

AIR PATHWAY EFFECTS OF
NUCLEAR MATERIALS PRODUCTION
AT THE HANFORD SITE, 1983 to 1992

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SUMMARY

This report describes the air pathway effects of Hanford Site operations from 1983 to 1992 on the local environment by summarizing the air concentrations of selected radionuclides at both onsite and offsite locations, comparing trends in environmental concentrations to changing facility emissions, and briefly describing trends in the radiological dose to the hypothetical maximally exposed member of the public. The years 1983 to 1992 represent the last Hanford Site plutonium production campaign, and this report deals mainly with the air pathway effects from the 200 Areas, in which the major contributors to radiological emissions were located. An additional purpose of this report was to review the environmental data for a long period of time to provide insight not available in an annual report format.

The sampling and analytical systems used by the Surface Environmental Surveillance Project (SESP) to collect air samples during the period of this report were sufficiently sensitive to observe locally elevated concentrations of selected radionuclides near onsite sources of emissions, as well as observing elevated levels, compared to distant locations, of some radionuclides at the downwind perimeter. The U.S. Department of Energy Derived Concentration Guides (DCGs) for airborne radionuclides were not exceeded for any air sample collected during 1983 to 1992, with annual average concentrations of all radionuclides at the downwind perimeter being considerably below the DCG values.

Air emissions at the Hanford Site during the period of this report were dominated by releases from the PUREX Plant, with ^{85}Kr being the major release on a curie basis and ^{129}I being the major release on a radiological dose basis. Air concentrations of ^{85}Kr measured at the 200 ESE sampling location (onsite) and at the downwind perimeter (Ringold) were elevated compared to those at the Yakima distant location during active PUREX operations. With the cessation of ^{85}Kr emissions from the PUREX Plant, the air concentrations of ^{85}Kr measured onsite and at the downwind perimeter decreased and were not distinguishable from those at the distant location. Air concentrations of ^{129}I were also elevated at the onsite and downwind perimeter locations compared to those at the distant location during the period of active PUREX

emissions. Overall, the air concentrations of ^{129}I have decreased at all locations from 1983 to 1992 (matching the decrease in PUREX emissions). However, despite the decrease in PUREX emissions, the air concentrations of ^{129}I at the downwind perimeter have remained elevated compared to those at the Yakima location, indicating the continuation of a measurable Hanford impact at the downwind perimeter. Air concentrations of $^{239,240}\text{Pu}$ measured at the 200 ESE location were highest for the period from 1983 to 1985 and decreased apparently following the installation of an additional high-efficiency particulate air filter on the PUREX main stack in 1986; there was no measurable impact at the downwind perimeter for $^{239,240}\text{Pu}$ emissions. There were no measurable differences between downwind perimeter and distant locations for air concentrations of either ^3H or ^{14}C .

The estimated potential radiological dose from Hanford Site point source emissions to the hypothetical maximally exposed individual (MEI) ranged from 0.02 to 0.22 mrem/yr (effective dose equivalent), which is well below the U.S. Department of Energy radiation limit to the public of 100 mrem/yr. The calculated location of the MEI changed from the Ringold to the Riverview area during the period of this report. The air pathway was the major contributor to dose from 1983 to 1989. With decreased Hanford Site emissions the relative importance of diffuse sources (e.g., windblown contaminated soil) has increased and initial upper-bound estimates have placed the offsite dose from diffuse sources at 0.1 to 0.16 mrem/yr. During the period of this report, the total estimated dose from both point source and diffuse emissions was less than the 10-mrem/yr limit specified by the Clean Air Act.

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1.0 INTRODUCTION

The Hanford Site in southeastern Washington State has been used by the federal government since 1943. For the first 30 years, the Site was used primarily for the production of nuclear materials for national defense and management of the associated waste. Major Site activities were the fabrication of nuclear reactor fuel assemblies in the 300 Area, irradiation of the fuel assemblies in reactors in the 100 Areas, dissolution of fuel assemblies and chemical separations in the 200 Areas, and the storage of waste primarily in the 200 Areas. Since the mid-1960s, the Site mission has diversified to include research and development in areas such as energy, waste management, and environmental science.

During this time, effluents and their effect on the environment have been monitored. A number of annual reports have been written to describe these effluents and environmental monitoring data, including data describing the air exposure pathway. (This pathway reconstructs how airborne effluents may affect the environment.) The U.S. Department of Energy funded the current Surface Environmental Surveillance Project (SESP), which is conducted by the Pacific Northwest Laboratory (PNL), to review and evaluate environmental data taken over a longer period (about 10 years) to provide insights not available when considering information in an annual report format.

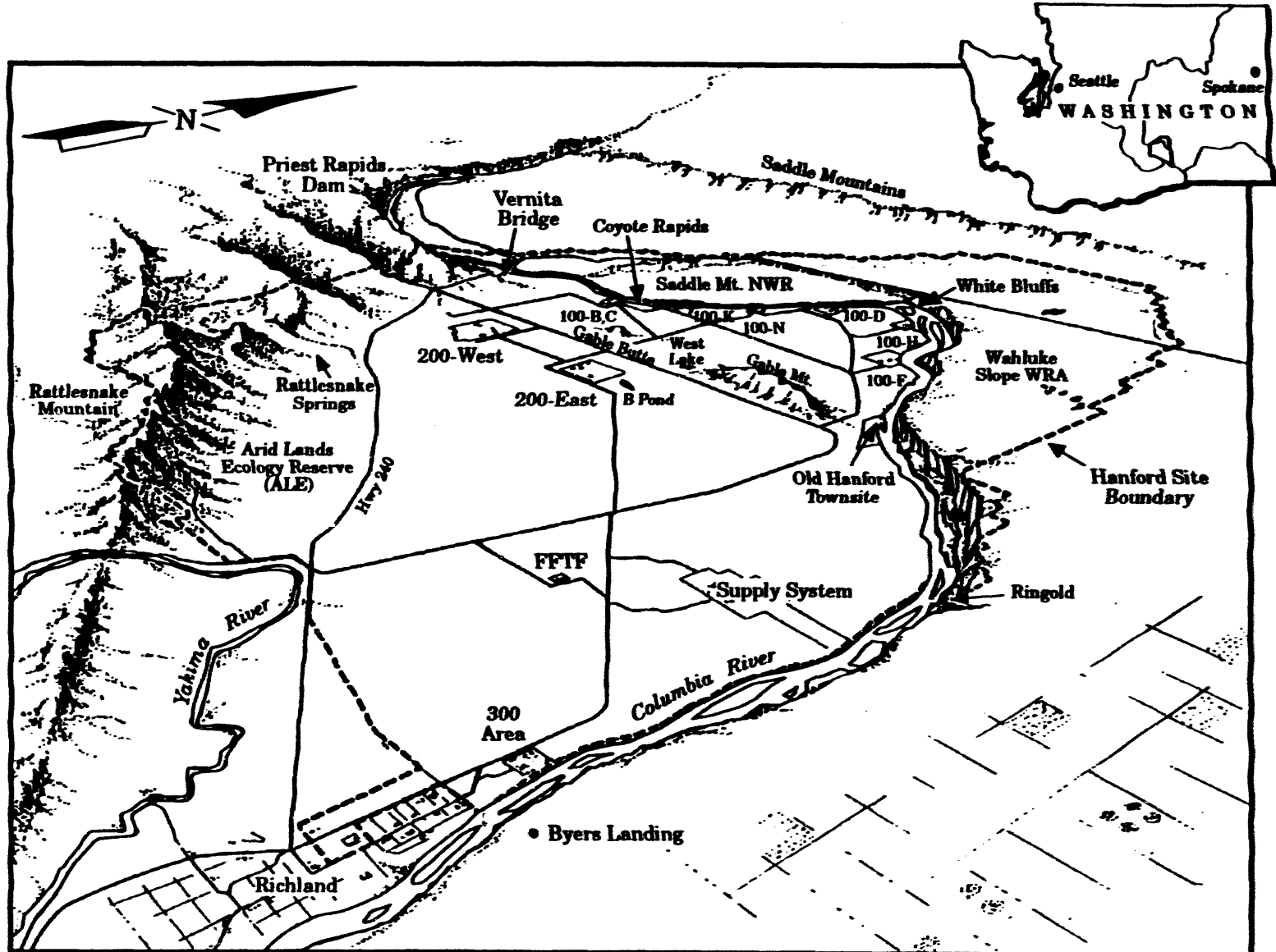
This report describes the effects of Hanford operations from 1983 to 1992 through the air pathway on the local environment. The report summarizes onsite and offsite monitoring data, compares environmental concentration trends to changing facility emissions, and summarizes trends in radiological dose to the hypothetical maximally exposed member of the public. The period from 1983 to 1992 represents the last plutonium production campaign at the Hanford Site. The major Site activities that affected the air pathway during this period were the operation of the Plutonium-Uranium Extraction (PUREX) Plant and Uranium-Oxide (UO_3) Plant in the 200 Areas. Consequently, this report will deal mainly with the air pathway effects from the 200 Areas.

2.0 BACKGROUND INFORMATION

The Hanford Site occupies an area of 1450 km² in southeastern Washington State (Figure 2.1). A detailed description of the Site environment is provided by Cushing (1990). The Columbia River is a dominant feature of the Site landscape, flowing eastward through the northern part of the Site before turning south to form the eastern boundary. The Yakima River forms a portion of the southern boundary. Rattlesnake Mountain and the Arid Lands Ecology Reserve form the western boundary of the Site. The region has a semiarid shrub-steppe ecosystem dominated by drought-resistant grasses and sagebrush. Most of the land is relatively undisturbed and provides a buffer from the approximately 6% of the Site that was used for the production of nuclear materials and waste disposal. Land use to the north, east, and west of the Site is mainly for agriculture, with crops ranging from irrigated vegetables to dry-land wheat. The cities of Richland, Kennewick, and Pasco are situated to the southeast of the Site and are the nearest population centers.

Nine nuclear reactors were built on the Site along the Columbia River for nuclear materials production. Eight of these reactors used once-through cooling, which resulted in the release of heated water, radionuclides, and chemicals to the environment. These eight reactors were shut down between 1965 and 1971, and the only production reactor to operate during the period of this report was the N Reactor. The N Reactor was used to produce both nuclear materials and electrical power and used a closed-loop cooling system, which essentially eliminated direct radioactive discharges to the river, although large amounts of heat were still released to the river and some radionuclides (primarily inert gases, e.g., ⁴¹Ar and ⁸⁵Kr) were released to the atmosphere. Other major Site facilities that operated during the period of this report were:

- PUREX Plant—the major source of emissions for airborne radionuclides during the report period, the plant, located in the 200-East Area, was used to dissolve irradiated fuel elements and extract uranium, plutonium, and neptunium using a solvent extraction column.



2.2

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FIGURE 2.1. U.S. Department of Energy's Hanford Site

- UO₃ Plant—this plant, located in the 200-West Area, was used to convert the aqueous uranyl nitrate hexahydrate product from the PUREX Plant into a dry UO₃ powder suitable for shipment to offsite customers for use as nuclear fuel.
- Plutonium Finishing Plant (PFP or Z Plant)—this plant, located in the 200-West Area, was used to process plutonium.
- Fast Flux Test Facility (FFTF)—this reactor, located in the 400 Area, was used to test breeder reactor systems.
- N Reactor—this reactor, located in the 100-N Area, was operated for nuclear materials production and electrical power generation.
- Washington Public Power Supply System (Supply System) Hanford Generating Project—adjacent to the N Reactor, this plant processed steam from the reactor into electricity.
- Supply System reactor facilities—located near the 400 Area, the WNP-1 reactor operated during the time of this report and was used to generate electricity.

In addition, U.S. Ecology operated a low-level radioactive waste burial site near the 200 Areas and Siemens Nuclear Power Corporation (formerly Advanced Nuclear Fuels and Exxon) operated a nuclear fuel fabrication facility adjacent to the southern boundary of the Site.

2.1 SURFACE ENVIRONMENTAL SURVEILLANCE PROJECT

Continuous surveillance of the environment both on and off the Hanford Site began in the 1940s and has developed into the present Hanford Site SESP, conducted by the Pacific Northwest Laboratory for the U.S. Department of Energy (DOE 1991). The overall objectives of the SESP are to:

- determine compliance with environmental quality standards and public exposure limits
- measure the regional background concentrations of pollutants and assess the potential Hanford Site contribution of contaminants to the environment
- assess the potential for long-term accumulation of radionuclides and assess any significant changes in the physical, chemical, and biological condition of the environment
- assess the validity of computer models used to predict environmental concentrations and radiological dose to the public

- identify and quantify any accidental emissions to the environment
- identify new or existing environmental quality problems.

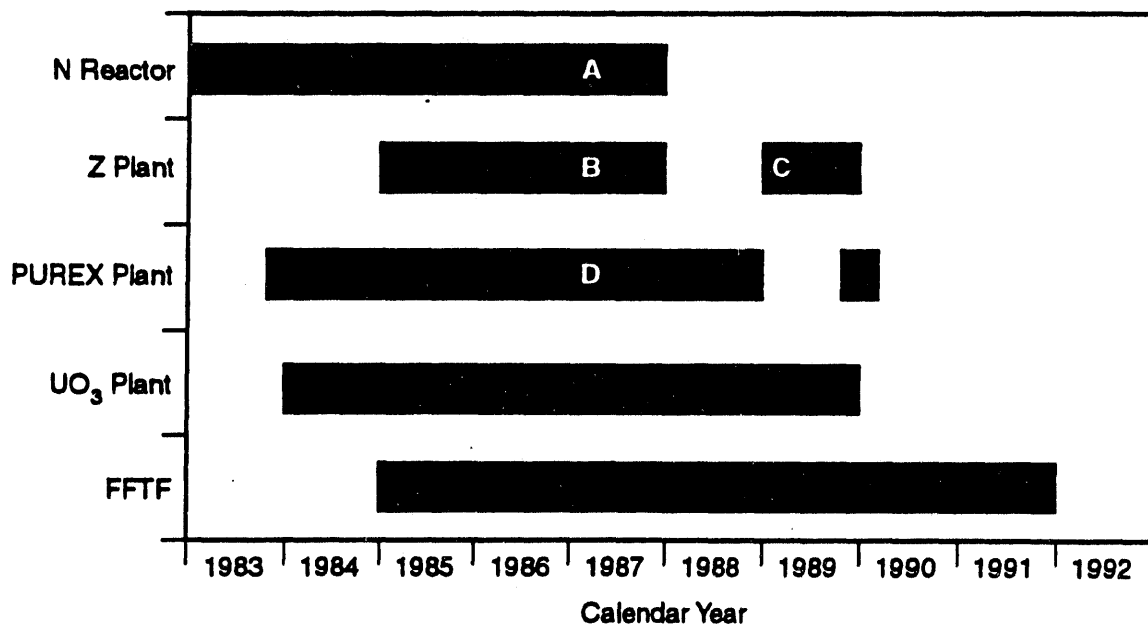
The SESP fulfills these objectives by collecting and analyzing samples of various environmental media at locations on and off the Hanford Site. The potential impacts of Hanford activities are estimated by evaluating any differences between concentrations measured at the downwind Site perimeter and distant locations. In addition, the SESP also fulfills these objectives by conducting annual human and aquatic organism exposure and dose assessments. During the period of this report, results from the environmental surveillance program were reported annually in Hanford Site environmental reports and environmental status reports. A comprehensive listing of annual surveillance reports from 1983 to 1992 is provide in the references ("Hanford Site Annual Environmental Reports").

