8.14 Potential Radiological Doses from 2004 Hanford Site Operations

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During 2004, potential radiological doses to the public and biota from Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. The potential sources of radionuclide contamination included gaseous emissions from stacks and ventilation exhausts, liquid effluent from operating wastewater treatment facilities, contaminated groundwater seeping into the Columbia River, and fugitive emissions from contaminated soil areas and facilities. The methods used to calculate the potential doses are detailed in Appendix E.

The radiological impact of 2004 Hanford Site operations was assessed in terms of the:

- dose to a hypothetical, maximally exposed individual at an offsite location using a multimedia pathway assessment (DOE Order 5400.5; Section 8.14.1)
- collective dose to the population residing within 80 kilometers (50 miles) of Hanford Site operating areas (Section 8.14.2)
- dose for air pathways, using EPA methods, for comparison to the *Clean Air Act* standards in 40 CFR 61, Subpart H, *National Emission Standards for Hazardous Air Pollutants* (Section 8.14.3)
- maximum dose rate from external radiation at a publicly accessible location at or just within the site boundary (Section 8.14.4.1)
- dose to a worker consuming drinking water on the site (Section 8.14.4.3)
- inhalation dose associated with measured radionuclide concentrations in air (Section 8.14.4.4)
- doses from non-DOE industrial sources on and near Hanford (Section 8.14.5)
- absorbed dose received by animals exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies (Section 8.14.6).

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations. However, the amounts of most radioactive materials released during 2004 from Hanford Site sources were, generally, too small to be measured directly once it was dispersed in the offsite environment. For many of the radionuclides present in measurable amounts, they were difficult to separate the contributions from Hanford sources from the contributions from fallout and from naturally occurring uranium and its decay products. Therefore, in nearly all instances, offsite doses were estimated using *GENII - The Hanford Environmental Radiation Dosimetry Software System*, Version 1.485 (PNL-6584) and the Hanford Site-specific parameters listed in Appendix E and in PNNL-15222, APP. 1.

Radiological doses from the water pathway were calculated based on the differences in radionuclide concentrations between upstream and downstream sampling points on the Columbia River. During 2004, tritium, iodine-129, two uranium isotopes, and plutonium-239/240 were found in the Columbia River downstream of Hanford at greater levels than predicted based on direct discharges from the 100-K Area (Section 8.4 and Appendix C). All other radionuclide concentrations were lower than those predicted from known releases. Riverbank spring water, containing radionuclides, is known to enter the Columbia River along the portion of the Hanford shoreline extending from the 100-B/C Area downstream to the 300 Area

(Sections 8.5 and 8.7). No direct discharge of radioactive materials from the 300 Area to the Columbia River was reported during 2004.

8.14.1 Maximally Exposed Individual Dose (Offsite Resident)

The maximally exposed individual is a hypothetical person who lives at a particular location and has a lifestyle that makes it unlikely that any other member of the public would have received a higher radiological dose from Hanford releases during 2004. This individual's exposure pathways were chosen to maximize the combined doses from all reasonable environmental routes of exposure to radionuclides in Hanford Site effluent and emissions using a multimedia pathway assessment (DOE Order 5400.5). In reality, such a combination of maximized parameters is highly unlikely to apply to any single individual.

The location of the hypothetical, maximally exposed individual varies from year to year, depending on the relative contributions of the several sources of radioactive emissions released to the air and liquid effluent released to the Columbia River from Hanford facilities (Figure 8.14.1). During 2004, the dose assessment determined that the maximally exposed individual was located across the Columbia River (east of the Hanford Site) at Sagemoor (Figure 8.14.1). For the calculation, it was assumed that this individual:

- inhaled and was submersed in airborne radionuclides
- received external exposure to radionuclides deposited on the ground
- ingested locally grown food products that had been irrigated with water withdrawn from the Columbia River downstream from the Hanford Site
- used the Columbia River near the Hanford Site for recreational purposes, resulting in direct exposure from radionuclides in water and radionuclides deposited on the shoreline
- ingested locally caught Columbia River fish.

Doses were calculated using Hanford Site air emissions and effluent data (Tables 8.1.1 and 8.3.2) and the calculated quantities of radionuclides assumed to be present in the Columbia River from riverbank spring discharges along the Hanford Site shoreline. The estimated contaminant releases to the river from these sources were derived from the difference between the upstream and downstream radionuclide concentrations in Columbia River water. These radionuclides were assumed to originate from historical releases of contaminants to the ground in the 100 and 200 Areas and to have entered the river through shoreline groundwater springs between the 100-B/C Area and the 300 Area.

Historically at Hanford, there has been one primary expression of radiological risk to an offsite individual – this is the maximally exposed individual dose. However, the maximally exposed individual dose is currently calculated by two different methods in response to two different requirements. One maximally exposed individual dose computation is required by DOE Order 5400.5 and is calculated using the GENII computer code. This calculation considers all reasonable environmental pathways (e.g., air, water, and food) that maximize a hypothetical individual's offsite exposure to Hanford's radiological effluent and emissions. A second estimate of maximally exposed individual dose is required by the *Clean Air Act* and is calculated using an EPA dose modeling computer code (CAP-88) or other methods accepted by EPA for estimating offsite exposure. This offsite dose is based solely on an airborne radionuclide emissions pathway and considers Hanford's stack emissions and emissions from diffuse and unmonitored sources (e.g., windblown dust).

