Watts Bar Nuclear Plant Intact Containment Loss of Coolant Accident (LOCA) Analysis

Prepared for:

Tennessee Valley Authority

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Prepared by:

Steven Mirsky
Science Applications International Corporation
20201 Century Boulevard
Germantown, Maryland 20874

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Executive Summary

The Tennessee Valley Authority (TVA) submitted a Supplemental Environmental Impact Statement (SEIS) for the Watts Bar Nuclear (WBN) Plant site to the Nuclear Regulatory Commission (NRC) in 2007 that included future operation of Watts Bar Unit 2. The SEIS included human health impacts from three severe accident categories. The term "accident" refers to any unintentional event (i.e., outside the normal or expected plant operation envelope) that results in a release or a potential for a release of radioactive material to the environment. The Nuclear Regulatory Commission (NRC) categorizes accidents as either design basis or severe. Design basis accidents are those for which the risk is great enough that NRC requires plant design and construction to prevent unacceptable accident consequences. Severe accidents are those that NRC considers too unlikely to warrant design controls.

NRC review of the SEIS resulted in the issuance of requests for additional information (RAI) in December 2009. One of these RAIs, designated SA-1, states:

As discussed at the site audit, provide MACCS input and output files for Watts Bar Unit 2 that include analyses for all severe accident release classes including the release class or classes in which radionuclides are released to containment and containment remains intact.

Since MACCS analyses that were previously performed in 2007 evaluated three severe accident classes of accidents that involved containment failure or bypass, the purpose of this analysis is to calculate human health impacts for a release class in which radionuclides are released to the containment, but the containment remains intact. This class of accident is represented by the design basis loss of coolant accident (LOCA) as described in Chapters 6 and 15 of the WBN Updated final safety analysis report (FSAR). The MACCS2 computer code (Version 1.13.1) was used to perform probabilistic analyses of radiological impacts. The generic input parameters given with the MACCS2 computer code that were used in the NRC's severe accident analysis (NUREG-1150) formed the basis for the analysis. These generic data values were supplemented with parameters specific to Watts Bar nuclear plant and the surrounding area. Site-specific data included population distribution, economic parameters, and agricultural product. Plant-specific release data included nuclide release, release duration, release energy (thermal content), and DB LOCA frequency. The behavior of the population during a release (evacuation parameters) was based on declaration of a general emergency and the emergency planning zone (EPZ) evacuation time. These data in combination with site specific meteorology were used to simulate the probability distribution of impact risks (exposure and fatalities) to the surrounding 80-kilometer (50 mile) population.

Table ES-1 summarizes the consequences of the design-basis accident, with mean meteorological conditions, to the maximally exposed offsite individual, and an average individual member of population residing within an 80-kilometer (50-mile) radius of the reactor site. The analysis assumed that a site emergency would have been declared early in the accident sequence and that all nonessential site personnel would have evacuated the site in accordance with site emergency procedures before any radiological releases to the environment occurred. In addition, emergency action guidelines would have been implemented to initiate evacuation of 99.5 percent of the public within 16 kilometers (10 miles) of the plant. The location of the maximally exposed offsite individual may or may not be at the site boundary for these accident sequences because emergency action guidelines would have been implemented and the population would be evacuating from the path of the radiological plume released by the accident.

Table ES–1 Intact Containment DB LOCA Annual Risks

Release Category (frequency per reactor year)	***Maximally Exposed Offsite Individual***		***Average Individual Member of Population within 80 Kilometers (50 miles)***	
	Dose Risk [a] (rem/year)	***Cancer Fatality [b]***	***Dose Risk [a] (rem/year)***	***Cancer Fatality [b]***
DB-LOCA Intact Containment (2.0×10^{-4})	6.0×10^{-7}	3.6×10^{-10}	3.0×10^{-9}	1.8×10^{-12}

[a] Includes the likelihood of occurrence.
[b] Increased likelihood of cancer fatality per year.

The results presented in this table indicates that the highest risk to the maximally exposed offsite individual is one fatality every 3 billion years (or 3.6×10^{-10} per year) and the highest risk to an average individual member of the public is one fatality every 555 billion years (or 1.8×10^{-12} per year). Overall, the risk results presented above are small. Completion and operation of WBN Unit 2 would not change the risks evaluated here because the likelihood of an accident that could affect both units and lead to radioactive releases beyond those analyzed here would be extremely low. This is consistent with the conclusions of NRC's Generic Environmental Impact Statement for License Renewal of Nuclear Plants, (GEIS).

