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Chapter 11 Radioactive Waste Management

11.2.3 Liquid Radioactive Releases

This section describes the radiological impacts of liquid radwaste effluents from normal plant operation on members of the public. Subsection 11.2.3.1 describes the exposure pathways by which radiation and radioactive effluents can be transmitted from the proposed units to individuals living near the plant. Subsection 11.2.3.2 estimates the maximum doses to the public and evaluates the impacts of these doses by comparing them to regulatory limits.

11.2.3.1 Exposure Pathways

Small quantities of radioactive liquids would be discharged to the Guadalupe River during normal operation of the proposed units. The discharge structure and associated blowdown piping provide a pathway for liquid effluents, including radioactive liquids, discharged to the Guadalupe River. The impact of these releases on individuals and the population in the vicinity of the proposed units is evaluated by considering the most important pathways from the release to the receptors of interest. The major pathways are those that could yield the highest radiological doses for a given receptor. The relative importance of a pathway is based on the type and amount of radioactivity released, the environmental transport mechanism, and the consumption or usage factors at the receptor.

The exposure pathways considered and the analytical methods used to estimate doses to the maximally exposed individual (MEI) and to the population surrounding the proposed units are based on NRC Regulatory Guide (RG) 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I, Revision 1, October 1977. An MEI is a member of the public located to receive the maximum possible calculated dose. The MEI allows dose comparisons with established criteria for the public.

Liquid effluent releases would be to the Guadalupe River. The discharge is assumed to be fully mixed with the river flow. The NRC-endorsed LADTAP II computer program (Reference 11.2.3-1) is used to calculate liquid effluent doses, with parameters specific to the river and downstream locations. This program implements the radiological exposure models described in RG 1.109 for radioactivity releases in liquid effluent, as well as exposure models for boating and swimming as described in NUREG/CR-4013 (Reference 11.2.3-1). The following exposure pathways are considered in LADTAP II in calculating MEI and population doses:

- Ingestion of aquatic foods
- Ingestion of drinking water
- Ingestion of irrigated meat, milk, and vegetables

- External exposure to shoreline sediments
- External exposure to water through boating and swimming

The input parameters for the liquid pathway are presented in Table 11.2.3-1.

11.2.3.2 Liquid Pathway Doses

Based on the parameters shown in Table 11.2.3-1, the LADTAP II computer program is used to calculate doses to the MEI and the population via the following activities:

- Eating fish caught in Guadalupe River
- Drinking water from Guadalupe River
- Ingesting meat, milk, and vegetables affected by irrigation
- Boating, swimming, and using the shoreline for recreational purposes

The liquid activity release source term for the proposed units is a conservative, bounding composite that was obtained by identifying the greatest activity for the technologies identified in Section 1.10 for each radionuclide and is shown in Table 11.2.3-2. These values are per reactor, except for mPower. For mPower, the activities from six reactors are considered when arriving at the composite values. Projected activity concentrations in the Guadalupe River are within the limits of 10 CFR 20, Appendix B, Table 2, Column 2 (Table 11.2.3-3). The calculated annual doses to the MEI are presented in Table 11.2.3-4. The maximum annual organ dose of 2.2 mrem per unit would be received by the lower large intestine in the GI tract (GI-LLI) of the maximally exposed adult.

Table 11.2.3-5 shows that the doses to the MEI from the liquid effluents of a proposed unit meet the design objectives of 10 CFR 50, Appendix I. The total site doses due to liquid and gaseous effluents from the proposed units would be well within the regulatory limits of 40 CFR 190, as shown in Table 11.2.3-6. Since 40 CFR 190 is more restrictive than 10 CFR 20.1301, compliance with the limits of 40 CFR 190 also demonstrates compliance with the 0.1 rem limit of 10 CFR 20.1301. Table 11.2.3-7 shows the doses from the proposed units to the population within 50 miles of the ESP site.

11.2.3.3 References

11.2.3-1 NUREG/CR-4013, *LADTAP II Technical Reference and User Guide*, U.S. Nuclear Regulatory Commission, 1986.

11.2.3-2 *Water Use Estimates by Location of Use*, Texas Water Development Board, 2004.

11.2.3-3 *State and County Quick Facts*, U.S. Census Bureau, 2006.

11.2.3-4 *2006 National Survey of Fishing, Hunting, and Wildlife — Associated Recreation — Texas*, U.S. Fish & Wildlife Service, 2006.

11.2.3-5 *2007 Census of Agriculture, Texas State and County Data*, Volume 1, USDA 2009.

11.2.3-6 National Agricultural Statistics Service, *2007 Texas Agricultural Statistics*, USDA, 2007.

11.2.3-7 *Exposure of the Population in the United States and Canada from Natural Background Radiation*, National Council on Radiation Protection and Measurements, 1987.

Table 11.2.3-1 (Sheet 1 of 3)
Liquid Pathway Parameters

Parameter	Value	Basis/Source(s)
Release Source Terms	See Table 11.2.3-2	Table 11.2.3-2 shows the activity releases by isotope.
Impoundment Reconcentration Model	None	This model does not apply to the river discharge scenario.
Individual Consumption/ Exposure Rates	See RG 1.109	The values from Tables E-5 and E-4 of RG 1.109 are used for the MEI and the average person within the population, respectively.
Site Water Type	River	Guadalupe River.
Discharge Flow Rate	480 cfs	This is a conservative flow rate that represents the 95th percentile of all observed annual average flow rates from 1935 to 2008.
Shore-Width Factor	0.2	This is the appropriate value for a river (RG 1.109, Table A-2).
Dilution factor for Discharge	1	No dilution is assumed beyond mixing in the river flow rate.
Transit Time to Receptor	See RG 1.109	The default transit times from RG 1.109, Table D-1 are used.
Irrigation Rate	110 l/m^2 per month	Based on an assumed value of 1 inch per week.
50-Mile Population	$4.15x10^5$	This is the projected population for the year 2080, the assumed end of plant life. It is used to conservatively maximize population doses. This projection represents an increase of a factor of 1.7 over the 2000 population.
50-Mile Drinking Water Population	$7.08x10^4$	Of the municipal water usage in the 12 counties within 50 miles of the plant, 17% comes from the Guadalupe River (Reference 11.2.3-2). Based on this, it is assumed that 17% of the population in 2080 receives its drinking water from Guadalupe River.
50-Mile Sport Fishing Harvest	$6.69x10^4$ kg/yr	Based on RG 1.109, Appendix D and Table E-4, the average individual consumes 5.9 kg/yr of fish. Multiplying this by the 2080 population yields the total annual consumption of fish within 50 miles of 2.43 $x10^6$ kg/yr. Of the state population of 20.9 million (Reference 11.2.3-3), 0.574 million (Reference 11.2.3-4) or about 2.75% engages in sport fishing in rivers. It is assumed that 2.75% of the fish consumption within 50 miles is due to sport fishing from Guadalupe River.
50-Mile Commercial Fishing Harvest	$1.15x10^6$ kg/yr	As the previous entry indicates, of the total fish consumption within 50 miles of 2.43 $x10^6$ kg/yr, 2.75% is due to sport fishing. It is assumed that Guadalupe River is the source of 50% of the fish consumed within 50 miles, with the remaining 47.25% coming from commercial fishing.
50-Mile Sport Invertebrate Harvest	$9.71x10^3$ kg/yr	Based on RG 1.109, Appendix D and Table E-4, the average individual consumes 0.85 kg/yr of invertebrate. Multiplying this by the 2080 population yields the total annual consumption of invertebrate within 50 miles of $3.53x10^5$ kg/yr. As with sport fishing, it is assumed that 2.75% of the invertebrate consumption within 50 miles is due to sport invertebrate harvest from the Guadalupe River.
50-Mile Commercial Invertebrate Harvest	$1.67x10^5$ kg/yr	As the previous entry indicates, of the total invertebrate consumption within 50 miles of $3.53x10^5$ kg/yr, 2.75% is due to sport invertebrate harvest. It is assumed that Guadalupe River is the source of 50% of the invertebrate consumed within 50 miles, with the remaining 47.25% coming from commercial harvest.