3.0 SITE OPERATIONS AND EMISSIONS

Major Site facilities that operated during 1983 to 1992 with a potential for airborne releases were the N Reactor, PUREX Plant, UO₃ Plant, Z Plant, and FFTF. A timeline of when these facilities operated is provided in Figure 3.1. Site emissions and specific emissions from the PUREX and UO₃ Plants are discussed below.

3.1 SITE EMISSIONS

Radionuclides released to the atmosphere from Hanford operations include volatile constituents (e.g., HTO, tritium as water vapor), inert gases (e.g., ⁴¹Ar and ⁸⁵Kr), and radionuclides associated with airborne particulate (e.g., ^{239,240}Pu). As a general rule, radionuclide emissions with the potential to be at 10% of the U.S. Department of Energy Derived Concentration Guides (DCGs, DOE Order 5400.5) were routinely monitored at facility stacks. Beginning in 1992, all radioactive emissions with the potential to exceed 1% of the offsite



- A) N Reactor only operated for 6.4 days during 1987.
- B) Z Plant operated for 6 months during 1987.
- C) Z Plant operated for 3 months in 1989.
- D) PUREX Plant operated for 2 months in 1987.

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FIGURE 3.1. Timeline for Operations at Major Site Facilities, 1983 to 1992

dose standard were continuously monitored (Woodruff et al. 1993). A detailed annual report on Site radionuclide air emissions is submitted to the U.S. Environmental Protection Agency each year to comply with Clean Air Act requirements (e.g., Diediker et al. 1992).

The amounts of major radionuclides emitted to the atmosphere from the Hanford Site from 1983 to 1992 (on a curie basis), as well as the radionuclides identified in Section 4.1 as being important to the air pathway, are summarized in Table 3.1 and shown in Figure 3.2. Site radionuclide emissions are described in more detail in the Hanford Site annual environmental reports (see references). An assessment of ^{220}Rn emissions from the PUREX Plant is given in Wedlick et al. (1989).

The inert gas ^{85}Kr was the major constituent released to the atmosphere from 1983 to 1988, with a total of 1,933,800 Ci released during this period. No airborne emissions of ^{85}Kr were reported for the Site after 1990, following the shutdown of the PUREX Plant. Substantial quantities of the inert gas ^{41}Ar (half-life of 1.8 hr) were also released from the N Reactor (390,500 Ci for

TABLE 3.1. Selected Radionuclides Discharged to the Atmosphere from Hanford Emissions, 1983 to 1992 (Ci)^(a)

Year	^3H (total)	^{14}C (CO_2)	^{41}Ar	^{85}Kr	^{129}I ^(b)	^{220}Rn	$^{239,240}\text{Pu}$ ^(c)
1992	44.5	-- ^(d)	8.5	--	0.03	34	0.00048
1991	85	0.08	27	--	0.048	33	0.00044
1990	31.6	0.56	29	5,700	0.11	380	0.0003
1989	181.2	0.22	22	--	0.11	1,600	0.00082
1988	500	5	--	200,000	0.6	2,333 ^(e)	0.0002 ^(f)
1987	70.5	1	4,536	70,000	0.5	3,042 ^(e)	0.00042
1986	77	90	120,000	545,000	0.5	2,125 ^(e)	0.003
1985	218	4	69,000	700,000	0.3	3,056 ^(e)	0.01
1984	201.4	3	77,000	401,000	0.08	--	0.0075
1983	55.9	0.6	120,000	17,800	0.02	--	0.00066

(a) Emission values are from Hanford Site Annual Environmental Reports.

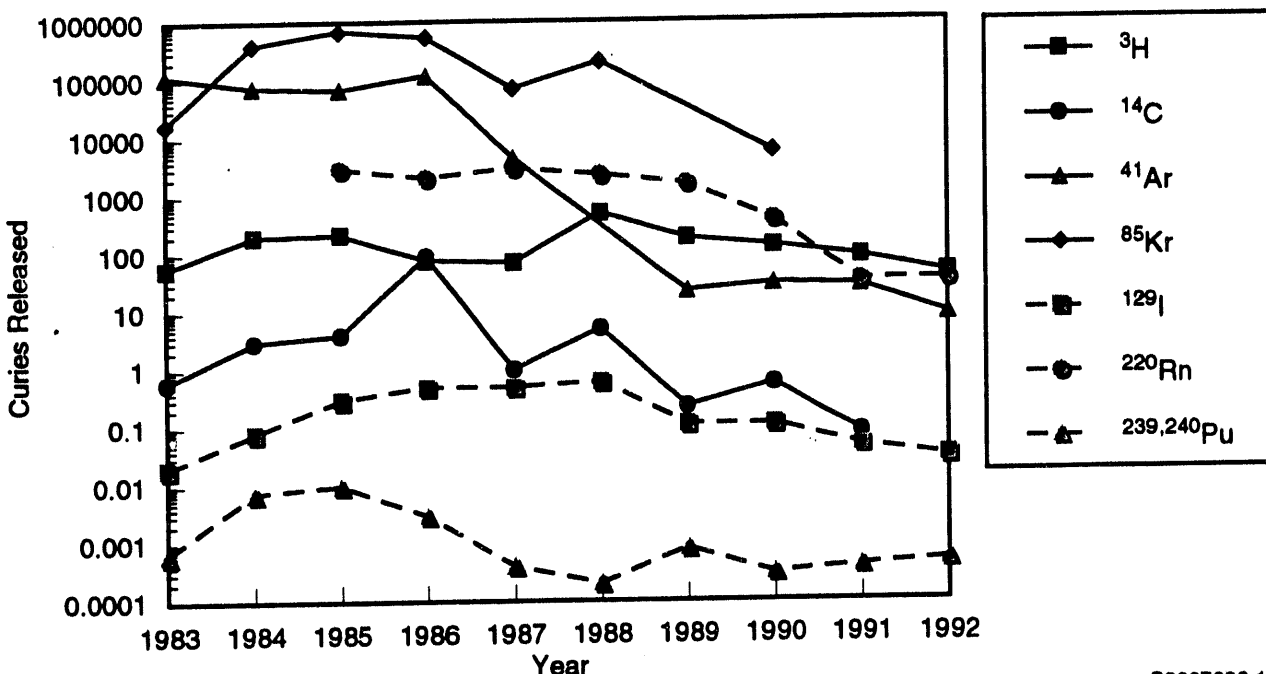
(b) Iodine-129 was only reported as an emission from the 200 Areas.

(c) Plutonium-239,240 values include total alpha activity for those facilities where $^{239,240}\text{Pu}$ was not measured directly.

(d) -- means that no emissions were reported for that year.

(e) Emission values from Wedlick et al. (1989).

(f) The 300 Area value for $^{239,240}\text{Pu}$ was reported as <0.0006 Ci.



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FIGURE 3.2. Selected Radionuclides Discharged to the Atmosphere from Hanford Emissions, 1983 to 1992

1983 to 1987) and 400 Areas (138 Ci for 1986 to 1992). Krypton-85 (0 Ci for 1989, 5700 Ci for 1990), ³H (199 Ci), and ²²⁰Rn (2000 Ci), all from the 200 Areas, were the major radionuclide contributors to airborne emissions for 1989 to 1990. Tritium (85 Ci) from the 300 Area, ²²⁰Rn from the 200 Area (33 Ci), and ⁴¹Ar from the 400 Area (27 Ci) were the major radionuclide contributors to Site air emissions for 1991. Radon-220 (34 Ci) from the 200 Area, ³H (44.5 Ci) from the 300 Area, and ⁴¹Ar (8.5 Ci) from 400 Area were the radionuclide effluents released in the largest quantities for 1992.

3.2 PUREX/UO₃ PLANTS

The PUREX Plant was built in the mid-1950s to process nuclear reactor fuel for the recovery of plutonium, uranium, and neptunium. The plant operated from 1956 to 1972, at which time it was placed in a standby mode. It was restarted and began routine operations in November 1983. The PUREX Plant was operated under a prevention of significant deterioration (PSD) permit issued in 1980 by the U.S. Environmental Protection Agency. This PSD permit limited NO_x annual

emissions from the plant to 424 MT (and UO₃ Plant annual NO_x emissions to 50 MT). The PUREX Plant was operated routinely from 1984 to 1988, except for 10 months of inactivity in 1987. The UO₃ Plant was undergoing modifications in 1987 and did not operate. Operation of the PUREX Plant was stopped on December 7, 1988, to evaluate safety concerns. The plant was restarted and operated from December 1989 to March 1990 to complete a stabilization run of fuel remaining in the plant from previous operations. The PUREX Plant has not operated since March 1990 and is proceeding toward a permanent shutdown.

3.2.1 Predicted Air Pathway Impacts for PUREX/UO₃ Plant Restart

For the time period covered by this report, the PUREX and UO₃ facilities in the 200 Areas were the major emissions sources to the air pathway; therefore, this report will focus primarily on the emissions from the 200 Areas to assess air pathway impacts. An environmental impact statement (EIS) for the operation of the PUREX and UO₃ facilities was produced before the 1983 restart of fuel reprocessing (DOE 1982; DOE 1983). In addition, Sula and Price (1983) produced a report describing preoperational and operational environmental surveillance conducted to support the 1983 restart of the PUREX Plant. These reports predicted that ³H, ¹⁴C, and ⁸⁵Kr would be the principal radionuclides discharged to the atmosphere on the basis of total curies released. Operation of the PUREX Plant was expected to increase the downwind perimeter concentration of ⁸⁵Kr in air by approximately an order of magnitude. The air concentrations of ³H and ¹⁴C in air near the operating facilities were predicted to be slightly elevated; however, the air concentrations of ³H and ¹⁴C at offsite locations were not expected to be distinguishable from background concentrations.

Table 3.2 shows the projected annual releases from the PUREX Plant and the projected Site perimeter concentrations versus the maximum reported annual emissions and the measured Site perimeter concentrations from 1983 to 1992. The projected emissions were exceeded for ¹²⁹I for all years of PUREX Plant operation, and the projected ¹⁴C emissions were exceeded during the 1986 operating year. Actual emissions of ³H and ⁸⁵Kr were below the projected emissions for all years.

TABLE 3.2. Projected and Measured Radionuclide Content of Airborne Effluents from the PUREX Plant

Radio-nuclide	Projected Annual Release, (a) Ci	1983-1992 Maxim. Annual Release, Ci	Projected Site Perimeter Concentration, (a) pCi/m ³	1983-1992 Perimeter Concentration, pCi/m ³	
				Maximum	Maximum Annual Mean
¹²⁹ I	0.04	0.06	6.8×10^{-6}	6.0×10^{-5}	3.0×10^{-5}
⁸⁵ Kr	13×10^5	7×10^5	210	910	150
¹⁴ C	6.9	90	1.4	1.6	1.4
³ H	2200	500	1.8	12	2.1

(a) Calculated based on processing of 2100 MTU/yr of 12% ²⁴⁰Pu, 180-day cooled fuel, 20% of which is spike fuel (Sula and Price 1983). These literature values did not include the contribution from background concentrations; therefore, the overall average air concentration at the distant locations (during the period of this report) were added to the projected values (added background concentrations were: ¹²⁹I = 1.2×10^{-6} pCi/m³; ⁸⁵Kr = 31 pCi/m³; ¹⁴C = 1.4 pCi/m³; and ³H = 1.5 pCi/m³).

The projected Site perimeter air concentrations reported by Sula and Price (1983) were based on the calculated dispersion of projected emissions and did not include the background concentrations of radionuclides present. To allow for comparisons between projected and measured concentrations, the overall average concentrations at the distant locations were added to the Sula and Price projected values (Table 3.2). A detailed description of the 1983 to 1992 monitoring results is provided in Section 5.0. The projected Site perimeter air concentrations of ¹²⁹I were exceeded (1.3 to 4.4 times) for the 1984 to 1988 annual mean air concentrations, and the concentrations measured at perimeter locations were elevated compared to the distant locations. The projected perimeter air concentrations for ¹⁴C and all measured annual average concentrations were similar; however, no difference was observed for air concentrations of ¹⁴C at perimeter locations compared to distant locations, thus no significant Hanford Site source was indicated. The maximum air concentrations of ⁸⁵Kr at the Site perimeter exceeded (1.3 to 4.3 times) the projected levels for 1984, 1985, 1986, and 1988, but the annual mean air concentrations for all locations were below the projected level for all years. All annual maximum ³H concentrations measured at the Site perimeter during PUREX Plant operations

were higher than the predicted concentrations. Measured annual average air concentrations of ^3H at the perimeter were similar to the projected values; however, during this time period, no apparent differences were observed between the annual average concentrations at Site perimeter and distant locations.

3.2.2 Predicted Dose

The radiation dose to the public from Hanford Site operations was expected to double following the restart of the PUREX Plant (Sula and Price 1983). Predicted whole-body radiation dose was estimated at 0.02 mrem for the hypothetical maximally exposed individual and 2.1 person-rem to the population (assuming 1-year release, 70-year accumulation, and 2100 MTU/yr PUREX Plant processing rate). The projected dose to the public from operations at the UO_3 Plant was much lower than the dose expected from PUREX Plant operations (DOE 1982). Soldat et al. (1986) reported that the estimated dose (whole-body, 50-year cumulative dose) to the hypothetical maximally exposed individual (MEI) rose from 0.7 mrem in 1982 (before PUREX Plant restart) to 1 mrem for 1983 (PUREX Plant restart) and 2 mrem for 1984 (first full year of renewed PUREX Plant operation), which was in agreement with the predicted dose increase (Sula and Price 1983). The radiological dose to the MEI from 1983 to 1992 is discussed in Section 5.2.

