Hanford Site

Environmental Report 1994

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Hanford Site Environmental Report for Calendar Year 1994

Scientific Editors

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Preface

U.S. Department of Energy (DOE) Order 5400.1, "General Environmental Protection Program," establishes the requirement for environmental protection programs at DOE sites and facilities. These programs ensure that DOE operations comply with applicable federal, state, and local environmental laws and regulations, executive orders, and department policies. The DOE, Richland Operations Office, has established a plan for implementing this order, *United States Department of Energy Richland Operations Office Environmental Protection Implementation Plan, November 9, 1994, to November 9, 1995* (DOE 1994a). This plan is updated annually.

The Hanford Site Environmental Report is prepared annually pursuant to DOE Order 5400.1 to summarize environmental data that characterize Hanford Site environmental management performance and demonstrate compliance status. The report also highlights significant environmental programs and efforts. More detailed environmental compliance, monitoring, surveillance, and study reports may be of value; therefore, to the extent practical, these additional reports have been referenced in the text.

Although this report was written to meet DOE reporting requirements and guidelines, it was also intended to be useful to members of the public, public officials, regulators, and Hanford Site contractors. The "Helpful Information" section lists acronyms, abbreviations, conversion information, and nomenclature useful for understanding the report.

This year, the report has been issued in both hard copy and electronic formats. As a result, fewer printed copies of the report have been produced. This cost-saving action is in line with other budget reduction efforts currently taking place at many DOE facilities and should have little impact on report availability; a significant number of report users now have access to both citywide and worldwide computer information networks. Hanford workers can access the report over the Hanford Local Area Network, and others will find the report available on the Internet (the address is http://w3.pnl.gov:2080/env/env_home.html).

This report is prepared for the Richland Operations Office, Quality, Safety, and Health Programs Division by the Pacific Northwest Laboratory's Office of Health and Environment as part of the Public Safety and Resource Protection Program. Pacific Northwest Laboratory is operated for DOE by Battelle Memorial Institute, a not-for-profit independent contract research institute. Major portions of the report were written by staff from the Pacific Northwest Laboratory (the Site research and development contractor) and Westinghouse Hanford Company (the Site operating and engineering contractor). The Washington Department of Fish and Wildlife and the Richland office of the U.S. Army Corps of Engineers also provided input to selected sections.

Copies of this report have been provided to many libraries in communities around the Hanford Site, and to several university libraries in Washington and Oregon. Copies can also be found at DOE's Hanford Reading Room located on the campus of Washington State University Tri-Cities. Copies of the report can be purchased from the National Technical Information Center, Springfield, Virginia 22161.

Inquiries regarding this report may be directed to the DOE Richland Operations Office, Quality, Safety, and Health Programs Division, P.O. Box 550, Richland, Washington 99352, or to Mr. Roger Dirkes, Pacific Northwest Laboratory, P.O. Box 999, Richland, Washington 99352.

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Summary

The Hanford Site Environmental Report is prepared annually to summarize environmental data and information, describe environmental management performance, and demonstrate the status of compliance with environmental regulations. The report also highlights major environmental programs and efforts.

The report is written to meet reporting requirements and guidelines of the U.S. Department of Energy (DOE) and to meet the needs of the public. This summary has been written with a minimum of technical terminology.

Individual sections of the report are designed to

- describe the Hanford Site and its mission
- summarize the status in 1994 of compliance with environmental regulations
- describe the environmental programs at the Hanford Site
- discuss estimated radionuclide exposure to the public from 1994 Hanford activities
- present information on effluent monitoring and environmental surveillance, including ground-water protection and monitoring
- discuss activities to ensure quality.

More detailed information can be found in the body of the report, the appendixes, and the cited references.

The Hanford Site and its Mission

The Hanford Site in southcentral Washington State is about 1,450 square kilometers (560 square miles) of semiarid shrub and grasslands located just north of the confluence of the Snake and Yakima rivers with the Columbia River. This land, with restricted public access, provides a buffer for the smaller areas historically used for the production of nuclear materials, waste storage, and waste disposal. About 6% of the land area has been disturbed and is actively used. This 6% is divided into operational areas:

- the 100-B/C, 100-D, 100-F, 100-H, 100-K, and 100-N Areas, which lie along the south shore of Columbia River in the northern portion of the Hanford Site
- the 200-East and 200-West Areas, which lie in the center of the Hanford Site near the basalt outcrops of Gable Mountain and Gable Butte
- the 300 Area, near the southern border of the Hanford Site
- the 400 Area, between the 300 and 200 Areas (home of the Fast Flux Test Facility [FFTF])
- the 1100 Area, a corridor northwest of the city of Richland used for vehicle maintenance and other support activities.

The 600 Area is the designation for land between the operational areas. Areas off the Hanford Site used for research and technology development and administrative functions can be found in Richland, Kennewick, and Pasco, the nearest cities.

The Hanford Site was acquired by the federal government in 1943 and for many years was dedicated primarily to the production of plutonium for national defense and the management of the resulting wastes. With the shutdown of the production facilities in the 1970s and 1980s, missions were diversified to include research and development in the areas of energy, waste management, and environmental restoration.

The DOE has ended the production of nuclear materials at the Hanford Site for weapons. The current mission being implemented by the DOE, Richland Operations Office, is now:

- waste management/cleanup
- technology development
- economic diversification.

Current waste management activities at the Hanford Site include primarily managing wastes with high and low levels of radioactivity (from the nuclear materials production activities) in the 200-East and 200-West Areas. Key waste management facilities include the waste storage tanks, Plutonium Uranium Extraction (PUREX) Plant, Plutonium Finishing Plant, Central Waste Complex, Low-Level Burial Grounds, B Plant, and 242-A Evaporator. In addition, irradiated nuclear fuel is stored in the 100-K Area in fuel storage basins.

Environmental restoration includes activities to decontaminate and decommission facilities and to clean up or restore inactive waste sites. The Hanford surplus facilities program conducts surveillance and maintenance of such facilities, and has begun to clean up and dispose of more than 100 facilities.

Research and technology development activities are intended to improve the techniques and reduce the costs of waste management, environmental protection, and Site restoration.

Operations and activities on the Hanford Site are managed by the Richland Operations Office through four prime contractors and numerous subcontractors. Each contractor is responsible for the safe, environmentally sound maintenance and management of its facilities and operations, waste management, and monitoring of operations and effluents for environmental compliance.

The principal contractors include:

- Westinghouse Hanford Company
- Battelle Memorial Institute
- Hanford Environmental Health Foundation
- Bechtel Hanford Incorporated.

Non-DOE operations and activities include commercial power production by the Washington Public Power Supply System's WNP-2 Reactor (near the 400 Area) and commercial low-level radioactive waste burial at a site leased and licensed by the state of Washington and operated by US Ecology (near the 200 Areas). Siemens Power Corporation operates a commercial nuclear fuel fabrication facility, and Allied Technology Group Corporation operates a low-level radioactive waste decontamination, supercompaction, and packaging disposal facility near the southern boundary of the Hanford Site.

Compliance With Environmental Regulations

The DOE Order 5400.1, "General Environmental Protection Program," describes the environmental standards and regulations applicable at DOE facilities. These environmental standards and regulations fall into three categories: 1) DOE directives, 2) federal legislation and executive orders, and 3) state and local statutes, regulations, and requirements. The following subsections summarize the status of Hanford's compliance with these applicable regulations and list environmental occurrences for 1994.

A key element in Hanford's compliance program is the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement). The Tri-Party Agreement is an agreement among the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), and DOE for achieving compliance with the remedial action provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (including Superfund Amendments and Reauthorization Act [SARA]) and with treatment, storage, and disposal unit regulation and corrective action provisions of the Resource Conservation and Recovery Act (RCRA).

Comprehensive Environmental Response, Compensation, and Liability Act

The CERCLA established a program to ensure that sites contaminated by hazardous substances are cleaned up by responsible parties or the government. The SARA broadened CERCLA and established provisions for federal facilities. CERCLA primarily covers waste cleanup of inactive sites.

The preliminary assessments conducted for the Hanford Site revealed approximately 1,100 known individual waste sites where hazardous substances may have been disposed of in a manner that requires further evaluation to determine impact to the environment.

The DOE is actively pursuing the remedial investigation/feasibility study process at some operable units on the Hanford Site. The selection of the operable units currently under investigation is a result of Tri-Party Agreement negotiations. The Hanford Site was in compliance with these CERCLA/SARA requirements in 1994.