Table 11.2.3-1 (Sheet 2 of 3)
Liquid Pathway Parameters

Parameter	Value	Basis/Source(s)
50-Mile Shoreline Usage	5.30×10^6 hr/yr	Based on RG 1.109, Appendix D and Table E-4, the average individual spends 12.8 hr/yr on shoreline recreation. This is multiplied by the 2080 population to yield the shoreline usage within 50 miles.
50-Mile Swimming Usage	5.30×10^6 hr/yr	Based on 12.8 hr/yr, same as shoreline usage.
50-Mile Boating Usage	5.30×10^6 hr/yr	Based on 12.8 hr/yr, same as shoreline usage.
50-Mile Leafy Vegetable Production	9.65×10^6 kg/yr	The harvested land area in the 12 counties within 50 miles represents about 3.5% of the state total (Reference 11.2.3-5). The annual production of leafy vegetables in the state (Reference 11.2.3-6) is multiplied by 3.5% to estimate the production within 50 miles. Assuming production to increase with the population, the production is also multiplied by the population growth factor of 1.7 to project the production in 2080.
50-Mile Leafy Vegetable Production with Irrigated Water	9.49×10^3 kg/yr	Within the 12 counties within 50 miles, 5.7% of the harvested land is irrigated (Reference 11.2.3-5). Of the water used for irrigation in the 12 counties, 1.7% comes from the Guadalupe River (Reference 11.2.3-2). The 50-mile leafy vegetable production is multiplied by these two fractions to estimate the production using irrigated water from the Guadalupe River.
50-Mile Vegetable Production	5.18×10^7 kg/yr	The harvested land area in the 12 counties within 50 miles represents about 3.5% of the state total (Reference 11.2.3-5). The annual production of vegetables in the state (Reference 11.2.3-6) is multiplied by 3.5% to estimate the production within 50 miles. Assuming production to increase with the population, the production is also multiplied by the population growth factor of 1.7 to project the production in 2080.
50-Mile Vegetable Production with Irrigated Water	5.09×10^4 kg/yr	Within the 12 counties within 50 miles, 5.7% of the harvested land is irrigated (Reference 11.2.3-5). Of the water used for irrigation in the 12 counties, 1.7% comes from the Guadalupe River (Reference 11.2.3-2). The 50-mile vegetable production is multiplied by these two fractions to estimate the production using irrigated water from the Guadalupe River.
50-Mile Milk Production	1.41×10^7 l/yr	Milk cows in the 12 counties within 50 miles represent about 0.24% of the state total (Reference 11.2.3-5). The annual production of milk in the state (Reference 11.2.3-6) is multiplied by 0.24% to estimate the production within 50 miles. Assuming production to increase with the population, the production is also multiplied by the population growth factor of 1.7 to project the production in 2080.
50-Mile Milk Production with Irrigated Water	1.60×10^5 l/yr	Within the 12 counties within 50 miles, 5.7% of the harvested land is irrigated (Reference 11.2.3-5). Of the water used for livestock in the 12 counties within 50 miles, 20% comes from the Guadalupe River (Reference 11.2.3-2). The 50-mile milk production is multiplied by these two fractions to estimate the production using irrigated water from the Guadalupe River.

Table 11.2.3-1 (Sheet 3 of 3)
Liquid Pathway Parameters

Parameter	Value	Basis/Source(s)
50-Mile Meat Production	2.23×10^{8} kg/yr	Beef cows and broilers in the 12 counties within 50 miles represent about 5.6% and 0.20%, respectively, of the state totals (Reference 11.2.3-5). The annual productions of red meat and broiler in the state (Reference 11.2.3-6) are multiplied by these percentages and summed to estimate the total meat production within 50 miles. Assuming production to increase with the population, the production is also multiplied by the population growth factor of 1.7 to project the production in 2080.
50-Mile Meat Production with Irrigated Water	2.52×10^{6} kg/yr	Within the 12 counties within 50 miles, 5.7% of the harvested land is irrigated (Reference 11.2.3-5). Of the water used for livestock in the 12 counties within 50 miles, 20% comes from the Guadalupe River (Reference 11.2.3-2). The 50-mile meat production is multiplied by these two fractions to estimate the production using irrigated water from the Guadalupe River.

Table 11.2.3-2 (Sheet 1 of 2)
Composite Liquid Effluent Activities

Radionucilde	AP1000	APWR	ABWR-GEH	ABWR –Toshiba	ESBWR	mPower	Max
H-3	1.01×10^{3}	1.60×10^{3}	8.00	6.00×10^{1}	1.40×10^{1}	7.56×10^{2}	1.60×10^{3}
C-14	0.00	0.00	0.00	1.60×10^{-4}	0.00	0.00	1.60×10^{-4}
Na-24	1.63×10^{-3}	4.70×10^{-3}	5.05×10^{-3}	2.81×10^{-3}	4.19×10^{-3}	1.22×10^{-3}	5.05×10^{-3}
P-32	0.00	1.80×10^{-4}	5.68×10^{-4}	1.80×10^{-4}	3.51×10^{-4}	0.00	5.68×10^{-4}
Cr-51	1.85×10^{-3}	6.00×10^{-3}	1.70×10^{-2}	7.70×10^{-3}	1.10×10^{-2}	1.39×10^{-3}	1.70×10^{-2}
Mn-54	1.30×10^{-3}	4.50×10^{-3}	3.97×10^{-3}	2.60×10^{-3}	1.30×10^{-4}	9.78×10^{-4}	4.50×10^{-3}
Mn-56	0.00	0.00	2.04×10^{-3}	3.81×10^{-3}	1.00×10^{-3}	0.00	3.81×10^{-3}
Fe-55	1.00×10^{-3}	7.70×10^{-3}	9.46×10^{-3}	5.81×10^{-3}	1.90×10^{-3}	7.50×10^{-4}	9.46×10^{-3}
Fe-59	2.00×10^{-4}	2.30×10^{-3}	2.23×10^{-3}	1.00×10^{-4}	6.00×10^{-5}	1.50×10^{-4}	2.30×10^{-3}
Co-56	0.00	0.00	0.00	5.19×10^{-3}	0.00	0.00	5.19×10^{-3}
Co-57	0.00	0.00	0.00	7.19×10^{-5}	0.00	0.00	7.19×10^{-5}
Co-58	3.36×10^{-3}	9.80×10^{-3}	8.38×10^{-3}	9.00×10^{-5}	3.70×10^{-4}	2.52×10^{-3}	9.80×10^{-3}
Co-60	4.40×10^{-4}	1.40×10^{-2}	1.54×10^{-2}	9.11×10^{-3}	7.51×10^{-4}	3.30×10^{-4}	1.54×10^{-2}
Ni-63	0.00	1.70×10^{-3}	1.70×10^{-3}	1.40×10^{-4}	0.00	0.00	1.70×10^{-3}
Cu-64	0.00	0.00	1.26×10^{-2}	7.51×10^{-3}	1.00×10^{-2}	0.00	1.26×10^{-2}
Zn-65	4.10×10^{-4}	2.20×10^{-4}	4.41×10^{-4}	9.00×10^{-5}	3.70×10^{-4}	3.08×10^{-4}	4.41×10^{-4}
Zn-69m	0.00	0.00	0.00	0.00	7.51×10^{-4}	0.00	7.51×10^{-4}
Br-83	0.00	0.00	0.00	0.00	1.00×10^{-4}	0.00	1.00×10^{-4}
Br-84	2.00×10^{-5}	0.00	0.00	0.00	0.00	1.50×10^{-5}	2.00×10^{-5}
Rb-88	2.70×10^{-4}	2.80×10^{-2}	0.00	0.00	0.00	2.03×10^{-4}	2.80×10^{-2}
Rb-89	0.00	0.00	0.00	4.41×10^{-5}	0.00	0.00	4.41×10^{-5}
Sr-89	1.00×10^{-4}	1.50×10^{-4}	3.14×10^{-4}	1.10×10^{-4}	1.90×10^{-4}	7.50×10^{-5}	3.14×10^{-4}
Sr-90	1.00×10^{-5}	1.80×10^{-5}	2.68×10^{-5}	3.51×10^{-5}	1.00×10^{-5}	7.50×10^{-6}	3.51×10^{-5}
Sr-91	2.00×10^{-5}	6.80×10^{-5}	1.25×10^{-3}	9.00×10^{-4}	9.51×10^{-4}	1.50×10^{-5}	1.25×10^{-3}
Sr-92	0.00	0.00	4.43×10^{-4}	8.00×10^{-4}	2.30×10^{-4}	0.00	8.00×10^{-4}
Y-90	0.00	0.00	0.00	3.11×10^{-6}	0.00	0.00	3.11×10^{-6}
Y-91m	1.00×10^{-5}	4.40×10^{-5}	0.00	0.00	0.00	7.50×10^{-6}	4.40×10^{-5}
Y-91	0.00	9.00×10^{-5}	2.35×10^{-4}	1.10×10^{-4}	1.20×10^{-4}	0.00	2.35×10^{-4}
Y-92	0.00	0.00	1.69×10^{-3}	6.00×10^{-4}	8.70×10^{-4}	0.00	1.69×10^{-3}
Y-93	9.00×10^{-5}	2.90×10^{-4}	1.36×10^{-3}	9.00×10^{-4}	1.00×10^{-3}	6.78×10^{-5}	1.36×10^{-3}
Zr-95	2.30×10^{-4}	1.30×10^{-3}	1.11×10^{-3}	8.41×10^{-4}	1.00×10^{-5}	1.73×10^{-4}	1.30×10^{-3}
Nb-95	2.10×10^{-4}	2.00×10^{-3}	3.14×10^{-4}	1.00×10^{-3}	1.00×10^{-5}	1.58×10^{-4}	2.00×10^{-3}
Mo-99	5.70×10^{-4}	1.70×10^{-3}	2.61×10^{-3}	8.30×10^{-4}	2.50×10^{-3}	4.28×10^{-4}	2.61×10^{-3}
Tc-99m	5.50×10^{-4}	1.70×10^{-3}	5.68×10^{-3}	8.00×10^{-4}	4.59×10^{-3}	4.13×10^{-4}	5.68×10^{-3}
Ru-103	4.93×10^{-3}	3.40×10^{-3}	3.27×10^{-4}	1.80×10^{-4}	4.00×10^{-5}	3.70×10^{-3}	4.93×10^{-3}
Ru-105	0.00	0.00	0.00	0.00	1.30×10^{-4}	0.00	1.30×10^{-4}
Ru-106	7.35×10^{-2}	4.70×10^{-2}	8.89×10^{-3}	1.70×10^{-4}	0.00	5.51×10^{-2}	7.35×10^{-2}
Rh-103m	4.93×10^{-3}	3.10×10^{-3}	0.00	9.00×10^{-6}	0.00	3.70×10^{-3}	4.93×10^{-3}
Rh-106	7.35×10^{-2}	3.90×10^{-2}	0.00	1.70×10^{-4}	0.00	5.51×10^{-2}	7.35×10^{-2}
Ag-110m	1.05×10^{-3}	1.80×10^{-3}	0.00	3.30×10^{-4}	0.00	7.86×10^{-4}	1.80×10^{-3}

