5.0 Potential Radiological Doses from 2002 Hanford Site Operations

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During 2002, 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, and contaminated groundwater seeping into the Columbia River. Other potential sources included 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 2002 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 (U.S. Department of Energy [DOE] Order 5400.5; Section 5.0.1).
- Collective dose to the population residing within 80 kilometers (50 miles) of Hanford Site operating areas (Section 5.0.2).
- Dose for air pathways, using U.S. Environmental Protection Agency (EPA) methods, for comparison to the *Clean Air Act* standards in Title 40, Code of Federal Regulations, Part 61 (40 CFR 61), Subpart H (Section 5.0.3).
- Maximum dose rate from external radiation at a publicly accessible location at or just within the site boundary (Section 5.0.4.1).
- Dose to an avid sportsman who consumes wildlife that may have been contaminated with radionuclides originating on the site (Section 5.0.4.2).
- Inhalation dose associated with measured radionuclide concentrations in air (Section 5.0.4.3).
- Absorbed dose received by animals exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies (Section 5.0.6).

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations. However, the amount of most radioactive materials released during 2002 from Hanford Site sources was generally too small to be measured directly once it was dispersed in the offsite environment. For many of the radionuclides present in measurable amounts, it was 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-14295, APP. 1. As a comparison, air surveillance data were used to assess the maximum inhalation doses at onsite and offsite monitoring stations.

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 2002, tritium, technetium-99, iodine-129, and uranium isotopes were found in the Columbia River downstream of Hanford at greater levels than predicted based on direct discharges from the 100-K Area (Section 4.2 and Appendix B). All other radionuclide concentrations were lower than those predicted from known releases. Riverbank spring water, containing radionuclides, is known to enter the river along the portion of shoreline extending from the 100-B/C Area downstream to the 300 Area (Sections 4.2 and 6.2). No direct discharge of radioactive materials from the 300 Area to the Columbia River was reported during 2002.

5.0.1 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 2002. 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 effluent released to the air and to the Columbia River from Hanford facilities (Figure 5.0.1). During 2002, the dose assessment determined that the maximally exposed individual was located across the Columbia River (east of the Hanford Site), at Riverview (Figure 5.0.1). 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 from the Columbia River.
- Used the Columbia River for recreational purposes, resulting in direct exposure from water and radionuclides deposited on the shoreline.
- Ingested locally caught fish.

Doses were calculated using Hanford Site effluent data (Tables 3.1.1 and 3.1.4) and the calculated quantities of radionuclides assumed to be present in the Columbia River from riverbank spring discharges. The estimated releases to the river from these sources were derived from the difference between the upstream and downstream concentrations in Columbia River water. These radionuclides were assumed to enter the river through shoreline groundwater seeps between the 100-B/C Area and the 300 Area.

During 2002, the total dose to the maximally exposed individual at Riverview was calculated to be 0.02 mrem (0.2 µSv) per year (Table 5.0.1). This dose was 0.02 mrem

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, food) that maximize a hypothetical individual 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 dose from both methods has 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.