Emergency Planning and Community Right-To-Know Act

The Emergency Planning and Community Right-To-Know Act requires that the public be provided with information about hazardous chemicals in the community and establishes emergency planning and notification procedures to protect the public from a release. Subtitle A of the law calls for creation of

state emergency response commissions to guide planning for chemical emergencies. State commissions have also created local emergency planning committees to ensure community participation and planning.

To provide the public with the basis for emergency planning, Subtitle B of the Act contains requirements for periodic reporting on hazardous chemicals stored and/or used near the community. The *1994 Hanford Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1995a) was issued to the State Emergency Response Commission, local county emergency management committees, and local fire departments. The report contained information on hazardous materials in storage across the Hanford Site. The *1993 Hanford Toxic Chemical Release Inventory* (DOE 1994b) was issued in July 1994 to the EPA and the state. This report contains information on releases to the environment of chemicals that were in excess of mandated thresholds. Accordingly, during 1994, the Hanford Site was in compliance with the reporting and notification requirements contained in this Act.

Resource Conservation and Recovery Act

The RCRA establishes regulatory standards for the generation, transportation, storage, treatment, and disposal of hazardous wastes. Ecology has been authorized by the EPA to implement its dangerous waste program in lieu of the EPA for Washington State, except for some provisions of the Hazardous and Solid Waste Amendments of 1984. Ecology also implements the state's regulations, which are often more stringent. RCRA primarily covers ongoing waste management at active facilities.

At the Hanford Site, over 60 treatment, storage, and disposal units have been identified that must be permitted or closed in accordance with RCRA and Washington State regulations. These units are required to operate under Ecology's interim-status compliance requirements. Approximately one-half of the units will be closed.

Subtitle I of RCRA deals with regulation of underground storage tank systems. These regulations were added to RCRA by the Hazardous and Solid Waste Amendments of 1984. The EPA has developed regulations implementing technical standards for tank performance and management, including standards governing the cleanup and closure of leaking tanks. These regulations do not apply to the single- and double-shell nuclear waste tanks, which are regulated as treatment, storage, and disposal facilities.

Clean Air Act

The purpose of the Clean Air Act is to protect public health and welfare by safeguarding air quality, bringing polluted air into compliance, and protecting clean air from degradation. In Washington State, the provisions of the Act are implemented by EPA, Ecology, Washington State Department of Health, and local air authorities.

The Washington State Department of Health, Division of Radiation Protection, Air Emissions and Defense Waste Section, has developed regulatory controls for radioactive air emissions under Section 116 of the Clean Air Act. Washington State regulations (Washington Administration Code [WAC] 246-247) require registration of all radioactive air emission point sources with the Washington State Department of Health. All significant Hanford Site stacks emitting radiation have been registered in accordance with applicable regulations.

Revised Clean Air Act requirements for radioactive air emissions were issued December 15, 1989, under National Emission Standards for Hazardous Air Pollutants, 40 Code of Federal Regulations 61 (40 CFR 61), Subpart H. Emissions from the Hanford Site,are well within the new EPA offsite emissions standard of 10 millirem/year (effective dose equivalent [see Appendix B, "Glossary"]). Hanford Site sources are in the process of meeting the procedural requirements for flow measurement, emissions measurement, quality assurance, and sampling documentation.

Pursuant to this program, EPA has developed regulations specifically addressing asbestos emissions (40 CFR 61, Subpart M). These regulations apply at the Hanford Site in building demolition/disposal and waste disposal operations. During 1994, 2,063 cubic meters (72,860 cubic feet) of asbestos were removed.

The local air authority, the Benton-Franklin Counties Clean Air Authority, enforces Regulation 1. This regulation pertains to detrimental effects, fugitive dust, incineration products, open burning, odor, opacity, asbestos, and emissions. The Authority has

also been delegated responsibility to enforce the EPA asbestos regulations under the National Emission Standards for Hazardous Air Pollutants. The Site remains in compliance with the regulations.

Clean Water Act

The Clean Water Act applies to point discharges to waters of the United States. At the Hanford Site, the regulations are applied through a National Pollutant Discharge Elimination System (NPDES) permit governing effluent discharges to the Columbia River. The permit (No. WA-000374-3) specifies discharge points (called outfalls), effluent limitations, and monitoring requirements. There were no instances of noncompliance in 1994 for this permit. NPDES permit No. WA-002591-7 was issued to the 300 Area Treated Effluent Disposal Facility that became operational on December 31, 1994.

Safe Drinking Water Act

The National Primary Drinking Water Regulations of the Safe Drinking Water Act apply to the drinking water supplies at the Hanford Site. These regulations are enforced by the Washington State Department of Health. In 1994, all Hanford Site water systems were in compliance with requirements and agreements.

Toxic Substances Control Act

The application of Toxic Substances Control Act requirements to the Hanford Site essentially involves regulation of the chemicals called polychlorinated biphenyls (PCBs). The Hanford Site is currently in compliance with regulations for nonradioactive PCBs. All radioactive PCB wastes are being stored pending development of treatment and disposal technologies and capabilities.

Federal Insecticide, Fungicide, and Rodenticide Act

The EPA is responsible for ensuring that a chemical, when used according to label instructions, will not present unreasonable risks to human health or the environment. This Act and the Revised Code of Washington (RCW) 17.21, "Washington Pesticide Application Act, 1961," as implemented by WAC 16-228, "General Pesticides Regulations," apply to storage and use of pesticides. In 1994, the Hanford Site was in compliance with the Act's requirements and WAC 16-228 regulations pertaining to storage and application of pesticides.

Endangered Species Act

A few rare species of native plants and animals are known to occur on the Hanford Site. Some of these are listed by the U.S. Fish and Wildlife Service as endangered or threatened (federally listed). Others are listed by the Washington Department of Fish and Wildlife as endangered, threatened, or sensitive species. The Site monitoring program is discussed in Section 4.2, "Wildlife." Hanford Site activities complied with the Endangered Species Act in 1994.

National Historic Preservation Act, Archaeological Resources Protection Act, Native American Graves Protection and Repatriation Act, and American Indian Religious Freedom Act

Cultural resources on the Hanford Site are subject to the provisions of these Acts. Compliance with these Acts is accomplished through a management and monitoring program, which is described in Section 4.3, "Hanford Cultural Resources Laboratory." In 1994, Hanford Site operations complied with these Acts.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) establishes environmental policy to prevent or eliminate damage to the environment and to enrich our understanding of ecological systems and natural resources. The NEPA requires that major federal projects with significant impacts be carefully reviewed and reported to the public in environmental impact statements (EISs). Other NEPA documents such as environmental assessments are also prepared in accordance with NEPA requirements.

Several EISs related to programs or activities on the Hanford Site are in process or in the planning stage.

Environmental Occurrences

Onsite and offsite environmental occurrences (spills, leaks, etc.) of radioactive and nonradioactive effluent materials during 1994 were reported to DOE as specified in DOE Order 5000.3B and to other federal and state agencies as required by law. All emergency, unusual, and off-normal occurrence reports, including event descriptions and corrective actions, are available for review in the DOE Public

Reading Room, Washington State University Tri-Cities campus, Richland, Washington. There were no emergency occurrences reported in 1994. There were 33 unusual occurrence reports for 1994. There were 16 off-normal environmental release-related occurrence reports filed at the Hanford Site during 1994.

Environmental Programs

Environmental programs were conducted at the Hanford Site to restore environmental quality, manage waste, develop appropriate technology for cleanup activities, and study the environment. These programs are discussed below.

Wildlife inhabiting the Hanford Site is monitored to determine the status and condition of the populations, and to assess effects of Hanford Site operations. Particular attention is paid to species that are rare, threatened, or endangered nationally or statewide and those species that are of commercial, recreational, or aesthetic importance statewide or locally. These species include the bald eagle, chinook salmon, Rocky Mountain elk, mule deer, Canada goose, several species of hawk, and other bird species. Fluctuations in wildlife and plant species on the Hanford Site appear to be a result of natural ecological factors and management of the Columbia River system.

The Hanford Cultural Resources Laboratory was established by the Richland Operations Office in 1987 as part of the Pacific Northwest Laboratory. Cultural resources on the Hanford Site are closely monitored, and projects are relocated to avoid sites in cases where there is a possibility of altering any properties that may be eligible for listing on the National Register of Historic Places.