Table 11.2.3-2 (Sheet 2 of 2)
Composite Liquid Effluent Activities

Radionucilde	AP1000	APWR	ABWR-GEH	ABWR –Toshiba	ESBWR	mPower	Max
Ag-110	1.40×10^{-4}	7.20×10^{-5}	0.00	0.00	0.00	1.05×10^{-4}	1.40×10^{-4}
Sb-124	0.00	4.30×10^{-4}	0.00	3.59×10^{-4}	0.00	0.00	4.30×10^{-4}
Te-129m	1.20×10^{-4}	7.80×10^{-5}	8.43×10^{-5}	1.70×10^{-5}	7.00×10^{-5}	9.00×10^{-5}	1.20×10^{-4}
Te-129	1.50×10^{-4}	3.10×10^{-4}	0.00	0.00	0.00	1.13×10^{-4}	3.10×10^{-4}
Te-131m	9.00×10^{-5}	2.50×10^{-4}	8.38×10^{-5}	3.41×10^{-5}	8.00×10^{-5}	6.78×10^{-5}	2.50×10^{-4}
Te-131	3.00×10^{-5}	7.60×10^{-5}	0.00	0.00	0.00	2.25×10^{-5}	7.60×10^{-5}
Te-132	2.40×10^{-4}	4.70×10^{-4}	1.35×10^{-5}	4.00×10^{-6}	1.00×10^{-5}	1.80×10^{-4}	4.70×10^{-4}
I-131	1.41×10^{-2}	2.00×10^{-3}	9.05×10^{-3}	3.19×10^{-3}	6.19×10^{-3}	1.06×10^{-2}	1.41×10^{-2}
I-132	1.64×10^{-3}	3.10×10^{-4}	1.93×10^{-3}	2.60×10^{-3}	9.30×10^{-4}	1.23×10^{-3}	2.60×10^{-3}
I-133	6.70×10^{-3}	8.10×10^{-4}	3.73×10^{-2}	1.00×10^{-2}	3.00×10^{-2}	5.03×10^{-3}	3.73×10^{-2}
I-134	8.10×10^{-4}	8.90×10^{-5}	1.14×10^{-4}	1.70×10^{-3}	4.00×10^{-5}	6.06×10^{-4}	1.70×10^{-3}
I-135	4.97×10^{-3}	7.80×10^{-4}	1.09×10^{-2}	7.51×10^{-3}	7.11×10^{-3}	3.73×10^{-3}	1.09×10^{-2}
Cs-134	9.93×10^{-3}	1.20×10^{-2}	1.13×10^{-2}	6.11×10^{-3}	5.70×10^{-4}	7.44×10^{-3}	1.20×10^{-2}
Cs-136	6.30×10^{-4}	2.20×10^{-2}	7.51×10^{-4}	3.19×10^{-4}	3.51×10^{-4}	4.73×10^{-4}	2.20×10^{-2}
Cs-137	1.33×10^{-2}	1.80×10^{-2}	1.78×10^{-2}	8.89×10^{-3}	1.50×10^{-3}	1.00×10^{-2}	1.80×10^{-2}
Cs-138	0.00	0.00	8.00×10^{-7}	1.90×10^{-4}	0.00	0.00	1.90×10^{-4}
Ba-137m	1.25×10^{-2}	4.60×10^{-4}	0.00	0.00	0.00	9.36×10^{-3}	1.25×10^{-2}
Ba-139	0.00	0.00	0.00	0.00	3.00×10^{-5}	0.00	3.00×10^{-5}
Ba-140	5.52×10^{-3}	5.80×10^{-3}	1.68×10^{-3}	6.81×10^{-4}	6.89×10^{-4}	4.14×10^{-3}	5.80×10^{-3}
La-140	7.43×10^{-3}	8.00×10^{-3}	0.00	1.70×10^{-4}	0.00	5.57×10^{-3}	8.00×10^{-3}
La-142	0.00	0.00	0.00	0.00	2.00×10^{-5}	0.00	2.00×10^{-5}
Ce-141	9.00×10^{-5}	2.90×10^{-4}	2.97×10^{-4}	1.20×10^{-4}	6.00×10^{-5}	6.78×10^{-5}	2.97×10^{-4}
Ce-143	1.90×10^{-4}	5.00×10^{-4}	0.00	0.00	3.00×10^{-5}	1.43×10^{-4}	5.00×10^{-4}
Ce-144	3.16×10^{-3}	5.60×10^{-3}	3.89×10^{-3}	1.90×10^{-3}	0.00	2.37×10^{-3}	5.60×10^{-3}
Pr-143	1.30×10^{-4}	7.90×10^{-5}	8.11×10^{-5}	1.30×10^{-6}	7.00×10^{-5}	9.78×10^{-5}	1.30×10^{-4}
Pr-144	3.16×10^{-3}	1.70×10^{-3}	0.00	0.00	0.00	2.37×10^{-3}	3.16×10^{-3}
Nd-147	0.00	0.00	2.00×10^{-6}	0.00	0.00	0.00	2.00×10^{-6}
W-187	1.30×10^{-4}	3.50×10^{-4}	2.23×10^{-4}	9.51×10^{-5}	2.00×10^{-4}	9.78×10^{-5}	3.50×10^{-4}
Np-239	2.40×10^{-4}	5.30×10^{-4}	9.49×10^{-3}	3.11×10^{-3}	9.30×10^{-3}	1.80×10^{-4}	9.49×10^{-3}
Total	1.01×10^{3}	1.60×10^{3}	8.21	6.01×10^{1}	1.41×10^{1}	7.56×10^{2}	1.60×10^{3}

Table 11.2.3-3 (Sheet 1 of 2)
Liquid Effluent Concentrations in the Guadalupe River

Radionuclide	Release per Unit (Ci/yr)	Concentration (µCi/ml)		Fraction of ECL
		River	ECL	
H-3	1.60×10^{3}	7.47×10^{-6}	1.0×10^{-3}	7.5×10^{-3}
C-14	1.60×10^{-4}	7.47×10^{-13}	3.0×10^{-5}	2.5×10^{-8}
Na-24	5.05×10^{-3}	2.36×10^{-11}	5.0×10^{-5}	4.7×10^{-7}
P-32	5.68×10^{-4}	2.65×10^{-12}	9.0×10^{-6}	2.9×10^{-7}
Cr-51	1.70×10^{-2}	7.93×10^{-11}	5.0×10^{-4}	1.6×10^{-7}
Mn-54	4.50×10^{-3}	2.10×10^{-11}	3.0×10^{-5}	7.0×10^{-7}
Mn-56	3.81×10^{-3}	1.78×10^{-11}	7.0×10^{-5}	2.5×10^{-7}
Fe-55	9.46×10^{-3}	4.41×10^{-11}	1.0×10^{-4}	4.4×10^{-7}
Fe-59	2.30×10^{-3}	1.07×10^{-11}	1.0×10^{-5}	1.1×10^{-6}
Co-56	5.19×10^{-3}	2.42×10^{-11}	6.0×10^{-6}	4.0×10^{-6}
Co-57	7.19×10^{-5}	3.35×10^{-13}	6.0×10^{-5}	5.6×10^{-9}
Co-58	9.80×10^{-3}	4.57×10^{-11}	2.0×10^{-5}	2.3×10^{-6}
Co-60	1.54×10^{-2}	7.19×10^{-11}	3.0×10^{-6}	2.4×10^{-5}
Ni-63	1.70×10^{-3}	7.93×10^{-12}	1.0×10^{-4}	7.9×10^{-8}
Cu-64	1.26×10^{-2}	5.88×10^{-11}	2.0×10^{-4}	2.9×10^{-7}
Zn-65	4.41×10^{-4}	2.06×10^{-12}	5.0×10^{-6}	4.1×10^{-7}
Zn-69m	7.51×10^{-4}	3.51×10^{-12}	6.0×10^{-5}	5.8×10^{-8}
Br-83	1.00×10^{-4}	4.67×10^{-13}	9.0×10^{-4}	5.2×10^{-10}
Br-84	2.00×10^{-5}	9.33×10^{-14}	4.0×10^{-4}	2.3×10^{-10}
Rb-88	2.80×10^{-2}	1.31×10^{-10}	4.0×10^{-4}	3.3×10^{-7}
Rb-89	4.41×10^{-5}	2.06×10^{-13}	9.0×10^{-4}	2.3×10^{-10}
Sr-89	3.14×10^{-4}	1.47×10^{-12}	8.0×10^{-6}	1.8×10^{-7}
Sr-90	3.51×10^{-5}	1.64×10^{-13}	5.0×10^{-7}	3.3×10^{-7}
Sr-91	1.25×10^{-3}	5.83×10^{-12}	2.0×10^{-5}	2.9×10^{-7}
Sr-92	8.00×10^{-4}	3.73×10^{-12}	4.0×10^{-5}	9.3×10^{-8}
Y-90	3.11×10^{-6}	1.45×10^{-14}	7.0×10^{-6}	2.1×10^{-9}
Y-91m	4.40×10^{-5}	2.05×10^{-13}	2.0×10^{-3}	1.0×10^{-10}
Y-91	2.35×10^{-4}	1.10×10^{-12}	8.0×10^{-6}	1.4×10^{-7}
Y-92	1.69×10^{-3}	7.89×10^{-12}	4.0×10^{-5}	2.0×10^{-7}
Y-93	1.36×10^{-3}	6.35×10^{-12}	2.0×10^{-5}	3.2×10^{-7}
Zr-95	1.30×10^{-3}	6.07×10^{-12}	2.0×10^{-5}	3.0×10^{-7}
Nb-95	2.00×10^{-3}	9.33×10^{-12}	3.0×10^{-5}	3.1×10^{-7}
Mo-99	2.61×10^{-3}	1.22×10^{-11}	2.0×10^{-5}	6.1×10^{-7}
Tc-99m	5.68×10^{-3}	2.65×10^{-11}	1.0×10^{-3}	2.7×10^{-8}
Ru-103	4.93×10^{-3}	2.30×10^{-11}	3.0×10^{-5}	7.7×10^{-7}
Ru-105	1.30×10^{-4}	6.07×10^{-13}	7.0×10^{-5}	8.7×10^{-9}