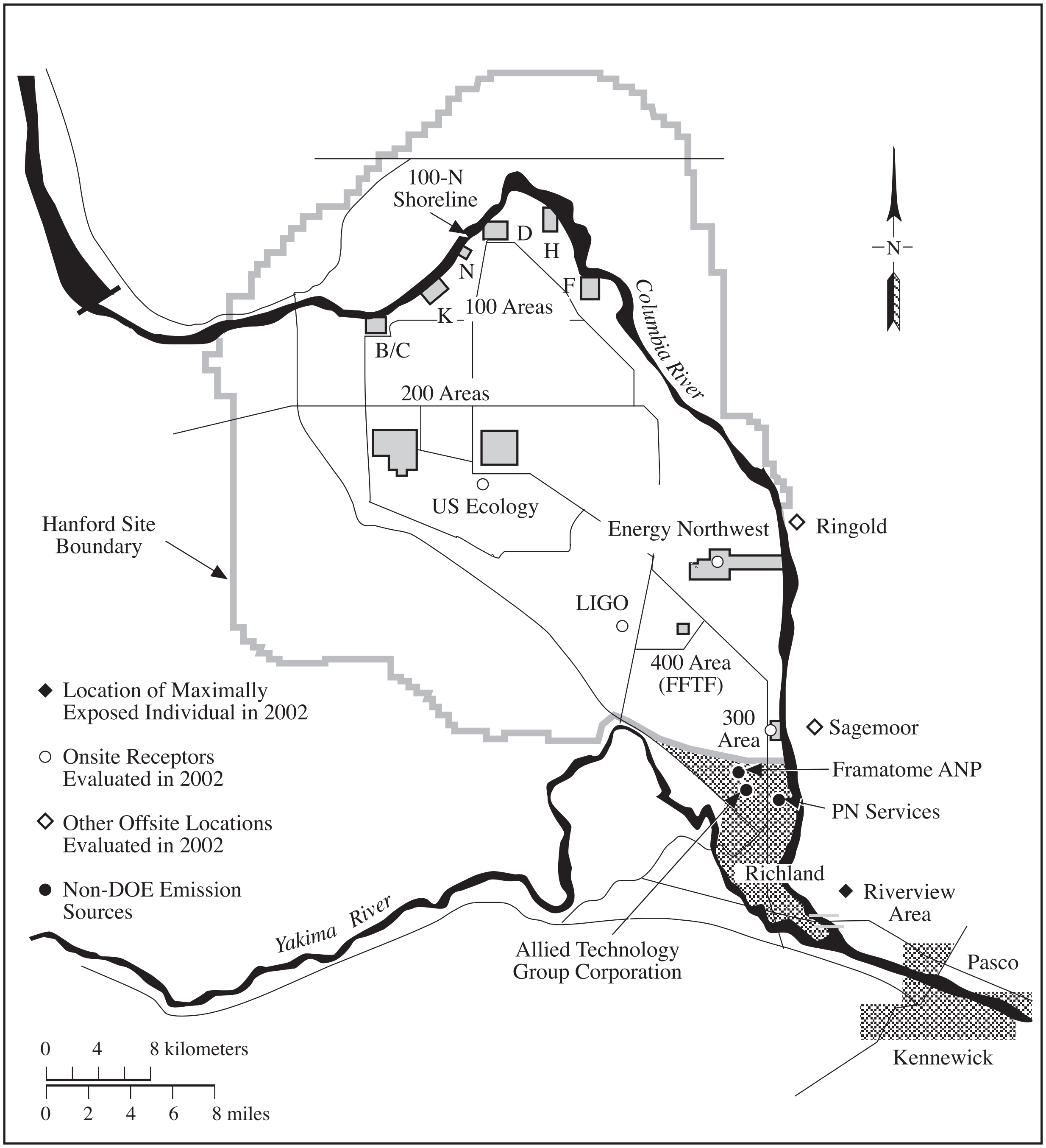

Figure 5.0.1. Locations Important to Dose Calculations at the Hanford Site

Table 5.0.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Riverview from 2002 Hanford Site Operations

		Dose Contributions from Operating Areas, mrem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	1.7×10^{-9}	9.7×10^{-8}	1.5×10^{-8}	4.7×10^{-9}	1.2×10^{-7}
	Inhalation	8.7×10^{-7}	1.6×10^{-5}	1.7×10^{-4}	5.9×10^{-7}	1.9×10^{-4}
	Foods	4.2×10^{-8}	6.5×10^{-5}	1.6×10^{-3}	1.5×10^{-7}	1.7×10^{-3}
	Subtotal air	9.1×10^{-7}	8.1×10^{-5}	1.8×10^{-3}	7.4×10^{-7}	1.9×10^{-3}
Water	Recreation	5.6×10^{-7}	8.1×10^{-5}	0.0[(a)]	0.0	8.2×10^{-5}
	Foods	2.8×10^{-4}	7.4×10^{-3}	0.0	0.0	7.7×10^{-3}
	Fish	2.4×10^{-4}	7.6×10^{-3}	0.0	0.0	7.8×10^{-3}
	Drinking water	1.8×10^{-5}	4.2×10^{-3}	0.0	0.0	4.2×10^{-3}
	Subtotal water	5.4×10^{-4}	1.9×10^{-2}	0.0	0.0	2.0×10^{-2}
Combined total		5.4×10^{-4}	1.9×10^{-2}	1.8×10^{-3}	7.4×10^{-7}	2.2×10^{-2}

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

or 0.02% of the DOE limit of 100 mrem (1 mSv) per year specified in DOE Order 5400.5 (Figure 5.0.2.). 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 consumption of fish from the Columbia River (35%), foods irrigated with water withdrawn downstream of Hanford (35%), and water (19%) withdrawn from the Columbia River containing principally uranium-234, uranium-238, and tritium
- the inhalation of air downwind of Hanford (1%) and the consumption of food products grown downwind of Hanford (7%), due principally to airborne releases of tritium from the 300 Area

5.0.2 Collective Dose

The regional collective dose from 2002 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. 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. During 2002, the collective dose calculated for the population was 0.3 person-rem (0.003 person-Sv) per year, slightly lower than the 2001 collective dose (0.4 person-rem [0.004 person-Sv]) per year (Table 5.0.2) (Appendix E, Tables E.5 to E.9).

