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MFN 09-786, Supplement 1, Revision 1

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Subject: **Revised Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) revised (Revision 1) partial response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) 12.2-28, sent by NRC Letter No. 394, Reference 1.

The GEH revised partial response to RAI 12.2-28 is provided in Enclosure 1. Note that this letter provides a partial response to Question 2, only, of the RAI, and is meant to replace the initial response provided by Reference 2. The response to all other questions in the RAI was provided by GEH via Reference 3. A partial response (Part 3 to RAI 12.2-28) to question 2 of the RAI was provided by Reference 4, and stands as submitted.

Enclosure 2 contains the DCD markups associated with this revised partial response.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

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NRO

References:

1. MFN 09-744, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, *Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application*, November 24, 2009
2. MFN 09-786, Supplement 1, Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28, January 19, 2010
3. MFN 09-786, Partial Response to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28, December 14, 2009
4. MFN 09-786, Supplement 2, Partial Response (Part 3) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28, January 29, 2010

Enclosures:

1. Revised Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28
2. Revised Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application – Dose Rates – RAI Number 12.2-28 – DCD Markups

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	TL Enfinger	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0110-8336 (Part 1 of response, for reference)
		0000-0112-1250, Rev. 1 (Part 2 of response, current revision)
		0000-0112-1251 (Part 3 of response, for reference)

Enclosure 1

MFN 09-786, Supplement 1, Revision 1

Revised Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application

Dose Rates

RAI Number 12.2-28

NRC RAI 12.2-28

Section 12.2 of the Tier 2 FSAR, "Plant Sources," states in part:

"Airborne sources are calculated using the source terms given in Section 11.1. . . ."

Table 11.1-3 was revised in Revision 6 of the Tier 2 FSAR to indicate that the ratio of condensate demineralizer flow to steam flow is 66.3%, versus the previous 100%. The staff was unable to determine the specific rationale for the change.

The staff noted that this change appears to result in greater buildup of radionuclides in liquid inventory, instantaneous liquid effluent release rates, and other aspects of plant operation potentially affecting worker and public dose. However, there did not appear to be a corresponding analysis of the change in dose estimations, in particular regarding whether and to what extent the radionuclide concentrations as listed in Tables 11.1-4a through 11.1-7b would be affected by the change in the ratio of condensate demineralizer versus steam flow rate. The staff needs to evaluate the effect on release rates and dose.

Please explain:

1. *The rationale that addresses the change in the ratio of condensate demineralizer flow to steam flow.*

2. *The effects on liquid and gaseous concentrations in systems and effluents, including any changes in public and population dose, and dose to the maximally exposed individual.*

3. *The interaction between the design basis and normal source term values in Section 11.1, and the doses listed in Section 12.2.*

4. *The effect of the changes to system radionuclide inventory on sources of in-plant exposure as described in Section 12.2.*

5. *Any implications for radiation protection design considerations (section 12.1.2 of the Tier 2 FSAR). The changes made to Table 11.1-3 appear to have resulted in increases in most or all of component activities listed in Tables 12.2-6 through 12.2-14. For <u>each</u> of these radioactive components,*

    a. *Verify that you have performed a detailed analysis on the affected components to determine the effects of the increased component activity on the expected component dose rates.*

    b. *Describe what effect the increase in component activity has on the dose rate levels and radioactive zone designations in the vicinity of <u>each of these components</u> (provide verification for your response) and reference*

appropriate Section 12.3 plant layout figures where radiation zone increases have been made.

c. *Describe what effect the increase in component activity will have on the doses to personnel performing maintenance on these components (in particular, describe how the doses associated with liquid and solid waste handling operations (such as condensate demineralizer maintenance) will be affected).*

d. *Describe what effect the potential increase in component doses will have on the total plant collective dose described in DCD Tables 12.4-1 through 12.4-7.*

e. *In describing the basis of the dose assessment for the ESBWR design, Section 12.4 of the DCD states the dose rates listed in Tier 2 Tables 12.4-2 through 12.4-7 are based on a combination of ESBWR radiation zoning levels and "experiential" data based on previous and current BWR plant designs. RG 8.19, "Occupational Radiation Dose Assessment in Light Water Reactor Power Plants- Design Stage Man-Rem Estimates" states that "to the extent possible, estimates should include consideration of the design of the proposed plant, including radiation field intensities calculated on the basis of the plant-specific shielding design, taking into account the effect of any dose-reducing design changes." Describe to what extent the estimated average dose rates listed in Tier 2 Tables 12.4-2 through 12.4-7 are based on the actual estimated ESBWR radiation zoning levels as depicted in Tier 2 Figures 12.3-1 through 12.3-22 and provide representative examples from Tables 12.4-2 through 12.4-7 where actual estimated ESBWR dose rates are used.*

In reviewing Tier 2 Section 12.4 of Revision 6 of the DCD, the staff noted that there are several references to the fact that 100% of the condensate water will be processed through the demineralizer instead of the 66.3% as listed in revised (Revision 6) Tier 2 Table 11.1-3.

6. *Modify the following sections of Tier 2 Section 12.4 to reflect the revised condensate cleanup percentage as reflected in Tier 2 Table 11.1-3:*

   (Section 12.4.6, paragraph 4 of "Drywell" section) "In addition, deposited activity in the feedwater lines is expected to be lower than typical BWRs owing to an enhanced condensate system with full cleanup of all condensate water ..."