Because the DOE and EPA computer codes use different input parameters, the location and predicted dose of each agency's maximally exposed individual may be different. However, the estimated doses from both methods have historically been significantly lower than health-based exposure criteria.

Recently, DOE has allowed private businesses to locate their activities and personnel on the Hanford Site. This has created the need to calculate a maximum onsite occupational dose for an individual who is employed by a non-DOE business and works within the boundary of the Hanford Site. This dose is based on a mix of air emission modeling data, the individual's exposure at an onsite work location, and the individual's potential offsite exposure.

Another way to estimate risk is to calculate the collective dose. This dose is based on exposure to Hanford radiological contaminants through the food, water, and air pathways and is calculated for the population residing within 80 kilometers (50 miles) of the Hanford Site operating areas. The collective dose is reported in units of person-rem (person-sievert), which is the average estimated individual dose multiplied by the total number of people in the population.

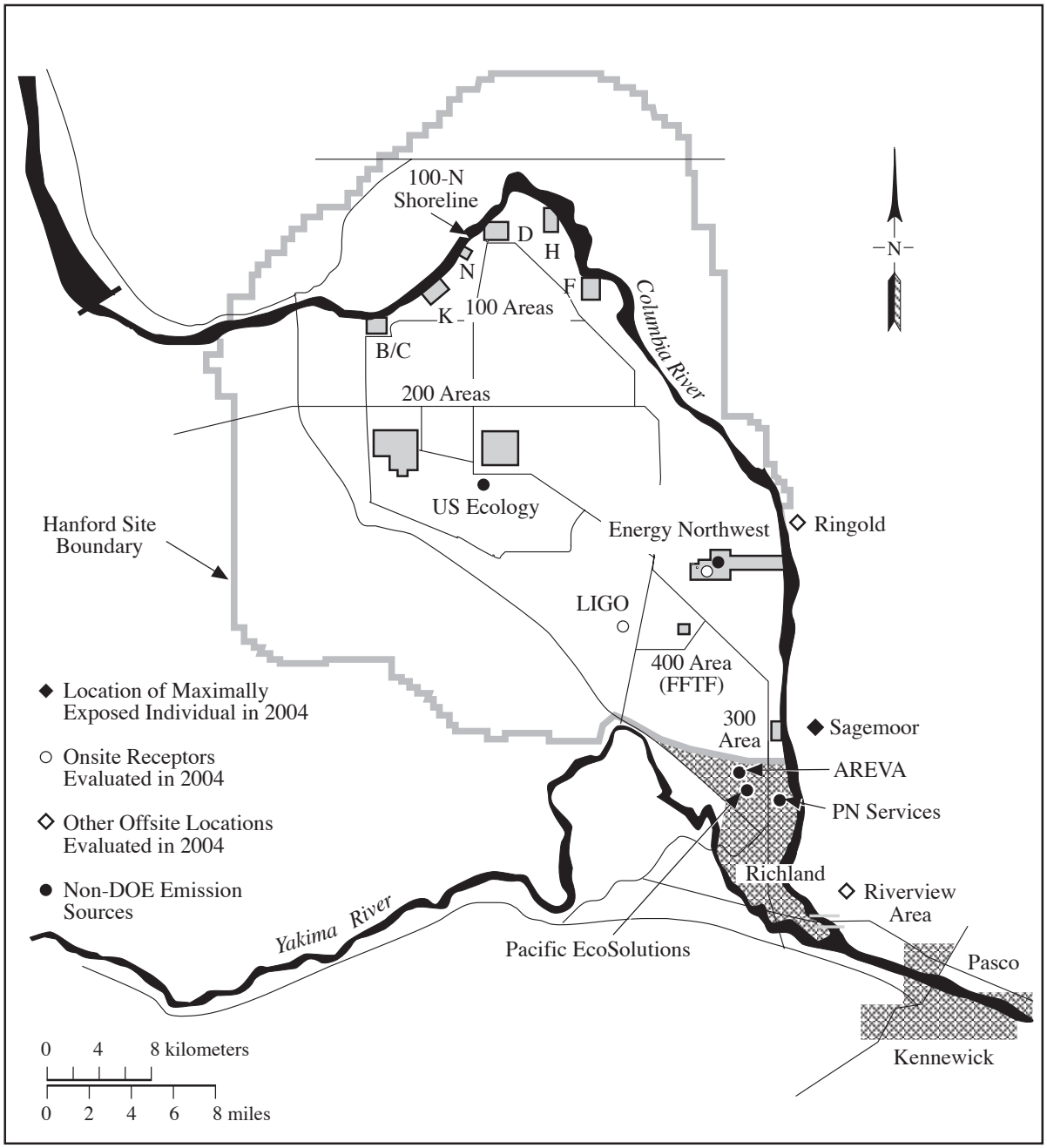

Figure 8.14.1. Locations Important to Dose Calculations at the Hanford Site, 2004

Table 8.14.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Sagemoor from 2004 Hanford Site Operations