Primary pathways contributing to the 2002 collective dose included

- the consumption of water withdrawn from the Columbia River (52%) and containing principally tritium, uranium-234, and uranium-238
- the consumption of foodstuffs (35%) contaminated with radionuclides, principally tritium from 300 Area stacks
- the inhalation of radionuclides (9%) that were released to the air, principally tritium from 300 Area airborne releases

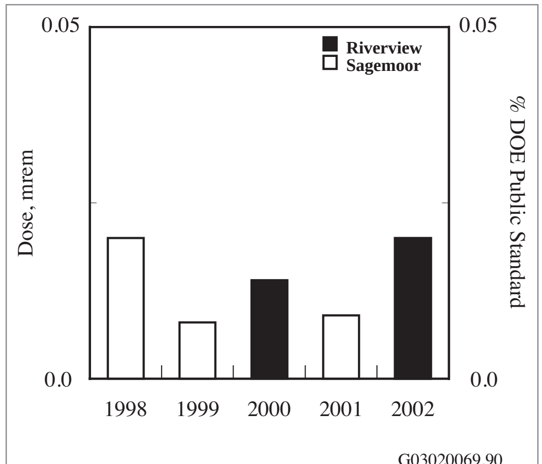

Figure 5.0.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual at the Hanford Site, 1998 through 2002

Table 5.0.2. Collective Dose to the Population from 2002 Hanford Site Operations

Effluent	Pathway	Dose Contributions from Operating Areas, person-rem: 100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	6.2×10^{-7}	1.3×10^{-5}	1.4×10^{-6}	6.7×10^{-7}	1.6×10^{-5}
	Inhalation	4.6×10^{-4}	3.4×10^{-3}	2.1×10^{-2}	1.3×10^{-4}	2.5×10^{-2}
	Foods	1.3×10^{-5}	9.8×10^{-3}	1.1×10^{-1}	2.0×10^{-5}	1.2×10^{-1}
	Subtotal air	4.7×10^{-4}	1.3×10^{-2}	1.3×10^{-1}	1.5×10^{-4}	1.4×10^{-1}
Water	Recreation	4.2×10^{-6}	4.6×10^{-4}	0.0[(a)]	0.0	4.6×10^{-4}
	Foods	2.9×10^{-4}	8.1×10^{-3}	0.0	0.0	8.4×10^{-3}
	Fish	8.8×10^{-5}	2.9×10^{-3}	0.0	0.0	3.0×10^{-3}
	Drinking water	7.3×10^{-4}	1.8×10^{-1}	0.0	0.0	1.8×10^{-1}
	Subtotal water	1.1×10^{-3}	1.9×10^{-1}	0.0	0.0	1.9×10^{-1}
Combined total		1.6×10^{-3}	2.0×10^{-1}	1.3×10^{-1}	1.5×10^{-4}	3.4×10^{-1}

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

Collective doses reported for 2002 are based on population data from the 2000 census, whereas doses for 1997 to 2001 were based on the 1990 census (Figure 5.0.3). 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 2002 Hanford Site operations based on a population of 486,000 within 80 kilometers (50 miles) was 0.7 mrem (7 nSv) 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 5.0.4). The estimated annual average individual dose to members of the public from Hanford Site sources during 2002 was ~0.0002% of the estimated annual individual dose received from natural background sources (300 mrem). The calculated radiological doses from Hanford Site operations in 2002 were a small percentage of the standards and of doses from natural background sources (Table 5.0.3).