   (Section 12.4.6, paragraph 4 of "Turbine Building" section) "Low-pressure feedwater drains from the feedwater heaters are cascaded back to the condenser, thus, all corrosion products from these drains are filtered via condensate filter/demineralizers before returning to the RPV."

GEH Revised Partial Response

Note: The response to all questions other than question 2 of this RAI was provided in Letter MFN 09-786, dated December 14, 2009. A partial response to question 2 was provided in Letter MFN 09-786, Supplement 2, dated January 29, 2010.

Question/Comment:
2. The effects on liquid and gaseous concentrations in systems and effluents, including any changes in public and population dose, and dose to the maximally exposed individual.

Revised Response (supersedes original response provided in Letter MFN 09-786, Supplement 1, dated January 19, 2010):

The effects on the liquid concentrations were incorporated in DCD Revision 6 Tables 11.1-4a through 11.1-5b, 11.1-7a, and 11.1-7b. The effects on liquid releases and dose results were incorporated in DCD Revision 6 Tables 12.2-19b and 12.2-20b respectively.

As a result of changes in the reactor coolant design basis concentrations, the ESBWR long-term dispersion estimates (X/Q and D/Q) were revised to ensure 10 CFR 50 Appendix I dose limits were not exceeded. The effect of the changes to the X/Q and D/Q values is shown in the updated DCD Tables 2.0-1 and 12.2-15.

Additionally, the text in DCD Tier 2 Subsection 12.2.2.1 is revised to provide a discussion of the X/Q and D/Q values in DCD Table 2.0-1. An analysis was performed for three potential ESBWR sites, using the site-specific meteorological data combined with the stack parameters in DCD Table 2B-1. The doses for all three sites using the ESBWR design met the 10 CFR 50 Appendix I gaseous effluent dose criteria. Since the discussion regarding the 27 representative sites and 800 meter distance was removed from the DCD Subsection 12.2.2.1 text, the value of 800 meters for the meteorology boundary was removed from DCD Table 12.2-15.

Footnote 12 in Table 2.0-1 was changed to point to the discussion in DCD Subsection 12.2.2.1, as well as emphasize the requirement for a specific site to use its site-specific X/Q and D/Q values in the determination of annual average airborne doses.

The revised offsite gaseous effluent releases are shown in Table 12.2-16.

The revised airborne releases and concentration values are shown in Table 12.2-17.

The revised annual average doses from airborne releases are shown in Table 12.2-18b.

The verified changes to building airborne radioactivity concentrations in DCD Tables 12.2-23a through 12.2-23e have been provided to the NRC in a partial response (Part 3), reference Letter MFN 09-786, Supplement 2, dated January 29, 2010.

DCD Impact

DCD Tier 2, Table 2.0-1 has been revised (Revision 7), and will be revised (Revision 8), as noted in the attached markups.

- Long-term Dispersion Estimated X/Q and D/Q value changes previously incorporated into DCD, Revision 7
- Change to Footnote 12 to be incorporated in DCD, Revision 8

DCD Tier 2, Subsection 12.2.2.1 will be revised (Revision 8) as noted in the attached markup.

DCD Tier 2, Table 12.2-15 has been revised (Revision 7), and will be revised (Revision 8), as noted in the attached markups.

- Meteorology X/Q and D/Q value changes previously incorporated into DCD, Revision 7
- Meteorology Boundary of 800 Meters to be deleted in DCD, Revision 8

DCD Tier 2, Tables 12.2-16, 12.2-17 and 12.2-18b have been revised (Revision 7) as noted in the attached markups.

Enclosure 2

MFN 09-786, Supplement 1, Revision 1

Revised Partial Response (Part 2) to NRC Request for Additional Information Letter No. 394 Related to ESBWR Design Certification Application

Dose Rates

RAI Number 12.2-28

DCD Markups

Table 2.0-1

Envelope of ESBWR Standard Plant Site Parameters[1] (continued)