		Dose Contributions from Operating Areas, mrem				
Effluent	**Pathway**	**100 Areas**	**200 Areas**	**300 Area**	**400 Area**	**Pathway Total**
Air	External	8.3×10^{-10}	2.7×10^{-7}	2.7×10^{-5}	4.4×10^{-8}	2.7×10^{-5}
	Inhalation	7.5×10^{-5}	7.1×10^{-5}	6.2×10^{-3}	2.0×10^{-6}	6.3×10^{-3}
	Foods	2.0×10^{-6}	2.0×10^{-4}	1.3×10^{-3}	8.7×10^{-6}	1.5×10^{-3}
	Subtotal air	7.7×10^{-5}	2.7×10^{-4}	7.5×10^{-3}	1.1×10^{-5}	7.9×10^{-3}
Water	Recreation	3.2×10^{-7}	3.0×10^{-5}	0.0[a]	0.0	3.0×10^{-5}
	Foods	1.6×10^{-4}	3.6×10^{-3}	0.0	0.0	3.8×10^{-3}
	Fish	1.4×10^{-4}	2.1×10^{-3}	0.0	0.0	2.2×10^{-3}
	Drinking water	0.0	0.0	0.0	0.0	0.0
	Subtotal water	3.0×10^{-4}	5.7×10^{-3}	0.0	0.0	6.0×10^{-3}
Combined total		3.8×10^{-4}	6.0×10^{-3}	7.5×10^{-3}	1.1×10^{-5}	1.4×10^{-2}

(a) Zeros indicate no dose contribution to maximally exposed individual through water pathway.

During 2004, the total dose to the maximally exposed individual at Sagemoor (Figure 8.14.1) was calculated to be 0.014 mrem (0.14 μSv) per year (Table 8.14.1). This dose was 0.014% of the DOE limit of 100 mrem (1 mSv) per year specified in DOE Order 5400.5 (Figure 8.14.2.). The primary pathways (Appendix E, Tables E.1, E.2, and E.4) contributing to this dose (and the percentage of all pathways) were:

- the inhalation of air downwind of Hanford (45%) and the consumption of food products grown downwind of Hanford (approximately 11%), resulting in exposure to airborne releases of radon and tritium from the 300 Area
- the consumption of foods irrigated with Columbia River water withdrawn downstream of Hanford (27%) and the consumption of fish from the Columbia River (16%), resulting in exposure to tritium and uranium isotopes in the river.

8.14.2 Collective Dose

Collective dose is defined as the sum of doses to all individual members of the public within 80 kilometers (50 miles) of the operating areas at Hanford. The regional collective dose from 2004 Hanford Site operations was estimated by calculating the radiological dose to the population residing within an 80-kilometer (50-mile) radius of the onsite operating areas. During 2004, the collective dose calculated for the population was 0.32 person-rem (0.0032 person-Sv) per year (Table 8.14.2; Figure 8.14.3), which is just over half of the 2003 collective dose (0.5 person-rem [0.005 person-Sv]) per year (Appendix E, Tables E.5 to E.10).

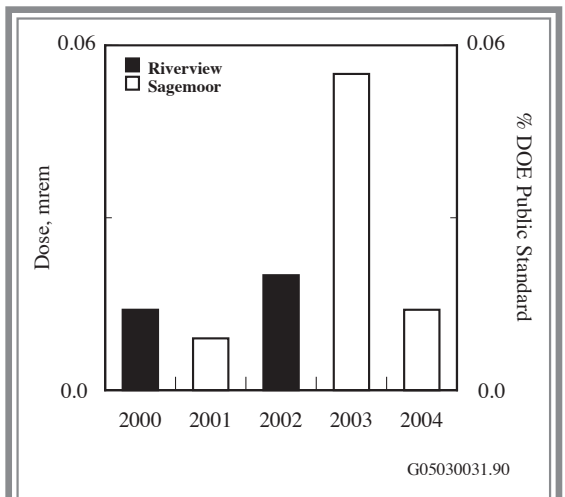

Figure 8.14.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual Near the Hanford Site, 2000 through 2004

Table 8.14.2. Collective Dose to the Population from 2004 Hanford Site Operations

		Dose Contributions from Operating Areas, person-rem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	1.4×10^{-7}	2.4×10^{-5}	4.7×10^{-4}	2.2×10^{-6}	5.4×10^{-4}
	Inhalation	1.9×10^{-2}	9.8×10^{-3}	7.5×10^{-2}	1.5×10^{-4}	1.0×10^{-1}
	Foods	2.4×10^{-4}	1.9×10^{-2}	1.0×10^{-2}	3.9×10^{-4}	3.0×10^{-2}
	Subtotal air	1.9×10^{-2}	2.9×10^{-2}	8.5×10^{-2}	5.4×10^{-4}	1.3×10^{-1}
Water	Recreation	2.4×10^{-6}	1.8×10^{-4}	0.0[a]	0.0	1.8×10^{-4}
	Foods	1.7×10^{-4}	3.9×10^{-3}	0.0	0.0	4.1×10^{-3}
	Fish	4.9×10^{-5}	8.0×10^{-4}	0.0	0.0	8.5×10^{-4}
	Drinking water	7.7×10^{-4}	1.8×10^{-1}	0.0	0.0	1.8×10^{-1}
	Subtotal water	9.9×10^{-4}	1.8×10^{-1}	0.0	0.0	1.9×10^{-1}
Combined total		2.0×10^{-2}	2.1×10^{-1}	8.5×10^{-2}	5.4×10^{-4}	3.2×10^{-1}

(a) Zeros indicate no dose contribution to the population through the water pathway.