4.0 AIR PATHWAY SURVEILLANCE

From 1983 to 1992, the SESP collected air samples from numerous onsite and offsite locations. At each sampling station, airborne particulate was collected and analyzed for total beta radiation. In addition, at selected locations, samples were collected and analyzed for total alpha radiation, ^3H (as HTO vapor), ^{14}C (as CO_2), ^{85}Kr , ^{129}I (gas, both elemental and molecular), and ^{131}I (gas, both elemental and molecular). For most particle-associated radionuclides, the amount of material collected on biweekly particulate filters was too small to be readily measured; therefore, the biweekly filters for specific geographical areas were combined into monthly, quarterly, or annual composite samples. Monthly or quarterly composite samples were scanned for gamma-emitting radionuclides (e.g., ^{60}Co , ^{106}Ru , and ^{137}Cs ; see Woodruff et al. 1992 for a complete list of constituents). Quarterly or annual composite samples were analyzed for isotopic strontium, uranium, and plutonium. The key radionuclides identified as contributing the most to the offsite dose during the time period of this report are discussed in detail below as well as some other radionuclides of special interest. The location of the MEI used to calculate dose from radiation from Hanford activity switched between the Ringold and Riverview areas during the years 1983 to 1992 (Byers Landing was the most representative air sampling location for the Riverview Area); therefore, particular attention will be paid to the Ringold and Byers Landing sampling locations in the following discussions.

4.1 KEY RADIONUCLIDES

The key radionuclides that contributed to dose to the MEI which were identified from analysis of the air pathway were ^3H , ^{129}I , and $^{239,240}\text{Pu}$ (Sula and Price 1983; and Hanford Site annual environmental reports); these are discussed in detail in Section 5.0. In addition, ^{14}C and ^{85}Kr were identified in the PUREX/ UO_3 EIS reports (DOE 1982, 1983) as significant emissions, and specific sampling programs were initiated to monitor for these contaminants. Therefore, these constituents will be discussed as well. Krypton-85 was of

particular interest because it was the major airborne emission (on a curie basis) during the period of this report and provided a good tracer of airborne emissions from the PUREX Plant. Although the inert gases ^{41}Ar (1.8-hr half-life) and ^{220}Rn (55.6-sec half-life) were a significant fraction of the total Hanford Site air emissions for most years, ambient air samples were not collected for these isotopes because of their short half-lives.

4.2 SAMPLE COLLECTION AND ANALYSIS METHODS

Tritium in the form of water vapor (H^3HO) was collected from ambient air by continuously passing air (0.01 to 0.014 m^3/hr) through silica-gel cartridges. The silica gel traps were exchanged every 2 or 4 weeks. The analytical laboratory recovered the trapped water from the silica gel using vacuum distillation with the water vapor trapped on a cryogenically cooled condenser. The ^3H concentrations were then determined with a liquid scintillation counter. The ^3H concentrations were reported either as the pCi/L for the water collected from the cryogenic trap or the pCi/ m^3 of air sampled. The pCi/L (water collected) can be converted to air concentrations by calculating the total pCi of ^3H collected and dividing this value by the air volume sampled.

Carbon-14 was collected as $^{14}\text{CO}_2$ by passing air through a soda lime cartridge at 0.03 m^3/hr . The soda lime cartridges were exchanged every 8 weeks. The $^{14}\text{CO}_2$ was released from the soda lime by treatment with acid and injected into an instrument that quantitatively converted the $^{14}\text{CO}_2$ into benzene using a series of catalysts. The benzene product was mixed with scintillation solution and counted using a low-temperature, liquid scintillation counter.

Krypton-85 samples were collected in 1983 by using an air compressor that cycled on every 50 min for a 10-sec duration to pump air into a pressure tank. Samples of about 0.5 m^3 were collected over a 4-week period. From 1984 to 1990, ^{85}Kr samples were collected by continuously pumping air at 0.0004 m^3/hr into a collection bag. Every 4 weeks, the air in the collection bag was transferred in the field to a compressed gas cylinder using an air compressor. The air from the compressed gas cylinder was then passed through a specially constructed cryogenic trapping instrument. The cryogenic

instrument uses a series of cold traps to remove unwanted gases and concentrate the krypton. The purified ^{85}Kr was then mixed with scintillation solution and counted using a low-temperature scintillation counter.

Iodine-129 was collected by passing air through a petroleum-based charcoal cartridge at $2.6 \text{ m}^3/\text{hr}$. The petroleum-based charcoal is superior to wood-based charcoal because it does not contain ^{129}I from atmospheric nuclear tests. The charcoal traps were collected every 4 week and combined into quarterly composite samples. The ^{129}I was removed from the charcoal, purified, and analyzed using high-resolution mass spectrometry.

Plutonium was analyzed from quarterly or annual composite samples of the particulate filters collected biweekly at all locations. The biweekly samples were collected by drawing air at $2.6 \text{ m}^3/\text{hr}$ through a 5-cm-diameter high-efficiency glass fiber filter; at some locations dual-particle filters were collected at a total flow rate of $5.2 \text{ m}^3/\text{hr}$. Plutonium was leached from the composited filters using nitric acid and collected on an ion exchange resin. Plutonium was removed from the resin using nitric and hydrofluoric acids and electrodeposited onto a stainless steel disk. The plutonium residue was then counted using an alpha spectrometer.

Table 4.1 compares the analytical laboratories' contractual minimum detectable concentrations (MDC) for key radionuclides (given in Hanford Site annual environmental reports) and the range of annual average air concentrations measured at the Site perimeter. It also compares these values to the U.S. Department of Energy's DCGs for radionuclides (DOE Order 5400.5). The DCG values are the concentration of a specific radionuclide in air that could be continuously inhaled at average annual rates and not exceed an effective dose equivalent of 100 mrem/yr. An exception is that the ^{85}Kr limit is based on a skin dose limit of 5 rem from immersion in a plume. For all radionuclides, the reported MDC values were at least three orders of magnitude less than the DCG values, except for the 1984 and 1985 reported MDC values for $^{239,240}\text{Pu}$ ($0.09 \text{ pCi}/\text{m}^3$), which were greater than the DCG value (Price et al. 1985; Price 1986). The reported 1984 and 1985 MDC values may be in error because the maximum air concentrations during that period were considerably less than both the MDC and DCG values (e.g., maximum air concentrations at the Site perimeter were $0.00001 \pm 0.000007 \text{ pCi}/\text{m}^3$ for 1984, and

TABLE 4.1. Comparison of Reported Minimum Detectable Concentrations (MDCs) to Annual Average Site Perimeter Concentrations and Derived Concentration Guides for Selected Air Contaminants (pCi/m³)

Radio-nuclide	MDC	Annual Perimeter Air Concentrations ^(a)	1992 Derived Concentration Guides
³ H	0.15	0.9 - 2.1 ^(b)	100,000
¹⁴ C	1	1.3 - 1.4	500,000
⁸⁵ Kr	2	18 - 150	3,000,000
¹²⁹ I	0.00001	0.000001 - 0.00003	70
^{239,240} Pu	0.00002 - 0.09 ^(c)	<0.0000003 - 0.00002	0.02

(a) From Tables 5.1, 5.2, 5.3, 5.4, and 5.5.

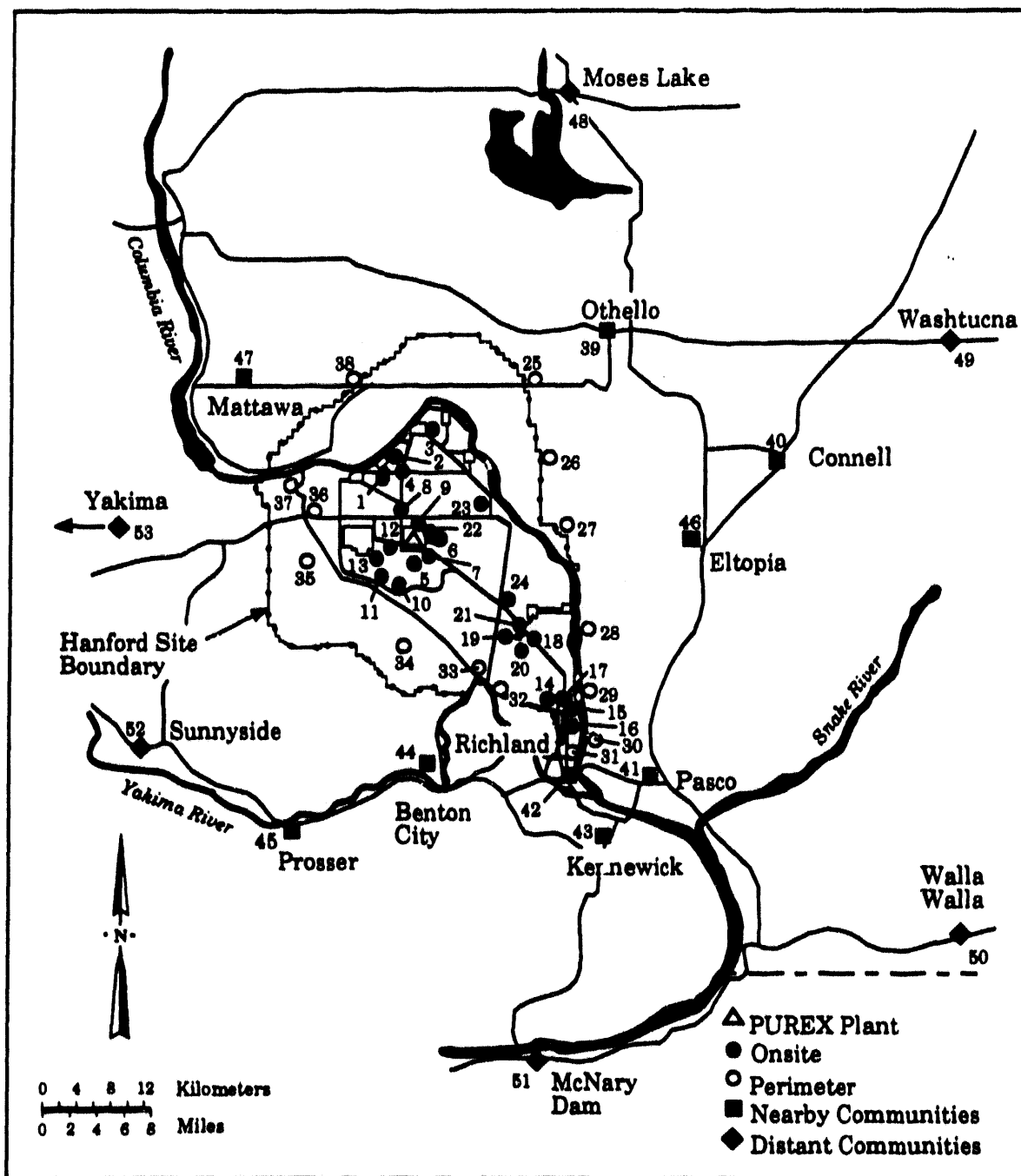
(b) Excluding the suspect values from January to May 1992 (Table 5.1).

(c) For 1984 and 1985, the reported MDC for ^{239,240}Pu was greater than the DCG value; however, the maximum ^{239,240}Pu air concentrations reported at the Site perimeter for 1984 and 1985 were 0.00001 ± 0.000007 pCi/m³ and 0.0000098 ± 0.0000065 pCi/m³, respectively, which were considerably less than the reported MDC.

0.0000098 ± 0.0000065 pCi/m³ for 1985). In all cases, the annual average air concentrations measured at the Site perimeter were orders of magnitude less than the DCG values. The MDC values were less than annual average Site perimeter air concentrations for ³H and ⁸⁵Kr, and were of similar magnitude for ¹⁴C. The annual average Site perimeter air concentrations were typically less than the reported MDC for ¹²⁹I, indicating that the system was more sensitive than specified by the MDC. For ^{239,240}Pu, the annual average Site perimeter air concentrations were equal to or less than the lower limit given for the MDC (0.00002 pCi/m³).

4.3 SAMPLING LOCATIONS

From 1983 to 1992, air samples were collected by a network of continuously operating stations at locations on the Hanford Site, and at the Site perimeter, nearby communities, and distant communities. Figure 4.1 shows the locations where samples were collected, and Table 4.2 identifies composite groups and lists the analyses performed on samples from each location for the



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FIGURE 4.1. Air Sampling Locations, 1990

TABLE 4.2. Air Sampling Locations, Sample Composite Groups, and Analyses, 1990

Map Location ^(a)	Sampling Location	Analyses	Composite Group	Analyses
Onsite				
1	100-K	Beta, ¹³¹ I (NRA) ^(b) Beta, ³ H, ¹³¹ I Beta, alpha, ³ H, ¹⁴ C, ¹³¹ I Beta, ¹³¹ I (NRA)	100 Areas	Gamma, Sr, Pu, U
2	100-N			
3	100-D			
4	Fire Station			
5	S of 200-East	Beta, alpha, ¹³¹ I Beta, alpha, ¹³¹ I Beta, alpha, ³ H, ¹⁴ C, ⁸⁵ Kr, ¹²⁹ I, ¹³¹ I	200-East Area	Gamma, Sr, Pu, U
6	E of 200-East			
7	200-East SE			
8	Rt. 11A, Mi. 9	Beta, alpha, ¹³¹ I (NRA) Beta, alpha, ¹³¹ I (NRA)	North of 200 Areas	Gamma, Sr, Pu
9	N of 200-East			
10	SW of BC Cribs	Beta, alpha, ¹³¹ I (NRA) Beta, alpha, ¹³¹ I (NRA) Beta, alpha, ³ H, ¹³¹ I (NRA)	200-West Area	Gamma, Sr, Pu, U
11	Army Loop Camp			
12	GTE Building			
13	200-West SE	Beta, alpha	200-West SE	Gamma, Sr, Pu, U
14	300 Trench	Beta, alpha, ¹³¹ I (NRA) ³ H, ¹⁴ C, ⁸⁵ Kr Beta, ¹³¹ I Beta, alpha, ¹³¹ I (NRA)	300 Area	Gamma, Sr, Pu, U
15	ACRMS (3614-A Bldg.)			
16	300-South Gate			
17	300 NE	Beta, alpha	300 NE	Gamma, Sr, Pu, U
18	400-East	Beta, alpha, ³ H, ¹³¹ I Beta, alpha, ¹³¹ I (NRA) Beta, alpha, ¹³¹ I (NRA) Beta, alpha, ¹³¹ I (NRA)	400 Area	Gamma, Sr, Pu
19	400-West			
20	400-South			
21	400-North			
22	B Pond	Beta, alpha	B Pond	Gamma, Sr, Pu, U
23	Hanford Townsite	Beta, alpha, ¹³¹ I (NRA)	Hanford Townsite	Gamma, Sr, Pu, U
24	Wye Barricade	Beta, alpha, ¹³¹ I (NRA)	Wye Barricade	Gamma, Sr, Pu, U
Perimeter				
25	Berg Ranch	Beta, alpha, ³ H, ¹³¹ I (NRA) Beta, alpha, ³ H, ⁸⁵ Kr, ¹³¹ I Beta, alpha, ³ H, ⁸⁵ Kr, ¹²⁹ I, ¹³¹ I, (NRA)	Northeast Perimeter	Gamma, Sr, Pu
26	Sagehill			
27	Ringold			