Table 11.2.3-3 (Sheet 2 of 2)
Liquid Effluent Concentrations in the Guadalupe River

Radionuclide	Release per Unit (Ci/yr)	Concentration (μCi/ml)		Fraction of ECL
		River	ECL	
Ru-106	7.35×10^{-2}	3.43×10^{-10}	3.0×10^{-6}	1.1×10^{-4}
Rh-103m	4.93×10^{-3}	2.30×10^{-11}	6.0×10^{-3}	3.8×10^{-9}
Rh-106	7.35×10^{-2}	3.43×10^{-10}	–	–
Ag-110m	1.80×10^{-3}	8.40×10^{-12}	6.0×10^{-6}	1.4×10^{-6}
Ag-110	1.40×10^{-4}	6.53×10^{-13}	–	–
Sb-124	4.30×10^{-4}	2.01×10^{-12}	7.0×10^{-6}	2.9×10^{-7}
Te-129m	1.20×10^{-4}	5.60×10^{-13}	7.0×10^{-6}	8.0×10^{-8}
Te-129	3.10×10^{-4}	1.45×10^{-12}	4.0×10^{-4}	3.6×10^{-9}
Te-131m	2.50×10^{-4}	1.17×10^{-12}	8.0×10^{-6}	1.5×10^{-7}
Te-131	7.60×10^{-5}	3.55×10^{-13}	8.0×10^{-5}	4.4×10^{-9}
Te-132	4.70×10^{-4}	2.19×10^{-12}	9.0×10^{-6}	2.4×10^{-7}
I-131	1.41×10^{-2}	6.59×10^{-11}	1.0×10^{-6}	6.6×10^{-5}
I-132	2.60×10^{-3}	1.21×10^{-11}	1.0×10^{-4}	1.2×10^{-7}
I-133	3.73×10^{-2}	1.74×10^{-10}	7.0×10^{-6}	2.5×10^{-5}
I-134	1.70×10^{-3}	7.93×10^{-12}	4.0×10^{-4}	2.0×10^{-8}
I-135	1.09×10^{-2}	5.09×10^{-11}	3.0×10^{-5}	1.7×10^{-6}
Cs-134	1.20×10^{-2}	5.60×10^{-11}	9.0×10^{-7}	6.2×10^{-5}
Cs-136	2.20×10^{-2}	1.03×10^{-10}	6.0×10^{-6}	1.7×10^{-5}
Cs-137	1.80×10^{-2}	8.40×10^{-11}	1.0×10^{-6}	8.4×10^{-5}
Cs-138	1.90×10^{-4}	8.87×10^{-13}	4.0×10^{-4}	2.2×10^{-9}
Ba-137m	1.25×10^{-2}	5.81×10^{-11}	–	–
Ba-139	3.00×10^{-5}	1.40×10^{-13}	2.0×10^{-4}	7.0×10^{-10}
Ba-140	5.80×10^{-3}	2.71×10^{-11}	8.0×10^{-6}	3.4×10^{-6}
La-140	8.00×10^{-3}	3.73×10^{-11}	9.0×10^{-6}	4.1×10^{-6}
La-142	2.00×10^{-5}	9.33×10^{-14}	1.0×10^{-4}	9.3×10^{-10}
Ce-141	2.97×10^{-4}	1.39×10^{-12}	3.0×10^{-5}	4.6×10^{-8}
Ce-143	5.00×10^{-4}	2.33×10^{-12}	2.0×10^{-5}	1.2×10^{-7}
Ce-144	5.60×10^{-3}	2.61×10^{-11}	3.0×10^{-6}	8.7×10^{-6}
Pr-143	1.30×10^{-4}	6.07×10^{-13}	2.0×10^{-5}	3.0×10^{-8}
Pr-144	3.16×10^{-3}	1.47×10^{-11}	6.0×10^{-4}	2.5×10^{-8}
Nd-147	2.00×10^{-6}	$9.33 \times 10\text{-}^{15}$	2.0×10^{-5}	4.7×10^{-10}
W-187	3.50×10^{-4}	1.63×10^{-12}	3.0×10^{-5}	5.4×10^{-8}
Np-239	9.49×10^{-3}	4.43×10^{-11}	2.0×10^{-5}	2.2×10^{-6}
Total	1.60×10^{3}	7.47×10^{-6}	–	7.9×10^{-3}

Note: The Guadalupe River flow rate is assumed to be 480 cfs (based on a 95th percentile value of 486 cfs from a statistical analysis of USGS data showing 80,811 daily flow rates for the Guadalupe River from 1935 to 2008).

Table 11.2.3-4
Liquid Pathway Doses for Maximally Exposed Individuals

Pathway	Dose (mrem/yr) per Unit							
	Total Body	**GI-LLI[(a)]**	**Bone**	**Liver**	**Kidney**	**Thyroid**	**Lung**	**Skin**
Fish	3.3×10^{-1}	1.5×10^{-1}	1.0	4.1×10^{-1}	1.3×10^{-1}	2.6×10^{-2}	4.4×10^{-2}	0
Invertebrate	4.4×10^{-2}	1.5×10^{-1}	7.7×10^{-2}	6.8×10^{-2}	2.4×10^{-2}	2.7×10^{-3}	6.4×10^{-3}	0
Drinking	1.7×10^{-1}	1.9×10^{-1}	1.6×10^{-2}	2.4×10^{-1}	2.3×10^{-1}	3.5×10^{-1}	2.2×10^{-1}	0
Shoreline	5.3×10^{-4}	5.3×10^{-4}	6.2×10^{-4}	6.2×10^{-4}	6.2×10^{-4}	6.2×10^{-4}	6.2×10^{-4}	3.5×10^{-3}
Swimming	1.5×10^{-5}	1.5×10^{-5}	1.7×10^{-5}	1.7×10^{-5}	1.7×10^{-5}	1.7×10^{-5}	1.7×10^{-5}	0
Boating	7.5×10^{-6}	7.5×10^{-6}	8.7×10^{-6}	8.7×10^{-6}	8.7×10^{-6}	8.7×10^{-6}	8.7×10^{-6}	0
Irrigated Vegetables	1.7×10^{-1}	3.1×10^{-1}	1.4×10^{-1}	3.6×10^{-1}	2.9×10^{-1}	2.7×10^{-1}	2.5×10^{-1}	0
Irrigated Meat	3.1×10^{-2}	1.4	3.8×10^{-2}	2.3×10^{-2}	6.4×10^{-2}	1.8×10^{-2}	1.8×10^{-2}	0
Total	7.4×10^{-1}	2.2	1.3	1.1	7.4×10^{-1}	6.7×10^{-1}	5.4×10^{-1}	3.5×10^{-3}
Maximum Dose Age Group	Adult	Adult	Child	Child	Child	Child	Child	Teen

(a) GI-LLI – Gastrointestinal Tract–Lower Large Intestine.