It appears that erosive processes and human activities are the most significant factors affecting most sites and buildings. Wind erosion from off-road vehicle use and vandalism plays a big part in the deterioration of sites inside and outside the Site boundary while alteration or demolition activities cause impacts to buildings and/or structures.

The community-operated environmental surveillance program was initiated in 1990 to increase the public's involvement in and awareness of Hanford's surveillance program. Three surveillance stations continued operation in 1994.

Environmental Monitoring Information

Environmental monitoring of the Hanford Site consists of 1) effluent monitoring and 2) environmental surveillance including ground-water monitoring. Effluent monitoring is performed as appropriate by the operators at the facility or at the point of release to the environment. Additional monitoring is conducted in the environment near facilities that discharge or have discharged effluents. Environmental surveillance consists of sampling and analyzing environmental media on and off the Hanford Site to detect and quantify potential contaminants, and to assess their environmental and human health significance.

The overall objectives of the monitoring and surveillance programs are to demonstrate compliance with applicable federal, state, and local regulations; confirm adherence to DOE environmental protection policies; and support environmental management decisions.

The following sections discuss the doses calculated from environmental data, and effluent monitoring and environmental surveillance on or near the Hanford Site in 1994.

Potential Radiation Doses from 1994 Hanford Operations

In 1994, potential public doses resulting from exposure to Hanford liquid and gaseous effluents were evaluated to determine compliance with pertinent regulations and limits. These doses were calculated from reported effluent releases and environmental surveillance data using Version 1.485 of the GENII code (Napier et al. 1988a, 1988b, 1988c) and Hanford site-specific parameters. Specific information on sample collection and analyses and the sample results used in these calculations are briefly discussed in the following summary sections discussing effluent monitoring and environmental surveillance.

The potential dose to the hypothetical maximally exposed individual (MEI) in 1994 from Hanford operations was 0.05 mrem (5×10^{-4} mSv), compared to 0.03 mrem (3×10^{-4} mSv) calcu-

lated for 1993. The potential dose to the local population of 380,000 persons from 1994 operations was 0.6 person-rem (0.006 person-Sv), compared to 0.4 person-rem (0.004 person-Sv) reported for 1993. The 1994 average dose to the population was 0.002 mrem (2×10^{-5} mSv) per person. The current DOE radiation limit for an individual member of the public is 100 mrem/yr (1 mSv/yr), and the national average dose from natural sources is 300 mrem/yr (3 mSv/yr). The MEI potentially received 0.05% of the DOE dose limit and 0.02% of the national average background dose from natural sources. The average individual potentially received 0.002% of the standard and 6×10^{-4} of the 300 mrem/yr received from typical natural sources.

Special exposure scenarios not included in the above dose estimates include the potential consumption of game residing on the Hanford Site and exposure to radiation at the publicly accessible location with the maximum exposure rate. Doses from these sources would also have been small compared to the dose limit.

Dose through the air pathways was 0.1% of the EPA limit of 10 mrem/yr (40 CFR 61).

Effluent Monitoring

Effluent monitoring includes facility effluent monitoring (monitoring effluents at the point of release to the environment) and near-facility environmental monitoring (monitoring the environment near operating facilities).

Facility Effluent Monitoring

Liquid and gaseous effluents that may contain radioactive and hazardous constituents are continually monitored at the Hanford Site. Facility operators monitor effluents mainly through analyzing samples collected near points of release into the environment. Effluent monitoring data are evaluated to determine their degree of compliance with applicable federal, state, and local regulations and permits.

Measuring devices are used to quantify most facility effluent flows, with a smaller number of flows calculated using process information. Liquid and gaseous effluents with a potential to contain radioactivity at prescribed threshold levels are monitored for total alpha and total beta activity and, as warranted, specific gamma-emitting radionuclides. Nonradioactive hazardous constituents are also monitored, as applicable.

Radioactive effluents from many facilities on the Site are approaching levels practically indistinguishable from the natural occurring radioactivity present everywhere. This decrease translates to a very small offsite radiation dose attributable to Site activities. A new Site mission of environmental restoration rather than nuclear materials production is largely responsible for this trend. Consistent with these conditions of diminishing releases, totals of radionuclides in effluents released at the Site in 1994 are not significantly different from totals in 1993.

Near-Facility Environmental Monitoring

The near-facility environmental monitoring program operated by Westinghouse Hanford Company provides environmental monitoring to protect the environment adjacent to facilities and ensure compliance with local, state, and federal environmental regulations.

Specifically, the near-facility environmental monitoring program monitored new and existing sites, processes, and facilities for potential impacts and releases; fugitive emissions and diffuse sources from contaminated areas; and surplus facilities before decontaminating or decommissioning. External radiation dose, ambient air particulates, soil, surface water, sediment, and biota were sampled. Parameters included, as appropriate, radionuclides, radiation exposure, hazardous constituents, pH, and water temperature.

The analytical results showed a large degree of variability; in general, the samples collected from media located on or directly adjacent to the waste disposal and other nuclear facilities had significantly higher concentrations than those farther away. As expected, certain radionuclides were found in higher concentrations within different operational areas. Generally speaking, the predominant radionuclides were activation products/gamma emitters in the 100 Areas, fission products in the 200/600 Areas, and uranium in the 300 Area.

Air Monitoring. Radioactivity in air was sampled by a network of continuously operated samplers at 41 locations near facilities: 4 located in the 100-K Area, 4 located in the 100-N Area, 31 in the

200/600 Areas, one located near the 300 Area Treated Effluent Disposal Facility, 1 station collocated with the Surface Environmental Surveillance Project and the Washington State Department of Health at the Wye Barricade. Air samplers were primarily located at or near sites and/or facilities having the potential or history for release, with an emphasis on the prevailing downwind directions. Of the radionuclide analyses performed, cesium-137, plutonium-239,240, strontium-90, and uranium were consistently detectable in the 200 Areas; cobalt-60 was detectable in the 100-N Area. Air concentrations for these radionuclides were elevated near facilities when compared to the concentrations measured offsite by the Surface Environmental Surveillance Project.

Monitoring of Surface-Water Disposal Units and Springs. Sampling of surface-water disposal units included water, sediment, and aquatic vegetation. Samples taken at river shoreline springs included water only. Radiological analysis of liquid samples from surface-water disposal units included plutonium-239,240, total alpha, total beta, tritium, and gamma-emitting radionuclides. Radiological analysis of sediment and aquatic vegetation included plutonium-239,240, strontium-90, uranium, and gamma-emitting radionuclides. Nonradiological analysis performed included pH, temperature, and nitrates.

Radionuclide concentrations in surface-water disposal units were below the applicable Derived Concentration Guides used as indexes of performance and in most cases at or below the analytical detection limit. Although some elevated levels were seen in both aquatic vegetation and sediment, in all cases the radiological analytical results were well below the standards for radiological control. The results for pH were well within the pH range of 2.0 - 12.5 standard for liquid effluent discharges as required by RCRA. The analytical results for nitrates were all below the 45-mg/L Drinking Water Standard.

Ground-water springs along the 100-N Area shoreline are sampled to verify the reported radionuclide releases to the Columbia River from past operations of the N Reactor. By characterizing the radionuclide concentrations in the springs along the shoreline, the results can be compared to the concentrations measured in the facility effluent monitoring well.

In 1994, the concentrations detected in the springs samples were highest in those springs nearest the facility effluent monitoring well, although the springs concentrations were considerably lower than those measured in the well.

Radiological Surveys. There were approximately 2,756 hectares (6,364 acres) of outdoor posted surface contamination and 981 hectares (2,423 acres) of posted underground radioactive material sitewide in 1994. These areas were typically associated with cribs, burial grounds, tank farms, and covered ponds, trenches, and ditches. The number of posted surface contamination areas varied because of an ongoing effort to clean, stabilize, and remediate areas of known contamination while new areas of contamination were being identified. New areas may have been identified because of contamination migration or the increased effort being made to investigate outdoor areas for radiological contamination. It was estimated that the external dose rate for 80% of the identified outdoor surface contamination areas was less than 1 millirem/hour, although isolated radioactive specks (less than 0.6 centimeters or 0.25 inches) could be considerably higher. Contamination levels of this type would not significantly add to external dose rates for the public or Site employees.

Soil and Vegetation Monitoring. Soil and vegetation samples were also collected on or adjacent to waste disposal units and from locations downwind and within the operating environment of facilities. Special samples were taken where physical or biological transport problems were identified. Soil and vegetation sample concentrations for some radionuclides were elevated near facilities when compared to the concentrations measured offsite. The concentrations show a large degree of variance; in general, samples collected on or directly adjacent to waste disposal facilities had significantly higher concentrations than those collected farther away.