5.0.3 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 the EPA for airborne radionuclide emissions under the *Clean Air Act* in 40 CFR 61, Subpart H. This

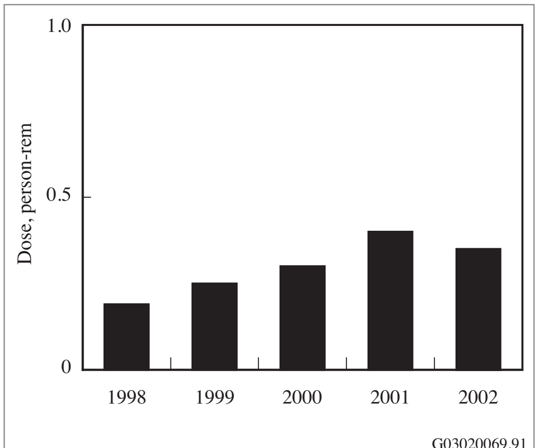

Figure 5.0.3. Collective Dose to the Population within 80 Kilometers (50 Miles) of the Hanford Site, 1998 through 2002

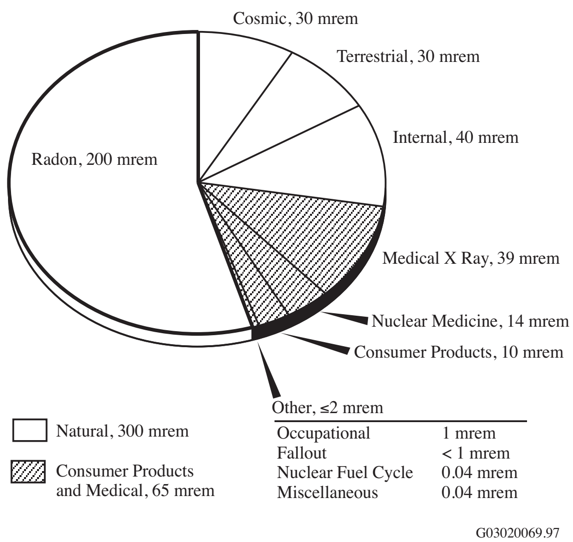

Figure 5.0.4. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

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 CAP-88 (EPA 402-R-00-004) or other EPA-approved models to demonstrate compliance with the requirements in 40 CFR 61, Subpart H. The assumptions embodied in the CAP-88 code differ slightly from standard assumptions used with the GENII 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 5.0.1).

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 about 2002 air emissions on the Hanford Site, refer to DOE's report to EPA (DOE/RL-2002-20).

Maximum Dose to Non-DOE Workers on the Site. The DOE Richland Operations Office received guidance from EPA Region 10 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 were evaluated for the 2002 EPA air emissions report (DOE/RL-2002-20). These locations included the Columbia Generating Station operated by Energy

Table 5.0.3. Comparison of Doses to the Public from Hanford Site Effluent to Federal Standards and Natural Background Levels

Standard	Hanford Dose[a]	Hanford Dose Percent of Standard
DOE - 100 mrem/yr all pathways MEI[b,c]	0.02 mrem/yr	0.02
EPA - 10 mrem/yr air pathway MEI[d]	0.023 mrem/yr	0.23
Background Dose		
300 mrem/yr average U.S. individual[e]	0.02 mrem/yr	0.007
110,000 person-rem/yr to population within 80 km (50 mi)	0.3 person-rem/yr	0.0003

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

Northwest, the Laser Interferometer Gravitational Wave Observatory (LIGO) operated by the University of California, and a research laboratory on the west side of the 300 Area leased to Washington State University through late March, 2002 (Figure 5.0.1). Because 300 Area emissions accounted for the majority of the air pathway dose during 2002, a person working in the Washington State University research laboratory 25% of the year received the highest dose for non-DOE employees who worked on the Hanford Site. The dose calculated using the CAP-88 code was 0.014 mrem (0.0012 mSv) per year, assuming full-time occupancy for the first quarter of the year. After the first quarter, the facility was no longer occupied by non-DOE workers.

EPA guidance does not currently permit adjustment of doses calculated using the CAP-88 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 to the maximally exposed offsite individual that has historically been evaluated for compliance with the EPA standard. Methods to estimate doses to individuals within the site boundary are currently under discussion by DOE and EPA.

Maximum Dose to an Offsite Maximally Exposed Individual. During 2002, the maximally exposed offsite individual for air pathways using EPA specified methods was determined to be at a location in the Sagemoor area of Franklin County, ~1.5 kilometers (~1 mile) directly across the Columbia River from the 300 Area (Figure 5.0.1). The potential air pathway dose from stack emissions to a maximally exposed individual at that location was calculated by using the CAP-88 code to be 0.023 mrem (0.00023 mSv) per year, which represented <0.3% of the EPA standard. This is similar to the dose for offsite individuals calculated for previous annual air emission reports to EPA.