Meteorological Dispersion (X/Q): [11] ***(continued)***	*Fuel Building*		
	0-2 hours:	*2.80E-03 s/m^3*	*2.80E-03 s/m^3*
	2-8 hours:	*2.50E-03 s/m^3*	*2.50E-03 s/m^3*
	8-24 hours:	*1.25E-03 s/m^3*	*1.25E-03 s/m^3*
	1-4 days:	*1.10E-03 s/m^3*	*1.10E-03 s/m^3*
	4-30 days:	*1.00E-03 s/m^3*	*1.00E-03 s/m^3*
* *First value is for unfiltered inleakage. Second value is for air intakes (emergency and normal)*	*Technical Support Center X/Q:**		
	Reactor Building		
	0-2 hours:	*1.00E-03 s/m^3*	*1.00E-03 s/m^3*
	2-8 hours:	*6.00E-04 s/m^3*	*6.00E-04 s/m^3*
	8-24 hours:	*3.00E-04 s/m^3*	*3.00E-04 s/m^3*
	1-4 days:	*2.00E-04 s/m^3*	*2.00E-04 s/m^3*
	4-30 days:	*1.00E-04 s/m^3*	*1.00E-04 s/m^3*
	Turbine Building		
	0-2 hours:	*2.00E-03 s/m^3*	*2.00E-03 s/m^3*
	2-8 hours:	*1.50E-03 s/m^3*	*1.50E-03 s/m^3*
	8-24 hours:	*8.00E-04 s/m^3*	*8.00E-04 s/m^3*
	1-4 days:	*6.00E-04 s/m^3*	*6.00E-04 s/m^3*
	4-30 days:	*5.00E-04 s/m^3*	*5.00E-04 s/m^3*
	Passive Containment Cooling System / Reactor Building Roof		
	0-2 hours:	*2.00E-03 s/m^3*	*2.00E-03 s/m^3*
	2-8 hours:	*1.10E-03 s/m^3*	*1.10E-03 s/m^3*
	8-24 hours:	*5.00E-04 s/m^3*	*5.00E-04 s/m^3*
	1-4 days:	*4.00E-04 s/m^3*	*4.00E-04 s/m^3*
	4-30 days:	*3.00E-04 s/m^3*	*3.00E-04 s/m^3*
Long Term Dispersion Estimates: [12]	***X/Q:***		
	Reactor/Fuel Building Ventilation Stack		~~*3.0E-07*~~*1.5E-07 s/m^3*
	Turbine Building Ventilation Stack		~~*2.0E-07*~~*1.2E-07 s/m^3*
	Radwaste Building Ventilation Stack		~~*2.0E-05*~~*5.0E-06 s/m^3*
	D/Q:		
	Reactor/Fuel Building Ventilation Stack		~~*1.0E-08*~~*4.8E-09 m^{-2}*
	Turbine Building Ventilation Stack		~~*6.0E-09*~~*3.5E-09 m^{-2}*
	Radwaste Building Ventilation Stack		~~*3.0E-08*~~*1.9E-08 m^{-2}*

(9) Safe Shutdown Earthquake (SSE) design ground response spectra of 5% damping, also termed Certified Seismic Design Response Spectra (CSDRS), are defined as free-field outcrop spectra at the foundation level (bottom of the base slab) of the Reactor/Fuel and Control Building structures. For the Firewater Service Complex, which is essentially a surface founded structure, the CSDRS is 1.35 times the values shown in Figures 2.0-1 and 2.0-2 and is defined as free-field outcrop spectra at the foundation level (bottom of the base slab) of the Firewater Service Complex structure.

(10) Values reported here are actually design criteria rather than site design parameters. They are included here because they do not appear elsewhere in the DCD.

(11) If a selected site has a X/Q value that exceeds the ESBWR reference site value, the COL Applicant will address how the radiological consequences associated with the controlling design basis accident continue to meet the dose reference values provided in 10 CFR 52.79(a)(1)(vi) and control room operator dose limits provided in General Design Criterion 19 using site-specific X/Q values.

(12) ~~If a selected site has X/Q values that exceed the ESBWR reference site values, the release concentrations in Table 12.2-17 would be adjusted proportionate to the change in X/Q values using the stack release information in Table 12.2-16. In addition, for a site selected that exceeds the bounding X/Q or D/Q values, the COL Applicant will address how the resulting annual average doses (Table 12.2-18b) continue to meet the dose reference values provided in 10 CFR 50 Appendix I using site specific X/Q and D/Q values~~Subsection 12.2.2.1 provides a discussion regarding the X/Q and D/Q values in this table. Per Subsection 12.2.2.2, a COL applicant is responsible for ensuring that offsite dose (using site-specific generated X/Q and D/Q values) due to radioactive airborne effluents complies with the regulatory dose limits in Sections II.B and II.C of 10 CFR 50, Appendix I.

(13) Value was selected to comply with expected requirements of southeastern coastal locations.

(14) Localized liquefaction potential under other than Seismic Category I structures is addressed per SRP 2.5.4 in Table 2.0-2.

(15) Settlement values are long-term (post-construction) values except for differential settlement within the foundation mat. The design of the foundation mat accommodates immediate and long-term (post-construction) differential settlements after the installation of the basemat.

(16) For sites not meeting the soil property requirements, a site-specific analysis is required to demonstrate the adequacy of the standard plant design.

*(17) The High Humidity Diurnal Swing and Daily Temperature Range are defined in Appendix 3H Subsection 3H.3.2.1]**

Text sections and table that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2. Prior NRC approval is required to change.

Guide 1.143 and the tank area concrete is provided with a sealant and a steel liner, as described in Subsection 11.2.2.3.2, to prevent any potential water releases from high activity areas.

12.2.1.5 Other Contained Sources

The COL Applicant will address any additional contained radiation sources (including sources for instrumentation and radiography) not identified in Subsection 12.2.1. (COL 12.2-4-A)

12.2.2 Airborne and Liquid Sources for Environmental Consideration

This subsection deals with the models, parameters, and sources required to evaluate the airborne concentration of radionuclides during plant operations in various plant radiation areas where personnel occupancy is expected. This subsection also deals with the sources and parameters required to evaluate airborne and liquid releases during normal plant operation for compliance with 10 CFR 20 and 10 CFR 50, Appendix I criteria.