Table 11.2.3-5
Comparison of Maximally Exposed Individual Doses with 10 CFR 50, Appendix I Criteria

Type of Dose	Location	Annual Dose per Unit	
		VCS	Limit
Liquid Effluent			
Total Body (mrem)	Guadalupe River	0.74	3
Maximum Organ – GI-LLI (mrem)	Guadalupe River	2.2	10

Table 11.2.3-6
Comparison of Maximally Exposed Individual Doses with 40 CFR 190 Criteria

	Site Dose for All Units (mrem/yr)				
	Liquid	Gaseous	Direct	Total	Limit
Total Body	1.5	5.8	5.0	12	25
Thyroid	1.3	16	5.0	22	75
Other Organ – Bone	2.6	11	5.0	19	25

Table 11.2.3-7
Collective Doses Within 50 Miles

Pathway	Dose per Unit (person-rem/yr)		Site Dose (person-rem/yr)	
	Total Body	**Thyroid**	**Total Body**	**Thyroid**
Liquid Effluents	8.7	8.4	17	17
Gaseous Effluents				
Noble Gases	2.9×10^{-1}	2.9×10^{-1}	5.8×10^{-1}	5.8×10^{-1}
Iodines	6.6×10^{-3}	2.6	1.3×10^{-2}	5.2
Particulates	1.4×10^{-1}	1.1×10^{-1}	2.8×10^{-1}	2.1×10^{-1}
C-14	5.9×10^{-1}	5.9×10^{-1}	1.2	1.2
H-3	1.0×10^{-1}	1.0×10^{-1}	2.1×10^{-1}	2.1×10^{-1}
Total Gaseous Effluents	1.1	3.7	2.3	7.4
Total	9.9	12	20	24
Natural Background[(a)]	1.2×10^{5}			

(a) Based on dose rate of 300 mrem/yr (Reference 11.2.3-7)

11.3.3 **Gaseous Radioactive Releases**

This section describes the radiological impacts of gaseous radwaste effluents from normal plant operation on members of the public. Subsection 11.3.3.1 describes the exposure pathways by which radiation and radioactive effluents can be transmitted from the proposed units to individuals living near the plant. Subsection 11.3.3.2 estimates the maximum doses to the public and evaluates the impacts of these doses by comparing them to regulatory limits.

11.3.3.1 **Exposure Pathways**

Small quantities of radioactive gases would be discharged to the environment during normal operation of the proposed units. Airborne effluents are normally released through plant stacks. The impact of these releases on individuals and the population in the vicinity of the proposed units is evaluated by considering the most important pathways from the release to the receptors of interest. The major pathways are those that could yield the highest radiological doses for a given receptor. The relative importance of a pathway is based on the type and amount of radioactivity released, the environmental transport mechanism, and the consumption or usage factors at the receptor.

The exposure pathways considered and the analytical methods used to estimate doses to the maximally exposed individual (MEI) and to the population surrounding the proposed units are based on NRC Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I, Revision 1, October 1977 and NRC Regulatory Guide 1.111, Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors, Revision 1, July 1977. An MEI is a member of the public located to receive the maximum possible calculated dose. The MEI allows dose comparisons with established criteria for the public.

The NRC-endorsed GASPAR II computer program (Reference 11.3.3-1) is used to calculate the doses to offsite receptors from the proposed units. This program implements the radiological exposure models described in RG 1.109 to estimate the doses resulting from radioactive releases in gaseous effluent. The atmospheric dispersion component of the analysis is calculated with the NRC-sponsored program XOQDOQ. Section 2.3.5 shows dispersion data for the locations shown in Table 11.3.3-4 as well as deposition and undecayed/undepleted dispersion factors within 50 miles of the plant. Decayed/undepleted and decayed/depleted dispersion factors within 50 miles are calculated using the same methodology as presented in Section 2.3.5.

The following exposure pathways are considered in GASPAR II:

- External exposure to airborne plume
- External exposure to contaminated ground

- Inhalation of airborne activity
- Ingestion of contaminated vegetables
- Ingestion of contaminated meat

The input parameters for the gaseous pathway are presented in Table 11.3.3-1 and the receptor locations are shown in Table 11.3.3-4.

11.3.3.2 Gaseous Pathway Doses

Based on the parameters in Table 11.3.3-1, the GASPAR II computer program is used to calculate doses to the maximally exposed adult, teenager, child, and infant at the following locations:

- Nearest site boundary
- Nearest residence
- Nearest vegetable garden
- Nearest meat animal

The gaseous activity release (source term) for the proposed units is a conservative, bounding composite that was obtained by identifying the greatest activity for the technologies identified in Section 1.10 for each radionuclide (the same values are used for the GE and Toshiba ABWRs) and is shown in Table 11.3.3-2. These values are per reactor, except for mPower. For mPower, with the exception of C-14, the activities from six reactors are considered when arriving at the composite values. As the source term for the mPower is still being developed, the design currently uses the C-14 value provided in NUREG-0017 (Reference 11.3.3-3) for a 3400 MWt PWR, using no scaling to adjust for the much lower thermal power of the mPower. However, multiplying this value by six to account for six mPower reactors (a total of 2550 MWt) would be overly conservative. As such, the next highest C-14 release (ESBWR) , which is greater than that in NUREG-0017, is used to represent the six mPower reactors in the composite source term. If the mPower design is selected, the C-14 releases will be confirmed and used in the gaseous effluent dose calculation at the COL stage. Projected activity concentrations are within the limits of 10 CFR 20, Appendix B, Table 2, Column 1 (Table 11.3.3-3). Although the sum of fractions of effluent concentration limits (ECLs) is just above the regulatory limit of 1, it reflects conservative, bounding calculations based on composite source terms. The sum of fractions of ECLs will be confirmed to be less than 1 at the COL stage, when the reactor technology has been selected. The calculated annual doses to the MEI from the gaseous pathway are presented in Table 11.3.3-5.

Table 11.3.3-6 shows that the doses to the MEI from the gaseous effluents of a proposed unit meet the design objectives of 10 CFR 50, Appendix I. The total site doses due to liquid and gaseous effluents from the proposed units would be well within the regulatory limits of 40 CFR 190, as shown in Table 11.3.3-7. Since 40 CFR 190 is more restrictive than 10 CFR 20.1301, compliance with the limits of 40 CFR 190 also demonstrates compliance with the 0.1 rem limit of 10 CFR 20.1301. Table 11.3.3-8 shows the doses from the proposed units to the population within 50 miles of the ESP site.

11.3.3.3 References

11.3.3-1 NUREG/CR-4653, GASPAR II-Technical Reference and User Guide, U. S. Nuclear Regulatory Commission, 1987.

11.3.3-2 *Exposure of the Population in the United States and Canada from Natural Background Radiation*, National Council on Radiation Protection and Measurements, 1987.

11.3.3-3 NUREG-0017, Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized-Water Reactors (PWR-GALE Code), Revision 1, April 1985.

Table 11.3.3-1
Gaseous Pathway Parameters

Parameter	Value	Basis/Source(s)
Release Source Terms	See Table 11.3.3-2	Table 11.3.3-2 shows the activity releases by isotope.
Atmospheric Dispersion and Deposition Factors	See Tables 2.3.5-3 through 2.3.5-8	Table 2.3.5-3 shows the dispersion and deposition data for the nearest site boundary, residence, vegetable garden, and meat animal. Tables 2.3.5-4, 2.3.5-5, 2.3.5-6, 2.3.5-7, and 2.3.5-8 show dispersion and deposition data for 160 sectors representing 16 directions and 10 distance segments out to 50 miles. The dispersion and deposition data at the assumed biota location at a distance of 0.25 mile are obtained from Table 2.3.5-3.
Individual Consumption Rates	See RG 1.109	The values from Tables E-5 and E-4 of RG 1.109 are used for the MEI and the average person within the population, respectively.
50-Mile Population	$4.15x10^5$	This is the projected population for the year 2080, the assumed end of plant life. It is used to conservatively maximize population doses.
50-Mile Population Distribution	See Figures 2.1-15 and 2.1-25	Figures 2.1-15 and 2.1-25 show the population distribution in 2080 for 160 sectors representing 16 directions and 10 distance segments out to 50 miles.
50-Mile Milk Production	$1.41x10^7$ l/yr	This is the projected production for 2080. See comment on milk production in Table 11.2.3-1.
50-Mile Meat Production	$2.23x10^8$ kg/yr	This is the projected production for 2080. See comment on meat production in Table 11.2.3-1.
50-Mile Vegetable Production	$5.18x10^7$ kg/yr	This is the projected production for 2080. See comment on vegetable production in Table 11.2.3-1.
Fraction of year leafy vegetables grown	1	This is the most conservative value.
Fraction of year milk cows on pasture	1	This is the most conservative value.
Fraction of maximum individual's vegetable intake from own garden	0.76	This is the default value from RG 1.109, Table E-15.
Fraction of milk-cow feed from pasture	1	This is the most conservative value.
Average absolute humidity for growing season	8 g/m^3	This is the default value in GASPAR II (Reference 11.3.3-1). It is used when a value of zero is input.
Fraction of year goats at pasture	1	This is the most conservative value.
Fraction of goat feed from pasture	1	This is the most conservative value.
Fraction of year beef cattle at pasture	1	This is the most conservative value.
Fraction of beef cattle feed from pasture	1	This is the most conservative value.