WATTS BAR NUCLEAR PLANT
INTACT CONTAINMENT LOCA ANALYSIS

1. Introduction

The Tennessee Valley Authority (TVA) submitted a Supplemental Environmental Impact Statement (SEIS) for the Watts Bar Nuclear (WBN) Plant site to the Nuclear Regulatory Commission (NRC) in 2007 that included future operation of Watts Bar Unit 2 (TVA 2007). The SEIS included human health impacts from three severe accident categories. The term “accident” refers to any unintentional event (i.e., outside the normal or expected plant operation envelope) that results in a release or a potential for a release of radioactive material to the environment. The Nuclear Regulatory Commission (NRC) categorizes accidents as either design basis or severe. Design basis accidents are those for which the risk is great enough that NRC requires plant design and construction to prevent unacceptable accident consequences. Severe accidents are those that NRC considers too unlikely to warrant design controls.

NRC review of the SEIS resulted in the issuance of requests for additional information (RAI) in 2009 (NRC 2009). One of these RAIs, designated SA-1, requests:

As discussed at the site audit, provide MACCS input and output files for Watts Bar Unit 2 that include analyses for all severe accident release classes including the release class or classes in which radionuclides are released to containment and containment remains intact.

Since MACCS analyses that were previously performed in 2007 (SAIC 2007) evaluated three severe accident classes of accidents that involved containment failure or bypass, the purpose of this analysis is to calculate human health impacts for a release class in which radionuclides are released to the containment, but the containment remains intact. This class of accident is represented by the design basis (DB) loss of coolant accident (LOCA) as described in Chapters 6 and 15 of the WBN final safety analysis report (TVA 2005). The MACCS2 computer code (Version 1.13.1) was used to perform probabilistic analyses of radiological impacts (NRC 1998). The input parameters used with the MACCS2 computer code in the 2007 severe accident formed the basis for the analysis. DB LOCA release data included nuclide release, release duration, release energy (thermal content), and DB LOCA frequency. The behavior of the population during a release (evacuation parameters) was based on declaration of a general emergency and the emergency planning zone (EPZ) evacuation time. These data in combination with site specific meteorology were used to simulate the probability distribution of impact risks (exposure and fatalities) to the surrounding 80-kilometer (50 mile) population. The DB LOCA is defined in **Table 1**. The magnitude of the radioactive release to the atmosphere resulting from this accident depends on the temporal containment leak rate and iodine removal efficiency of ice condenser and ventilation system charcoal filters. Source terms associated with various release categories describe the fractional releases for representative radionuclide groups, as well as the timing, duration, and energy of potential releases.

Table 1 Definition and Cause of Intact Containment LOCA Class

Failure mode	*Definition and Causes*
Design Basis Loss of Coolant Accident with Intact Containment	Involves large diameter primary coolant system double ended guillotine break resulting in core damage and release of radionuclides to the containment. The WBN primary and secondary containment systems remain intact and remove a significant fraction of the iodine radionuclides due to the presence of the ice condenser in primary containment and charcoal filters in the annulus and auxiliary building secondary containment ventilation systems. Radionuclide release to the atmosphere occurs at the design containment leak rate

2. Intact Containment LOCA Accident Scenario

The selected release category and design basis LOCA accident scenario leading to core damage with no containment failure and/or bypass is presented below. **Table 2** shows the equilibrium reactor core nuclide inventory released into the containment and available for leakage to the atmosphere at the time of a reactor trip (TVA 2005). **Table 3** provides important information on containment leakage rate, release duration, and the isotope release fractions associated with each of the four plumes used to model the intact containment DB LOCA release category (TVA 2005). The first plume represents the release that occurs during the time period when the ice condenser ice inside the primary containment is effective in removing some of the iodine source. The second plume models the source term after the ice has melted and is no longer effective in removing iodine. The third and fourth plumes provide the post-24 hour smaller containment leak rate source term. Since MACCS2 is limited to four plumes and a maximum plume release time of 24 hours, these four plumes provide a 3-day release including the highest iodine source and containment leak rate during the first 24-hours. **Table 4** provides a representation of the accident scenario and its likelihood of their occurrence (TVA 2005).