12.2.2.1 Airborne Releases Offsite

Airborne sources are calculated using the source terms given in Section 11.1.

The bases for these calculations are shown in Table 12.2-15.

The ESBWR standard design employs three ventilation stacks (airborne release points). Individual stacks service the ventilation flows from the RB/FB, the TB and the RW. The offsite airborne release analysis of the ESBWR ventilation stack design employs separate long term atmospheric dispersion (X/Q) and deposition (D/Q) parameter values for each release location. The specific values for these parameters are shown in Table 12.2-15 ~~and were determined by performing an analysis of available meteorological data for 25 locations evaluated for the ABWR program and two existing nuclear power plant sites. The meteorological data were used to generate X/Q and D/Q parameters for the each of the described release points using the XOQDOQ computer code (NUREG/CR-2919 Reference 12.2-5). The atmospheric dispersion X/Q and D/Q parameters were generated for each of the 27 locations assuming an 800 meter exclusion area boundary (site boundary). The values shown in Table 12.2-15 bound (i.e., are greater than) a significant majority of the maximum generated X/Q and D/Q parameters for all the evaluated locations. Because the 27 locations represent a sampling of geographic areas, site-specific X/Q and D/Q are to be used for airborne dose evaluations at a specific site~~. The selected X/Q and D/Q values in Table 12.2-15 (and Table 2.0-1) yield a maximum organ dose just below the 10 CFR 50 Appendix I criterion, as can be seen in Table 12.2-18b. To demonstrate that the ESBWR design yields acceptable gaseous effluent doses for a reasonable number of sites that have been or may be considered for a COL application, a dose analysis was performed for three plant sites using the ESBWR design. The meteorological data for these sites, combined with the stack parameters listed in Table 2B-1, were used to calculate site-specific X/Q and D/Q values. While several X/Q and D/Q values for these three sites were not bounded by the ones listed in Tables 12.2-15 and 2.0-1, the regulatory criterion requiring compliance is the offsite dose. As a result, the site-specific X/Q and D/Q values were utilized in calculating the site annual average doses. The doses met the 10 CFR 50 Appendix I gaseous effluent dose criteria for all three sites using the ESBWR design.

Table 12.2-15

Airborne Sources Calculation

Calculation Bases	
Methodology	Appendix 12B
Noble Gas Source at t=30 min	740 MBq/sec (20,000 μCi/sec)
I-131 Release Rate	3.7 MBq/sec (100 μCi/sec)
~~Meteorology Boundary~~	~~800 Meters~~
Meteorology χ/Q	
RB/FB Ventilation Stack	~~3.0E-07~~1.5E-07 s/m^3
TB Ventilation Stack	~~2.0E-07~~1.2E-07 s/m^3
RW Ventilation Stack	~~2.0E-05~~5.0E-06 s/m^3
Meteorology D/Q	
RB/FB Ventilation Stack	~~1.0E-08~~4.8E-09 m^{-2}
TB Ventilation Stack	~~6.0E-09~~3.5E-09 m^{-2}
RW Ventilation Stack	~~3.0E-08~~1.9E-08 m^{-2}
Plant Availability Factor	0.92
Offgas System:	
Offgas stream temperature	100°F
Flow rate at 100°F	54 m^3/hr
K_d (Kr)	18.5 cm^3/g
K_d (Xe)	330 cm^3/g
K_d (Ar)	6.4 cm^3/g
Guard tank charcoal mass	7,500 kg (single tank)
Adsorber tank charcoal mass	27,750 kg (each)
Adsorber tank arrangement	2 parallel trains of 4 tanks each
Turbine Gland Sealing System Exhaust:	
I-131 release	0.81 Ci/yr per μCi/g of I-131 in coolant
I-133 release	0.22 Ci/yr per μCi/g of I-133 in coolant

Table 12.2-16

Annual Airborne Releases for Offsite Dose Evaluations (MBq)**

Nuclide*	Reactor Building	Turbine Building	Radwaste Building	Mechanical Vacuum Pump	Turbine Seal	Offgas System	Drywell
Kr-83m						1.4E-04	8.5E+01
Kr-85m	9.0E+04	5.6E+05				6.6E+03	3.4E+02
Kr-85						5.2E+06	7.5E+01
Kr-87	4.5E+04	1.4E+06				8.5E-10	3.1E+02
Kr-88	9.0E+04	2.0E+06				1.4E+01	6.9E+02
Kr-89	4.5E+04	1.3E+07	6.5E+05				8.3E+01
Xe-131m						1.5E+05	4.1E+01
Xe-133m						8.1E-01	1.9E+02
Xe-133	2.5E+06	3.4E+06	5.0E+06	2.9E+07		8.5E+05	1.1E+04
Xe-135m	1.4E+06	9.0E+06	1.2E+07				8.5E+01
Xe-135	2.9E+06	7.4E+06	6.3E+06	1.1E+07		4.4E-37	2.6E+03
Xe-137	4.1E+06	2.3E+07	1.9E+06				1.2E+02
Xe-138	1.8E+05	2.3E+07	4.5E+04				2.7E+02
I-131	2.0E+039.4E+02	1.1E+045.2E+03	7.0E+023.4E+02	3.9E+031.8E+03	9.8E+014.7E+01		7.1E+023.4E+02
I-132	1.4E+048.5E+03	7.5E+044.6E+04	4.9E+033.0E+03				8.0E+014.9E+01
I-133	1.3E+046.2E+03	7.0E+043.4E+04	4.6E+032.2E+03		1.7E+028.4E+01		6.8E+023.3E+02
I-134	2.1E+041.5E+04	1.2E+058.4E+04	7.6E+035.5E+03				4.8E+013.4E+01
I-135	1.7E+048.6E+03	9.4E+044.7E+04	6.1E+033.1E+03				2.9E+021.4E+02
H-3	1.2E+06	1.2E+06					2.6E+05
C-14						5.3E+05	
Na-24							5.9E+005.4E+00
P-32							1.5E+001.3E+00
Ar-41						1.4E+03	