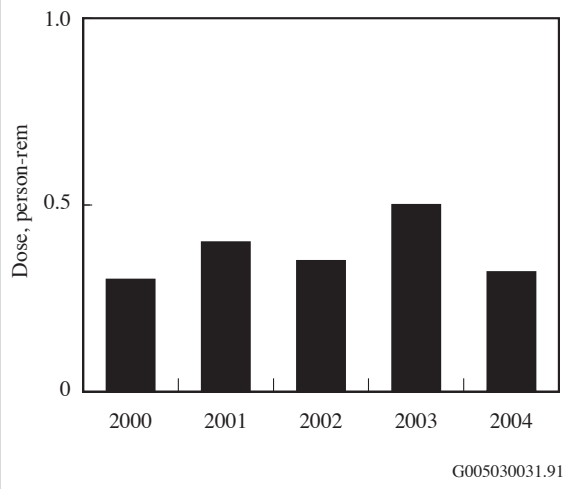

Figure 8.14.3. Collective Dose to the Population within 80 Kilometers (50 Miles) of the Hanford Site, 2000 through 2004

Primary pathways contributing to the 2004 collective dose (and the percentage of all pathways) included:

- inhalation of radionuclides that were released to the air, principally radon from the 300 Area and iodine-129 from the 200 Areas (31%), and consumption of food grown downwind of Hanford (approximately 9%)
- the consumption of water withdrawn from the Columbia River downstream of Hanford (56%) and foods irrigated with water withdrawn from the Columbia River downstream of Hanford (approximately 1%) containing principally tritium, uranium-234, and uranium-238.

Collective doses reported for 2004 are based on population data from the 2000 census. The collective dose is reported in units of person-rem (person-sievert), which is the average estimated individual dose multiplied by the total number of people in the population. Between 1990 and 2000, the population within 80 kilometers (50 miles) of the major operating areas on the Hanford Site increased by 24% to 29%.

The average individual dose from 2004 Hanford Site operations based on a population of 486,000 within 80 kilometers (50 miles) of the site was 0.0007 mrem (0.007 μSv) per year. To place this estimated dose into perspective, it may be compared with doses received from other routinely encountered sources of radiation such as natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural radionuclides in the body, and inhalation of naturally occurring radon (Figure 8.14.4). The estimated annual average individual dose to members of the public from Hanford Site sources during 2004 was approximately 0.0002% of the estimated annual individual dose received from natural background sources (300 mrem). The calculated radiological doses from Hanford Site operations in 2004 were a small percentage of the federal standards and of doses from natural background sources (Table 8.14.3).

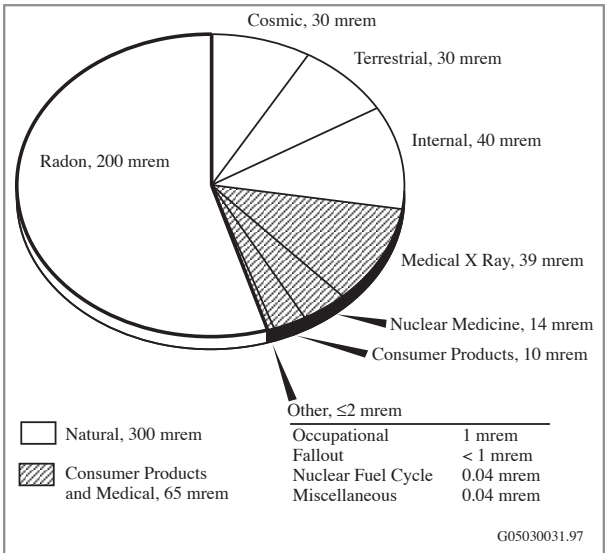

Figure 8.14.4. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

8.14.3 Compliance with Clean Air Act Standards

In addition to complying with the all-pathways dose limits established by DOE Order 5400.5, DOE facilities are required to demonstrate that they comply with standards established by EPA for airborne radionuclide emissions under the *Clean Air Act* in 40 CFR 61, Subpart H. This regulation specifies that no member of the public shall receive a dose greater than 10 mrem (0.1 mSv) per year from exposure to airborne radionuclide emissions, other than radon, released at DOE facilities. Whereas DOE uses the GENII computer code at Hanford to determine dose to the all-pathways maximally exposed individual, EPA requires the use of the CAP-88 computer code (EPA 402-R-00-004) or other EPA-approved computer models to demonstrate compliance with the requirements in 40 CFR 61, Subpart H. The assumptions embodied in the CAP-88 computer code differ slightly from standard assumptions used with the GENII computer code. Therefore, air pathway doses calculated by the two codes may differ somewhat. In addition, the maximally exposed individual for air pathways may be evaluated at a different location from the all-pathways maximally exposed individual because of the relative contributions from each exposure pathway (Section 8.14.1).

The EPA regulation also requires that each DOE facility submit an annual report to EPA that supplies information about atmospheric emissions for the preceding year and their potential offsite dose. For more detailed information

Table 8.14.3. Comparison of 2004 Doses to the Public from Hanford Site Effluent and Emissions to Federal Standards and Natural Background Levels

Federal Standard	Hanford Dose[a]	Percent of Standard or of Background Dose
DOE - 100 mrem/yr all pathways MEI[b]	0.014 mrem/yr	0.014
EPA - 10 mrem/yr air pathway MEI[c]	0.0022 mrem/yr	0.23
Background Dose		
300 mrem/yr average U.S. individual[d]	0.0007 mrem/yr	0.0002
145,800 person-rem/yr to population within 80 km (50 mi)	0.32 person-rem/yr	0.0002

(a) To convert the dose values to mSv or person-Sv, divide by 100.
(b) DOE Order 5400.5.
(c) 40 CFR 61.
(d) National Council on Radiation Protection and Measurements (1987).
MEI = Maximally exposed individual.

about 2004 air emissions on the Hanford Site, refer to DOE's report to the EPA, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2004* (DOE/RL-2005-06).