Table 2 Watts Bar Unit 1 Containment Inventory for DB LOCA

Nuclide	*Isotope*	*Group* [a]	*Curies* [b]
Krypton	Kr-83m	1	1.15E+07
	Kr-85m	1	2.39E+07
	Kr-85	1	1.03E+06
	Kr-87	1	4.81E+07
	Kr-88	1	6.66E+07
Xenon	Xe-133	1	1.91E+08
	Xe-135	1	6.43E+07
	Xe-138	1	1.67E+08
Iodine	I-130	2	1.93E+06
	I-131	2	9.46E+07
	I-132	2	1.39E+08
	I-133	2	1.95E+08
	I-134	2	2.16E+08
	I-135	2	1.86E+08

[a] The grouping is based on NUREG-1465.
[b] Source: TVA 2005.

Table 3 Release Category Timing and Source Terms

Release Times, Heights, Energies, and Source Terms for Selected Release Categories					
Release Category	*Release Height (meters)*	*Warning Time (hours)*	*Release Time (hours)*	*Release Duration (hours)*	*Release Energy* [a] *(megawatts)*
Intact Containment LOCA (4 plumes)	39.6 39.6 39.6 39.6	20	0 0.824 24 48	0.824 23.176 24 24	0.0 0.0 0.0 0.0

Fission Product Source Terms (fraction of total inventory)										
Release Plume	*NG*	*I*	*Cs*	*Te*	*Sr*	*Ru*	*La*	*Ce*	*Ba*	*Mo*
1	0.0001	0.0000001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0024	0.0000019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0025	0.00000102	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0025	0.00000102	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NG = Noble gases.
[a] Based on LOCA blow down steam heat removal by ice condenser, passive heat sinks, and secondary containment.
Source: TVA 2005.

Table 4 Frequency and Related Intact Containment DB LOCA Sequence

Release Category	*Frequency*	*Remarks (Example Scenario)*
Design Basis LOCA – Intact Containment	2.0×10^{-4}	Involves large diameter primary coolant system double ended guillotine break resulting in core damage and release of radionuclides to the containment. The WBN primary and secondary containment systems remain intact and remove a significant fraction of the iodine radionuclides due to the presence of the ice condenser in primary containment and charcoal filters in the annulus and auxiliary building secondary containment ventilation systems. Radionuclide release to the atmosphere occurs at the design containment leak rate

Source: TVA 2005, DOE 1999.

3. Methodology for Estimating Radiological Impacts

3.1 Introduction

The MACCS2 computer code (Version 1.13.1) was used to perform probabilistic analyses of radiological impacts. A detailed description of the MACCS model is provided in NUREG/CR-4691 (NRC 1990a). The enhancements incorporated in MACCS2 are described in the MACCS2 User's Guide (NRC 1998).

3.2 Site-Specific Parameters

The identical site specific parameters that were used in the 2007 severe accident MACCS2 analyses for population, agriculture, economy, evacuation, and meteorology (2002 data) were used for this analysis.

4. Analysis Results

Table 5 summarizes the consequences of the intact containment LOCA accident, with mean meteorological conditions, to the maximally exposed offsite individual and an average individual in the public within an 80-kilometer (50-mile) radius of the reactor site. The analysis assumes that a site emergency would have been declared early in the LOCA sequence and that all nonessential site personnel would have evacuated the site in accordance with site emergency procedures before any radiological releases to the environment occurred. In addition, emergency action guidelines would be implemented to initiate evacuation of the public within 16.1 kilometers (10 miles) of the plant. The location of the maximally exposed offsite individual for the three-day exposure to the plume was assumed to be at 16.1 kilometers (10-miles) from the plant because emergency action guidelines would have been implemented and the population would be evacuating from the path of the radiological plume released by the accident. The MACCS2 computer code models the evacuation sequence to estimate the dose to the maximally exposed individual and the general population within 80 kilometers (50 miles) of the accident. **Table 6** summarizes the risks associated with the accident to the same receptors in terms of latent cancer fatalities (considering the likelihood of occurrence). The frequency of the DB LOCA is given in Table 4. **Table 7** shows the population dose risks (accident consequence multiplied by the release frequency) for the intact containment LOCA accident release category.