External Radiation. External radiation fields were surveyed near operating facilities and waste-handling, storage, and disposal sites to measure, assess, and control the impacts of operations.

Hand-held microroentgen meters (to measure low-level radiation exposure) were used in the 100-N

Area to survey points near and within the N Springs area, 1301-N Liquid Waste Disposal Facility, and 1325-N Liquid Waste Disposal Facility. The radiation rates measured in the N Springs area continued to decline in 1994, reflecting discontinued discharges to the 1301-N Liquid Waste Disposal Facility and the continuing decay of its radionuclide inventory. Radiation measurements taken at the 1325-N Liquid Waste Disposal Facility in 1994 and in the previous years were slightly elevated. Discontinued discharges to the facility resulted in the loss of the water that formerly provided shielding for the gamma-emitting radionuclides in sediments of the facility.

Radiation levels measured with thermoluminescent dosimeters were highest near facilities that had contained or received liquid effluent from N Reactor, primarily the 1325-N Liquid Waste Disposal Facility and the 1301-N Liquid Waste Disposal Facility. Dose rates for 1994 for these two facilities decreased approximately 5% compared to 1993.

The highest dose rates measured in the 200/600 Areas were near waste-handling facilities such as tank farms. The average annual dose rate for 1994 in the 200/600 Areas was 160 mrem/year, which was a decrease of 6% when compared to 1993.

The highest dose rates measured in the 300 Area were near waste-handling facilities such as the 340 Waste Handling Facility. The average annual dose rate for 1994 in the 300 Area was 170 mrem/year, which was a 15% decrease of the average dose rate of 200 mrem/year measured in 1993.

The highest dose rates measured in the 400 Area were near the main gate of the Fuels and Materials Examination Facility. The average annual dose rate for 1994 in the 400 Area was 110 mrem/year, an increase of 12% of the average annual dose rate of 98 mrem/year in 1993.

Environmental Surveillance

Environmental surveillance at the Hanford Site includes sampling environmental media on and off the Site for potential chemical and radiological contaminants originating from Site operations. The media sampled included air, surface water, soil and vegetation, fish and wildlife, food and farm products, external radiation levels, and ground water.

Air Surveillance

Atmospheric releases of radioactive and nonradioactive materials from the Hanford Site to the surrounding region represent a potential pathway for human exposure. Radioactive materials in air were sampled continuously at 36 locations onsite, at the Site perimeter, and in nearby and distant communities, and at 3 community-operated environmental surveillance stations that were managed and operated by local school teachers. Particulates were filtered from the air at all locations and analyzed for radionuclides. Air was sampled and analyzed for selected gaseous radionuclides at key locations. Several radionuclides released at the Hanford Site are also found world-wide from two other sources: naturally occurring radionuclides and radioactive fallout from nuclear activities worldwide. The potential influence of emissions from Site activities on local radionuclide concentrations was evaluated by comparing differences between concentrations measured at distant locations within the region and concentrations measured at the Site perimeter.

For 1994, no differences were observed between the annual average total beta air concentrations measured at the Site perimeter and distant community locations. Air concentrations of total alpha are slightly elevated at the Site perimeter and nearby communities were within the range of historical values. Numerous specific radionuclides in quarterly composite samples were analyzed using gamma scan analysis; however, no radionuclides of Hanford origin were detected consistently.

Tritium concentrations for 1994 were similar to values reported for previous years and did not show the highly elevated and variable results reported for 1991 and 1992. The tritium samples collected from January to May 1992 may have been contaminated during the analytical process because most locations including the distant communities reported unusually high concentrations. Tritium concentrations for 1994 were elevated for two individual samples but consistently elevated concentrations were not seen at any location, and there was little difference between concentrations at the distant locations and those at the Site perimeter.

Air concentrations of plutonium-238, 239,240, and strontium-90 for samples collected both onsite and offsite were below detection limits. Average uranium concentrations in airborne particulate matter

were similar at the Site perimeter and distant locations. Iodine-129 concentrations were statistically elevated at the Site perimeter relative to the distant locations indicating a measurable Hanford source; however, the average concentration at the Site perimeter was only 0.000002% of the Derived Concentration Guide of 70 picocuries/cubic meter. The Derived Concentration Guide is the air concentration that would result in a radiation dose equal to the DOE public dose limit (100 millirem/year).

Air samples were collected at several Hanford Site locations for volatile organic compounds. All measured air concentrations of these organic compounds were well below applicable occupational maximum allowable concentration standards for air contaminants for these compounds. No ambient air standards are currently available.

Surface-Water Surveillance

The Columbia River was one of the primary environmental exposure pathways to the public during 1994 as a result of operations at the Hanford Site. Radiological and chemical contaminants entered the river along the Hanford Reach primarily through the seepage of contaminated ground water. Water samples were collected from the river at various locations throughout the year to determine compliance with applicable standards.

Although radionuclides associated with Hanford operations continued to be routinely identified in Columbia River water during the year, concentrations remained extremely low at all locations and were well below applicable standards. The concentrations of tritium were significantly higher (5% significance level) at the Richland Pumphouse (downstream from the Site) than at Priest Rapids Dam (upstream from the Site), indicating a contribution along the Hanford Reach. For chemical water quality constituents measured in Columbia River water during 1994, metals and anions were generally similar upstream and downstream and in compliance with applicable primary drinking water standards. Volatile organic compounds were generally less than analytical detection levels.

During 1994, samples were collected from seven Columbia River shoreline springs, contaminated as a result of past waste disposal practices at the Hanford Site. Contaminant concentrations in the springs were similar to those found in the ground water. All radionuclide concentrations measured in riverbank springs in 1994 were less than applicable DOE Derived Concentration Guides. However, strontium-90 in the 100-D and 100-H Areas, tritium in the 100-N Area and along the old Hanford Townsite, and total alpha in the 300 Area exceeded Washington State and federal Drinking Water Standards. Total uranium exceeded the Site-specific proposed EPA Drinking Water Standard in the 300 Area. Chromium and nitrate in the 100-D Area spring were the only nonradiological contaminants measured in riverbank springs in 1994 that exceeded Drinking Water Standards.

Samples of Columbia River surface sediments were collected from behind McNary Dam (downstream from the Site) and Priest Rapids Dam and from four shoreline locations along the Hanford Reach of the Columbia River during 1994. As in the past, radionuclide concentrations in sediments behind McNary Dam were generally higher than those observed in sediments collected from behind Priest Rapids Dam and along the Site.

Three onsite ponds were sampled to determine radionuclide concentrations. These ponds are accessible to migratory waterfowl and other animals. As a result, a potential biological pathway exists for the removal and dispersal of contaminants that may be in the ponds. Concentrations of radionuclides in water collected from these ponds during 1994 were similar to those observed during past years. With the exception of uranium-234 and -238 in the July sample of West Lake, radionuclide concentrations in the onsite pond water were below applicable DOE Derived Concentration Guides.

Offsite water, used for irrigation and/or drinking water, was sampled in 1994 to determine radionuclide concentrations in water used by the nearby public. Elevated total alpha and total beta concentrations, attributed to naturally occurring uranium, were observed at some locations. All radionuclide concentrations measured in offsite water supplies and irrigation water were below applicable DOE Derived Concentration Guides and applicable Drinking Water Standards. The proposed EPA Drinking Water Standard for total uranium, however, was exceeded at Alexander Farm. Radionuclide concentrations in offsite irrigation water were similar to those observed in the Columbia River.

Soil and Vegetation Surveillance

In 1994, a total of 20 surface soil samples were collected on and off the Hanford Site; 15 from onsite locations, 4 from near the Hanford Site perimeter, and one from a distant location. Radionuclides, potentially from the Hanford Site, consistently detected in soil samples were cesium-137, plutonium-239,240, strontium-90, and uranium-238.

An evaluation of potential Hanford impacts was made by comparing onsite and offsite results. No statistical differences in analytical results were identified.

In 1994, four onsite, one distant, and four perimeter locations were sampled for perennial vegetation. Vegetation results were compared using the same rationale as soil sampling. Radionuclides, potentially from the Hanford Site, consistently detected in vegetation samples were strontium-90, uranium-238, and plutonium-239,240. Cesium-137 was also detected in four of the nine samples. A statistical difference was noted between Cesium-137 concentrations at onsite and perimeter locations and offsite and onsite locations. A difference was also seen in uranium-238 concentrations in samples collected on and off the Site. In a special study of Columbia River milfoil, a nuisance aquatic plant, slightly elevated concentrations of uranium-238 were found in plants growing near the 300 Area.

