14E-07	2.41E-07	7.66E-02	5.87E-02	3.06	2.35	0.71
3	1.14E-06	1.14E-06	4.87E-01	4.87E-01	19.48	19.46	0.02
4	3.10E-08	3.10E-08	1.41E-02	1.41E-02	0.56	0.56	0.00
5	1.03E-05	7.95E-06	9.48E-01	7.31E-01	37.92	29.26	8.66
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.00
7	5.56E-06	5.50E-06	3.04E+00	3.01E+00	121.67	120.43	1.24
8	3.10E-05	2.42E-05	8.29E-03	6.49E-03	0.33	0.26	0.07
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	5.38E-06	8.43E-04	8.39E-04	0.03	0.03	0.00
TOTAL	5.77E-05	4.84E-05	5.28E+00	5.02E+00	211.34	200.64	10.71

TABLE 4-17c

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - CHANGE CHARGING PUMP COOLING FROM CCS TO ERCW

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.29E-01	25.14	25.14	0.00
2	3.14E-07	2.17E-07	7.66E-02	5.29E-02	3.06	2.12	0.95
3	1.14E-06	1.13E-06	4.87E-01	4.83E-01	19.48	19.32	0.16
4	3.10E-08	3.09E-08	1.41E-02	1.40E-02	0.56	0.56	0.00
5	1.03E-05	7.25E-06	9.48E-01	6.67E-01	37.92	26.69	11.23
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.00
7	5.56E-06	5.27E-06	3.04E+00	2.89E+00	121.67	115.44	6.23
8	3.10E-05	2.20E-05	8.29E-03	5.89E-03	0.33	0.24	0.10
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	5.19E-06	8.43E-04	8.10E-04	0.03	0.03	0.00
TOTAL	5.77E-05	4.51E-05	5.28E+00	4.82E+00	211.34	192.68	18.67

TABLE 4-20c

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - INSTALL MG SET TRIP BREAKERS IN CONTROL ROOM (ATWS)

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.29E-01	25.14	25.14	0.00
2	3.14E-07	2.93E-07	7.66E-02	7.15E-02	3.06	2.86	0.20
3	1.14E-06	1.14E-06	4.87E-01	4.87E-01	19.48	19.48	0.00
4	3.10E-08	2.91E-08	1.41E-02	1.32E-02	0.56	0.53	0.03
5	1.03E-05	1.02E-05	9.48E-01	9.34E-01	37.92	37.37	0.55
6	2.74E-06	2.51E-06	7.85E-02	7.20E-02	3.14	2.88	0.26
7	5.56E-06	5.48E-06	3.04E+00	3.00E+00	121.67	120.00	1.68
8	3.10E-05	2.85E-05	8.29E-03	7.63E-03	0.33	0.31	0.03
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	4.21E-06	8.43E-04	6.58E-04	0.03	0.03	0.01
TOTAL	5.77E-05	5.35E-05	5.28E+00	5.21E+00	211.34	208.58	2.76

TABLE 4-21c

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - IMPROVE PROCEDURES TO PROVIDE TEMPORARY HVAC DURING LOSS OF COOLING (LOSS OF CCS)

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.29E-01	25.14	25.14	0.00
2	3.14E-07	3.11E-07	7.66E-02	7.58E-02	3.06	3.03	0.03
3	1.14E-06	1.14E-06	4.87E-01	4.87E-01	19.48	19.48	0.00
4	3.10E-08	3.10E-08	1.41E-02	1.41E-02	0.56	0.56	0.00
5	1.03E-05	1.02E-05	9.48E-01	9.39E-01	37.92	37.57	0.35
6	2.74E-06	2.73E-06	7.85E-02	7.85E-02	3.14	3.14	0.00
7	5.56E-06	5.56E-06	3.04E+00	3.04E+00	121.67	121.67	0.00
8	3.10E-05	3.07E-05	8.29E-03	8.21E-03	0.33	0.33	0.00
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	5.34E-06	8.43E-04	8.33E-04	0.03	0.03	0.00
TOTAL	5.77E-05	5.72E-05	5.28E+00	5.27E+00	211.34	210.96	0.39

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - ADDITIONAL CONTAINMENT BYPASS INSTRUMENTATION

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.29E-01	25.14	25.14	0.00
2	3.14E-07	3.14E-07	7.66E-02	7.66E-02	3.06	3.06	0.00
3	1.14E-06	1.14E-06	4.87E-01	4.87E-01	19.48	19.48	0.00
4	3.10E-08	3.10E-08	1.41E-02	1.41E-02	0.56	0.56	0.00
5	1.03E-05	1.03E-05	9.48E-01	9.48E-01	37.92	37.92	0.00
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.00
7	5.56E-06	5.52E-06	3.04E+00	3.02E+00	121.67	120.82	0.86
8	3.10E-05	3.10E-05	8.29E-03	8.29E-03	0.33	0.33	0.00
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	5.40E-06	8.43E-04	8.43E-04	0.03	0.03	0.00
TOTAL	5.77E-05	5.76E-05	5.28E+00	5.26E+00	211.34	210.49	0.86