Table 5 Intact Containment LOCA Reactor Accident Consequences

Release Category	*Maximally Exposed Offsite Individual*		*Average Individual Population within 80 Kilometers (50 miles)*	
	Dose (rem)	*Cancer Fatality* [a]	*Dose (rem)*	*Cancer Fatality* [a]
Weather Bin Sampling				
Intact Containment DB LOCA	0.00304	0.0000018	0.000016	9.6×10^{-9}
Weather Stratified Sampling				
Intact Containment DB LOCA	0.00265	0.0000016	0.0000132	7.9×10^{-9}

[a] Increased likelihood of cancer fatality based on the health risk factor of 0.0006 cancers per rem for exposures below 20 rem.(ISCORS 2002) For exposures greater than or equal to 20 rem, the health risk factor would be doubled.

Table 6 Intact Containment LOCA Reactor Accident Annual Risks

Release Category	*Maximally Exposed Offsite Individual*		*Average Individual Population within 80 Kilometers (50 miles)*	
	Dose [a] (rem/year)	*Cancer Fatality [b]*	*Dose [a] (rem/year)*	*Cancer Fatality [b]*
Weather Bin Sampling				
Intact Containment DB LOCA	6.0×10^{-7}	3.6×10^{-10}	3.0×10^{-9}	1.8×10^{-12}
Weather Stratified Sampling				
Intact Containment DB LOCA	5.4×10^{-7}	3.2×10^{-10}	2.6×10^{-9}	1.6×10^{-12}

[a] Includes the likelihood of occurrence of a DB LOCA that is assumed to be 0.0002 per year (DOE 1999)
[b] Increased likelihood of cancer fatality per year.

Table 7 Annual 80-Kilometer (50-mile) Population Dose Risk

Release Category	*Weather Bin Sampling*	*Weather Stratified Sampling*
	Dose [a] (person-rem/year)	*Dose [a] (person-rem/year)*
Intact Containment DB LOCA	0.0062	0.0056

[a] Includes the likelihood of occurrence of 0.0002 per year that is assumed for the DB LOCA. The population within 80 kilometers (50 miles) is projected to be 2,104,700.

The results presented in Tables 5 through 7 indicate that the highest risk to the maximally exposed offsite individual is one fatality every 3 billion years (or 3.6×10^{-10} per year), and highest risk to an average individual member of the public is one fatality every 555 billion years (or 1.8×10^{-12} per year). Overall, the risk results presented above are small. Completion and operation of WBN Unit 2 would not change the risks evaluated here because the likelihood of an accident that could affect both units and lead to radioactive releases beyond those analyzed here is extremely low. This is consistent with the conclusions of NRC's *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (GEIS) (NRC 1996). Accidents that could affect multiunit sites are initiated by external events. Severe accidents initiated by external events as tornadoes, floods, earthquakes, and fires traditionally have not been discussed in quantitative terms in final environmental statements and were not considered in the GEIS (NRC 1996). In the GEIS, however, NRC staff did evaluate existing impact assessments performed by NRC and the industry at 44 nuclear plants in the United States and concluded that the risk from beyond-design-basis earthquakes at existing nuclear power plants is small. Additionally, the staff concluded that the risks from other external events are adequately addressed by a generic consideration of internally initiated severe accidents.

4.1 Sensitivity Analysis

The sensitivity analysis presented in the 2007 severe accident MACCS2 analysis applies to this calculation since the same site model (population and meteorology) was used in both analyses.

5. MACCS2 Computer Code

The MACCS2 computer code, Version 1.13.1 (NRC 1998), was used to estimate the radiological doses and health effects that could result from postulated accidental releases of radioactive materials to the atmosphere. This is the identical computer code that was used in the 2007 severe accident analyses and all descriptions of the models and methodology from the 2007 report (SAIC 2007) apply equally to this intact containment DB LOCA analysis.

5.1 Data and General Assumptions

To assess the consequences of the intact containment DB LOCA accident, the following data and assumptions were incorporated into the MACCS2 analysis.

- The **nuclide inventory** at accident initiation (e.g., reactor trip) of those radioactive nuclides that are important for the calculation of offsite consequences is given in Table 2.

- The **atmospheric source term** produced by the accident was described by the number of plume segments released; sensible heat content; timing; duration; height of release for each plume segment; time when offsite officials are warned that an emergency response should be initiated; and for each important radionuclide, the fraction of that radionuclide's inventory released with each plume segment. The release fractions for each accident scenario are provided in Table 3. MACCS2 calculates the atmospheric source terms based on the core nuclide inventory at the time of reactor trip, release time after the reactor trip, and the associated release fractions.