Table 12.2-16

Annual Airborne Releases for Offsite Dose Evaluations (MBq)**

Nuclide*	Reactor Building	Turbine Building	Radwaste Building	Mechanical Vacuum Pump	Turbine Seal	Offgas System	Drywell
Cr-51	5.5E+012.6E+01	4.5E+012.2E+01	3.5E+011.7E+01				1.3E+021.1E+02
Mn-54	7.0E+013.3E+01	3.0E+011.4E+01	2.0E+029.6E+01				1.8E+001.7E+00
Mn-56							1.2E+011.1E+01
Fe-55							5.1E+014.7E+01
Fe-59	2.0E+019.3E+00	5.0E+002.4E+00	1.5E+017.2E+00				1.4E+001.2E+00
Co-58	1.5E+017.2E+00	5.0E+012.4E+01	1.0E+014.8E+00				4.8E+004.4E+00
Co-60	2.5E+021.2E+02	5.0E+012.4E+01	3.5E+021.7E+02				1.0E+019.4E+00
Ni-63							5.2E-024.7E-02
Cu-64							7.5E+006.9E+00
Zn-65	2.5E+021.2E+02	3.0E+021.4E+02	1.5E+017.2E+00				5.1E+014.6E+01
Rb-89							2.0E-01
Sr-89	2.5E+001.2E+00	3.0E+021.4E+02					4.7E+004.3E+00
Sr-90	5.0E-012.4E-01	1.0E+004.8E-01					3.6E-013.3E-01
Y-90							8.9E-028.1E-02
Sr-91							7.5E+006.7E+00
Sr-92							4.9E+004.6E+00
Y-91							1.9E+001.7E+00
Y-92							3.8E+003.7E+00
Y-93							8.1E+007.2E+00
Zr-95	5.0E+012.4E+01	2.0E+009.6E-01	4.0E+011.9E+01				3.8E-013.5E-01
Nb-95	5.0E+022.	3.0E-	2.0E-019.6E-				3.6E-

Table 12.2-16

Annual Airborne Releases for Offsite Dose Evaluations (MBq)**

Nuclide*	Reactor Building	Turbine Building	Radwaste Building	Mechanical Vacuum Pump	Turbine Seal	Offgas System	Drywell
	4E+02	011.4E-01	02				013.3E-01
Mo-99	3.3E+031.6E+03	1.0E+024.8E+01	1.5E-017.2E-02				2.6E+012.4E+01
Tc-99m							2.4E+002.2E+00
Ru-103	2.1E+021.0E+02	2.5E+001.2E+00	5.0E-022.4E-02				9.1E-018.2E-01
Rh-103m							3.8E-033.5E-03
Ru-106							1.6E-011.4E-01
Rh-106							5.2E-064.5E-06
Ag-110m	1.2E-015.7E-02						5.1E-024.6E-02
Sb-124	2.5E+001.2E+00	5.0E+002.4E+00	3.5E+001.7E+00				
Te-129m							1.8E+001.6E+00
Te-131m							6.0E-015.5E-01
Te-132							1.5E-011.4E-01
Cs-134	2.4E+021.1E+02	1.0E+014.8E+00	1.2E+025.7E+01				1.4E+003.3E+00
Cs-136	2.5E+012.2E+01	5.0E+002.4E+00					6.4E-015.8E-01
Cs-137	3.0E+024.4E+02	5.0E+012.4E+01	2.0E+029.6E+01				3.7E+003.4E+00
Cs-138							8.5E-01
Ba-140	1.1E+035.3E+02	5.0E+022.4E+02	2.0E-019.6E-02				1.4E+013.3E+01
La-140							1.4E+013.3E+01
Ce-141	4.5E+012.2E+01	5.0E+022.4E+02	3.5E-011.7E-01				1.4E+002.2E+00
Ce-144							1.6E-011.3E-01
Pr-144							1.8E-041.6E-04

Table 12.2-16

Annual Airborne Releases for Offsite Dose Evaluations (MBq)**

Nuclide*	Reactor Building	Turbine Building	Radwaste Building	Mechanical Vacuum Pump	Turbine Seal	Offgas System	Drywell
W-187							1.4E+00~~1.3E+00~~
Np-239							9.0E+01~~8.3E+01~~

* Table 11.1-5a provides the basis for the airborne releases of the following radionuclide pairs:
Sr-90/Y-90
Zr-95/Nb-95
Mo-99/Tc-99m
Ru-103/Rh-103m
Ru-106/Rh-106
Ba-140/La-140
Ce-144/Pr-144
The coolant concentration of the daughter in Table 11.1-5a is assumed to be that of the parent. The annual airborne release of each radionuclide is determined utilizing the methodology provided in Appendix 12B.