TABLE 4.2. (Contd)

Map Location ^(a)	Sampling Location	Analyses	Composite Group	Analyses
28	Fir Road Pettett	Beta, alpha, ³ H, ⁸⁵ Kr, ¹³¹ I } Beta, alpha, ¹³¹ I }	East Perimeter	Gamma, Sr, Pu, U
29				
30	Byers Landing RRC No. 64	Beta, alpha, ³ H, ¹²⁹ I, ¹³¹ I } Beta, alpha, ¹³¹ I (NRA) }	Southeast Perimeter	Gamma, Sr, Pu, U
31				
34	ALE	Beta, ¹³¹ I (NRA)	ALE	Archive
35	Rattlesnake Springs Yakima Barricade	Beta, ¹³¹ I (NRA) } Beta, alpha, ³ H, ¹³¹ I } (NRA)	West Perimeter	Gamma, Sr, Pu
36				
37	Vernita Bridge Wahlake Slope No. 2	Beta, ¹³¹ I (NRA) } Beta, alpha, ³ H, ¹³¹ I } (NRA)	Northwest Perimeter	Gamma, Sr, Pu
38				
Nearby Communities				
39	Othello Connell	Beta, ⁸⁵ Kr, ¹³¹ I (NRA) } Beta, ¹³¹ I (NRA) }	Northeast Communities	Gamma, Sr, Pu
40				
41	Pasco Richland Kennewick	Beta, ⁸⁵ Kr, ¹³¹ I (NRA) } Beta, alpha, ³ H, ¹³¹ I } Beta, ¹³¹ I (NRA) }	Tri-Cities	Gamma, Sr, Pu
42				
43				
44	Benton City Prosser	Beta, alpha, ¹³¹ I } Beta, ¹³¹ I (NRA) }	Benton City	Gamma, Sr, Pu
45				
46	Eitopia	Beta, ⁸⁵ Kr, ¹³¹ I (NRA)	Eitopia	Gamma, Sr, Pu
47	Mattawa	Beta, ⁸⁵ Kr, ¹³¹ I (NRA)	Mattawa	Gamma, Sr, Pu
Distant Communities				
48	Moses Lake Washtuona	Beta, ¹³¹ I (NRA) } Beta, ¹³¹ I (NRA) }	Outer Northeast	Gamma, Sr, Pu
49				
50	Walla Walla McNary Dam	Beta, ¹³¹ I (NRA) } Beta, ¹³¹ I (NRA) }	Outer Southeast	Gamma, Sr, Pu
51				
52	Sunnyside	Beta, alpha, ³ H, ¹⁴ C, } ⁸⁵ Kr, ¹³¹ I }	Sunnyside	Gamma, Sr, Pu, U
53	Yakima	Beta, alpha, ³ H, ¹⁴ C, } ⁸⁵ Kr, ¹²⁹ I, ¹³¹ I }	Yakima	Gamma, Sr, Pu, U

(a) Locations are identified in Figure 4.1.

(b) The sample was collected but was not routinely analyzed.

1990 calendar year (1990 was selected because it represented the maximum number of air stations during PUREX Plant activity). The total number of sampling stations operating from 1983 to 1992 ranged from 45 to 53, and some modifications to the geographic sample compositing process occurred during this decade.

Air samplers on the Site were located primarily around major operating areas. Site perimeter samplers were located around the Site with emphasis on the downwind perimeter (generally to the southeast). The Ringold and Byers Landing (Riverview) air samplers were the stations closest to the calculated location of the MEI during the period of this report. Nearby community samples were collected in population centers closest to the Site to verify the dose estimates to the largest populations potentially exposed to Site emissions. To provide background information, samples were collected at distant communities essentially unaffected by Site emissions. The distant and upwind Yakima location (installed in 1986) provided an additional reference point for regional background concentrations.

Beginning in 1991, air samples were also collected at three community-operated environmental surveillance stations (COESS) located at the Basin City Elementary School in Basin City, Edwin Markham Elementary School in North Franklin County, and Leslie Groves Park in Richland (Woodruff et al. 1992). These samples were collected by local teachers using the same equipment and analytical laboratory as the SESP. The COESS program was implemented to improve public awareness of the environmental monitoring programs at the Hanford Site. Data from the COESS have been included in the overall data reported during the decade of this report.

5.0 SURVEILLANCE RESULTS AND DISCUSSION

5.1 AIR CONCENTRATIONS

Hanford Site annual environmental reports for 1983 to 1992 (see references) consistently reported numerical and sometimes statistical differences in air concentrations measured at the Site perimeter compared to those at the distant locations for ^{85}Kr , ^{129}I , and isotopic uranium. For some years, differences between the Site perimeter and distant locations were also reported for ^3H , ^{90}Sr , ^{106}Ru , ^{137}Cs , $^{239,240}\text{Pu}$, and total alpha and total beta radiation. The elevated air concentrations for isotopic uranium and total alpha and beta radiation measured at the Site perimeter were attributed to the effects of natural geographic variations. Strontium-90, ^{106}Ru , and ^{137}Cs annual average air concentrations were numerically greater at the Site perimeter compared to the distant location for some years; however no statistical difference was reported for these constituents. The measured air concentrations for the key constituents identified in Section 4.1 are discussed in more detail below.

One exceptional event that occurred during this time period was the detection during May and June 1986 of radionuclides attributed to the Chernobyl accident (Pacific Northwest Laboratory 1987). The passage of the Chernobyl plume was indicated by a maximum monthly average total-beta concentration of 0.4 pCi/m^3 , which resulted in a doubling of the annual average values for 1986 compared to the previous year. Elevated air concentrations of ^{106}Ru , ^{131}I , and ^{137}Cs observed for some samples at the distant location during 1986 were also attributed to the Chernobyl accident.

All statistical tests and correlations discussed in the following sections were generated using Microsoft Excel 4.0. Tests for differences between locations were paired two-tailed t tests evaluated at the 5% significance level, with the raw data being transformed (natural ln) to ensure a more normal distribution of the differences. Calculated Pearson correlation coefficients (r) between annual air concentrations and annual Site emissions were considered significant at the 5% level.

5.1.1 Air Concentrations of Tritium (^3H)

Air samples were collected for ^3H analysis throughout 1983 to 1992. During this time period, over 2200 samples were analyzed from up to 41 locations. The results ranged from -5.1 to 4900 pCi/m³ (the maximum value was reported at the Ringold Meteorological Tower location, December 1991, and is considered to be highly suspect and likely due to laboratory contamination). The ^3H air concentrations were very consistent during the time of PUREX Plant operation (1983 to 1990). In the summer of 1990, PNL terminated its contract with the analytical service laboratory (Woodruff et al. 1991). Tritium results reported from the new analytical service contract laboratory were substantially elevated at onsite, perimeter, and downwind locations for a large number of samples collected from winter 1991 to May 1992; however, these results, including the above maximum value, were reported as being suspect and likely due to laboratory contamination, especially considering the substantially elevated concentrations reported at distant locations (Woodruff et al. 1993). Mean ^3H concentrations returned to normal values for June to December 1992 (Woodruff et al. 1993).

Because the major focus of this report concerns air pathway effects associated with nuclear materials production, the ^3H concentrations are discussed in detail for the years 1983 to May 1990, after which time ^3H emissions from the 200 Areas had essentially ended. For the period from 1983 to May 1990, the 8-year mean concentrations of ^3H in air were 2.3 and 1.5 pCi/m³ (Figure 5.1) for onsite and distant locations, respectively. Table 5.1 gives the maximum and average concentrations reported for all onsite, perimeter, and distant locations during this time. The maximum value (32 pCi/m³) measured during this time was less than 0.04% of the 1992 DCG of 100,000 pCi/m³.

Figure 5.2 shows the air concentrations of ^3H at the 200 ESE, Byers Landing, Ringold, and Yakima locations from 1983 to 1990. During 1986 to 1990, the concentrations of ^3H measured at the Site's downwind perimeter (Byers Landing and Ringold) were not statistically elevated compared to those at the distant location (paired two-tailed t test, 5% significance level), indicating no measurable Hanford Site impact at the downwind perimeter. The

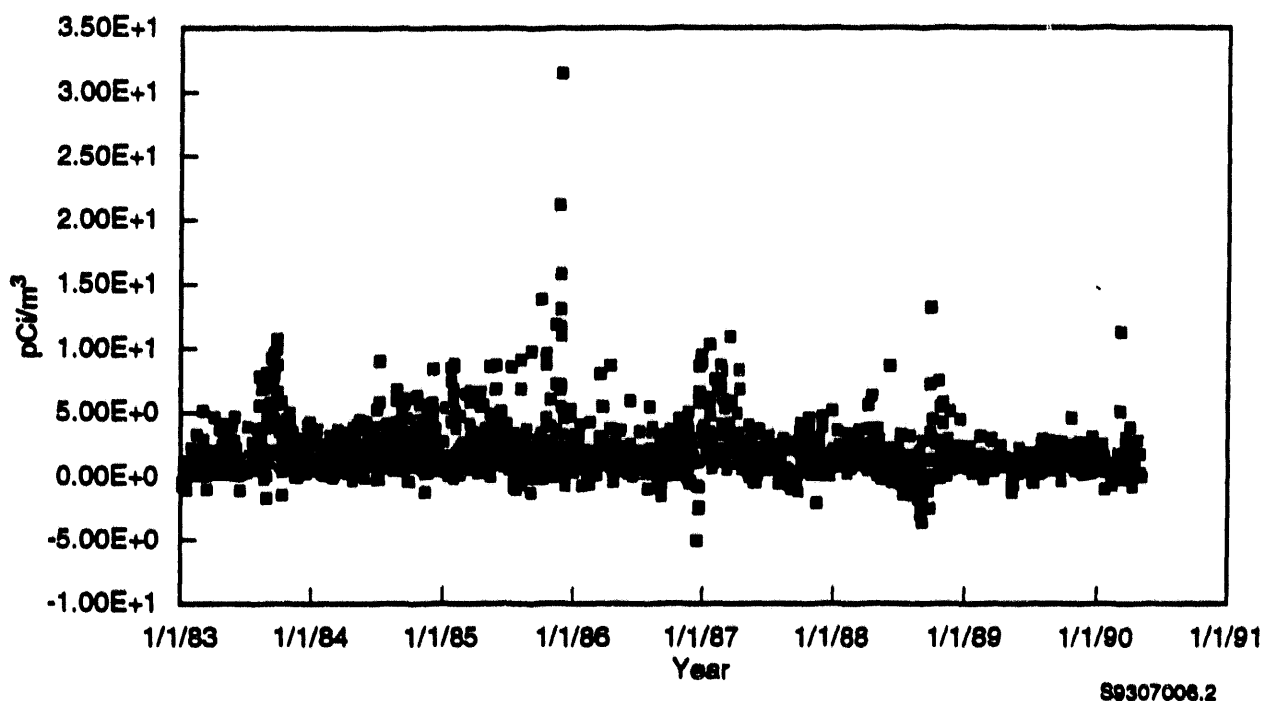


FIGURE 5.1. Air Concentrations of Tritium (^3H) at All Locations, 1983 to 1990

average ^3H concentrations at the 200 ESE location were statistically elevated compared to concentrations at the Ringold and Byers Landing (Site perimeter) locations, as well as the Yakima distant location (paired two-tailed t test, 5% significance level), indicating that the sampling system had adequate sensitivity to detect locally elevated concentrations onsite. There was no correlation (5% significance level, $r = 0.41$) between the annual ^3H emissions and the annual average air concentrations reported for the 200 ESE location. In addition, there was no correlation (5% significance level) between annual emissions and annual average air concentrations for Ringold ($r = -0.02$), Byers Landing ($r = 0.55$), and the Yakima distant location ($r = 0.02$). The lack of substantial correlation between emissions and the sampling locations indicates that the system was not detecting Site emissions on an annual basis.