Table 11.3.3-2 (Sheet 1 of 2)
Composite Gaseous Effluent Activities

Isotope	AP1000	APWR	ABWR	ESBWR	mPower	Max
H-3	3.50×10^{2}	1.80×10^{2}	7.30×10^{1}	7.57×10^{1}	2.64×10^{2}	3.50×10^{2}
C-14	7.30	7.30	9.19	1.43×10^{1}	4.38×10^{1} (a)	1.43×10^{1}
Na-24	0.00	0.00	4.05×10^{-3}	1.46×10^{-4}	0.00	4.05×10^{-3}
P-32	0.00	0.00	9.19×10^{-4}	3.51×10^{-5}	0.00	9.19×10^{-4}
Ar-41	3.40×10^{1}	3.40×10^{1}	6.76	3.78×10^{-2}	2.04×10^{2}	2.04×10^{2}
Cr-51	6.10×10^{-4}	6.10×10^{-4}	3.51×10^{-2}	4.86×10^{-3}	4.56×10^{-4}	3.51×10^{-2}
Mn-54	4.30×10^{-4}	4.30×10^{-4}	5.41×10^{-3}	4.05×10^{-3}	3.24×10^{-4}	5.41×10^{-3}
Mn-56	0.00	0.00	3.51×10^{-3}	2.97×10^{-4}	0.00	3.51×10^{-3}
Fe-55	0.00	0.00	6.49×10^{-3}	1.27×10^{-3}	0.00	6.49×10^{-3}
Fe-59	7.90×10^{-5}	7.90×10^{-5}	8.11×10^{-4}	5.41×10^{-4}	5.94×10^{-5}	8.11×10^{-4}
Co-57	8.20×10^{-6}	8.20×10^{-6}	0.00	0.00	6.00×10^{-6}	8.20×10^{-6}
Co-58	2.30×10^{-2}	2.30×10^{-2}	2.41×10^{-3}	1.08×10^{-3}	1.74×10^{-2}	2.30×10^{-2}
Co-60	8.70×10^{-3}	8.80×10^{-3}	1.30×10^{-2}	8.65×10^{-3}	6.60×10^{-3}	1.30×10^{-2}
Ni-63	0.00	0.00	6.49×10^{-6}	1.27×10^{-6}	0.00	6.49×10^{-6}
Cu-64	0.00	0.00	1.00×10^{-2}	1.86×10^{-4}	0.00	1.00×10^{-2}
Zn-65	0.00	0.00	1.11×10^{-2}	8.65×10^{-3}	0.00	1.11×10^{-2}
Kr-83m	0.00	0.00	8.38×10^{-4}	2.30×10^{-3}	0.00	2.30×10^{-3}
Kr-85m	3.60×10^{1}	0.00	2.11×10^{1}	1.78×10^{1}	2.70×10^{1}	3.60×10^{1}
Kr-85	4.10×10^{3}	1.40×10^{3}	5.68×10^{2}	1.41×10^{2}	3.06×10^{3}	4.10×10^{3}
Kr-87	1.50×10^{1}	0.00	2.51×10^{1}	3.78×10^{1}	1.14×10^{1}	3.78×10^{1}
Kr-88	4.60×10^{1}	0.00	3.78×10^{1}	5.68×10^{1}	3.48×10^{1}	5.68×10^{1}
Kr-89	0.00	0.00	2.41×10^{2}	3.78×10^{2}	0.00	3.78×10^{2}
Kr-90	0.00	0.00	3.24×10^{-4}	0.00	0.00	3.24×10^{-4}
Rb-89	0.00	0.00	4.32×10^{-5}	5.41×10^{-6}	0.00	4.32×10^{-5}
Sr-89	3.00×10^{-3}	3.00×10^{-3}	5.68×10^{-3}	4.05×10^{-3}	2.28×10^{-3}	5.68×10^{-3}
Sr-90	1.20×10^{-3}	1.20×10^{-3}	7.03×10^{-5}	2.70×10^{-5}	9.00×10^{-4}	1.20×10^{-3}
Sr-91	0.00	0.00	1.00×10^{-3}	1.81×10^{-4}	0.00	1.00×10^{-3}
Sr-92	0.00	0.00	7.84×10^{-4}	1.24×10^{-4}	0.00	7.84×10^{-4}
Y-90	0.00	0.00	4.59×10^{-5}	2.19×10^{-6}	0.00	4.59×10^{-5}
Y-91	0.00	0.00	2.41×10^{-4}	4.59×10^{-5}	0.00	2.41×10^{-4}
Y-92	0.00	0.00	6.22×10^{-4}	1.00×10^{-4}	0.00	6.22×10^{-4}
Y-93	0.00	0.00	1.11×10^{-3}	1.95×10^{-4}	0.00	1.11×10^{-3}
Zr-95	1.00×10^{-3}	1.00×10^{-3}	1.59×10^{-3}	1.19×10^{-3}	7.80×10^{-4}	1.59×10^{-3}
Nb-95	2.50×10^{-3}	2.50×10^{-3}	8.38×10^{-3}	6.49×10^{-3}	1.86×10^{-3}	8.38×10^{-3}
Mo-99	0.00	0.00	5.95×10^{-2}	4.59×10^{-2}	0.00	5.95×10^{-2}
Tc-99m	0.00	0.00	2.97×10^{-4}	5.95×10^{-5}	0.00	2.97×10^{-4}
Ru-103	8.00×10^{-5}	8.00×10^{-5}	3.51×10^{-3}	2.70×10^{-3}	6.00×10^{-5}	3.51×10^{-3}
Ru-106	7.80×10^{-5}	7.80×10^{-5}	1.89×10^{-5}	3.78×10^{-6}	5.88×10^{-5}	7.80×10^{-5}
Rh-103m	0.00	0.00	1.11×10^{-4}	9.46×10^{-8}	0.00	1.11×10^{-4}
Rh-106	0.00	0.00	1.89×10^{-5}	1.22×10^{-10}	0.00	1.89×10^{-5}

Table 11.3.3-2 (Sheet 2 of 2)
Composite Gaseous Effluent Activities

Isotope	AP1000	APWR	ABWR	ESBWR	mPower	Max
Ag-110m	0.00	0.00	2.00×10^{-6}	2.70×10^{-6}	0.00	2.70×10^{-6}
Sb-124	0.00	0.00	1.81×10^{-4}	1.43×10^{-4}	0.00	1.81×10^{-4}
Sb-125	6.10×10^{-5}	6.10×10^{-5}	0.00	0.00	4.56×10^{-5}	6.10×10^{-5}
Te-129m	0.00	0.00	2.19×10^{-4}	4.32×10^{-5}	0.00	2.19×10^{-4}
Te-131m	0.00	0.00	7.57×10^{-5}	1.49×10^{-5}	0.00	7.57×10^{-5}
Te-132	0.00	0.00	1.89×10^{-5}	3.78×10^{-6}	0.00	1.89×10^{-5}
I-131	1.20×10^{-1}	4.20×10^{-3}	2.59×10^{-1}	2.35×10^{-1}	9.00×10^{-2}	2.59×10^{-1}
I-132	0.00	0.00	2.19	1.57	0.00	2.19
I-133	4.00×10^{-1}	6.40×10^{-2}	1.70	1.16	3.00×10^{-1}	1.70
I-134	0.00	0.00	3.78	2.97	0.00	3.78
I-135	0.00	0.00	2.41	1.59	0.00	2.41
Xe-131m	1.80×10^{3}	2.60×10^{2}	5.14×10^{1}	4.05	1.38×10^{3}	1.80 x 103
Xe-133m	8.70×10^{1}	2.00	8.65×10^{-2}	5.14×10^{-3}	6.60×10^{1}	8.70×10^{1}
Xe-133	4.60×10^{3}	0.00	2.41×10^{3}	1.11×10^{3}	3.48×10^{3}	4.60×10^{3}
Xe-135m	7.00	4.00	4.05×10^{2}	5.95×10^{2}	5.28	5.95×10^{2}
Xe-135	3.30×10^{2}	2.00	4.59×10^{2}	7.57×10^{2}	2.46×10^{2}	7.57×10^{2}
Xe-137	0.00	4.00	5.14×10^{2}	7.57×10^{2}	0.00	7.57×10^{2}
Xe-138	6.00	1.00	4.32×10^{2}	6.22×10^{2}	4.50	6.22×10^{2}
Xe-139	0.00	0.00	4.05×10^{-4}	0.00	0.00	4.05×10^{-4}
Cs-134	2.30×10^{-3}	2.30×10^{-3}	6.22×10^{-3}	4.86×10^{-3}	1.74×10^{-3}	6.22×10^{-3}
Cs-136	8.50×10^{-5}	8.50×10^{-5}	5.95×10^{-4}	4.05×10^{-4}	6.60×10^{-5}	5.95×10^{-4}
Cs-137	3.60×10^{-3}	3.60×10^{-3}	9.46×10^{-3}	7.30×10^{-3}	2.70×10^{-3}	9.46×10^{-3}
Cs-138	0.00	0.00	1.70×10^{-4}	2.30×10^{-5}	0.00	1.70×10^{-4}
Ba-137m	0.00	3.60×10^{-3}	0.00	0.00	0.00	3.60×10^{-3}
Ba-140	4.20×10^{-4}	4.20×10^{-4}	2.70×10^{-2}	2.11×10^{-2}	3.18×10^{-4}	2.70×10^{-2}
La-140	0.00	0.00	1.81×10^{-3}	3.51×10^{-4}	0.00	1.81×10^{-3}
Ce-141	4.20×10^{-5}	4.20×10^{-5}	9.19×10^{-3}	7.03×10^{-3}	3.18×10^{-5}	9.19×10^{-3}
Ce-144	0.00	0.00	1.89×10^{-5}	3.51×10^{-6}	0.00	1.89×10^{-5}
Pr-144	0.00	0.00	1.89×10^{-5}	4.32×10^{-9}	0.00	1.89×10^{-5}
W-187	0.00	0.00	1.89×10^{-4}	3.51×10^{-5}	0.00	1.89×10^{-4}
Np-239	0.00	0.00	1.19×10^{-2}	2.24×10^{-3}	0.00	1.19×10^{-2}
Total	1.14×10^{4}	1.89×10^{3}	5.26×10^{3}	4.57×10^{3}	8.83×10^{3}	1.44×10^{4}

(a) Refer to Subsection 11.3.3.2 for basis for C-14 maximum value.
Note: The ABWR values apply to both GE and Toshiba.