** The releases (as designed in the table column headings) from the building stacks are as follows:
Reactor Building/Fuel Building stack: "Reactor Building" and "Drywell"
Turbine Building stack: "Turbine Building", "Mechanical Vacuum Pump", "Turbine Seal", and "Offgas System"
Radwaste Building stack: "Radwaste Building"

Table 12.2-17

Comparison of Airborne Concentrations with 10 CFR 20 Concentrations

	Airborne Release	Concentration	10 CFR 20
Nuclide	MBq/yr	Bq/m^3	Bq/m^3
Kr-83m	8.5E+01	4.0E-07~~8.0E-07~~	2.E+06
Kr-85m	6.6E+05	2.6E-03~~4.5E-03~~	4.E+03
Kr-85	5.2E+06	2.0E-02~~3.3E-02~~	3.E+04
Kr-87	1.4E+06	5.4E-03~~9.1E-03~~	7.E+02
Kr-88	2.1E+06	8.2E-03~~1.4E-02~~	3.E+02
Kr-89	1.4E+07	1.5E-01~~5.0E-01~~	4.E+01
Xe-131m	1.5E+05	5.6E-04~~9.3E-04~~	7.E+04
Xe-133m	1.9E+02	9.2E-07~~1.8E-06~~	2.E+04
Xe-133	4.1E+07	9.3E-01~~3.4E+00~~	2.E+04
Xe-135m	2.2E+07	1.9E+00~~7.6E+00~~	1.E+03
Xe-135	2.8E+07	1.1E+00~~4.1E+00~~	3.E+03
Xe-137	2.8E+07	4.0E-01~~1.4E+00~~	4.E+01
Xe-138	2.3E+07	9.4E-02~~1.7E-01~~	7.E+02
I-131	1.8E+04~~8.7E+03~~	1.8E-04~~2.7E-04~~	7.E+00
I-132	9.4E+04~~5.8E+04~~	1.1E-03~~2.3E-03~~	7.E+02
I-133	8.9E+04~~4.3E+04~~	1.1E-03~~1.7E-03~~	4.E+01
I-134	1.5E+05~~1.1E+05~~	1.8E-03~~4.2E-03~~	2.E+03
I-135	1.2E+05~~5.9E+04~~	1.4E-03~~2.3E-03~~	2.E+02
H-3	2.8E+06	1.2E-02~~2.2E-02~~	4.E+03
C-14	5.3E+05	2.0E-03~~3.4E-03~~	1.E+02
Na-24	5.9E+00~~5.4E+00~~	2.8E-08~~5.2E-08~~	3.E+02
P-32	1.5E+00~~1.3E+00~~	7.1E-09~~1.3E-08~~	2.E+01
Ar-41	1.4E+03	5.4E-06~~9.0E-06~~	4.E+02
Cr-51	2.7E+02~~1.8E+02~~	6.6E-06~~1.2E-05~~	1.E+03
Mn-54	3.0E+02~~1.5E+02~~	3.2E-05~~6.1E-05~~	4.E+01
Mn-56	1.2E+01~~1.1E+01~~	5.6E-08~~1.0E-07~~	7.E+02