No offsite accumulation of radionuclides of Hanford origin was identifiable from the soil and vegetation samples collected and analyzed in 1993.

Fish and Wildlife Surveillance

The Hanford Site contains large tracts of undeveloped land that serve as refuges for many species of wildlife. The Columbia River, which borders the Site, also provides habitat for wildlife and fish that are of economic and recreational importance to the area. Terrestrial wildlife like deer, rabbits, and upland gamebirds have access to parts of the Site that contain low levels of radionuclides attributable to current and past Site operations. Wildlife are monitored for radionuclides as indicators of possible exposure to the Site surface contamination. Similarly, Columbia River fish are monitored to detect any radioactivity that may arise from Site activities as well as to help estimate the dose to those who may consume these fish.

Analysis of wildlife for radioactivity indicated that some species had accumulated levels of radioactivity greater than background levels. Background samples collected for a number of species over the past 4 years are summarized in this year's report. Strontium-90 was detected in deer and rabbit bone as well as Columbia River fish carcasses at levels exceeding concentrations reported in background locations. Cesium-137 was detected at higher concentrations in the muscle of deer collected in 1992 from a background location in Stevens County, north of Spokane, than has been observed in Hanford Site populations of mule deer. The levels of cesium-137 in the deer from Stevens County were attributed to past atmospheric fallout from weapons testing. Collectively, the observations of radioactivity in Hanford fish and wildlife indicate accumulation of small amounts of specific radionuclides originating from the Hanford Site.

The radionuclide concentrations measured in fish and wildlife were used to estimate potential doses to hunters and fishers who might have consumed Hanford Site game. The resulting doses were much less than applicable guidelines developed to protect the public.

Food and Farm Product Surveillance

The Hanford Site is situated in a large agricultural area that produces a wide variety of food products and alfalfa. Milk, eggs, poultry, beef, vegetables, fruit, wheat, alfalfa, and wine were collected from areas generally downwind from the Site and upwind and distant locations. The principal downwind locations include Wahluke, Sagemoor, and Riverview. Alfalfa and farm products were analyzed for cesium-137, cobalt-60, iodine-129, plutonium-238, plutonium-239,240, strontium-90, technetium-99, tritium, and uranium-234, -235, -238.

Most of the farm products sampled did not contain measurable concentrations of radionuclides. Tritium was measured at levels very close to the detection level, and there was no apparent upwind or downwind effect noted. Iodine-129 was found at slightly elevated levels in downwind milk samples, but the levels were very low and have been decreasing over the past 6 years.

External Radiation Surveillance

In 1994, radiological dose rates were measured at a number of locations on and off the Hanford Site using thermoluminescent dosimeters (TLDs). Contributors to the radiological doses measured included natural (uranium, thorium and their progeny in soil and other primordial radionuclides) and artificial sources. Onsite dose rates were unchanged while offsite dose rates increased slightly compared to 1993.

The average background radiological dose rate, calculated from TLDs at Yakima and Sunnyside (both locations are distant and upwind relative to Hanford), was 96 ± 8 mrem/year as compared to the average downwind perimeter dose rate of 110 ± 9 mrem/year. These represent an approximate 8% decrease in the background and a 9% increase in the perimeter locations when compared to 1993 measurements. Dose rates at the Columbia River shoreline near the 100-N Area were approximately two times the typical shoreline dose rates and the higher dose rates may be attributable to radiation from the 100-N Area liquid waste disposal facilities. Onsite dose rates measured near operational areas were higher than the average background dose rate.

Ground-Water Protection and Monitoring

Radiological and chemical constituents in ground water were monitored during 1994 throughout the Hanford Site in support of the overall objectives described in Section 5.0. Monitoring activities were conducted to identify and quantify existing, emerging, or potential ground-water quality problems; assess the potential for contaminants to migrate off the Hanford Site; and prepare an integrated assessment of the condition of ground water on the Site. To comply with RCRA, additional monitoring was conducted to assess the impact that specific facilities have had on ground-water quality. During 1994, approximately 800 Hanford Site wells were sampled to satisfy ground-water monitoring needs. As discussed in Section 5.3, four additional wells located across the Columbia River and east of the Site were sampled to determine whether Hanford operations had affected water quality offsite.

Analytical results for samples were compared with EPA's Drinking Water Standards (Tables C.2 and C.3, Appendix C) and DOE's Derived Concentration Guides (Table C.6, Appendix C). Ground water beneath the Hanford Site is used for drinking at five locations. Only the drinking water in the 400 Area at the FFTF Visitors Center is available for public consumption; this source is discussed in Section 5.8. In addition, water supply wells for the city of Richland are located adjacent to the southern boundary of the Hanford Site.

Radiological monitoring results indicated that cesium-137, cobalt-60, iodine-129, strontium-90, technetium-99, total alpha, total beta, tritium, uranium, and plutonium concentrations were detected in levels greater than the Drinking Water Standard in one or more wells onsite. Concentrations of tritium greater than the Derived Concentration Guide were detected in the 200 Areas. Concentrations of strontium-90 greater than the Derived Concentration Guide were detected in the 100-N Area and 200-East Area. Concentrations of uranium greater than the Derived Concentration Guide were detected in the 200-West Area. Plutonium concentrations greater than the Derived Concentration Guide were detected in the 200-East Area.

Extensive tritium plumes extend from the 200-East and 200-West Areas into the 600 Area. The plume from the 200-East Area extends east and southeast, discharging to the Columbia River. This plume has impacted tritium concentrations in the 300 Area but at levels less than the Drinking Water Standard. The spread of this plume farther south than the 300 Area is restricted by the ground-water flow away from the Yakima River and the North Richland well field. Ground water with tritium at levels above the Drinking Water Standard also discharges to the Columbia River in the 100-N Area and immediate vicinity. A small but high concentration tritium plume near the 100-K East Reactor also may discharge to the river. Tritium at levels greater than the Drinking Water Standard was also found in the 100-D and 100-F Areas.

Cobalt-60 was detected in the northeastern part of the 200-East Area and parts of the surrounding 600 Area but at levels less than the Drinking Water Standard. Cobalt-60 detections in the 100-N Area at levels greater than the Drinking Water Standard appear to be related to high suspended sediments in the samples and are not indicative of ground-water concentrations.

Concentrations of strontium-90 at levels greater than the Derived Concentration Guide were measured in the 100-N Area. This plume discharges to the Columbia River. A localized area in the 200-East Area also contains ground water with strontium-90 at levels greater than the Derived Concentration Guide. Strontium-90 at levels greater than the Drinking Water Standard is found in the 100-B, 100-F, 100-H, and 100-K Areas. These plumes extend to the Columbia River. Only one well in the 100-D Area showed strontium-90 at levels greater than the Drinking Water Standard.

Technetium-99 at concentrations greater than the Drinking Water Standard was found in the northeastern part of the 200-East Area and adjacent 600 Area. Technetium-99 was also detected at levels greater than the Drinking Water Standard in the 200-West Area and extends into the 600 Area.

Iodine-129 was detected at levels greater than the Drinking Water Standard in the 200-East Area and in an extensive part of the 600 Area to the east and southeast. The iodine-129 and tritium share common sources; however, there is no indication that iodine-129 is present at concentrations greater than the Drinking Water Standard in the ground water currently discharging to the Columbia River. Iodine-129 at levels greater than the Drinking Water Standard also extends into the 600 Area to the northwest of the 200-East Area. The southern part of the 200-West Area is also a source of iodine-129 extending into the 600 Area. There is a less extensive iodine-129 plume at levels greater than the Drinking Water Standard in the north-central part of the 200-West Area.

Cesium-137 was only detected in the 200-East Area. The concentrations detected were greater than the Drinking Water Standard but were restricted to the immediate vicinity of one well.

Uranium was detected at levels greater than the Drinking Water Standard in wells in the 100-F, 100-H, 200-East, 200-West, and 300 Areas. Ground water with uranium concentrations greater than the Drinking Water Standard appears to be discharging to the Columbia River from the 100-H and 300 Areas. One well in the 200-West Area had concentrations greater than the Derived Concentration Guide.