Table 11.3.3-3 (Sheet 1 of 2)
Gaseous Effluent Concentrations at the Site Boundary

		Concentration (µCi/ml)		
Radionuclide	**Release per Unit (Ci /yr)**	**Site Boundary**	**ECL**	**Fraction of ECL**
H-3	3.5×10^{2}	2.8×10^{-10}	1.0×10^{-7}	2.8×10^{-3}
C-14	1.4×10^{1}	1.2×10^{-11}	3.0×10^{-9}	3.9×10^{-3}
Na-24	4.1×10^{-3}	3.3×10^{-15}	7.0×10^{-9}	4.7×10^{-7}
P-32	9.2×10^{-4}	7.4×10^{-16}	5.0×10^{-10}	1.5×10^{-6}
Ar-41	2.0×10^{2}	1.6×10^{-10}	1.0×10^{-8}	1.6×10^{-2}
Cr-51	3.5×10^{-2}	2.8×10^{-14}	3.0×10^{-8}	9.5×10^{-7}
Mn-54	5.4×10^{-3}	4.4×10^{-15}	1.0×10^{-9}	4.4×10^{-6}
Mn-56	3.5×10^{-3}	2.8×10^{-15}	2.0×10^{-8}	1.4×10^{-7}
Fe-55	6.5×10^{-3}	5.2×10^{-15}	3.0×10^{-9}	1.7×10^{-6}
Fe-59	8.1×10^{-4}	6.6×10^{-16}	5.0×10^{-10}	1.3×10^{-6}
Co-57	8.2×10^{-6}	6.6×10^{-18}	9.0×10^{-10}	7.4×10^{-9}
Co-58	2.3×10^{-2}	1.9×10^{-14}	1.0×10^{-9}	1.9×10^{-5}
Co-60	1.3×10^{-2}	1.0×10^{-14}	5.0×10^{-11}	2.1×10^{-4}
Ni-63	6.5×10^{-6}	5.2×10^{-18}	1.0×10^{-9}	5.2×10^{-9}
Cu-64	1.0×10^{-2}	8.1×10^{-15}	3.0×10^{-8}	2.7×10^{-7}
Zn-65	1.1×10^{-2}	9.0×10^{-15}	4.0×10^{-10}	2.2×10^{-5}
Kr-83m	2.3×10^{-3}	1.9×10^{-15}	5.0×10^{-5}	3.7×10^{-11}
Kr-85m	3.6×10^{1}	2.9×10^{-11}	1.0×10^{-7}	2.9×10^{-4}
Kr-85	4.1×10^{3}	3.3×10^{-9}	7.0×10^{-7}	4.7×10^{-3}
Kr-87	3.8×10^{1}	3.1×10^{-11}	2.0×10^{-8}	1.5×10^{-3}
Kr-88	5.7×10^{1}	4.6×10^{-11}	9.0×10^{-9}	5.1×10^{-3}
Kr-89	3.8×10^{2}	3.1×10^{-10}	1.0×10^{-9}	3.1×10^{-1}
Kr-90	3.2×10^{-4}	$2.6 \times 10\text{-}^{16}$	1.0×10^{-9}	2.6×10^{-7}
Rb-89	4.3×10^{-5}	3.5×10^{-17}	2.0×10^{-7}	1.7×10^{-10}
Sr-89	5.7×10^{-3}	4.6×10^{-15}	2.0×10^{-10}	2.3×10^{-5}
Sr-90	1.2×10^{-3}	9.7×10^{-16}	6.0×10^{-12}	1.6×10^{-4}
Sr-91	1.0×10^{-3}	8.1×10^{-16}	5.0×10^{-9}	1.6×10^{-7}
Sr-92	7.8×10^{-4}	6.3×10^{-16}	9.0×10^{-9}	7.0×10^{-8}
Y-90	4.6×10^{-5}	3.7×10^{-17}	9.0×10^{-10}	4.1×10^{-8}
Y-91	2.4×10^{-4}	1.9×10^{-16}	2.0×10^{-10}	9.7×10^{-7}
Y-92	6.2×10^{-4}	5.0×10^{-16}	1.0×10^{-8}	5.0×10^{-8}
Y-93	1.1×10^{-3}	9.0×10^{-16}	3.0×10^{-9}	3.0×10^{-7}
Zr-95	1.6×10^{-3}	1.3×10^{-15}	4.0×10^{-10}	3.2×10^{-6}
Nb-95	8.4×10^{-3}	6.8×10^{-15}	2.0×10^{-9}	3.4×10^{-6}
Mo-99	5.9×10^{-2}	4.8×10^{-14}	2.0×10^{-9}	2.4×10^{-5}
Tc-99m	3.0×10^{-4}	2.4×10^{-16}	2.0×10^{-7}	1.2×10^{-9}

Table 11.3.3-3 (Sheet 2 of 2)
Gaseous Effluent Concentrations at the Site Boundary

		Concentration (µCi/ml)		
Radionuclide	Release per Unit (Ci /yr)	Site Boundary	ECL	Fraction of ECL
Ru-103	3.5×10^{-3}	2.8×10^{-15}	9.0×10^{-10}	3.2×10^{-6}
Ru-106	7.8×10^{-5}	6.3×10^{-17}	2.0×10^{-11}	3.2×10^{-6}
Rh-103m	1.1×10^{-4}	9.0×10^{-17}	2.0×10^{-6}	4.5×10^{-11}
Rh-106	1.9×10^{-5}	1.5×10^{-17}	1.0×10^{-9}	1.5×10^{-8}
Ag-110m	2.7×10^{-6}	2.2×10^{-18}	1.0×10^{-10}	2.2×10^{-8}
Sb-124	1.8×10^{-4}	1.5×10^{-16}	3.0×10^{-10}	4.9×10^{-7}
Sb-125	6.1×10^{-5}	4.9×10^{-17}	7.0×10^{-10}	7.0×10^{-8}
Te-129m	2.2×10^{-4}	1.8×10^{-16}	3.0×10^{-10}	5.9×10^{-7}
Te-131m	7.6×10^{-5}	6.1×10^{-17}	1.0×10^{-9}	6.1×10^{-8}
Te-132	1.9×10^{-5}	1.5×10^{-17}	9.0×10^{-10}	1.7×10^{-8}
I-131	2.6×10^{-1}	2.1×10^{-13}	2.0×10^{-10}	1.0×10^{-3}
I-132	2.2	1.8×10^{-12}	2.0×10^{-8}	8.8×10^{-5}
I-133	1.7	1.4×10^{-12}	1.0×10^{-9}	1.4×10^{-3}
I-134	3.8	3.1×10^{-12}	6.0×10^{-8}	5.1×10^{-5}
I-135	2.4	1.9×10^{-12}	6.0×10^{-9}	3.2×10^{-4}
Xe-131m	1.8×10^{3}	1.5×10^{-9}	2.0×10^{-6}	7.3×10^{-4}
Xe-133m	8.7×10^{1}	7.0×10^{-11}	6.0×10^{-7}	1.2×10^{-4}
Xe-133	4.6×10^{3}	3.7×10^{-9}	5.0×10^{-7}	7.4×10^{-3}
Xe-135m	5.9×10^{2}	4.8×10^{-10}	4.0×10^{-8}	1.2×10^{-2}
Xe-135	7.6×10^{2}	6.1×10^{-10}	7.0×10^{-8}	8.7×10^{-3}
Xe-137	7.6×10^{2}	6.1×10^{-10}	1.0×10^{-9}	6.1×10^{-1}
Xe-138	6.2×10^{2}	5.0×10^{-10}	2.0×10^{-8}	2.5×10^{-2}
Xe-139	4.1×10^{-4}	3.3×10^{-16}	1.0×10^{-9}	3.3×10^{-7}
Cs-134	6.2×10^{-3}	5.0×10^{-15}	2.0×10^{-10}	2.5×10^{-5}
Cs-136	5.9×10^{-4}	4.8×10^{-16}	9.0×10^{-10}	5.3×10^{-7}
Cs-137	9.5×10^{-3}	7.6×10^{-15}	2.0×10^{-10}	3.8×10^{-5}
Cs-138	1.7×10^{-4}	1.4×10^{-16}	8.0×10^{-8}	1.7×10^{-9}
Ba-137m	3.6×10^{-3}	2.9×10^{-15}	1.0×10^{-9}	2.9×10^{-6}
Ba-140	2.7×10^{-2}	2.2×10^{-14}	2.0×10^{-9}	1.1×10^{-5}
La-140	1.8×10^{-3}	1.5×10^{-15}	2.0×10^{-9}	7.3×10^{-7}
Ce-141	9.2×10^{-3}	7.4×10^{-15}	8.0×10^{-10}	9.3×10^{-6}
Ce-144	1.9×10^{-5}	1.5×10^{-17}	2.0×10^{-11}	7.6×10^{-7}
Pr-144	1.9×10^{-5}	1.5×10^{-17}	2.0×10^{-7}	7.6×10^{-11}
W-187	1.9×10^{-4}	1.5×10^{-16}	1.0×10^{-8}	1.5×10^{-8}
Np-239	1.2×10^{-2}	9.6×10^{-15}	3.0×10^{-9}	3.2×10^{-6}
Total	1.4×10^{4}	1.2×10^{-8}	–	1.0

Table 11.3.3-4
Distance to Sensitive Receptors

Nearest Receptor	Direction	Distance (mi)
Site Boundary	SW	0.62
Residence	NNW	1.40
Vegetable Garden	NW	1.65
Meat Animal	NNW	1.40

Note: The site boundary and residence, garden, and meat animal locations are shown in Figure 11.3.3-1. The distances to the receptor locations are from the edge of the power block.