Table 12.2-17

Comparison of Airborne Concentrations with 10 CFR 20 Concentrations

	Airborne Release	Concentration	10 CFR 20
Nuclide	MBq/yr	Bq/m^3	Bq/m^3
Fe-55	5.1E+01~~4.7E+01~~	2.4E-07~~4.5E-07~~	1.E+02
Fe-59	4.1E+01~~2.0E+01~~	2.5E-06~~4.7E-06~~	2.E+01
Co-58	8.0E+01~~4.0E+01~~	1.9E-06~~3.3E-06~~	4.E+01
Co-60	6.6E+02~~3.2E+02~~	5.7E-05~~1.1E-04~~	2.E+00
Ni-63	5.2E-02~~4.7E-02~~	2.5E-10~~4.5E-10~~	4.E+01
Cu-64	7.5E+00~~6.9E+00~~	3.6E-08~~6.6E-08~~	1.E+03
Zn-65	6.2E+02~~3.2E+02~~	5.0E-06~~7.0E-06~~	1.E+01
Rb-89	2.0E-01	9.5E-10~~1.9E-09~~	7.E+03
Sr-89	3.1E+02~~1.5E+02~~	1.2E-06~~9.6E-07~~	7.E+00
Sr-90	1.9E+00~~1.0E+00~~	7.9E-09~~8.4E-09~~	2.E-01
Y-90	8.9E-02~~8.1E-02~~	4.2E-10~~7.7E-10~~	3.E+01
Sr-91	7.5E+00~~6.7E+00~~	3.6E-08~~6.4E-08~~	2.E+02
Sr-92	4.9E+00~~4.6E+00~~	2.3E-08~~4.4E-08~~	3.E+02
Y-91	1.9E+00~~1.7E+00~~	9.2E-09~~1.7E-08~~	7.E+00
Y-92	3.8E+00~~3.7E+00~~	1.8E-08~~3.5E-08~~	4.E+02
Y-93	8.1E+00~~7.2E+00~~	3.8E-08~~6.9E-08~~	1.E+02
Zr-95	9.2E+01~~4.4E+01~~	6.6E-06~~1.2E-05~~	1.E+01
Nb-95	5.0E+02~~2.4E+02~~	2.4E-06~~2.3E-06~~	7.E+01
Mo-99	3.4E+03~~1.7E+03~~	1.6E-05~~1.6E-05~~	7.E+01
Tc-99m	2.4E+00~~2.2E+00~~	1.2E-08~~2.1E-08~~	7.E+03
Ru-103	2.1E+02~~1.0E+02~~	1.0E-06~~9.9E-07~~	3.E+01
Rh-103m	3.8E-03~~3.5E-03~~	1.8E-11~~3.3E-11~~	7.E+04
Ru-106	1.6E-01~~1.4E-01~~	7.4E-10~~1.3E-09~~	7.E-01
Rh-106	5.2E-06~~4.5E-06~~	2.5E-14~~4.3E-14~~	4.E+01
Ag-110m	1.7E-01~~1.0E-01~~	8.1E-10~~9.9E-10~~	4.E+00
Sb-124	1.1E+01~~5.3E+00~~	5.9E-07~~1.1E-06~~	1.E+01
Te-129m	1.8E+00~~1.6E+00~~	8.6E-09~~1.5E-08~~	1.E+01
Te-131m	6.0E-01~~5.5E-01~~	2.9E-09~~5.2E-09~~	4.E+01
Te-132	1.5E-01~~1.4E-01~~	7.3E-10~~1.3E-09~~	3.E+01
Cs-134	3.7E+02~~1.8E+02~~	2.0E-05~~3.8E-05~~	7.E+00
Cs-136	3.1E+01~~1.5E+01~~	1.4E-07~~1.3E-07~~	3.E+01
Cs-137	5.5E+02~~2.7E+02~~	3.3E-05~~6.2E-05~~	7.E+00

Table 12.2-17

Comparison of Airborne Concentrations with 10 CFR 20 Concentrations

	Airborne Release	Concentration	10 CFR 20
Nuclide	MBq/yr	Bq/m^3	Bq/m^3
Cs-138	8.5E-01	4.0E-09~~8.1E-09~~	3.E+03
Ba-140	1.6E+03~~7.8E+02~~	7.2E-06~~6.7E-06~~	7.E+01
La-140	1.4E+01~~1.3E+01~~	6.8E-08~~1.2E-07~~	7.E+01
Ce-141	5.5E+02~~2.6E+02~~	2.2E-06~~1.8E-06~~	3.E+01
Ce-144	1.6E-01~~1.3E-01~~	7.4E-10~~1.3E-09~~	7.E-01
Pr-144	1.8E-04~~1.6E-04~~	8.6E-13~~1.5E-12~~	7.E+00
W-187	1.4E+00~~1.3E+00~~	6.6E-09~~1.2E-08~~	4.E+02
Np-239	9.0E+01~~8.3E+01~~	4.3E-07~~7.9E-07~~	1.E+02

Table 12.2-18b

ESBWR Annual Average Doses from Airborne Releases

	Annual Dose (mSv/year)							
PATHWAY	**T. BODY**	**GI-TRACT**	**BONE**	**LIVER**	**KIDNEY**	**THYROID**	**LUNG**	**SKIN**
PLUME	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.20E-03 8.15E-03	2.23E-03 8.27E-03	5.38E-03 1.94E-02
GROUND	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.51E-03 2.04E-03	2.95E-03 2.38E-03
VEGETABLE								
ADULT	7.46E-04 7.07E-04	5.61E-04 5.59E-04	1.22E-03 1.44E-03	1.01E-03 9.25E-04	5.57E-04 5.52E-04	3.44E-02 2.89E-02	1.82E-04 2.36E-04	9.97E-05 1.67E-04
TEEN	7.78E-04 7.87E-04	6.58E-04 6.93E-04	1.95E-03 2.32E-03	1.55E-03 1.43E-03	8.48E-04 8.48E-04	4.44E-02 3.73E-02	3.10E-04 3.95E-04	1.62E-04 2.72E-04
CHILD	1.02E-03 1.18E-03	7.30E-04 9.40E-04	4.63E-03 5.51E-03	2.68E-03 2.57E-03	1.47E-03 1.56E-03	8.40E-02 7.09E-02	6.08E-04 8.34E-04	3.88E-04 6.50E-04
MEAT								
ADULT	8.99E-05 1.07E-04	2.09E-04 2.23E-04	2.25E-04 3.42E-04	1.11E-04 1.26E-04	6.97E-05 9.12E-05	6.57E-04 5.81E-04	4.36E-05 6.78E-05	3.75E-05 6.25E-05
TEEN	5.96E-05 7.66E-05	1.27E-04 1.41E-04	1.89E-04 2.88E-04	8.95E-05 1.03E-04	5.65E-05 7.48E-05	4.80E-04 4.28E-04	3.72E-05 5.74E-05	3.14E-05 5.25E-05
CHILD	8.58E-05 1.22E-04	1.09E-04 1.45E-04	3.51E-04 5.38E-04	1.32E-04 1.61E-04	8.93E-05 1.25E-04	7.36E-04 6.66E-04	6.54E-05 1.04E-04	5.89E-05 9.82E-05
MILK								
ADULT	4.27E-04 3.93E-04	1.23E-04 1.44E-04	5.33E-04 6.14E-04	6.07E-04 5.48E-04	3.29E-04 3.15E-04	1.78E-02 1.49E-02	9.12E-05 1.11E-04	4.16E-05 6.96E-05
TEEN	4.88E-04 4.77E-04	1.76E-04 2.17E-04	9.61E-04 1.11E-03	1.06E-03 9.59E-04	5.74E-04 5.52E-04	2.82E-02 2.37E-02	1.76E-04 2.10E-04	7.59E-05 1.27E-04