Plutonium was only detected in ground-water samples near one well in the 200-East Area. There is no explicit Drinking Water Standard for plutonium; however, the levels were greater than the Drinking Water Standard for gross alpha.

Certain nonradioactive chemicals regulated by the EPA and the State of Washington were also present in Hanford Site ground water. These constituents were also characterized by the monitoring programs.

Nitrate concentrations exceeded the Drinking Water Standard at locations in all 100 Areas with the exception of the 100-B Area. Those ground-water plumes discharge to the Columbia River. Nitrate from the 200-East Area extends east and southeast in the same area as the tritium plume. Nitrate from sources in the northwestern part of the 200-East Area is present in the adjacent 600 Area at levels greater than the Drinking Water Standard. Nitrate is present at levels greater than the Drinking Water Standard in the 200-West Area and adjoining 600 Area locations. Some of the nitrate in the 600 Area, 1100 Area, and North Richland area is believed to result from offsite sources.

Fluoride was measured at levels greater than the primary Drinking Water Standard in the 200-West Area.

Chromium was found at levels greater than the Drinking Water Standard in the 100-D, 100-F, 100-H, and 100-K Areas.

An extensive plume of carbon tetrachloride at levels greater than the Drinking Water Standard was found in ground water at the 200-West Area and extends into the 600 Area. This plume is associated with a less extensive plume of chloroform which may be a degradation product of the carbon tetrachloride. Maximum chloroform levels are also greater than its Drinking Water Standard.

Trichloroethylene was found at levels greater than the Drinking Water Standard in the 100-F Area and in the 600 Area to the west. Trichloroethylene was also detected at levels greater than the Drinking Water Standard in the 100-K and 200-West Areas. Trichloroethylene in the 300 Area was also measured at levels greater than the Drinking Water Standard.

Samples from one monitoring well in the deeper confined aquifer in the 100-B Area contained no

strontium-90 at levels greater than the Drinking Water Standard. A few wells near source areas exhibited impacts of past site disposal practices.

A comprehensive review of all ground-water monitoring work on the Site is published annually. Before 1989, these reports contained complete listings of all radiological and chemical data collected during the reporting periods. Currently, complete listings for ground-water data can be found in a companion volume to this annual report and in data listings published by other programs.

Quality Assurance

Comprehensive quality assurance (QA) programs, which include various quality control practices and methods to verify data, are maintained to ensure data quality. The QA programs are implemented through QA plans designed to meet requirements in the American National Standards Institute/American Society of Mechanical Engineers NQA-1 QA program document and DOE Orders. Quality assurance plans are maintained for all activities, and conformance is verified through auditors. Quality control methods include but are not limited to replicate sampling and analysis, analysis of field blanks and blind reference standards, participation in interlaboratory cross-check studies, and splitting samples with other laboratories. Sample collection and laboratory analyses are conducted using documented and approved procedures. When sample results are received, they are screened for anomalous values by comparing them to recent results and historical data. Analytical laboratory performance on the submitted double-blind samples, the EPA Laboratory Intercomparison Studies Program, and the national DOE Quality Assessment Program indicated that laboratory performance was adequate overall; was excellent in some areas; and needed improvement in others.

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Helpful Information

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Helpful Information

R. W. Hanf

The following information is provided to assist the reader in understanding the report. Definitions of technical terms can be found in Appendix B, "Glossary." A public information summary pamphlet is available by following the directions in the "Preface."

Scientific Notation

Scientific notation is used in this report to express very large or very small numbers. For example, the number 1 billion could be written as 1,000,000,000 or using scientific notation as 1×10^9. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from the number. If the value given is 2.0×10^3, the decimal point should be moved three numbers (insert zeros if no numbers are given) to the **right** of its present location. The number would then read 2,000. If the value given is 2.0×10^{-5}, the decimal point should be moved five numbers to the **left** of its present location. The result would become 0.00002.

Metric Units

The primary units used in this report are metric. Table H.1 summarizes and defines the terms and corresponding symbols (metric and nonmetric) found throughout this report. A conversion table is given at the end of this section.

Table H.1 Names and Symbols for Units of Measure

Symbol	Name	Symbol	Name
Temperature:		**Length:**	
°C	degrees Centigrade	cm	centimeter (1×10^{-2} m)
°F	degrees Fahrenheit	ft	foot
Time:		in.	inch
d	day	km	kilometer (1×10^3 m)
h	hour	m	meter
min	minute	mi	mile
s	second	mm	millimeter (1×10^{-3} m)
yr	year	µm	micrometer (1×10^{-6} m)
Rate:		**Area:**	
cfs	cubic feet per second	ha	hectare (1×10^4 m^2)
gpm	gallons per minute	km^2	square kilometer
mph	miles per hour	mi^2	square mile
Volume:		ft^2	square foot
cm^3	cubic centimeter	**Mass:**	
ft^3	cubic foot	g	gram
gal	gallon	kg	kilogram (1×10^3 g)
L	liter	mg	milligram (1×10^{-3} g)
m^3	cubic meter	µg	microgram (1×10^{-6} g)
mL	milliliter (1×10^{-3} L)	ng	nanogram (1×10^{-9} g)
ppb	parts per billion	lb	pound
ppm	parts per million	wt%	weight percent
yd^3	cubic yard		

Radioactivity Units

Much of this report deals with levels of radioactivity in various environmental media. Radioactivity in this report is usually discussed in units of curies (Ci) (Table H.2). The curie is the basic unit used to describe the amount of radioactivity present, and concentrations are generally expressed in terms of fractions of curies per unit mass or volume. One curie is equivalent to 37 billion disintegrations per second or is a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. Disintegrations generally produce spontaneous emissions of alpha or beta particles, gamma radiation, or combinations of these. In some instances in this report, radiation values are expressed with two sets of units. One set of units is usually included in parenthesis or footnotes. These units belong to the International System of Units (SI), and their inclusion in this report is mandated by DOE. SI units are the internationally accepted units and will eventually be the standard for reporting radioactivity and radiation dose in the United States. The basic unit for discussing radioactivity, the curie, can be converted to the equivalent SI unit, the becquerel (Bq), by multiplying the number of curies by 3.7×10^{10}. One becquerel is equivalent to one nuclear disintegration per second.

Table H.2 Names and Symbols for Units of Radioactivity

Symbol	Name
Ci	curie
cpm	counts per minute
mCi	millicurie (1×10^{-3} Ci)
µCi	microcurie (1×10^{-6} Ci)
nCi	nanocurie (1×10^{-9} Ci)
pCi	picocurie (1×10^{-12} Ci)
aCi	attocurie (1×10^{-18} Ci)
Bq	becquerel

Radiation Dose Units

The amount of radiation received by a living organism is expressed in terms of radiation dose. Radiation dose in this report is usually written in terms of effective dose equivalent and reported numerically in units of rem or in the SI unit, sievert (Sv) (Table H.3). Rem (sievert) is a term that relates ionizing radiation and biological effect or risk. A dose of 1 millirem has a biological effect similar to the dose received from about a 1-day's exposure to natural background radiation (see "Hanford Public Radiation Dose in Perspective" in Section 6.0 for a more in-depth discussion of risk comparisons). To convert the most commonly used dose term in this report, the millirem, to the SI equivalent, the millisievert, multiply millirem by 0.01.

Additional information on radiation and dose terminology can be found in the glossary of this report (Appendix B). A list of the radionuclides discussed in this report and their half-lives is included in Table H.4.