Dose from Diffuse and Fugitive Sources of Airborne Radionuclides. 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 and fugitive sources as well as monitored point sources (i.e., stacks). EPA has not specified or approved methods to estimate air emissions from diffuse sources, and standardization has been difficult because of the wide variety of such sources at DOE sites. The method developed at Hanford to estimate potential diffuse source emissions is based on environmental surveillance measurements of airborne radionuclides at the site perimeter (DOE/RL-2002-20). During 2002, the estimated dose to a maximally exposed individual at a location in the Sagemoor area from diffuse sources was calculated using the CAP-88 code to be 0.44 mrem (0.0044 mSv) per year. The dose to a non-DOE worker in the 300 Area from diffuse and fugitive sources would be similar to, or lower than, the dose at the site perimeter. Therefore, the potential combined dose from stack emissions and diffuse sources during 2002 was well below the EPA 10 mrem (0.1 mSv) per year standard for either onsite or offsite members of the public.

5.0.4 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) an individual 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.

5.0.4.1 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 at locations where elevated dose rates might be expected on the site and at representative locations off the site. 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 measured during 2002 were made along the 100-N Area shoreline (Figure 5.0.1) (Section 4.6). The measurements were consistently above background levels and represented the highest measured boundary dose rates. The Columbia River allows public access to within ~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 2002 was about 0.011 mrem (0.11 μSv) per hour, or 10% 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 2002, the external radiological dose received from Hanford operations was ~0.001 mrem (~0. 01 μSv) above the average shoreline dose rate. If an individual had spent 2 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 Riverview. 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 area is very rocky and visitors are not likely to remain on shore for extended periods.

5.0.4.2 Sportsman Dose

Wildlife have access to areas of the Hanford Site that are contaminated with radioactive materials. Sometimes wildlife 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.

Uranium isotopes were detected in bass and carp muscle samples collected from the Columbia River near the 300 Area (Section 4.5). The radiological dose to a person consuming 1 kilogram (2.2 pounds) of the bass containing the maximum measured concentrations of uranium was calculated to be ~3 μrem (~0.03 μSv). It should be noted that the ratios of the uranium isotopes found in the sample were not those of natural uranium and were higher in uranium-235.

The radiological dose to a person consuming 1 kilogram (2.2 pounds) of carp containing the maximum measured concentrations of uranium was calculated to be ~0.6 μrem (~0.006 μSv). Strontium-90 was the only other radionuclide, possibly of Hanford origin, detected in wildlife samples during 2002 and was only found in bone or offal samples. Because bone or offal are not normally consumed by humans, a dose to a sportsman from this pathway was viewed as relatively implausible and was not included in this report.

5.0.4.3 Onsite Drinking Water

During 2002, groundwater was used as drinking water by workers at the Fast Flux Test Facility in the 400 Area, and Columbia River water was used as a drinking water source in the 100-B, 100-D, 100-K, and 200 Areas. Therefore, these water supplies were sampled and analyzed throughout the year in accordance with applicable drinking water regulations (40 CFR 141). All annual average radionuclide concentrations measured during 2002 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 (Section 4.3 and Appendix E).

Based on the measured concentrations, the potential annual dose to Fast Flux Test Facility workers (an estimate derived by assuming a consumption of 1 liter [0.26 gallon] per day for 240 working days) would be ~0.02 mrem (~0.2 μSv). This dose is well below the drinking water dose limit of 4 mrem (40 μSv) per year for public drinking water supplies.

5.0.4.4 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 (Tables 4.1.2 and 4.1.3). 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 air surveillance stations during their workday are presented in Table 5.0.4. The maximum air concentrations (Table 4.1.2) were used in the calculations and assumed to be constant for the year-long evaluation period. Inhalation doses calculated using this method ranged from 0.079 mrem (0.00079 mSv) at onsite and distant locations to 0.21 mrem (0.0021 mSv) at the site perimeter. These were comparable to doses calculated using CAP-88 code and reported for various air pathways (Section 5.0.3).