Table 11.3.3-5
Gaseous Pathway Doses for Maximally Exposed Individuals

Pathway	Dose (mrem/yr) per Unit							
	Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Site Boundary								
External								
Plume	1.9	1.9	1.9	1.9	1.9	1.9	2.0	6.7
Ground	0.85	0.85	0.85	0.85	0.85	0.85	0.85	1.0
Total	2.8	2.8	2.8	2.8	2.8	2.8	2.8	7.7
Inhalation								
Adult	0.11	0.13	0.029	0.13	0.14	3.2	0.17	0
Teen	0.12	0.13	0.037	0.14	0.16	4.1	0.21	0
Child	0.11	0.11	0.047	0.13	0.14	5.0	0.18	0
Infant	0.062	0.060	0.030	0.084	0.085	4.6	0.12	0
Total								
Adult	2.9	2.9	2.8	2.9	2.9	5.9	3.0	7.7
Teen	2.9	2.9	2.8	2.9	2.9	6.9	3.1	7.7
Child	2.9	2.9	2.8	2.9	2.9	7.8	3.0	7.7
Infant	2.8	2.8	2.8	2.9	2.9	7.4	3.0	7.7
Residence								
External								
Plume	0.54	0.54	0.54	0.54	0.54	0.54	0.55	1.7
Ground	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.27
Total	0.77	0.77	0.77	0.77	0.77	0.77	0.78	2.0
Inhalation								
Adult	0.025	0.028	0.0062	0.029	0.032	0.70	0.038	0
Teen	0.026	0.029	0.0080	0.031	0.035	0.90	0.046	0
Child	0.024	0.024	0.010	0.028	0.032	1.1	0.039	0
Infant	0.014	0.013	0.0065	0.019	0.019	1.0	0.026	0
Vegetable								
Adult	0.24	0.24	1.2	0.25	0.23	4.3	0.20	0
Teen	0.35	0.35	1.8	0.39	0.36	5.4	0.31	0
Child	0.75	0.73	4.2	0.84	0.78	10	0.70	0
Meat								
Adult	0.10	0.16	0.45	0.11	0.10	0.39	0.094	0
Teen	0.083	0.11	0.38	0.089	0.083	0.29	0.078	0
Child	0.15	0.16	0.71	0.16	0.15	0.46	0.14	0
Total MEI Dose*								
Adult	1.1	1.2	2.4	1.2	1.1	6.1	1.1	2.0
Teen	1.2	1.3	2.9	1.3	1.2	7.4	1.2	2.0
Child	1.7	1.7	5.6	1.8	1.7	13	1.7	2.0
Infant	0.78	0.78	0.77	0.79	0.79	1.8	0.81	2.0

Note: Total MEI dose is the sum of the residence, vegetable, and meat pathways.

Table 11.3.3-6
Comparison of Maximally Exposed Individual Doses with 10 CFR 50, Appendix I Criteria

Type of Dose	Location	Annual Dose per Unit	
		VCS	Limit
Gaseous Effluent			
Gamma Air (mrad)	Site Boundary	3.0	10
Beta Air (mrad)	Site Boundary	7.5	20
Total Body (mrem)	Site Boundary	2.8	5
Skin (mrem)	Site Boundary	7.7	15
Iodines and Particulates Maximum Organ — Thyroid (mrem)	Residence/Garden/Meat Cow	11	15

Table 11.3.3-7
Comparison of Maximally Exposed Individual Doses with 40 CFR 190 Criteria

	Site Dose for All Units (mrem/yr)				
	Liquid	Gaseous	Direct	Total	Limit
Total Body	1.5	5.8	5.0	12	25
Thyroid	1.3	16	5.0	22	75
Other Organ — Bone	2.6	11	5.0	19	25

Table 11.3.3-8
Collective Doses Within 50 Miles

Pathway	Dose per Unit (person-rem/yr)		Site Dose (person-rem/yr)	
	Total Body	Thyroid	Total Body	Thyroid
Liquid Effluents	8.7	8.4	17	17
Gaseous Effluents				
Noble Gases	2.9×10^{-1}	2.9×10^{-1}	5.8×10^{-1}	5.8×10^{-1}
Iodines	6.6×10^{-3}	2.6	1.3×10^{-2}	5.2
Particulates	1.4×10^{-1}	1.1×10^{-1}	2.8×10^{-1}	2.1×10^{-1}
C-14	5.9×10^{-1}	5.9×10^{-1}	1.2	1.2
H-3	1.0×10^{-1}	1.0×10^{-1}	2.1×10^{-1}	2.1×10^{-1}
Total Gaseous Effluents	1.1	3.7	2.3	7.4
Total	9.9	12	20	24
Natural Background[(a)]	1.2×10^{5}			

(a) Based on dose rate of 300 mrem/yr (Reference 11.3.3-2)

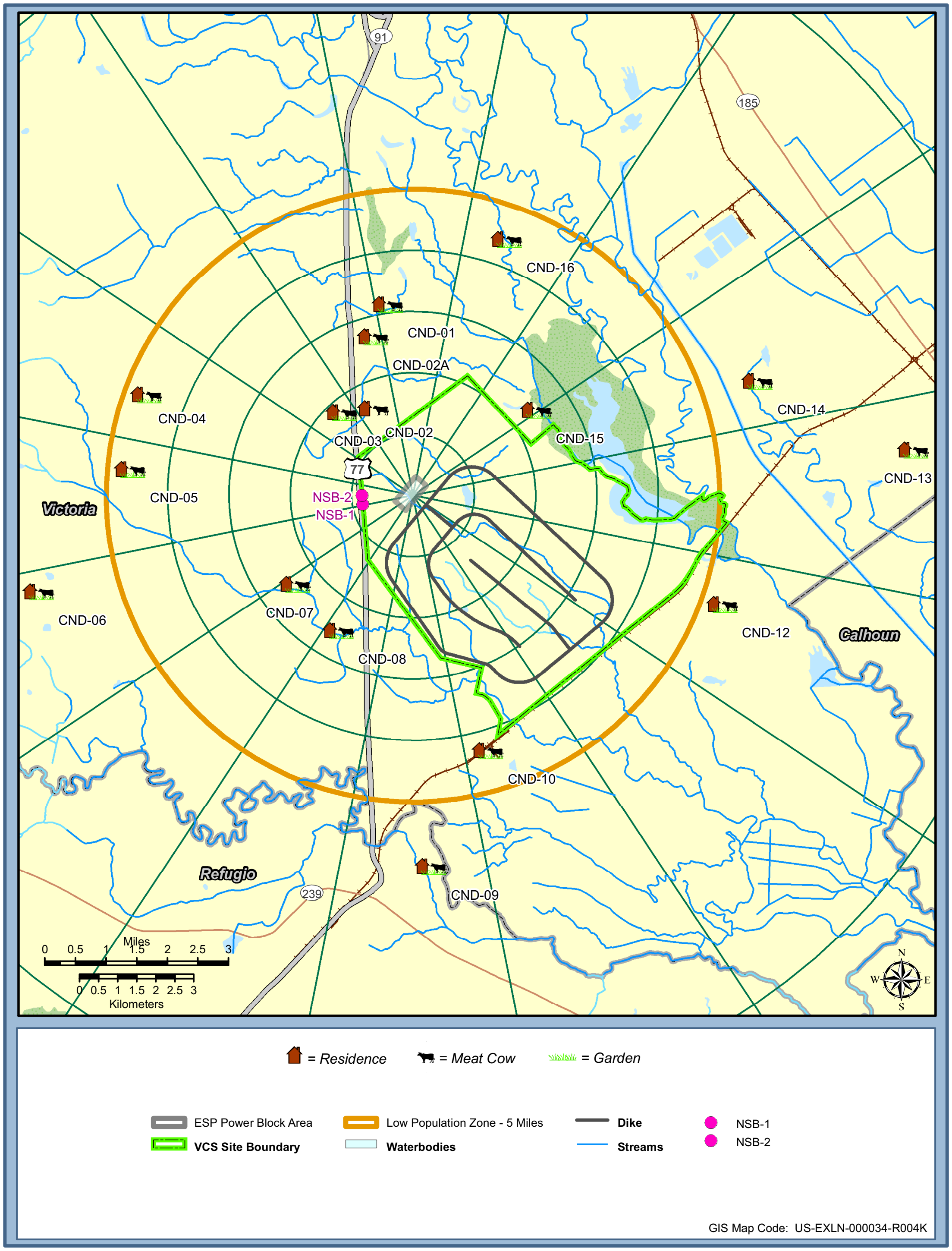

Figure 11.3.3-1 Receptors