Table H.3 Names and Symbols for Units of Radiation Dose

Symbol	Name
mrad	millirad (1×10^{-3} rad)
mrem	millirem (1×10^{-3} rem)
Sv	sievert
mSv	millisievert (1×10^{-3} Sv)
µSv	microsievert (1×10^{-6} Sv)
R	roentgen
mR	milliroentgen (1×10^{-3} R)
µR	microroentgen (1×10^{-6} R)
Gy	gray

Table H.4 Radionuclide Nomenclature[a]

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
^{3}H	tritium	12.3 yr	^{144}Ce	cerium-144	284 d
^{7}Be	beryllium-7	53.4 d	^{147}Pm	promethium-147	2.6 yr
^{14}C	carbon-14	5730 yr	^{152}Eu	europium-152	13.3 yr
^{22}Na	sodium-22	2.6 yr	^{154}Eu	europium-154	8.8 yr
^{40}K	potassium-40	1.3×10^{8} yr	^{155}Eu	europium-155	5 yr
^{41}Ar	argon-41	1.8 h	^{208}Tl	thallium-208	3.1 min
^{51}Cr	chromium-51	27.7 d	^{212}Bi	bismuth-212	61 min
^{54}Mn	manganese-54	312 d	^{212}Pb	lead-212	10.6 h
^{57}Co	cobalt-57	270.9 d	^{212}Po	polonium-212	0.3×10^{-6} s
^{60}Co	cobalt-60	5.3 yr	^{216}Po	polonium-216	0.15 s
^{63}Ni	nickel-63	96 yr	^{220}Rn	radon-220	56 s
^{65}Zn	zinc-65	243.9 d	^{222}Rn	radon-222	3.8 d
^{85}Kr	krypton-85	10.7 yr	^{226}Ra	radium-226	1600 yr
^{89}Sr	strontium-89	50.5 d	^{228}Ra	radium-228	5.8 yr
^{90}Sr	strontium-90	29.1 yr	^{232}Th	thorium-232	1.4×10^{10} yr
^{95}Nb	niobium-95	35 d	U or uranium[b]	uranium total	---
^{95}Zr	zirconium-95	64 d	^{234}U	uranium-234	2.4×10^{5} yr
^{99}Mo	molybdenum-99	66 h	^{235}U	uranium-235	7×10^{8} yr
^{99}Tc	technetium-99	2.1×10^{5} yr	^{236}U	uranium-236	2.3×10^{7} yr
^{103}Ru	ruthenium-103	39.3 d	^{238}U	uranium-238	4.5×10^{9} yr
^{106}Ru	ruthenium-106	368 d	^{238}Pu	plutonium-238	87.7 yr
^{125}Sb	antimony-125	2.8 yr	^{239}Np	neptunium-239	2.4 d
^{129}I	iodine-129	1.6×10^{7} yr	^{239}Pu	plutonium-239	2.4×10^{4} yr
^{131}I	iodine-131	8 d	^{240}Pu	plutonium-240	6.5×10^{3} yr
^{133}Ba	barium-133	10.7 yr	^{241}Pu	plutonium-241	14.4 yr
^{134}Cs	cesium-134	2.1 yr	^{241}Am	americium-241	432 yr
^{137}Cs	cesium-137	30 yr			

(a) From Shleien 1992.
(b) Total uranium may also be indicated by U-natural (U-nat) or U-mass.

Understanding the Data Tables

Measuring any physical quantity (for example, temperature, distance, time, or radioactivity) has some degree of inherent uncertainty. This uncertainty results from the combination of all possible inaccuracies in the measurement process, including such factors as the reading of the result, the calibration of the measurement device, numerical rounding errors, and the random nature of radioactivity. In this report, individual radioactivity measurements are accompanied by a plus or minus (±) value (sometimes expressed as a percentage of the related concentration value), which is an uncertainty term known as either the two-sigma counting error or the total propagated analytical uncertainty (see Sections 5.4 and 5.6). Total propagated analytical uncertainty includes counting uncertainty and analytical uncertainty. Because measuring a radionuclide requires a process of counting random radioactive emissions from a sample, the counting uncertainty gives information on what the measurement might be if the same sample were counted again under identical conditions. The counting uncertainty implies that approximately 95% of the time, a recount of the same sample would give a value somewhere between the reported value minus the counting uncertainty and the reported value plus the counting uncertainty. Values in the tables that are less than the counting uncertainty indicate that the reported result might have come from a sample with no radioactivity. Such values are considered as below detection. Also note that each radioactive measurement must have the random background radioactivity of the measuring instrument subtracted; therefore, negative results are possible, especially when the sample has very little radioactivity.

Just as individual values are accompanied by counting uncertainties, mean values are accompanied by two times the standard error of the calculated mean (2 standard error of the mean). In this report, 2 standard error of the mean is sometimes expressed as a percentage of the mean concentration value. If the data fluctuate randomly, then the 2 standard error of the mean is a measure of the uncertainty in the estimated mean of the data from this randomness. If trends or periodic (for example, seasonal) fluctuations are present, then the 2 standard error of the mean is primarily a measure of the variability in the trends and fluctuations about the mean of the data.

Understanding Graphical Information

Presenting data on a graph is useful when comparing numbers collected at several locations or at one location over time. Graphs make it easier to visualize differences where they exist. However, while graphs may make it easier to evaluate data, they may also lead the reader to incorrect conclusions if they are not interpreted correctly. Careful consideration should be given to the scale (linear or logarithmic) concentration units, and the type of uncertainty used.

Some of the data graphed in this report are plotted using logarithmic (or compressed) scales. Logarithmic scales are useful when plotting two or more numbers that differ greatly in size. For example, a sample with a concentration of 5 g/L would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 3000 g/L (Figure H.1). A logarithmic plot of these same tw numbers allows the reader to clearly see both data points (Figure H.2).

The mean or median values graphed in this report have vertical lines extending above and below the data point. These lines (called error bars), which are usually capped at both ends with a short horizontal line, indicate the amount of uncertainty (± 2 standard error of the mean) in the reported result. The error bars in this report represent a 95% chance that the mean is between the upper and lower ends of the error bar, and a 5% chance that the true mean is either lower or higher than the error bar.[a] For example, in Figure H.3, the first plotted mean is 2.0 $\pm$ 1.1, so there is a 95% chance that the actual result is between 0.9 and 3.1, a 2.5% chance it is less than 0.9, and a 2.5% chance it is greater than 3.1. Error bars are computed statistically employing all of the information used to generate the data point plotted on the graph. These bars provide a quick visual indication that one mean may be statistically similar to or different from another mean. If the error bars (or range of values) of two or more means overlap, as is the case with means 1

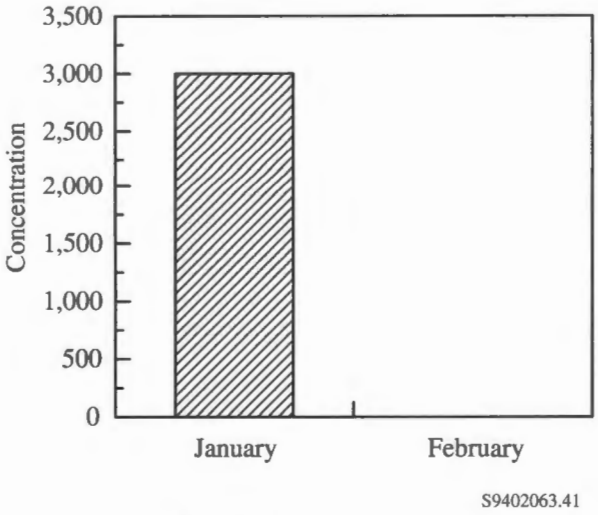

Figure H.1 Data Plotted Using a Linear Scale

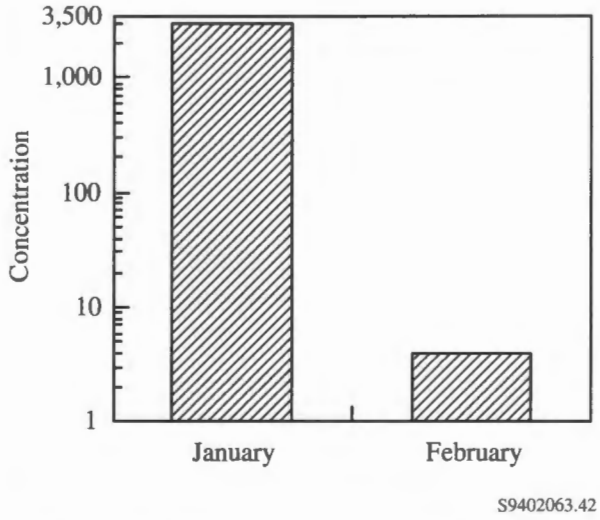

Figure H.2 Data Plotted Using a Logarithmic Scale

[a] Assuming the Normal statistical distribution of the data.