5.1.2 Air Concentrations of Carbon-14 (^{14}C)

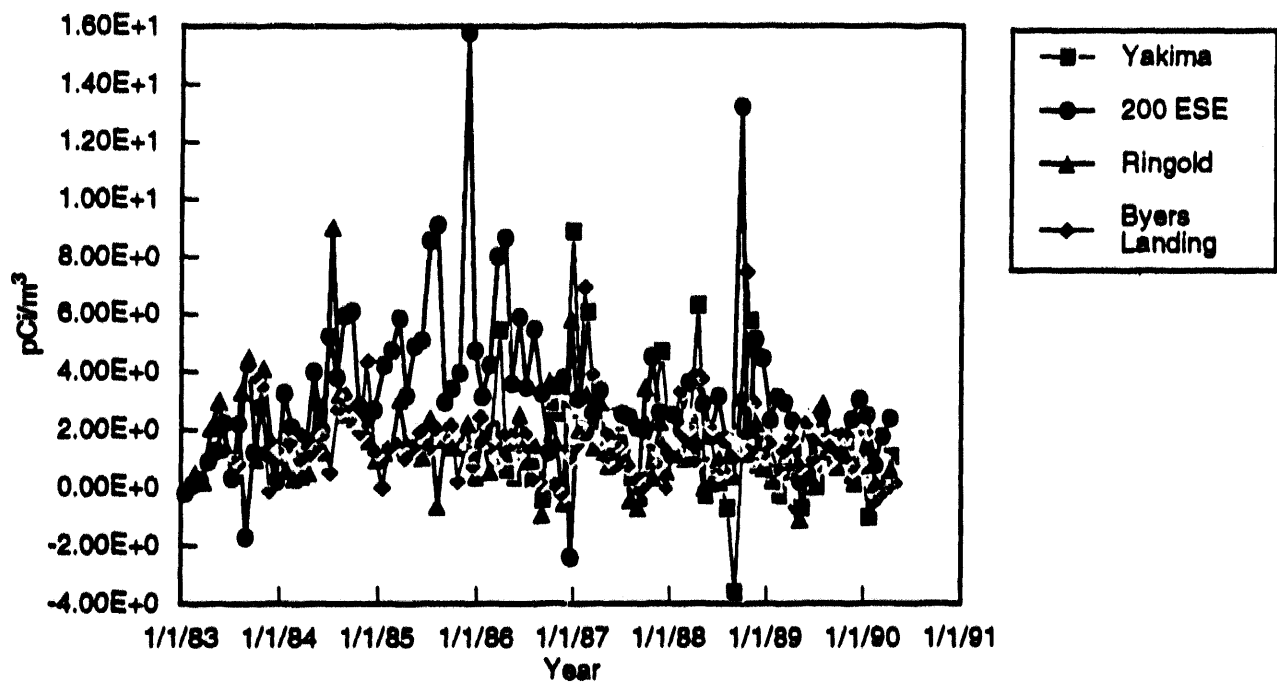
The collection of air samples for ^{14}C analysis began in 1983 and continued until 1990. During this time, 331 samples were analyzed from up to

TABLE 5.1. Airborne Concentrations of Tritium (^3H) in the Hanford Environs, 1983 to 1992^(a) (pCi/m³)

Year	Onsite			Perimeter			Distant		
	n ^(b)	Maximum	Mean	n	Maximum	Mean	n	Maximum	Mean
1983	116	11 ± 3.9	2.2 ± 0.4	110	7.8 ± 3.5	2.1 ± 0.3	10	7.7 ± 3.1	2.7 ± 1.8
1984	176	6.8 ± 2.2	2.2 ± 0.3	139	9.0 ± 4.5	1.9 ± 0.3	26	4.2 ± 2.6	1.6 ± 0.6
1985	177	32 ± 6.7	3.1 ± 0.6	141	13 ± 7.8	1.7 ± 0.4	26	8.6 ± 5.1	1.8 ± 0.9
1986	69	8.7 ± 1.7	2.2 ± 0.5	91	4.5 ± 2.8	1.1 ± 0.3	24	5.4 ± 2.6	1.4 ± 0.8
1987	77	10 ± 1.3	2.1 ± 0.5	104	11 ± 1.8	1.9 ± 0.4	26	6.1 ± 2.4	2.2 ± 0.8
1988	78	13 ± 2.4	2.0 ± 0.5	104	7.5 ± 2.1	1.2 ± 0.3	25	6.3 ± 3.0	0.8 ± 0.9
1989	77	4.5 ± 1.3	1.4 ± 0.2	100	2.9 ± 1.2	0.9 ± 0.2	26	2.4 ± 1.3	0.8 ± 0.3
1990 ^(c)	27	5.0 ± 0.7	1.2 ± 0.5	34	11 ± 1.0	1.0 ± 0.7	8	1.6 ± 0.78	0.36 ± 0.6
1991	75	31 ± 1.7	2.2 ± 0.9	60	12 ± 1.4	1.6 ± 0.5	22	9.0 ± 0.45	1.1 ± 0.8
1992 ^(d)	35	770 ± 6.0	130 ± 90	24	1600 ± 9.4	190 ± 300	10	350 ± 3.7	71 ± 58
1992 ^(e)	60	28 ± 1.1	2.4 ± 0.02	40	330 ± 5.0	1.5 ^(f) ± 0.02	16	380 ± 5.4	1.4 ^(g) ± 0.02

5.4

- (a) Maximum single sample results ± 2 sigma counting error. Mean of all samples ± 2 times the standard error of the calculated mean.
- (b) n = number of samples.
- (c) Results from January to May 1990 (before termination of analytical contract; see text).
- (d) January to May 1992 values. These results are suspect and are likely the result of laboratory contamination (see Section 5.1.1).
- (e) June to December 1992 values.
- (f) Two suspect values (possible laboratory contamination) at the Prosser Barricade were excluded from the average (280 and 330 pCi/m³).
- (g) One suspect value (possible laboratory contamination) at Sunnyside was excluded from the average (380 pCi/m³).



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FIGURE 5.2. Air Concentrations of Tritium (^3H) at the 200 ESE, Byers Landing, Ringold, and Yakima Locations, 1983 to 1990

13 locations. The results ranged from 0.80 to 2.3 pCi/m³ (Figure 5.3), with average concentrations of 1.3 to 1.5 pCi/m³. Table 5.2 gives the maximum and average concentrations reported for onsite, perimeter, and distant locations during this time. All measured ^{14}C concentrations were orders of magnitude less than the 1992 DCG of 500,000 pCi/m³. Essentially, no measurable differences were observed between concentrations at onsite locations and either those at the perimeter or distant locations during the entire time. Carbon-14 was therefore not an important radionuclide for the air pathway during this time period, and collection of air samples for ^{14}C was discontinued.

5.1.3 Air Concentrations of Krypton-85

The collection of air samples for ^{85}Kr analysis began in 1983 and continued through 1990. Air measurements of ^{85}Kr were generally useful during the period of this report as an indicator of the locations affected by PUREX Plant operations plume. Onsite concentrations of ^{85}Kr increased with the

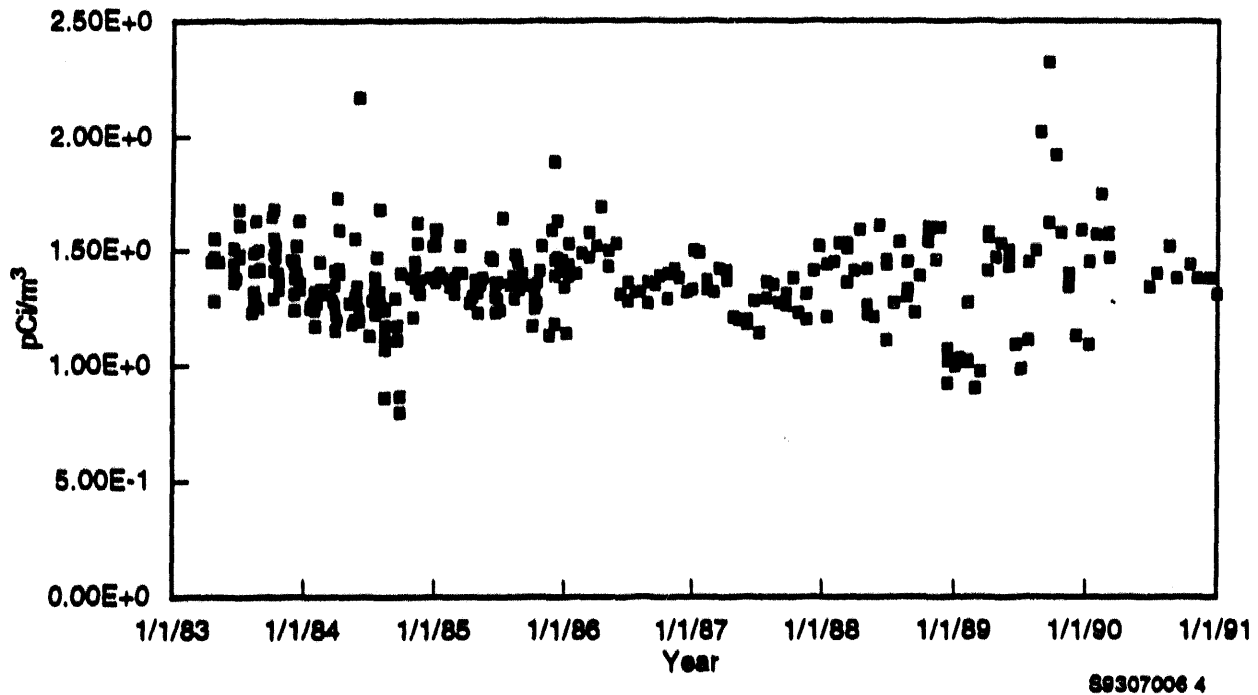


FIGURE 5.3. Air Concentrations of Carbon-14 (^{14}C) at All Locations, 1983 to 1990

resumption of PUREX Plant activity in 1983 and were elevated relative to those from the distant locations during the years of PUREX Plant operation. Air concentrations of ^{85}Kr decreased following the shutdown of operations at the PUREX Plant. During this time, 758 samples were analyzed from up to 15 locations. Results for all locations are shown in Figure 5.4. The results ranged from 3.4 to 6100 pCi/m³, with mean concentrations of 410 and 31 pCi/m³ for onsite and distant locations, respectively. Table 5.3 gives the maximum and average concentrations reported for onsite, perimeter, and distant locations during this time. All measured concentrations of ^{85}Kr were orders of magnitude less than the 1992 DCG value of 3,000,000 pCi/m³.

Figure 5.5 shows the air concentrations of ^{85}Kr measured at the 200 ESE, Ringold, and Yakima locations from 1983 to 1990. Overall, there was a large decrease in ^{85}Kr air concentrations at the 200 ESE location following the termination of ^{85}Kr emissions at the PUREX Plant by the end of 1988. From 1986 to 1988, the concentrations of ^{85}Kr at the Site perimeter were statistically

TABLE 5.2. Airborne Concentrations of Carbon-14 (^{14}C) in the Hanford Environs, 1983 to 1990^(a) (pCi/m³)

Year	Onsite			Perimeter			Distant		
	n ^(b)	Maximum	Mean	n	Maximum	Mean	n	Maximum	Mean
1983 ^(c)	5	1.6 ± 0.1	1.5 ± 0.1	13	1.6 ± 0.2	1.4 ± 0.08	5	1.5 ± 0.1	1.4 ± 0.2
1984	21	1.7 ± 0.1	1.3 ± 0.1	33	1.5 ± 0.1	1.3 ± 0.06	7	1.4 ± 0.1	1.3 ± 0.08
1985	18	1.6 ± 0.09	1.4 ± 0.1	31	1.6 ± 0.1	1.3 ± 0.1	6	1.5 ± 0.1	1.3 ± 0.3
1986	12	1.7 ± 0.09	1.4 ± 0.07			— ^(d)	12	1.6 ± 0.07	1.4 ± 0.06
1987	13	1.5 ± 0.1	1.3 ± 0.1			—	12	1.4 ± 0.1	1.3 ± 0.1
1988	20	1.6 ± 0.1	1.4 ± 0.1			—	12	1.6 ± 0.1	1.3 ± 0.1
1989	19	2.3 ± 0.1	1.4 ± 0.2			—	14	1.6 ± 0.09	0.4 ± 0.1
1990	6	1.8 ± 0.08	1.4 ± 0.1			—	6	1.6 ± 0.1	1.5 ± 0.08

(a) Maximum single sample results ± 2 sigma counting error. Mean of all samples ± 2 times the standard error of the calculated mean.

(b) n = number of samples.

(c) 1983 onsite values are for the 200-East Area.

(d) — indicates that no samples were analyzed.

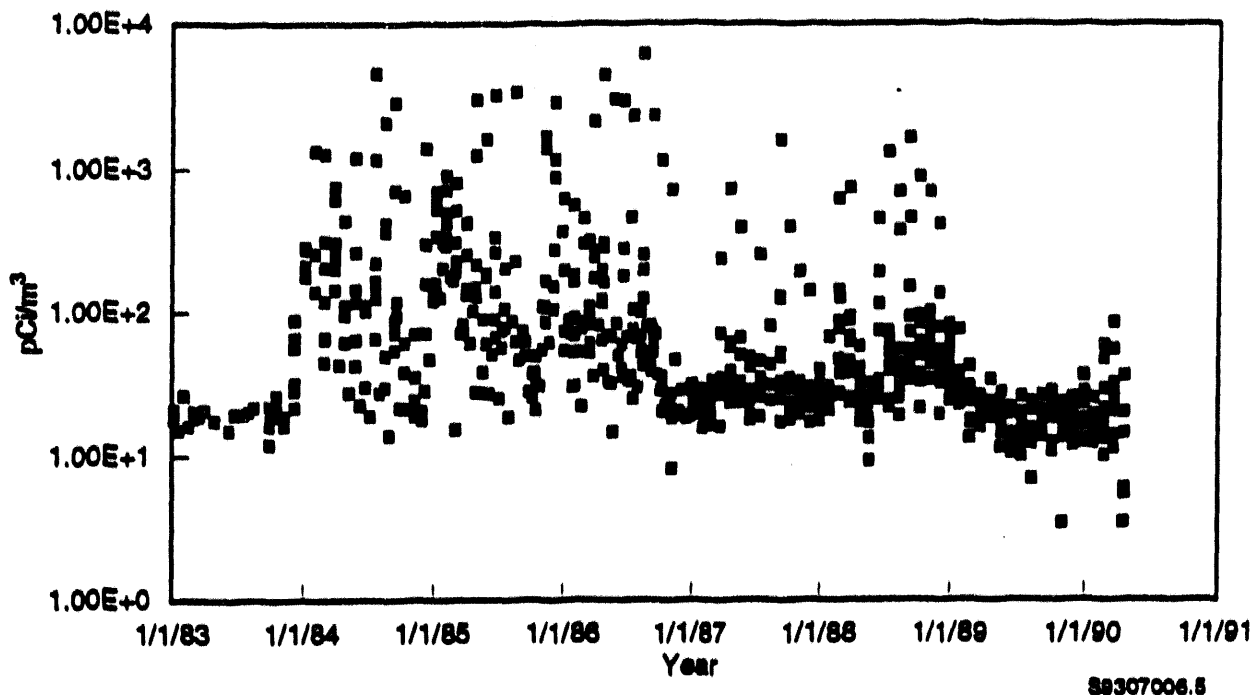


FIGURE 5.4. Air Concentrations of Krypton-85 (^{85}Kr) at All Locations, 1983 to 1990

elevated compared to those at the Yakima distant location (paired two-tailed t test, 5% significance level), indicating that the Hanford Site operations impacted the air concentrations at the downwind perimeter. As would be expected for the substantial Hanford Site emissions of ^{85}Kr , onsite air concentrations of ^{85}Kr were also statistically elevated compared to both the Ringold (perimeter) and Yakima (distant) locations (paired two-tailed t test, 5% significance level). For 1989 to 1990 (following the decrease in ^{85}Kr emissions from the PUREX Plant; 0 Ci released in 1989, 5700 Ci released in 1990), there were no statistical differences (paired two-tailed t test, 5% significant level) between ^{85}Kr air concentrations measured at the downwind perimeter, Yakima, or 200 ESE locations.