8.14.3.1 Dose to an Offsite Maximally Exposed Individual

During 2004, the maximally exposed offsite individual for air pathways using EPA-specified methods was determined to be at a location in the Ringold area of Franklin County, approximately 13 kilometers (8 miles) directly north of the 300 Area, across the Columbia River (Figure 8.14.1). The potential air pathway dose from stack emissions to a maximally exposed individual at that location calculated using the CAP-88 computer code was determined to be 0.0022 mrem (0.000022 mSv) per year, which represented less than 0.4% of the EPA standard. This is similar to the offsite individual doses calculated for EPA in previous years and to the air pathway doses for stack emissions in Table 8.14.1.

8.14.3.2 Maximum Dose to Non-DOE Workers on the Site

The DOE Richland Operations Office received guidance from EPA's Region 10 office and the Washington State Department of Health that, in demonstrating compliance with the 40 CFR 61 standards, it should evaluate potential doses to non-DOE employees who work on the Hanford Site but who are not under direct DOE control. Accordingly, the doses to members of the public employed at non-DOE facilities that were outside access-controlled areas on the Hanford Site (those requiring DOE access authorization for entry) were evaluated for the 2004 EPA air emissions report (DOE/RL-2005-06). These locations included the Columbia Generating Station operated by Energy Northwest and the Laser Interferometer Gravitational Wave Observatory (LIGO) operated by the University of California (Figure 8.14.1). Of those locations, an employee at the LIGO facility received the highest dose for non-DOE employees who worked on the Hanford Site. The dose from stack emissions calculated using the CAP-88 computer code was 0.0019 mrem (0.000019 mSv) per year, assuming full-time occupancy.

EPA guidance does not currently allow for adjustment of doses calculated using the CAP-88 computer code to account for less than full-time occupancy at locations within the site boundary. However, if a selected occupancy period of 2,000 hours per year were assumed for workers at onsite non-DOE facilities, the doses to individuals at any of the locations evaluated would be lower than the dose reported for LIGO. In 2004, the estimated doses to non-DOE onsite workers were lower than the doses to offsite individuals for all locations.

8.14.3.3 Dose from Diffuse and Fugitive Radionuclide Emissions

The December 15, 1989, revisions to the *Clean Air Act* (40 CFR 61, Subpart H) required DOE facilities to estimate the dose to a member of the public for radionuclides released from all potential sources of airborne radionuclides. DOE and EPA interpreted the regulation to include diffuse (widespread) and fugitive (unintended) emissions as well as emissions from monitored point sources (i.e., stacks). EPA has not specified or approved standardized methods to estimate diffuse air emissions because of the wide variety of sources at DOE sites. The method developed at Hanford to estimate potential diffuse emissions is based on environmental monitoring measurements of airborne radionuclides at the site perimeter (DOE/RL-2005-06). During 2004, the estimated dose from diffuse emissions to a maximally exposed individual at a location in the Ringold area was calculated using the CAP-88 computer code to be 0.031 mrem (0.00031 mSv) per year. This is consistent with results for recent years, where the dose from diffuse emissions has been greater than the dose from stack emissions because radionuclide emissions from operating Hanford facilities are currently very low. The dose to an onsite non-DOE worker from diffuse and fugitive emissions would be similar to, or lower than, the dose at the site perimeter. Therefore, the potential combined dose from stack emissions and diffuse emissions during 2004 was well below the EPA 10 mrem (0.1 mSv) per year standard for either onsite or offsite members of the public.

8.14.4 Special Case Dose Estimates

The parameters used to calculate the dose to the maximally exposed individual were selected to provide a scenario yielding a reasonable upper (or bounding) estimate of the

dose. However, such a scenario may not have necessarily resulted in the highest conceivable radiological dose. Other low-probability exposure scenarios existed that could have resulted in somewhat higher doses. Four scenarios that could have potentially led to larger doses included (1) an individual who spent time at the site boundary location with the maximum external radiological dose rate, (2) a sportsman who consumed contaminated wildlife that migrated from the site, (3) a person who drank water at the Fast Flux Test Facility in the 400 Area, and (4) individuals at various locations who breathed the measured radionuclide concentrations in air for an entire year. The potential doses resulting from these scenarios are examined in the following sections.

8.14.4.1 Maximum Boundary Dose Rate

The boundary radiological dose rate is the external radiological dose rate measured at publicly accessible locations at or near the Hanford Site boundary. The maximum boundary dose rate was determined from radiation exposure measurements using thermoluminescent dosimeters where elevated dose rates might be expected at site-wide locations and at representative locations offsite. These boundary dose rates were not used to calculate annual doses to the general public because no one could actually reside at any of these boundary locations. However, these rates were used to determine the dose to a specific individual who might have spent some time at that location.

External radiological dose rates measurements during 2004 were made along the 100-N Area shoreline (Figure 8.13.1) (Section 8.13). The measurements were consistently above background levels and represented the highest measured boundary dose rates. The Columbia River allows public access to within approximately 100 meters (330 feet) of the N Reactor and supporting facilities at this location.