5.0.5 Doses from Non-DOE Sources

DOE Order 5400.5, Section II, paragraph 7, has a reporting requirement for combined DOE and other manmade doses exceeding 100 mrem (1 mSv) per year. During 2002, 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

Table 5.0.4. Inhalation Doses On and Around the Hanford Site Based on 2002 Air Surveillance Data[(a)]

Radionuclide	Location	Dose Based on Maximum Air Data (mrem/yr)[(b,c)]
Tritium	300 Area	1.81×10^{-3}
	Onsite	1.81×10^{-3}
	Perimeter	1.22×10^{-2}
	Nearby communities	1.75×10^{-2}
	Distant communities	1.59×10^{-7}
Cobalt-60	Onsite	4.89×10^{-4}
	Perimeter	2.14×10^{-3}
	Nearby communities	1.39×10^{-3}
	Distant communities	8.81×10^{-4}
Strontium-90	Onsite	3.24×10^{-3}
	Perimeter	1.42×10^{-2}
	Nearby communities	5.89×10^{-4}
	Distant communities	3.27×10^{-3}
Iodine-129	Onsite	7.72×10^{-6}
	Perimeter	1.32×10^{-6}
	Distant communities	8.92×10^{-8}
Cesium-137	Onsite	2.76×10^{-5}
	Perimeter	1.21×10^{-4}
	Nearby communities	1.34×10^{-4}
	Distant communities	1.42×10^{-4}
Plutonium-238	Onsite	2.47×10^{-3}
	Perimeter	4.03×10^{-3}
	Nearby communities	5.54×10^{-3}
	Distant communities	9.32×10^{-4}
Plutonium-239/240	Onsite	5.50×10^{-3}
	Perimeter	3.05×10^{-3}
	Nearby communities	5.82×10^{-3}
	Distant communities	6.65×10^{-3}
Uranium-234	Onsite	3.74×10^{-2}
	Perimeter	9.49×10^{-2}
	Nearby communities	6.33×10^{-2}
	Distant communities	3.60×10^{-2}
Uranium-235	Onsite	9.20×10^{-4}
	Perimeter	3.83×10^{-3}
	Nearby communities	4.63×10^{-3}
	Distant communities	3.12×10^{-3}
Uranium-238	Onsite	2.76×10^{-2}
	Perimeter	7.45×10^{-2}
	Nearby communities	4.63×10^{-2}
	Distant communities	2.82×10^{-2}
Totals	Onsite	7.9×10^{-2}
	Perimeter	2.1×10^{-1}
	Nearby communities	1.5×10^{-1}
	Distant communities	7.9×10^{-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.

the site by Framatome ANP Richland, Inc.; a commercial, low-level, radioactive waste treatment facility operated near the site by Allied Technology Group Corporation; and a commercial decontamination facility operated near the site by PN Services (Figure 5.0.1).

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 2002 individual dose from their combined activities was on the order of 0.05 mrem (0.0005 mSv) per year. Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 2002 was well below any regulatory dose limit.

5.0.6 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 aquatic biota is 1 rad (10 mGy) per day. The proposed limit for terrestrial biota is 0.1 rad (1 mGy) per day. Surveillance data from soil, Columbia River shoreline spring water, the Fast Flux Test Facility pond water, and West Lake sediment and water were evaluated using the RAD-BCG Calculator (a screening method to estimate radiological doses to aquatic and terrestrial biota). The RAD-BCG Calculator[a] is a Microsoft® Excel spreadsheet that initially compares radionuclide concentrations in soil, water, or sediment measured by routine surveillance programs to a set of biota concentration guides (i.e., soil or water concentrations that result in a dose rate of l rad [10 mGy] per day for aquatic biota or 0.1 rad [1 mGy] per day for terrestrial organisms). The process involves two screening tiers. Tier 1 is a screening assessment based on maximum measured radionuclide concentrations, and Tier 2 is a screening assessment based on average measured radionuclide concentrations.

For soil and water samples containing multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to its corresponding dose guideline. If the sum of fractions for the maximum radionuclide concentrations exceeds 1.0 (Tier 1), the dose guideline has been exceeded and the screening assessment has failed. Tier 2 screening, where mean radionuclide concentrations are employed, is then conducted.

The biota concentration guides are very different from the DOE derived concentration guides that are used to assess radiological doses to humans. If the estimated screening value exceeds the guideline (Tiers 1 and 2 sum of fractions >1.0), additional calculations are performed 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 2002, biota dose assessments were conducted by operational areas (Table 5.0.5) and for special situations.