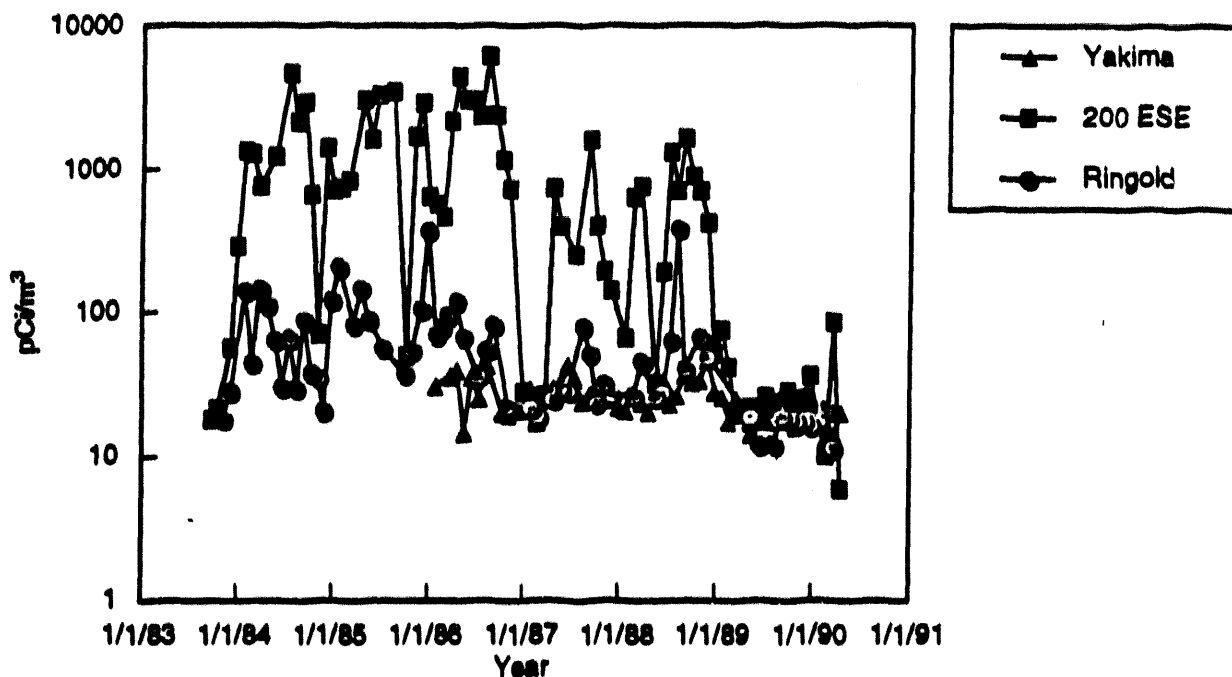
There was a correlation (5% significance level, $r = 0.94$) between the annual emissions of ^{85}Kr and the annual average air concentrations reported for the 200 ESE sampling location. In addition, there was also a correlation between annual emissions and annual average air concentrations for the Ringold location (5% significance level, $r = 0.88$). This correlation between Site emissions of ^{85}Kr and concentrations at onsite and downwind locations

TABLE 5.3. Airborne Concentrations of Krypton-85 (^{85}Kr) in the Hanford Environs, 1983 to 1990^(a) (pCi/m³)

Year	Onsite			Perimeter			Distant		
	n ^(b)	Maximum	Mean	n	Maximum	Mean	n	Maximum	Mean
1983	26	88 ± 12	26 ± 6.8	6	28 ± 5.5	21 ± 3.2	5	20 ± 3.9	17 ± 2.7
1984	41	4600 ± 590	590 ± 280	22	280 ± 37	75 ± 26	9	47 ± 9.0	27 ± 8.0
1985	39	3400 ± 440	710 ± 300	41	910 ± 120	150 ± 47	12	180 ± 24	58 ± 28
1986	28	6100 ± 780	1000 ± 590	38	460 ± 61	100 ± 31	20	110 ± 16	37 ± 10
1987	20	1600 ± 200	220 ± 170	36	130 ± 18	34 ± 7.0	23	48 ± 11	28 ± 4.0
1988	23	1600 ± 210	350 ± 190	45	450 ± 60	70 ± 20	25	46 ± 1.0	30 ± 3.0
1989	21	42 ± 9.0	22 ± 3.0	45	30 ± 9.0	18 ± 1.0	25	28 ± 9.0	20 ± 2.0
1990	6	85 ± 13	33 ± 26	14	55 ± 9.5	23 ± 7.4	6	29 ± 6.2	20 ± 5.2

(a) Maximum single sample results ± 2 sigma counting error. Mean of all samples ± 2 times the standard error of the calculated mean.

(b) n = number of samples.



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FIGURE 5.5. Air Concentrations of Krypton-85 (^{85}Kr) at the 200 ESE, Ringold, and Yakima Locations, 1983 to 1990

indicates that the air measurements were detecting Hanford emissions and that 75% (r^2) of the variance in reported downwind perimeter air concentrations was explained by variances in Site emissions. There was no correlation between annual emissions and air concentrations measured at Yakima (5% significance level, $r = -0.43$), as would be expected for an upwind and distant location.

5.1.4 Air Concentrations of Iodine-129 (^{129}I)

The collection of air samples for ^{129}I analysis began in 1984 and continued through 1992. During this time, 134 samples were analyzed from up to six locations. The results for all samples are shown in Figure 5.6 and Table 5.4. The results ranged from 0.02 to 1800 aCi/m³, with mean concentrations of 260 and 1.2 aCi/m³ for onsite and distant locations, respectively. (One aCi/m³ = 0.000001 pCi/m³.) All measured concentrations of ^{129}I were orders of magnitude less than the 1992 DCG value of 70,000,000 aCi/m³.

Figure 5.7 shows the air concentrations of ^{129}I reported for the 200 ESE, Byers Landing, Ringold, and Yakima locations for 1984 to 1992. For 1986 to 1992 the concentrations of ^{129}I measured at the downwind Site perimeter (Byers

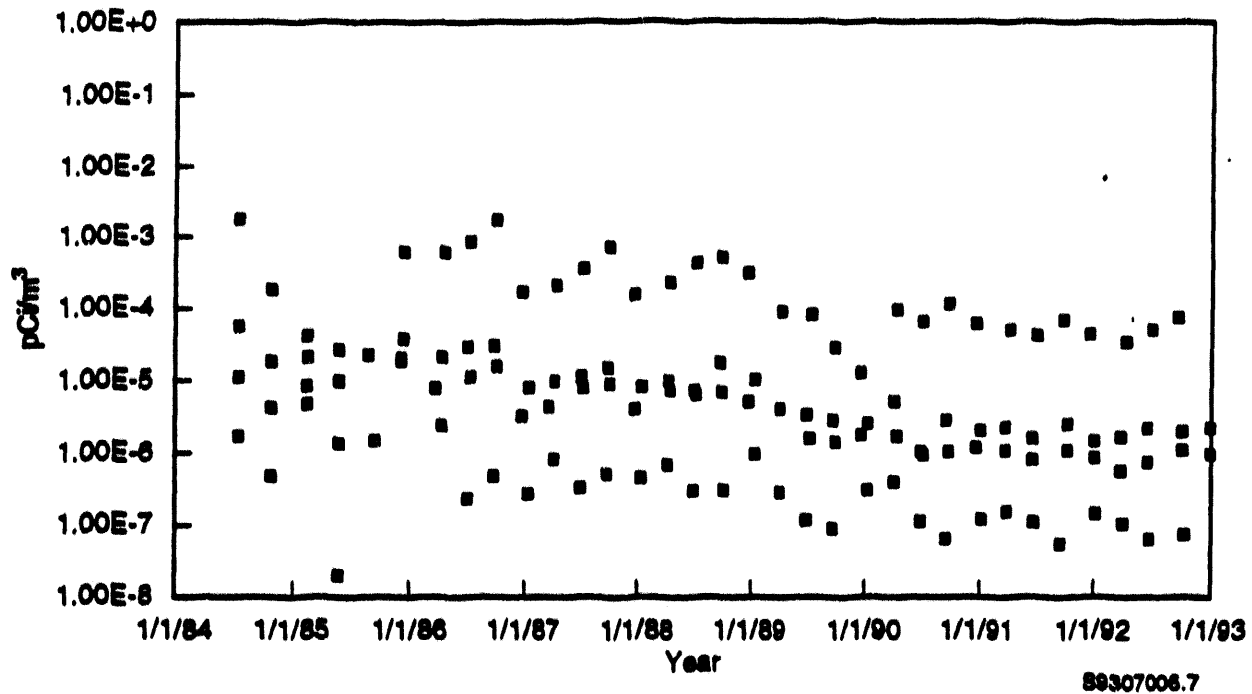


FIGURE 5.6. Air Concentrations of Iodine-129 (^{129}I) at All Locations, 1984 to 1992

Landing and Ringold) were statistically elevated compared to those at the Yakima distant location (two-tailed t test, 5% significance level), indicating a Hanford Site impact to the downwind locations. For all but two samples collected in 1985, the air concentrations of ^{129}I were consistently higher at the onsite locations compared to the downwind perimeter (Ringold and Byers Landing) locations, and the differences between locations were statistically significant (5% level).

There was a correlation (5% significance level, $r = 0.82$) between the annual 200 Area emissions of ^{129}I (all reported ^{129}I emissions for 1983 to 1992 were from the 200 Areas) and the annual average air concentrations reported for the 200 ESE location. In addition, there was a correlation between 200 Area annual emissions and annual average air concentrations for the Ringold location (5% significance level, $r = 0.94$), suggesting that 88% (r^2) of the variance in perimeter air concentrations was explained by variances in Site emissions. Surprisingly, there was no correlation at the 5% significance level between 200 Area emissions and concentrations at the Byers Landing

TABLE 5.4. Airborne Concentrations of Iodine-129 (^{129}I) in the Hanford Environs, 1984 to 1992^(a) (aCi/m³)

Year	Onsite			Perimeter			Distant		
	n ^(b)	Maximum	Mean	n	Maximum	Mean	n	Maximum	Mean
1984	4	2000 ± 300	500 ± 900	2	60 ± 6.0	30 ± 70	2	2.0 ± 0.2	1.0 ± 2.0
1985	7	610 ± 76	110 ± 170	3	21 ± 2.9	17 ± 7.9	4	19 ± 2.3	7.2 ± 9.1
1986	4	1700 ± 230	820 ± 740	8	30 ± 2.5	16 ± 6.6	5	2.4 ± 0.23	0.87 ± 0.85
1987	4	710 ± 54	360 ± 270	8	15 ± 1.2	8.8 ± 2.7	4	0.82 ± 0.08	0.53 ± 0.24
1988	4	500 ± 100	370 ± 120	8	18 ± 3.0	9.0 ± 3.0	4	1.0 ± 0.20	0.60 ± 0.30
1989	4	90 ± 7.7	53 ± 38	7	4.1 ± 0.60	2.5 ± 0.07	4	0.3 ± 0.015	0.20 ± 0.11
1990	4	110 ± 11	84 ± 25	8	5.2 ± 0.39	2.0 ± 1.0	4	0.4 ± 0.049	0.17 ± 0.15
1991	4	69 ± 5.2	51 ± 12	8	2.5 ± 0.13	1.5 ± 0.46	4	0.15 ± 0.013	0.12 ± 0.04
1992	4	74 ± 7.2	50 ± 18	8	2.2 ± 0.15	1.4 ± 0.46	4	0.13 ± 0.013	0.09 ± 0.03

(a) Maximum single sample results ± 2 sigma counting error. Mean of all samples ± 2 times the standard error of the calculated mean.

(b) n = number of samples.



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FIGURE 5.7. Air Concentrations of Iodine-129 (^{129}I) at the 200 ESE, Byers Landing, Ringold, and Yakima Locations, 1984 to 1992

location ($r = 0.33$). This is surprising especially because the Byers Landing location typically reported slightly higher concentrations than those at Ringold. An unexpected result was that the 200 Area annual emissions were correlated with the annual air concentrations measured at the distant location (5% significance level, $r = 0.99$), suggesting that there may be some potential Hanford contribution (albeit small) to the air concentrations reported at the background location.

5.1.5 Air Concentrations of Plutonium-239,240 ($^{239,240}\text{Pu}$)

Air samples were collected for $^{239,240}\text{Pu}$ analysis throughout 1983 to 1992. During this time, 914 samples were analyzed for up to 37 locations (Figure 5.8). The results ranged for -0.028 to 240 aCi/m³, with 10-year mean concentrations of 6.8 and 2.8 aCi/m³ for onsite and distant locations, respectively. Table 5.5 gives the maximum and average concentrations reported for onsite, perimeter, and distant locations during this time. The highest concentrations of $^{239,240}\text{Pu}$ were reported for 1983; however, these data were biased high because a less sensitive analytical technique was used compared to

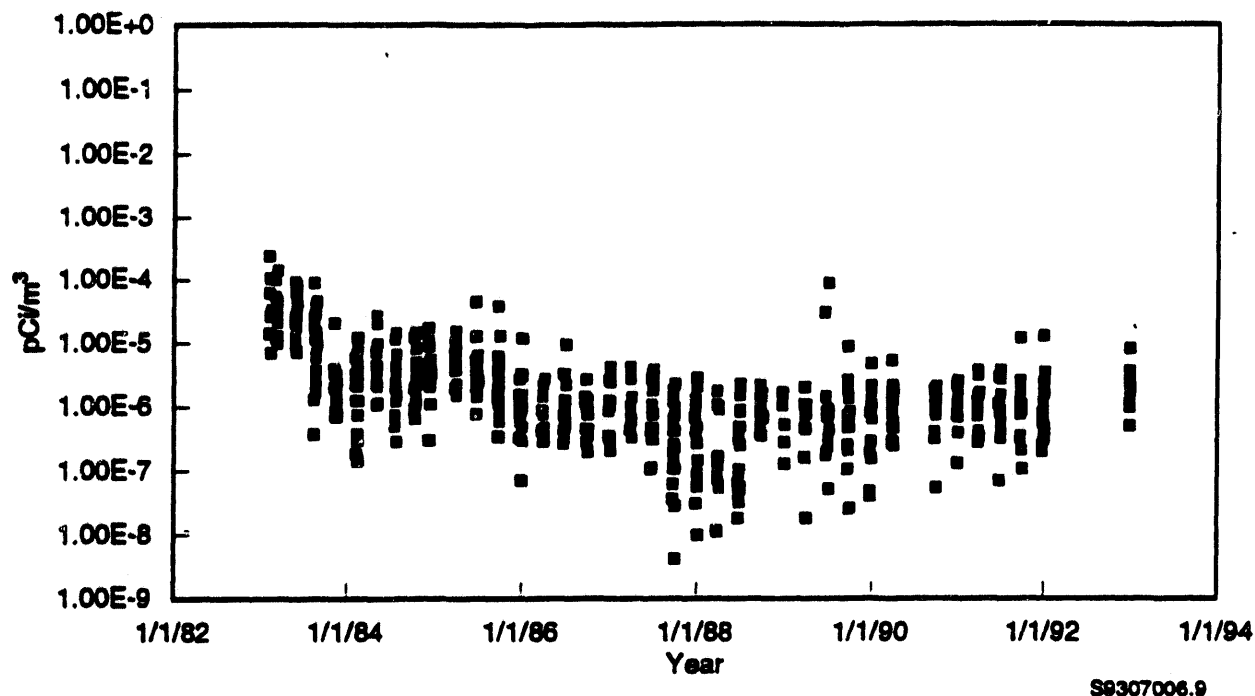


FIGURE 5.8. Air Concentrations of Plutonium-239,240 ($^{239,240}\text{Pu}$) at All Locations, 1983 to 1992

all other years (Pacific Northwest Laboratory 1987, Section 3.1). All measured concentrations were much less than the 1992 DCG value of $20,000 \text{ aCi/m}^3$, with the maximum value being 1.2% of the DCG.