The highest dose rate along the 100-N Area shoreline during 2004 was about 0.012 mrem (0.12 µSv) per hour, or approximately 20% higher than the average dose rate of 0.01 mrem (0.1 µSv) per hour normally observed at other shoreline locations. Therefore, for every hour someone spent near the 100-N Area shoreline during 2004, the external radiological dose received from Hanford operations was approximately 0.002 mrem (0.02 µSv) above the average shoreline dose rate. If an individual had spent 7 hours at that location, he or she would have received a dose comparable to the annual dose calculated for the hypothetical, maximally exposed individual at Sagemoor. Members of the public could reach the 100-N Area shoreline by boat and could have legally occupied the shoreline area below the high water line. However, the topography of the shoreline below the high water line near the N Reactor is very rocky and visitors are not likely to remain on shore for extended periods.

8.14.4.2 Sportsman Dose

Wildlife have access to areas of the Hanford Site that are contaminated with radioactive materials. Wildlife have the potential to acquire radioactive contamination and migrate off the site. Wildlife sampling was conducted on the site to estimate the maximum contamination levels that might have existed in animals from Hanford that were hunted off the site. Because this scenario had a relatively low probability of occurrence, this pathway was not considered in the maximally exposed individual calculation.

The only radionuclides detected in wildlife samples collected in 2004 were potassium-40, a primordial radioisotope not of Hanford origin; strontium-90, which was only detected in bone samples; and technetium-99, detected in a composite sample of deer mouse carcasses taken from the Vernita Bridge area and in other composite samples of sculpin carcasses collected from the Columbia River near the Vernita Bridge and near shoreline springs at the 100-K Area, 100-H Area, 100-F Area, Hanford town site, and the 300 Area. Because concentrations of Hanford contaminants in edible wildlife tissues were below detection limits in 2004, the dose to a sportsman who might consume the game animals was not calculated.

8.14.4.3 Onsite Drinking Water

During 2004, groundwater from wells in the 400 Area was used as drinking water by workers in the Fast Flux Test Facility. Columbia River water was used for drinking water in the 100 and 200 Areas. Drinking water was sampled and analyzed throughout the year in accordance with applicable regulations (40 CFR 141). All annual average radionuclide concentrations measured during 2004 were below applicable drinking water standards. However, tritium in

the Fast Flux Test Facility groundwater wells was detected at levels greater than typical background values and radium isotopes were identified in the 100-K Area drinking water (Section 8.6).

Based on the measured concentrations, the potential annual dose to onsite workers (an estimate derived by assuming a consumption of 1 liter [0.26 gallon] per day for 240 working days) would be approximately 0.49 mrem (4.9 μSv). This dose is well below the drinking water dose limit of 4 mrem (40 μSv) per year for public drinking water supplies.

8.14.4.4 Inhalation Doses for Entire Year

A nominal inhalation rate of 23 cubic meters (812 cubic feet) per day of air and an exposure period of 8,766 hours (365 days) were assumed for all offsite calculations. For onsite locations, the exposure period was reduced to 2,000 hours (250, 8-hour workdays) to simulate a typical work year, and the breathing rate was increased to 28.8 cubic meters (1,017 cubic feet) per day to account for light duty work.

Radiological inhalation doses to hypothetical offsite individuals modeled to be in the same location for the entire year and to onsite individuals located near site-wide air monitoring stations during their workday are presented in Table 8.14.4. The average radionuclide concentrations measured at the air monitoring stations were used in the calculations (Table 8.2.4) and assumed to be constant for the year-long evaluation period. Inhalation doses calculated using this method ranged from 0.017 mrem (0.00017 mSv) at distant locations to 0.06 mrem (0.0006 mSv) at the site perimeter. These were comparable to doses calculated using the CAP-88 computer code and reported for various air pathways (Section 8.14.3).

Table 8.14.4. Inhalation Doses On and Around the Hanford Site Based on 2004 Average Air Monitoring Data[a]

Radionuclide	Group	Dose (mrem/yr)[b,c]
Tritium	Onsite	4.07×10^{-4}
	300 Area	5.19×10^{-4}
	Perimeter	3.43×10^{-3}
	Nearby community	4.57×10^{-3}
	Distant communities	2.94×10^{-3}
Iodine-129	Onsite	6.17×10^{-6}
	Perimeter	7.92×10^{-7}
	Distant communities	6.50×10^{-8}
Cesium-137	Onsite	1.16×10^{-4}
	Perimeter	6.90×10^{-4}
Uranium-234	Onsite	4.81×10^{-3}
	Perimeter	2.77×10^{-2}
	Nearby communities	2.73×10^{-2}
	Distant communities	1.39×10^{-2}
Uranium-238	Onsite	4.35×10^{-3}
	Perimeter	2.21×10^{-2}
	Nearby communities	2.12×10^{-2}
	Distant communities	2.09×10^{-4}
Plutonium-238	Onsite	2.84×10^{-3}
Plutonium-239/240	Onsite	4.72×10^{-3}
	Perimeter	7.04×10^{-3}
Totals	Onsite	1.72×10^{-2}
	300 Area	5.19×10^{-2}
	Perimeter	6.09×10^{-2}
	Nearby communities	5.30×10^{-2}
	Distant communities	1.70×10^{-2}

(a) Onsite inhalation dose calculations were based on 2,000-hour exposure period and 1.2 m^3/h breathing rate; all offsite inhalation dose calculations were based on a 8,766-hour exposure period and a 0.958 m^3/h breathing rate.
(b) Includes contributions from DOE activities as well as contributions from atmospheric fallout, naturally occurring radionuclides, and non-DOE facilities on and near the site.
(c) To convert to international metric system units (mSv/yr), divide reported values by 100.