- **Meteorological data** characteristics of the site region were described by 1 year of hourly windspeed, atmospheric stability, and rainfall recorded at each site. Although 1 year of hourly readings contains 8,760 weather sequences, MACCS2 calculations examine only a representative subset of these sequences. Two types of weather sampling were used: bin sampling and stratified sampling. These two methods are the most used methods selected by MACCS users. Bin sampling requires the user to provide rain intensity at downwind distances; stratified sampling is a purely random selection of hourly data from those occurring at the site. The analysis was based on 125 weather data in bin sampling and 1460 weather data in stratified sampling.

- **Population distribution information** regarding the Watts Bar site was based on data from the 2000 census as used in the SECPOP 2000 computer code (NRC 2003). The generated population data for the site was extrapolated to the year 2030 using the incremental increase in population during the decade recorded from census 1990 to 2000.

- **Habitable land fractions** for the region around each reactor site were determined in a manner similar to the population distribution. The census block group boundary files include polygons that are classified as water features. The percentage of each sector that is covered by water was determined by fitting this data to the polar coordinate grid.

- **Farmland fractions** are the percentage of land devoted to farming.

- **Emergency response assumptions** for evacuation, including delay time before evacuation, area evacuated, average evacuation speeds, and travel distance, are provided in the Tennessee Multi-Jurisdictional Plans (TVA 2006). Average evacuation speeds are based on the most conservative general population evacuation times.

- **Shielding and exposure data** must be input into the MACCS2 code. The code requires shielding factors to be specified for people evacuating in vehicles (cars, buses); taking shelter in structures (houses, offices, schools); and continuing normal activities either outdoors, in vehicles, or indoors. Because inhalation doses depend on breathing rate, breathing rates must be specified for people who are continuing normal activities, taking shelter, and evacuating. Since indoor concentrations of gasborne radioactive materials are usually substantially less than outdoor concentrations, MACCS2 also requires that inhalation and skin protection shielding factors (indoor/outdoor concentration ratios) be provided.

  The protection factors presented in **Table 8** were used in this analysis. The values in this table are for the Sequoyah Nuclear Plant, as stated in NUREG/CR-4551, and were used in the analysis for the WBN Plant.

Table 8 NUREG/CR–4551 (NRC 1990b) Protection Factors

Protection Factor [a]	***Evacuees***	***Sheltering***	***Normal Activities***
Cloudshine Shielding Factor	1.0	0.65	0.75
Skin Protection Factor	1.0	0.33 [b]	0.41 [b]

Inhalation Protection Factor	1.0	0.33 [b]	0.41 [b]
Groundshine Shielding Factor	0.5	0.2	0.33 [c]

[a] A protection factor of 1.0 indicates no protection, while a protection factor of 0.0 indicates 100 percent protection.
[b] These values were based on the recommendation from S. Acharya of NRC as it appears in Appendix A-2 of NUREG/CR-4551, Vol. 2 (NRC 1990b). The recommended values in the report are 0.2 and 0.5 for sheltering and normal activities, respectively (NUREG/CR-4551, Vol. 2, Table 3.12).
[c] This value was based on the recommendation from S. Acharya of NRC as it appears in Appendix A-2 of NUREG/CR-4551, Vol. 2. The recommended value in the report is 0.5 (NUREG/CR-4551, Vol. 2, Table 3.12).

For this analysis, the evacuation and sheltering region was defined as a 10-mile radial distance centered on the plant. A sheltering period was defined as the phase occurring before initiation of the evacuation. During the sheltering period, shielding factors appropriate for sheltered activity were used to calculate doses for individuals in contaminated areas. At the end of the sheltering period, residents begin traveling out of the region. Travel speeds and delay times are based on the Tennessee Multi-Jurisdictional Plans (TVA 2006). The general population evacuation times for the various areas within the 10-mile radius were averaged to determine an overall evacuation delay time and evacuation speed for the WBN Plant.

- Maximally Exposed Offsite Individual (MEI) dose is the total dose estimated to be incurred by a hypothetical individual assumed to reside at a particular location on the spatial grid. Population data, therefore, have no bearing on the generation of this consequence measure. Only direct exposure is considered in these results. Exposures from ingestion of contaminated food and water are not included. In addition, generation of these results takes full account of any mitigative action models activated by exceeding the dose thresholds. During evacuation, individuals have no protection from direct exposure. Therefore, in certain scenarios, it is possible that an evacuee may incur a larger direct exposure dose than an individual who does not evacuate.