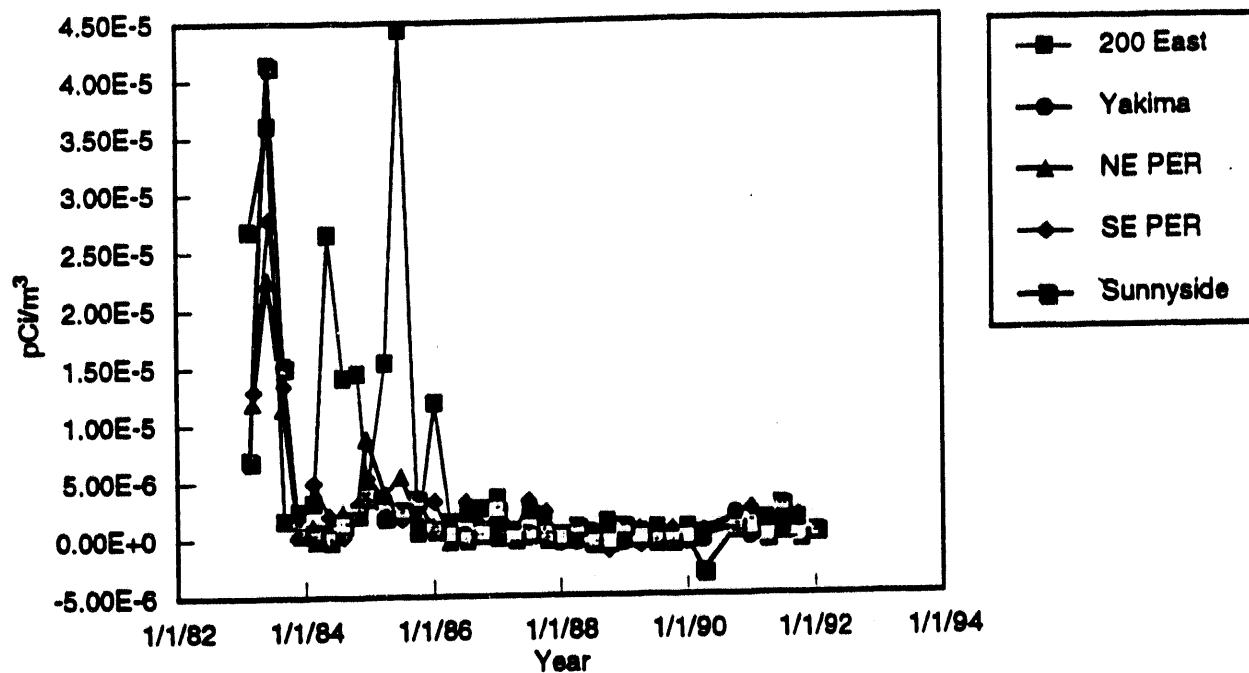
Figure 5.9 shows the air concentrations of $^{239,240}\text{Pu}$ measured at the 200 ESE, Southeast perimeter (the composite group that included the Byers Landing location for all years), Northeast perimeter (the composite group that included the Ringold location for all years), Sunnyside, and Yakima locations for 1983 to 1991 (1992 results were not included because the sample compositing process changed from quarterly to annual composites in 1992). Overall the $^{239,240}\text{Pu}$ air concentrations were elevated during the period 1982 to 1985 (which was before the installation of the fourth high-efficiency particulate air filter on the main stack at the PUREX Plant in 1986), compared to the period from 1986 to 1991. Because the Yakima location was not established until 1986, the values from the upwind and distant Sunnyside location were used to compare air pathway trends from 1982 to 1985, and the more distant

TABLE 5.5. Airborne Concentrations of Plutonium-239,240 ($^{239,240}\text{Pu}$) in the Hanford Environs, 1983 to 1992^(a) (aCi/m³)

Year	Onsite			Perimeter			Distant		
	n ^(b)	Maximum	Mean	n	Maximum	Mean	n	Maximum	Mean
1983	32	240 ± 45	36 ± 18	32	81 ± 49	20 ± 7.1	12	60 ± 50	20 ± 10
1984	40	30 ± 7.0	7.0 ± 2.0	40	10 ± 7.0	3.0 ± 1.0	15	4.0 ± 4.0	2.0 ± 1.0
1985	32	44 ± 8.4	6.4 ± 3.0	31	9.8 ± 6.5	3.2 ± 1.0	12	13 ± 5.1	2.9 ± 2.1
1986	32	9.3 ± 2.8	1.4 ± 0.7	24	3.2 ± 2.3	0.5 ± 0.4	16	3.2 ± 2.3	0.8 ± 0.5
1987	28	4.1 ± 2.9	1.0 ± 0.5	25	3.3 ± 2.3	0.5 ± 2.7	16	2.7 ± 4.3	0.3 ± 0.6
1988	32	3.6 ± 2.8	0.6 ± 0.4	24	0.5 ± 1.1	-0.2 ± 0.3	15	1.0 ± 2.0	0.13 ± 0.28
1989	37	86 ± 11	4.0 ± 4.8	24	1.1 ± 1.3	0.2 ± 0.3	15	1.0 ± 1.2	0.1 ± 0.3
1990	15	5.1 ± 3.0	0.98 ± 0.6	18	2.4 ± 2.3	1.0 ± 0.4	12	2.0 ± 1.8	0.4 ± 0.72
1991	41	12 ± 2.8	1.8 ± 0.8	15	2.5 ± 2.0	0.7 ± 0.4	12	2.8 ± 2.4	0.45 ± 0.50

(a) Maximum single sample results ± 2 sigma counting error. Mean of all samples ± 2 times the standard error of the calculated mean.

(b) n = number of samples.



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FIGURE 5.9. Air Concentrations of Plutonium-239,240 ($^{239,240}\text{Pu}$) at the 200 ESE, Southeast Perimeter (Byers Landing), Northeast Perimeter, Sunnyside, and Yakima Locations, 1983 to 1991

Yakima location was used to compare air pathway trends for 1986 to 1991. For both early and late periods, there were no significant differences (5% level, two-tailed t test) between concentrations measured at the downwind perimeter locations (Southeast Perimeter and Northeast Perimeter) and the distant locations, indicating no measurable Hanford Site impact on the downwind air concentrations. The $^{239,240}\text{Pu}$ air concentrations measured at the 200 ESE location were statistically elevated (5% level, paired two-tailed t test) compared to those at the Northeast Perimeter for both early and late periods, indicating that the sampling system was capable of detecting locally elevated concentrations onsite.

There was a correlation (5% significance level, $r = 0.74$) between the annual Site emissions of $^{239,240}\text{Pu}$ and the annual average air concentrations reported for the 200 ESE location, indicating that 55% (r^2) of the variance in 200 ESE air concentrations was explained by variances in Site emissions. There was no correlation (5% significance level) between annual emissions of

^{239,240}Pu and annual average air concentrations for either the Northeast or Southeast composite results (with $r = 0.12$ and $r = 0.02$, respectively). There was no significant correlation (5% level) between the annual emissions and the concentrations measured at the Yakima location ($r = 0.58$), as would be expected for an upwind and distant location.

5.2 DOSE ESTIMATES (MEI)

Since 1957, the potential radiation dose from Hanford Site operations to members of the public has been calculated and reported (Soldat et al. 1986). During that time, various computer models, associated assumptions, and reporting units have been used to calculate and report radiation doses. In 1989, Soldat (1989) compared the results for two dose calculation methods for offsite radiation dose rates from 1983 to 1987, and this section of the report summarizes those results and conclusions. The most significant change in the method of estimating radiation doses was that by the early 1970s the installation of effluent treatment systems and an overall reduction in the number of operating facilities reduced Site emissions to the point that it was no longer practical to estimate offsite doses based on the near-background concentrations of contaminants reported from direct environmental measurements. In 1974, offsite air pathway doses began to be estimated primarily using Hanford effluent source terms and environmental transport models.

Beginning in 1977, radiation doses were calculated using a 50-year cumulative dose equivalent (CDE). These CDE values used both internal and external exposure from radionuclides remaining in the environment for the 49 years following the year of release. This system was used because it provided the most realistic method of estimating long-term doses available at the time. The system provided conservative estimates for radiation doses for constituents that were present at very low concentrations.

In 1985, the dose estimation method was changed to the present system that evaluates long-term dose in terms of an effective dose equivalent (EDE). The EDE method of dose estimation was recommended by the International Commission on Radiation Protection (ICRP 1977) and adopted by the U.S. Department of Energy in 1985. The EDE calculations include both the internal committed effective dose equivalent (i.e., total dose equivalent accumulated in an organ

or tissue in the 50 year following the uptake of the radionuclide) and the effective dose from external exposure to radionuclides released to the environment during that year. The EDE is the sum of 50-year committed organ doses adjusted by a set of weighting factors. The weighting factors relate the fractional dose contribution from each organ to the total health risk to an individual from a uniform whole-body external irradiation. The EDE method provides dose estimates that more directly relate to human health than did previous methods.

The radiation dose estimates to the MEI from Hanford releases from 1983 to 1992 are listed in Table 5.6 and shown in Figure 5.10. The MEI was calculated as located in the Ringold area (across the Columbia River from the Site and approximately 24 km east-southeast from the PUREX Plant) from 1983 to 1990 (Soldat 1989). For 1991 and 1992, the MEI location changed to the Riverview irrigation area (across the Columbia River from the Site and west of Pasco, Washington), which is roughly 44 km southeast of the PUREX Plant stack. [There was only a difference in dose estimate of about 5% between the Riverview and Ringold MEI (Woodruff et al. 1992, 1993)]. The potential dose (EDE) to the MEI from Hanford effluents (both air and water pathways) ranged from 0.02 to 0.22 mrem/yr, which is less than the 1992 DOE radiation limit for an individual member of the public of 100 mrem/yr and the national average dose from natural sources (300 mrem/yr) (Woodruff et al. 1993). However, as Hanford effluents decreased, the relative effects of diffuse sources (e.g., windblown dust for contaminated areas) have increased. Upper-bound estimates of the dose from this source are summarized in Section 5.2.2.

In 1989, Wedlick et al. reported that ^{220}Rn emissions from the PUREX Plant had been underestimated for the years 1985 to 1988, because of an erroneous parent-to-daughter ratio assumption (^{220}Rn was not reported for earlier years). The dose estimates discussed in this report (Table 5.6) have not been adjusted for these higher ^{220}Rn emissions. Wedlick et al. (1989) calculated the offsite EDE from these releases to be on the order of 0.001 mrem/yr, which is less than 2% of the air pathway dose for those years (Table 5.6).

TABLE 5.6. Radiation Dose Estimates to the Hypothetical Maximally Exposed Individual at the Riverview and Ringold Locations, 1983 to 1992^(a)

<u>Year/Location</u>	<u>GENII^(b) Version</u>	<u>Direct- Air^(c)</u>	<u>Air- Food^(d)</u>	<u>Total Dose</u>	<u>Air Pathway Contribution to Total Dose</u>	<u>Reference</u>
1983 Riverview	1.272	0.012	0.0017	0.049	28%	(e)
1983 Ringold	1.272	0.075	0.0032	0.11	71%	(e)
1984 Riverview	1.272	0.019	0.0058	0.082	30%	(e)
1984 Ringold	1.272	0.069	0.010	0.13	61%	(e)
1985 Riverview	1.272	0.028	0.019	0.12	39%	(e)
1985 Ringold	1.272	0.12	0.037	0.22	71%	(e)
1986 Riverview	1.272	0.024	0.024	0.093	52%	(e)
1986 Ringold	1.272	0.094	0.049	0.19	75%	(e)
1987 Riverview	1.272	0.0018	0.026	0.049	57%	(e)
1987 Ringold	1.272	0.0064	0.055	0.080	77%	(e)
1988 Riverview	-- ^(f)	--	--	--	--	--
1988 Ringold	1.272	0.005	0.06	0.08	61%	(g)
1989 Riverview	--	--	--	--	--	--
1989 Ringold	1.436	0.002	0.009	0.05	22%	(h)
1990 Riverview	--	--	--	--	--	--
1990 Ringold	1.485	0.001	0.01	0.03	36%	(i)
1991 Riverview	1.485	0.001	0.006	0.02	35%	(j)
1991 Ringold	--	--	--	--	--	--
1992 Riverview	1.485	0.001	0.004	0.02	25%	(k)
1992 Ringold	1.485	0.001	0.004	0.02	25%	(l)

(a) ²²⁰Rn emissions from the PUREX Plant were underestimated for 1985 to 1988 (Wedlick et al. 1989). Wedlick et al. calculated the offsite EDE from these releases to be on the order of 0.001 mrem/yr (see Section 5.2). Values in this table have not been adjusted for these higher ²²⁰Rn emissions.

(b) Napler et al. (1988a, 1988b, 1988c).

(c) Includes inhalation, submersion, and direct exposure to ground deposition.

(d) Includes consumption of food contaminated by deposition from air.

(e) Soldat (1989).

(f) Data not published; only the value for the maximum location was given in reference.

(g) Jaquish and Bryce (1989).