8.14.5 Doses from Non-DOE Sources

DOE Order 5400.5, Chapter II, paragraph 7, has a reporting requirement for a combined dose due to DOE and other manmade sources that exceeds 100 mrem (1 mSv) per year. During 2004, various non-DOE industrial sources of public radiation exposure existed on or near the Hanford Site. These included a commercial, low-level, radioactive waste burial ground at Hanford operated by US Ecology; a nuclear power-generating station at Hanford operated by Energy Northwest; a nuclear-fuel production plant operated near the site by AREVA; a commercial, low-level, radioactive waste treatment facility operated near the site by Pacific EcoSolutions (formerly Allied Technology Group Corporation); and a commercial decontamination facility operated near the site by PN Services (Figure 8.14.1).

DOE maintains an awareness of these other sources of radiation, which, if combined with the DOE sources, might have the potential to cause a dose exceeding 10 mrem (0.1 mSv) per year to any member of the public. With

information gathered from these companies via personal communication and annual reporting, it was conservatively estimated that the total 2004 individual dose from their combined activities was on the order of 0.067 mrem (0.00067 mSv) per year. Therefore, the combined annual dose from Hanford area non-DOE and DOE sources to a member of the public for 2004 was well below any regulatory dose limit.

8.14.6 Dose Rates to Animals

Upper estimates have been made of the radiological dose to aquatic organisms in accordance with the DOE Order 5400.5 interim requirement for management and control of liquid discharges. The current dose limit for native aquatic biota is 1 rad (10 mGy) per day. The proposed limit for terrestrial biota is 0.1 rad (1 mGy) per day.

Concentration guides for assessing doses to biota are very different from the DOE derived concentration guides that are used to assess radiological doses to humans. A screening method is used to estimate radiological doses to aquatic and terrestrial biota. This method uses the RESRAD-BIOTA computer code (DOE/EH-0676; DOE/STD-1153-2002) to compare radionuclide concentrations measured by routine monitoring programs to a set of conservative biota concentration guides (e.g., 1 rad [10 mGy] per day for aquatic biota). For samples containing multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to the dose guideline. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded. If the initial estimated screening value (Tier 1 [Table 8.14.5]) exceeds the guideline (sum of fractions >1.0), another screening calculation is performed (Tier 2 [Table 8.14.5]) to more accurately evaluate exposure of the biota to the radionuclides. The process may culminate in a site-specific assessment requiring additional sampling and study of exposure. During 2004, biota dose screening assessments were conducted on and off the site (Table 8.14.5).

Maximum concentrations of radionuclides measured in soil, Columbia River sediment, onsite pond water and sediment, and Columbia River riverbank spring water were evaluated using the RESRAD-BIOTA computer code. Riverbank springs carry groundwater contaminants into the Columbia River at greater concentrations than observed in river water and provide another level of conservatism in the biota dose assessment process. The results of the screening calculations indicated that the concentrations in all but one of the samples (West Lake) passed the Tier 1 screen, indicating that the calculated doses were below the dose limits and guidelines (sum of fractions <1.0). The West Lake sample was evaluated by further screening calculations (Tier 2) and its calculated dose was also below the dose limits and guidelines (sum of fractions <1.0) (Table 8.14.5).

8.14.7 Radiological Dose in Perspective

Scientific studies (National Research Council 1980, 1990; United Nations Science Committee on the Effects of Atomic Radiation 1988) have been performed to estimate the possible risk from exposure to low levels of radiation. These studies provided information to government and scientific organizations and are used to recommend radiological dose limits and standards for public and occupational safety.

Although no increase in the incidence of health effects from low doses of radiation has actually been confirmed by the scientific community, regulatory agencies cautiously assume that the probability of these types of health effects occurring due to exposure to low doses (down to zero dose) is the same per unit dose as the health effects observed after an exposure to much higher doses (e.g., in atomic bomb survivors, individuals receiving medical exposure, or radium-dial painters). This concept is known as the linear no threshold hypothesis. Under these assumptions, even natural background radiation, which is hundreds of times greater than radiation from current Hanford Site releases, increases each person's probability or chance of developing a detrimental health effect.

Scientists do not agree on how to translate the available data on health effects into the numerical probability (risk) of detrimental effects from low radiological doses. Some scientific studies have indicated that low radiological doses result in beneficial effects (Sagan 1987). Because cancer and hereditary diseases in the general population are caused by many sources (e.g., genetic defects, sunlight, chemicals, and background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be proven conclusively. In developing *Clean Air*

Table 8.14.5. Results of Using the RESRAD-BIOTA[a] Computer Code to Estimate Radiological Doses to Biota On and Around the Hanford Site, 2004