Table 12.2-18b

ESBWR Annual Average Doses from Airborne Releases

	Annual Dose (mSv/year)							
PATHWAY	**T. BODY**	**GI-TRACT**	**BONE**	**LIVER**	**KIDNEY**	**THYROID**	**LUNG**	**SKIN**
CHILD	6.07E-04~~6.75E-04~~	2.55E-04~~3.72E-04~~	2.31E-03~~2.69E-03~~	1.83E-03~~1.70E-03~~	9.93E-04~~9.98E-04~~	5.60E-02~~4.71E-02~~	3.36E-04~~4.35E-04~~	1.85E-04~~3.10E-04~~
INFANT	9.04E-04~~1.09E-03~~	6.40E-04~~8.88E-04~~	4.09E-03~~4.92E-03~~	3.58E-03~~3.34E-03~~	1.68E-03~~1.75E-03~~	1.36E-01~~1.14E-01~~	6.55E-04~~8.67E-04~~	3.86E-04~~6.43E-04~~
INHALE								
ADULT	1.45E-05~~2.62E-05~~	1.49E-05~~2.50E-05~~	1.22E-05~~2.14E-05~~	2.38E-05~~4.24E-05~~	2.37E-05~~4.09E-05~~	1.42E-03~~2.23E-03~~	1.18E-04~~2.17E-04~~	2.31E-06~~4.32E-06~~
TEEN	1.40E-05~~2.50E-05~~	1.59E-05~~2.64E-05~~	1.70E-05~~2.97E-05~~	3.14E-05~~5.59E-05~~	3.13E-05~~5.40E-05~~	1.85E-03~~2.92E-03~~	1.71E-04~~3.16E-04~~	2.33E-06~~4.36E-06~~
CHILD	1.12E-05~~1.98E-05~~	9.74E-06~~1.69E-05~~	2.28E-05~~3.98E-05~~	2.96E-05~~5.26E-05~~	2.89E-05~~4.95E-05~~	2.28E-03~~3.60E-03~~	1.39E-04~~2.57E-04~~	2.06E-06~~3.85E-06~~
INFANT	6.64E-06~~1.15E-05~~	4.80E-06~~8.70E-06~~	1.58E-05~~2.73E-05~~	2.35E-05~~4.16E-05~~	1.83E-05~~3.13E-05~~	2.08E-03~~3.28E-03~~	9.09E-05~~1.66E-04~~	1.19E-06~~2.22E-06~~
TOTAL**	**Annual Dose (mSv/year)**							
ADULT	3.79E-03~~3.27E-03~~	3.42E-03~~2.99E-03~~	4.50E-03~~4.45E-03~~	4.26E-03~~3.68E-03~~	3.49E-03~~3.04E-03~~	5.67E-02~~4.87E-02~~	2.94E-03~~2.67E-03~~	3.13E-03~~2.69E-03~~
TEEN	3.85E-03~~3.40E-03~~	3.48E-03~~3.11E-03~~	5.63E-03~~5.78E-03~~	5.24E-03~~4.59E-03~~	4.02E-03~~3.56E-03~~	7.75E-02~~6.64E-02~~	3.20E-03~~3.01E-03~~	3.22E-03~~2.84E-03~~
CHILD	4.23E-03~~4.04E-03~~	3.61E-03~~3.51E-03~~	9.82E-03~~1.08E-02~~	7.18E-03~~6.51E-03~~	5.09E-03~~4.77E-03~~	1.46E-01~~1.24E-01~~	3.66E-03~~3.67E-03~~	3.58E-03~~3.45E-03~~
INFANT	3.42E-03~~3.14E-03~~	3.15E-03~~2.93E-03~~	6.61E-03~~6.98E-03~~	6.11E-03~~5.42E-03~~	4.21E-03~~3.81E-03~~	1.41E-01~~1.20E-01~~	3.25E-03~~3.07E-03~~	3.33E-03~~3.03E-03~~

Annual beta air dose = ~~1.14E-02~~3.23E-03 mGy
Annual gamma air dose = ~~1.24E-02~~ 3.36E-03 mGy

** Total doses correspond to the organ doses from all pathways of exposure (excluding the plume pathway) due to radioactive iodine and radioactive material in particulate form in accordance with 10 CFR 50, Appendix I, Section II.C