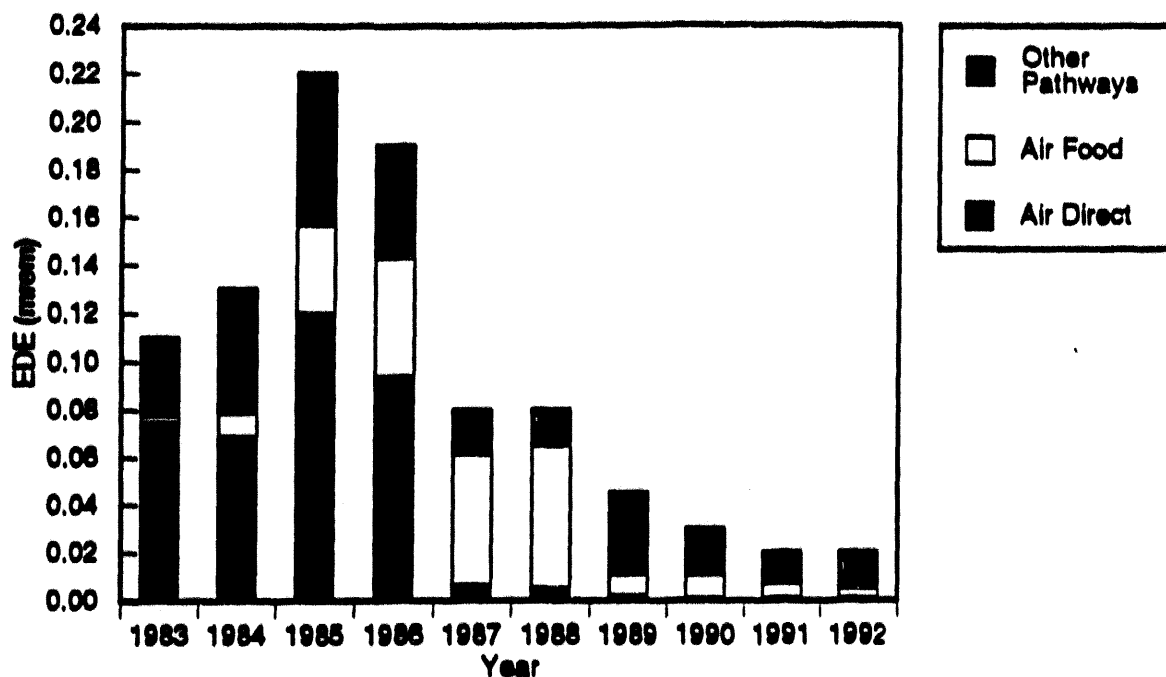
(h) Jaquish and Bryce (1990).

(i) Woodruff et al. (1991).

(j) Woodruff et al. (1992).

(k) Woodruff et al. (1993).

(l) J. K. Soldat, PNL scientist, personal communication, dose summary sheet for SESP, April 13, 1993.



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FIGURE 5.10. Radiation Dose to the Hypothetical Maximally Exposed Individual for Hanford Emissions, 1983 to 1992 (Value from Table 5.6)

5.2.1 Air Pathway

Although the relative contributions changed during the decade of this report, the principal components of the air pathway that contributed to off-site dose were the direct-air component (inhalation, submersion, and direct exposure to ground deposition) and the air-food component (consumption of locally grown food contaminated with radionuclides from airborne Site releases). The radionuclides that contributed the most to dose from the two components were ^{129}I , $^{239,240}\text{Pu}$, ^{241}Am , and decay products of radon.

Although ^{85}Kr was the major airborne radionuclide released as Site emissions from 1983 to 1988, it was only a limited contributor to offsite dose. Krypton-85 is an inert gas that does not accumulate in human tissue or environmental media, and the inhalation dose from ^{85}Kr was small compared to other radionuclides. For example, in 1988 200,000 Ci of ^{85}Kr were released to the air from the 200 Areas; however, the predicted EDE at Ringold was only 0.001 mrem (Jaquish and Bryce 1989). In comparison, in 1988 0.6 Ci of ^{129}I

were released to the air from the 200 Areas but this resulted in a predicted EDE at Ringold of 0.004 mrem, with a thyroid dose of 0.1 mrem.

The direct-air component was the major contributor to offsite dose from 1983 to 1987 (Table 5.6 and Figure 5.10) with a maximum direct-air dose of 0.12 mrem (EDE) for the year 1985 (54% of the total dose from all pathways). The air-food component was the main contributor to offsite dose for 1988, and composed 75% of the total dose from all pathways of 0.08 mrem (EDE). By 1989, the air pathway was no longer the dominant offsite dose pathway, with the total contribution to offsite dose ranging from 22% to 36% for the period from 1989 to 1992. In addition, for 1989 to 1992 the air-food component contributed from 4 to 10 times the offsite dose as the direct-air component. The decreasing trends in offsite dose and the decreasing importance of the direct-air component to the total dose were related to the decrease in Hanford Site air emissions during 1989 to 1992.

5.2.2 Diffuse Source Estimates

The contribution of diffuse sources to offsite dose from Hanford operations (e.g., windblown soil from contaminated areas) has become relatively more significant because of the substantial decrease in airborne releases from facilities. Directly measuring diffuse emissions for trace concentrations of radionuclides from an area as vast as the Hanford Site is not practical at this time. Although specific methods for estimating the dose contribution from diffuse sources are still being developed, some preliminary bounding estimates of the dose from this source have been produced (Woodruff et al. 1992, 1993). These estimates used air concentrations that were measured at receptor locations (corrected for contributions for Site release and regional background) to calculate an upper-bound dose estimate of 0.1 to 0.16 mrem/yr, which was less than the 10-mrem/yr value specified by the Clean Air Act (Woodruff et al. 1993). These estimates were based on conservative assumptions and would be expected to decrease as more refined diffuse source estimation methods are developed. The potential sources of diffuse emission on the Hanford Site are discussed in more detail in the radionuclide air emission reports for calendar years 1991 and 1992 (DOE 1992, 1993).

6.0 CONCLUSIONS

During the period of this report, the SESP air sampling network collected air samples for a wide variety of radionuclides at locations both on and off the Hanford Site. The sampling and analytical systems were sufficiently sensitive to observe locally elevated concentrations of selected radionuclides near onsite sources of emissions, as well as being sufficiently sensitive to observe elevated air concentrations at the downwind perimeter compared to those at the distant locations for some radionuclides. The DOE DCGs were not exceeded for any air sample collected during this period, with the maximum value for an individual sample at any location being less than 5% of the DCG. Annual average concentrations of radionuclides at the downwind perimeter were orders of magnitude less than the DCG values for all radionuclides.

6.1 TRENDS IN AIR CONCENTRATIONS RELATIVE TO SITE EMISSIONS

Air emissions at the Hanford Site during the period of this report were dominated by releases from the PUREX Plant, with ^{85}Kr being the major release on a curie basis and ^{129}I being the major release on a radiological dose basis. Air concentrations of ^{85}Kr measured onsite (200 ESE) and at the downwind perimeter (Ringold) were elevated compared to the Yakima distant station during the 1983-to-1988 period of active PUREX operations. With the cessation of ^{85}Kr emissions from the PUREX Plant, the air concentrations of ^{85}Kr measured onsite and at the downwind perimeter decreased and were not distinguishable from those at the distant location. Air concentrations of ^{129}I were also elevated at the onsite and downwind perimeter locations compared to the distant location during the period of active PUREX emissions. Overall the air concentrations of ^{129}I have decreased at all locations from 1983 to 1992 (tracking the decrease in PUREX emissions). However, following the cessation of active PUREX emissions, the concentrations of ^{129}I measured in air at the downwind perimeter have remained elevated compared to those at the Yakima distant location, indicating the continuation of a measurable Hanford impact at the downwind perimeter. Air concentrations of $^{239,240}\text{Pu}$ measured at the 200 ESE sampling location were highest for the period from 1983 to 1985 and

decreased apparently following the installation of an additional high-efficiency particulate air filter on the PUREX main stack in 1986. There were no apparent trends between Site emissions and measured concentrations of either ^3H or ^{14}C .

Table 6.1 summarizes the linear correlations of annual concentrations measured at the 200 ESE, Ringold, Byers Landing, and Yakima locations compared to annual Site emissions for ^3H , ^{85}Kr , ^{129}I , $^{239,240}\text{Pu}$ (the correlations were considered significant at the 5% level). There was no statistical correlation between annual ^3H emissions and average annual air concentrations measured at any of the above locations. Krypton-85 annual emissions were correlated with the annual average concentrations reported for both the 200 ESE and Ringold locations, with no correlations between emissions and concentrations at the distant location. This pattern of correlations indicates that the air sampling system was detecting Hanford Site emissions, in that a large amount of the variance in air concentrations was explained by variances in Site emissions. Iodine-129 annual emissions were correlated with annual mean concentrations reported at the 200 ESE and Ringold locations; however, there was no correlation between emissions and the levels measured at Byers Landing. An unexpected correlation between ^{129}I emissions and the levels measured at the Yakima distant location was also discovered. Ideally, the distant location should not be impacted by Site emissions (i.e., show no correlation to Site activity), and this correlation may indicate some potential (albeit small) Hanford Site impact at the Yakima location from Site emissions. The $^{239,240}\text{Pu}$ annual emissions were correlated with annual average concentrations measured at the 200 ESE location, but there was no correlation between these emissions and annual average air concentrations measured at any of the other locations.

6.2 COMPARISON OF AIR CONCENTRATIONS AT ONSITE, DOWNWIND, PERIMETER, AND DISTANT LOCATIONS

Table 6.2 summarizes the statistical comparisons (paired two-tailed t-test, 5% significance level) between air concentrations at onsite, perimeter, and distant locations. For all the key radionuclides (^3H , ^{85}Kr , ^{129}I , and $^{239,240}\text{Pu}$), the differences in measured air concentrations between the onsite

TABLE 6.1. Summary of Correlations of Annual Concentrations at Onsite, Downwind Perimeter, and Distant Locations Versus Annual Site Emissions

<u>Radionuclide</u>	<u>Sampling Location</u>	<u>Calculated Value of the Pearson r</u>	<u>Alpha Value at Which the Pearson r is Significant</u>
³ H	200 ESE	0.41	>0.10
	Ringold	-0.02	>0.10
	Byers Landing	0.55	>0.10
	Yakima	0.02	>0.10
⁸⁵ Kr	200 ESE	0.94	<0.01
	Ringold	0.88	0.02
	Yakima	-0.43	>0.10
¹²⁹ I	200 ESE	0.82	<0.01
	Ringold	0.94	<0.01
	Byers Landing	0.33	>0.10
	Yakima	0.99	<0.01
^{239,240} Pu	200 ESE	0.74	0.02
	Ringold	0.12	>0.10
	Byers Landing	0.02	>0.10
	Yakima	0.58	>0.10

200 ESE location compared to those at the perimeter locations as well as those at the 200 ESE location compared those at to the Yakima distant location were statistically significant at the 5% level, indicating that the elevated concentrations reported at the 200 ESE location were influenced by Hanford Site activities. In addition, both ⁸⁵Kr (before the termination of ⁸⁵Kr emissions onsite) and ¹²⁹I air concentrations measured at the Site perimeter were statistically elevated compared to those at the Yakima location. Elevated concentrations at the Site perimeter compared to those at the distant location indicates a Hanford Site influence on the offsite environment. Following the termination of ⁸⁵Kr emissions from the PUREX Plant (end of 1990), there was no statistical difference between air concentrations measured at the Ringold downwind perimeter and those at the Yakima distant location. There was no statistical difference for either ³H or ^{239,240}Pu air concentrations reported for downwind perimeter and distant locations.

TABLE 6.2. Summary of Paired t Tests for Air Concentrations from Onsite, Downwind Perimeter, and Distant Locations

Radionuclide	Location	Paired t test, Significant Difference at Alpha = 0.05	Degrees of Freedom	P < =
³ H	200 ESE versus Ringold	Yes	79	0.0000
	200 ESE versus Byers Landing	Yes	79	0.0000
	200 ESE versus Yakima	Yes	44	0.0000
	Ringold versus Yakima	No	40	0.3681
	Byers Landing versus Yakima	No	40	0.5518
⁸⁵ Kr (1983 to 1988)	200 ESE versus Ringold	Yes	48	0.0000
	200 ESE versus Yakima	Yes	30	0.0000
	Ringold versus Yakima	Yes	24	0.0032
⁸⁵ Kr (1989 to 1990)	200 ESE versus Ringold	No	8	0.1205
	200 ESE versus Yakima	No	14	0.2770
	Ringold versus Yakima	No	8	0.1311
¹²⁹ I	200 ESE versus Ringold	Yes	26	0.0000
	200 ESE versus Byers Landing	Yes	31	0.0000
	200 ESE versus Yakima	Yes	27	0.0000
	Ringold versus Yakima	Yes	26	0.0000
	Byers Landing versus Yakima	Yes	27	0.0000
^{239,240} Pu (1983 to 1985)	200 ESE versus NE Perimeter ^(a)	Yes	12	0.0394
	200 ESE versus SE Perimeter ^(a)	No	12	0.0861
	200 ESE versus Sunnyside	No	11	0.0517
	NE Perimeter ^(a) versus Sunnyside	No	11	0.1350
	SE Perimeter ^(a) versus Sunnyside	No	11	0.3556
^{239,240} Pu (1986 to 1992)	200 ESE versus NE Perimeter ^(a)	Yes	13	0.0017
	200 ESE versus SE Perimeter ^(a)	No	12	0.5421
	200 ESE versus Yakima	Yes	10	0.0053
	NE Perimeter ^(a) versus Yakima	No	7	0.7830
	SE Perimeter ^(a) versus Yakima	No	8	0.1162

(a) See Section 5.1.

6.3 DOSE SUMMARY

The estimated potential dose from Hanford Site point source emissions to the MEI ranged from 0.02 to 0.22 mrem/yr (EDE) during the period of this report, which was much less than the 1992 DOE radiation limit (100 mrem/yr) for an individual member of the public and considerably less than the national average dose from natural sources (300 mrem/yr). The air pathway was the major contributor to offsite dose for the years 1983 to 1989. The direct-air component (inhalation, submersion, and direct exposure to ground deposition) was the major contributor to offsite dose from 1983 to 1986, with the air-food component being the major contributor to offsite dose for 1987 and 1988. By 1989, the air pathway was no longer the major contributor to offsite dose. The decreasing trends in offsite dose and decreasing importance of the direct-air component was related to the decrease in Hanford Site emissions during this period. However, with the decrease in Hanford Site point source emissions, the relative importance of diffuse sources (e.g., wind-blown soil from contaminated areas) has increased. Although methods to calculate the impact from diffuse sources are still being developed, an upper-bound estimate of the offsite dose from diffuse sources at the Hanford Site of 0.1 to 0.16 mrem/yr has been calculated. During the period of this report, the estimated dose from both point sources and diffuse emissions was less than the 10-mrem/yr limit specified by the Clean Air Act.

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