- Long-term protective measures such as decontamination, temporary relocation, contaminated crops, milk condemnation, and farmland production prohibition are based on U.S. Environmental Protection Agency (EPA) Protective Action Guides.

- Mitigative actions (relocation, evacuation, interdiction, condemnation) are implemented for design-basis accidents (LOCA with intact containment).

- Dose conversion factors required by MACCS2 for the calculation of committed effective dose equivalents are cloudshine dose-rate factor; groundshine dose-rate factor; "lifetime" 50-year committed inhalation dose (used for calculation of individual and societal doses and stochastic health effects); and 50-year committed ingestion dose (used for calculation of individual and societal doses and stochastic health effects from food and water ingestion).

5.2 Health Effects Calculations

The health consequences from exposure to radionuclides due to accidental releases were calculated. Total effective dose equivalents were calculated and converted to estimates of cancer fatalities using dose conversion factors recommended by the International Commission on Radiological Protection. For individuals, the estimated probability of a latent cancer fatality occurring was reported for the maximally exposed individual, and an average individual in the population within 80 kilometers (50 miles). The nominal values of lifetime cancer risk for low dose or low dose rate exposure (less than 20 rad) used in this EIS are 0.0006 per person-rem for a population of all ages, including workers (ISCORS 2002).

The MACCS2 code was applied in a probabilistic manner using a weather bin and a stratified sampling method. Each of the sampled meteorological sequences was applied to each of the 16 sectors (accounting for the frequency of occurrence of the wind blowing in that direction). Individual doses as a function of distance and direction were calculated for each of the meteorological sequence samples. The mean dose values of the sequences were generated for each of the 16 sectors. The highest of these dose values was used for the maximally exposed individual.

6. Conclusions

Table 9 summarizes the consequences of the beyond design-basis accident, with mean meteorological conditions, to the maximally exposed offsite individual, an average individual, and the population residing within an 80-kilometer (50-mile) radius of the reactor site. The analysis assumed that a site emergency would have been declared early in the accident sequence and that all nonessential site personnel would have evacuated the site in accordance with site emergency procedures before any radiological releases to the environment occurred. In addition, emergency action guidelines would have been implemented to initiate evacuation of 99.5 percent of the public within 16 kilometers (10 miles) of the plant. The location of the maximally exposed offsite individual is at the 16-kilometer (10-mile) evacuation radius given the long time frame of the intact containment DB LOCA scenario because emergency action guidelines would have been implemented and the population would be evacuating from the path of the radiological plume released by the accident.

Table 9 Intact Containment DB LOCA Annual Risks

Release Category (frequency per reactor year)	*Maximally Exposed Offsite Individual*		*Population within 80 Kilometers (50 miles)*		
			Average Individual		*General public*
	Dose Risk [a] *(rem/year)*	*Cancer Fatality* [b]	*Dose Risk* [a] *(rem/year)*	*Cancer Fatality* [b]	*Dose Risk* [a] *(person-rem/year)*
Maximum dose and risk [c]					
Intact Containment DB LOCA	6.0×10^{-7}	3.6×10^{-10}	3.0×10^{-9}	1.8×10^{-12}	0.0062

[a] Includes the likelihood of occurrence of 0.0002 for a DB LOCA.
[b] Increased likelihood of cancer fatality per year.
[c] These values are taken from Tables 8 and 9; the maximum dose to a maximally exposed offsite individual is from weather bin sampling and the maximum dose to an average individual and population is from weather stratified sampling.

The results presented in this table indicates that the highest risk to the maximally exposed offsite individual is one fatality every 3 billion years (or 3.6 x 10^{-10} per year), and the highest risk to an average individual member of the public is one fatality every 555 billion years (or 1.8 x 10^{-12} per year). Overall, the risk results presented above are small. Completion and operation of WBN Unit 2 would not change the risks evaluated here because the likelihood of an accident that could affect both units and lead to radioactive releases beyond those analyzed here would be extremely low. This is consistent with the conclusions of NRC's GEIS (NRC 1996). Accidents that could affect multiple units are initiated by external events.

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