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - AC INDEPENDENT COOLING INJECTION SYSTEM

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	0.00E+00	6.29E-01	0.00E+00	25.14	0.00	25.14
2	3.14E-07	0.00E+00	7.66E-02	0.00E+00	3.06	0.00	3.06
3	1.14E-06	0.00E+00	4.87E-01	0.00E+00	19.48	0.00	19.48
4	3.10E-08	0.00E+00	1.41E-02	0.00E+00	0.56	0.00	0.56
5	1.03E-05	0.00E+00	9.48E-01	0.00E+00	37.92	0.00	37.92
6	2.74E-06	0.00E+00	7.85E-02	0.00E+00	3.14	0.00	3.14
7	5.56E-06	5.56E-06	3.04E+00	3.04E+00	121.67	121.67	-0.00
8	3.10E-05	0.00E+00	8.29E-03	0.00E+00	0.33	0.00	0.33
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00
10	5.40E-06	0.00E+00	8.43E-04	0.00E+00	0.03	0.00	0.03
TOTAL	5.77E-05	5.56E-06	5.28E+00	3.04E+00	211.34	121.67	89.67

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - DELIBERATE IGNITION SYSTEM

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.29E-01	25.14	25.14	0.000
2	3.14E-07	3.14E-07	7.66E-02	7.66E-02	3.06	3.06	0.000
3	1.14E-06	1.14E-06	4.87E-01	4.85E-01	19.48	19.41	0.069
4	3.10E-08	3.10E-08	1.41E-02	1.40E-02	0.56	0.56	0.002
5	1.03E-05	1.03E-05	9.48E-01	5.08E-01	37.92	19.15	18.769
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.000
7	5.56E-06	5.56E-06	3.04E+00	3.04E+00	121.67	121.67	0.000
8	3.10E-05	3.10E-05	8.29E-03	8.29E-03	0.33	0.33	0.000
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.000
10	5.40E-06	5.40E-06	8.43E-04	8.43E-04	0.03	0.03	0.000
TOTAL	5.77E-05	5.77E-05	5.28E+00	4.84E+00	211.34	192.50	18.84

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - CORE RETENTION DEVICE

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.29E-01	25.14	25.14	0.000
2	3.14E-07	3.14E-07	7.66E-02	7.66E-02	3.06	3.06	0.000
3	1.14E-06	0.00E+00	4.87E-01	0.00E+00	19.48	0.00	19.479
4	3.10E-08	0.00E+00	1.41E-02	0.00E+00	0.56	0.00	0.563
5	1.03E-05	0.00E+00	9.48E-01	0.00E+00	37.92	0.00	37.918
6	2.74E-06	0.00E+00	7.85E-02	0.00E+00	3.14	0.00	3.140
7	5.56E-06	5.56E-06	3.04E+00	3.04E+00	121.67	121.67	-0.000
8	3.10E-05	0.00E+00	8.29E-03	0.00E+00	0.33	0.00	0.331
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.000
10	5.40E-06	0.00E+00	8.43E-04	0.00E+00	0.03	0.00	0.034
TOTAL	5.77E-05	7.10E-06	5.28E+00	3.75E+00	211.34	149.88	61.47

CALCULATION OF AVERTED OFFSITE DOSE
ENHANCEMENT CASE - REACTOR DEPRESSURIZATION SYSTEM

APB ID	BASE CASE APB FREQUENCY (EVENTS/RX-YR)	REVISED APB FREQUENCY (EVENTS/RX-YR)	BASE CASE POPULATION DOSE RATE (Man-REM/YR)	REVISED POPULATION DOSE RATE (Man-REM/YR)	BASE CASE POPULATION DOSE (Man-REM)	REVISED POPULATION DOSE (Man-REM)	AVERTED POPULATION DOSE (Man-REM)
1	1.23E-06	1.23E-06	6.29E-01	6.29E-01	25.14	25.14	0.000
2	3.14E-07	3.14E-07	7.66E-02	7.66E-02	3.06	3.06	0.000
3	1.14E-06	0.00E+00	4.87E-01	0.00E+00	19.48	0.00	19.479
4	3.10E-08	3.10E-08	1.41E-02	1.41E-02	0.56	0.56	0.000
5	1.03E-05	1.03E-05	9.48E-01	9.48E-01	37.92	37.92	0.000
6	2.74E-06	2.74E-06	7.85E-02	7.85E-02	3.14	3.14	0.000
7	5.56E-06	5.56E-06	3.04E+00	3.04E+00	121.67	121.67	-0.000
8	3.10E-05	3.10E-05	8.29E-03	8.29E-03	0.33	0.33	0.000
9	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.000
10	5.40E-06	5.40E-06	8.43E-04	8.43E-04	0.03	0.03	0.000
TOTAL	5.77E-05	5.65E-05	5.28E+00	4.80E+00	211.34	191.87	19.48

ENCLOSURE 1

WATTS BAR NUCLEAR PLANT UNIT 1
REQUEST FOR ADDITIONAL INFORMATION
AVAILABLE EQUIPMENT BY FIRE ZONES/AREAS
FINAL ANALYSES COMPLETE

OCTOBER 21, 1994