Maximum concentrations of radionuclides in Columbia River sediment, onsite pond sediment, riverbank spring water, and pond water were evaluated using the RAD-BCG Calculator. 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 indicate that all spring data from the 100 Areas, Hanford town site, and 300 Areas resulted in doses below the guidelines in the Columbia River (sum of fractions <1.0) (Table 5.0.5). The Tier 1 West Lake evaluation produced a total sum of fraction greater than unity and was consistent with past assessments (PNNL-13910, APP. 1). Tier 2 West Lake evaluations using average sediment data provided a more realistic sum of fractions (0.54) using a more representative assessment of average exposure levels over time and space at West Lake.

For the terrestrial evaluations, the screening assessments were based on radionuclide concentrations in soil collected between 1997 and 2001 by the Surface Environmental Surveillance Project. At locations where a body of water is located near the soil collection location and radiological

(a) Memorandum from Dr. David Michaels (Assistant Secretary for Environmental, Safety, and Health) to Distribution, *Availability of DOE Technical Standard, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (Project ENVR-0011)," for use in DOE Compliance and Risk Assessment Activities*, dated July 19, 2000.

Table 5.0.5. Results of RAD-BCG Calculator[a] Screenings at the Hanford Site, 2002

Location	Tier 1 Screen Sum of Fraction	Pass or Fail	Tier 2 Screen Sum of Fraction	Pass or Fail
		100 Areas		
Aquatic	**0.002-0.07**			
100-B Area	0.040	Pass	NA[b]	
100-F Area	0.018	Pass	NA	
100-F Area Spring	0.024	Pass	NA	
100-H Area Springs	0.021	Pass	NA	
100-K Area Springs	0.072	Pass	NA	
100-N Area	0.002	Pass	NA	
Terrestrial	**0.03-0.10**			
100-K Area	0.097	Pass	NA	
100-N Area	0.053	Pass	NA	
100-D Area	0.049	Pass	NA	
100-F Area	0.026	Pass	NA	
		200 Areas		
Terrestrial				
200-East and 200-West Areas	0.73	Pass	NA	
		300 and 400 Areas		
Aquatic	**0.00015-0.48**			
300 Area	0.023	Pass	NA	
300 Area Springs	0.48	Pass	NA	
400 Area Pond	0.00015	Pass	NA	
Terrestrial	**0.06**			
300 and 400 Areas Combined	0.063	Pass	NA	
		600 Area		
Aquatic	**0.017-1.05**			
Hanford Town Site	0.017	Pass	NA	
Hanford Town Site Springs	0.018	Pass	NA	
West Lake	1.05	Fail	0.54	Pass
Terrestrial	**0.07**			
600 Area with Hanford Town Site Water	0.071	Pass	NA	

(a) A screening method to estimate radiological doses to aquatic and terrestrial biota.
(b) NA = Not applicable.

analyses have been performed for that water, the water data was used for the terrestrial screening evaluation. For example, in the 100-F Area terrestrial evaluation, the water data from the 100-F Area spring were imported into the calculation to account for aquatic pathways. All biota assessments of terrestrial locations passed the Tier 1 screening sum of fraction.

5.0.7 Radiological Dose in Perspective

Two scientific studies (National Research Council 1980, 1990; United Nations Science Committee on the Effects of Atomic Radiation 1988) were performed to estimate the possible risk from exposure to low levels of radiation. These studies provided information to government and scientific organizations and 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 at low doses (down to zero dose) is the same per unit dose as the health effects observed at 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-level 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, background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be proven conclusively. In developing *Clean Air Act* regulations, EPA uses a probability value of ~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 risk is safe for members of the public exposed to pollutants from industrial operations (e.g., DOE facilities, nuclear power plants, chemical plants, 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 to the risks of some activities encountered in everyday life (Table 5.0.6).

Table 5.0.6. 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 approximately 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 0.008×10^{-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 5.0.7. Activities Comparable in Risk to the 0.02-mrem (0.002-mSv) Dose Calculated for the Hanford Site's 2002 Maximally Exposed Individual

Driving or riding in a car 2 km (1.2 mi)
Smoking less than 1/50 of a cigarette
Flying approximately 5 km (3 mi) on a commercial airliner
Eating approximately 5 tsp of peanut butter
Eating one 0.4-kg (12-oz) charcoal-broiled steak
Drinking 2 L (approximately 66 oz) of chlorinated tap water
Being exposed to natural background radiation for 35 min in a typical terrestrial location
Drinking approximately 0.07 L (1.2 oz) of wine or 0.2 L (3.5 oz) of beer

Some activities are considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluent during 2002 (Table 5.0.7).

5.0.8 References

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