Location	Tier 1 Screen Sum of Fraction[b]	Pass or Fail	Tier 2 Screen Sum of Fraction[b]	Pass or Fail
Aquatic	0.000013-1.05			
100-B Area Spring	0.015	Pass	NA	
100-D Area	0.0052	Pass	NA	
100-F Area Slough	0.021	Pass	NA	
100-F Area Spring	0.015	Pass	NA	
100-H Area Spring	0.039	Pass	NA	
100-N Area	0.0029	Pass	NA	
300 Area Springs	0.24	Pass	NA	
FFTF Pond	0.000013	Pass	NA	
Hanford Town Site Slough	0.015	Pass	NA	
Hanford Town Site Springs	0.025	Pass	NA	
White Bluffs Slough	0.15	Pass	NA	
McNary Dam	0.19	Pass	NA	
Priest Rapids Dam	0.045	Pass	NA	
Richland	0.035	Pass	NA	
West Lake	1.05	Fail	0.22[c]	Pass
Terrestrial	0.000018-0.022			
Prosser Barricade	0.022	Pass	NA	
Rattlesnake Springs	0.0068	Pass	NA	
Ringold Area	0.015	Pass	NA	
Riverview	0.0027	Pass	NA	
S of 200-East	0.011	Pass	NA	
S of 200-West	0.0037	Pass	NA	
Sagemoor Farm	0.0027	Pass	NA	
SE Side of FFTF	0.0014	Pass	NA	
S of 300 Area	0.000018	Pass	NA	
Sunnyside	0.013	Pass	NA	
SW BC Cribs	0.0037	Pass	NA	
Taylor Flats	0.0038	Pass	NA	
Toppenish	0.00544	Pass	NA	
West End Fir Road	0.0041	Pass	NA	
Wahluke Slope	0.0064	Pass	NA	
Walla Walla	0.0072	Pass	NA	
Wanapum	0.0013	Pass	NA	
Washtucna	0.011	Pass	NA	
Wye Barricade	0.0048	Pass	NA	
Yakima Barricade	0.013	Pass	NA	

(a) A screening method to estimate radiological doses to aquatic and terrestrial biota.
(b) A sum of fractions is calculated to account for the contribution to dose from each radionuclide. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded and further screening is required.
(c) Tier 2 screening based on mean measured concentrations.
FFTF = Fast Flux Test Facility
NA = Not applicable.

Act regulations, EPA used a probability value of approximately 4 per 10 million (0.0004) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) (EPA 520/1-89-005). Additional data (National Research Council 1990) support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time.

Government agencies are trying to determine what level of exposure is safe for members of the public exposed to pollutants from industrial operations (e.g., DOE facilities, nuclear power plants, chemical plants, and hazardous waste sites). All of these industries are considered beneficial to people in some way such as providing electricity, national defense, waste disposal, and consumer products. Government agencies have a complex task to establish environmental regulations that control levels of risk to the public without unnecessarily reducing needed benefits from industry.

One perspective on risks from industry is to compare them to risks involved in other typical activities. For instance, two risks that an individual experiences when flying on an airplane are added radiological dose (from a stronger cosmic radiation field that exists at higher altitudes) and the possibility of being in an aircraft accident. The estimated risks from various radiological doses are compared to the risks of some activities encountered in everyday life in Table 8.14.6. Some activities are considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluent during 2004 (Table 8.14.7).

Table 8.14.6. Estimated Risk from Various Activities and Exposure[a]

Activity or Exposure Per Year	Risk of Fatality
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	$3{,}600 \times 10^{-6}$
Home accidents	100×10^{-6}[b]
Taking contraceptive pills (side effects)	20×10^{-6}
Drinking 1 can of beer or 0.12 L (4 oz) of wine per day (liver cancer/cirrhosis)	10×10^{-6}
Firearms, sporting (accidents)	10×10^{-6}[b]
Flying as an airline passenger (cross-country roundtrip - accidents)	8×10^{-6}[b]
Eating ~54 g (4 Tbsp) of peanut butter per day (liver cancer)	8×10^{-6}
Pleasure boating (accidents)	6×10^{-6}[b]
Drinking chlorinated tap water (trace chloroform - cancer)	3×10^{-6}
Riding or driving in a passenger vehicle (483 km [300 mi])	2×10^{-6}[b]
Eating 41 kg (90 lb) of charcoal-broiled steaks (gastrointestinal tract cancer)	1×10^{-6}
Natural background radiological dose (300 mrem [3 mSv])	0 to 120×10^{-6}
Flying as an airline passenger (cross-country roundtrip - radiation)	0 to 5×10^{-6}
Dose of 1 mrem (0.01 mSv) for 70 yr	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford	0 to 0.02×10^{-6}

(a) These values are generally accepted approximations with varying levels of uncertainty; there can be significant variation as a result of differences in individual lifestyle and biological factors (Atallah 1980; Dinman 1980; Ames et al. 1987; Wilson and Crouch 1987; Travis and Hester 1990).

(b) Real actuarial values. Other values are predicted from statistical models. For radiological dose, the values are reported in a possible range from the least conservative (0) to the currently accepted most conservative value.

Table 8.14.7. Activities Comparable in Risk to the 0.014-mrem (0.0014-mSv) Dose Calculated for the Hanford Site's 2004 Maximally Exposed Individual

Driving or riding in a car 1.4 km (0.84 mi)
Smoking less than 1/100 of a cigarette
Flying ~7.6 km (4.7 mi) on a commercial airliner
Eating ~1 Tbsp of peanut butter
Eating one 0.227-kg (~8-oz) charcoal-broiled steak
Drinking 1.4 L (~0.37 gal) of chlorinated tap water
Being exposed to natural background radiation for 25 min in a typical terrestrial location
Drinking ~0.02 L (0.82 oz) of wine or 0.07 L (2.5 oz) of beer