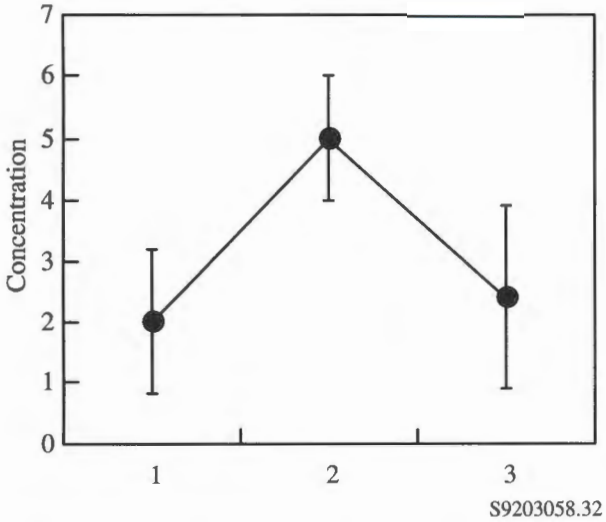

Figure H.3 Data With Error Bars Plotted Using a Linear Scale

and 3 and means 2 and 3, the means may be similar, statistically. If the error bars do not overlap (means 1 and 2), the means may be statistically different. Means that appear to be very different visually (means 2 and 3) may actually be quite similar when compared statistically.

Median, maximum, and minimum values are illustrated when small numbers of soil and vegetation samples are collected and analyzed during the year.

Greater Than (>) or Less Than (<) Symbols

Greater than (>) or less than (<) symbols are used to indicate that the actual value may either be larger than the number given or smaller than the number given. For example, >0.09 would indicate that the actual value is greater than 0.09. An inequality symbol pointed in the opposite direction (<0.09) would indicate that the number is less than the value presented. If an inequality symbol is used in association with an underscore ($\leq$ or $\geq$), this indicates that the actual value is less-than-or-equal-to or greater-than-or-equal-to the number given, respectively.

More comprehensive readings on radiation and radiation dose can be found in most public libraries and in many local book stores.

Nomenclature Conversion Table

Multiply	By	To Obtain	Multiply	By	To Obtain
in.	2.54	cm	cm	0.394	in.
ft	0.305	m	m	3.28	ft
mi	1.61	km	km	0.621	mi
lb	0.454	kg	kg	2.205	lb
gal	3.785	L	L	0.264	gal
ft^2	0.093	m^2	m^2	10.76	ft^2
acres	0.405	ha	ha	2.47	acres
mi^2	2.59	km^2	km^2	0.386	mi^2
ft^3	0.028	m^3	m^3	35.7	ft^3
nCi	0.001	pCi	pCi	1,000	nCi
pCi/L	10^{-9}	µCi/mL	µCi/mL	10^{9}	pCi/L
pCi/m^3	10^{-12}	Ci/m^3	Ci/m^3	10^{12}	pCi/m^3
pCi/m^3	10^{-15}	mCi/cm^3	mCi/cm^3	10^{15}	pCi/m^3
mCi/km^2	1.0	nCi/m^2	nCi/m^2	1.0	mCi/km^2
becquerel	2.7×10^{-11}	curie	curie	3.7×10^{10}	becquerel
gray	100	rad	rad	0.01	gray
sievert	100	rem	rem	0.01	sievert
ppb	0.001	ppm	ppm	1,000	ppb
°F	(°F - 32) ÷ 9/5	°C	°C	(°C x 9/5) + 32	°F
g	.035	oz	oz	28.349	g

Element and Chemical Nomenclature

Symbol	Constituent	Symbol	Constituent
Ag	silver	K	potassium
Al	aluminum	LiF	lithium fluoride
As	arsenic	Mg	magnesium
B	boron	Mn	manganese
Ba	barium	Mo	molybdenum
Be	beryllium	NH_3	ammonia
Br	bromine	NH_4^+	ammonium
C	carbon	N	nitrogen
Ca	calcium	Na	sodium
CaF_2	calcium fluoride	Ni	nickel
CCl_4	carbon tetrachloride	NO_2^-	nitrate
Cd	cadmium	NO_3^-	nitrate
$CHCl_3$	trichloromethane	Pb	lead
Cl^-	chloride	PO_4^{-3}	phosphate
CN^-	cyanide	P	phosphorus
Cr^{+6}	chromium (species)	Sb	antimony
Cr	chromium (total)	Se	selenium
CO_3^{-2}	carbonate	Si	silicon
Co	cobalt	Sr	strontium
Cu	copper	SO_4^{-2}	sulfate
Dy	dysprosium	Ti	titanium
F^-	fluoride	Tl	thallium
Fe	iron	V	vanadium
HCO_3^-	bicarbonate	Zn	zinc
Hg	mercury		

Acronyms and Abbreviations

AALG
ambient air level goals

ALARA
as low as reasonably achievable

ALE
Arid Lands Ecology (Reserve)

ASME
American Society of Mechanical Engineers

ASTM
American Society for Testing and Materials

BHI
Bechtel Hanford Inc.

CERCLA
Comprehensive Environmental Response, Compensation, and Liability Act

CFR
Code of Federal Regulations

COE
U.S. Army Corps of Engineers

DCG
Derived Concentration Guide

DDT
dichlorodiphenyltrichloroethane

DHHS
U.S. Department of Health and Human Services

DOE
U.S. Department of Energy

DOH
Washington State Department of Health

DWS
Drinking Water Standard

Ecology
Washington State Department of Ecology

EIS
environmental impact statement

EMSL
Environmental and Molecular Science Laboratory

EPA
U.S. Environmental Protection Agency

ERC
environmental restoration contractor

ETF
Effluent Treatment Facility

FFTF
Fast Flux Test Facility

FR
Federal Register

HCRL
Hanford Cultural Resources Laboratory

HPS
Health Physics Society

ICP
inductively coupled plasma (method)

ICRP
International Commission on Radiological Protection

IT
International Technology Corporation

LEPS
low-energy photon

LIGO
Laser Interferometer Gravitational-Wave Observatory

LLNL
Lawrence Livermore National Laboratory

MDC
minimum detectable concentration

MEI
maximally exposed individual

MEPAS
Multimedia Environmental Pollutant Assessment System

NCRP
National Council on Radiation Protection and Measurements

NEPA
National Environmental Policy Act

NESHAP
National Emission Standards for Hazardous Air Pollutants

NIST
National Institute of Standards and Technology

NPDES
National Pollutant Discharge Elimination System

NRC
U.S. Nuclear Regulatory Commission

NS
no standard or no sample

NTU
nephelometric turbidity unit

PAH
polyclyclic aromatic hydrocarbons

PCB
polychlorinated biphenyl

PFP
Plutonium Finishing Plant

PNL
Pacific Northwest Laboratory

PSD
prevention of significant deterioration

PUREX
Plutonium Uranium Extraction (Plant)

QA
quality assurance

QC
quality control

RCRA
Resource Conservation and Recovery Act

RCW
Revised Code of Washington

REDOX
Reduction-Oxidation (Plant)

SAIC
Science Application International Corporation

SALDS
State-Approved Land Disposal Structure

SARA
Superfund Amendments and Reauthorization Act

SE
standard error

SI
International System of Units

TBP
tributyl phosphate

TCE
trichloroethylene

TLD
thermoluminescent dosimeter

TOC
total organic carbon

TSCA
Toxic Substance Control Act

UNSCEAR
United Nations Science Committee on the Effects of Atomic Radiation

USDHEW
U.S. Department of Health, Education, and Welfare

USGS
U.S. Geological Survey

UST
Underground Storage Tank

WAC
Washington Administrative Code

WHC
Westinghouse Hanford Company

WSDA
Washington State Department of Agriculture

WTSP
Waste Tank Safety Program

Introduction

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1.0 Introduction

The Hanford Site environmental report is produced through the joint efforts of the principal Site contractors (Pacific Northwest Laboratory [PNL], Westinghouse Hanford Company [WHC], Bechtel Hanford Inc. [BHI]) and other organizations and agencies involved in environmental and compliance work on the Site. This report, published annually since 1958, includes information and summary data that 1) characterize environmental management performance at the Hanford Site; 2) demonstrate the status of the Site's compliance with applicable federal, state, and local environmental laws and regulations; and 3) highlight significant environmental monitoring and surveillance programs.

Specifically, the report provides a short introduction to the Hanford Site, discusses the current Site mission, and briefly discusses the Site's various waste management, effluent monitoring, environmental surveillance, and environmental compliance programs. Included are summary data and program descriptions for the sitewide Ground-Water Monitoring Program, the Near-Facility Environmental Monitoring Program, the Surface Environmental Surveillance Program, wildlife studies, climate and meteorological monitoring, as well as information about other programs. Also included are sections discussing environmental occurrences, current issues and actions, environmental cleanup activities, compliance issues, descriptions of major operations and activities, and an introduction to the Hanford Site. Readers interested in more detail than the summary information provided in this report should consult the technical documents cited in the report text. Descriptions of specific analytical and sampling methods used in the monitoring programs are contained in the *Hanford Site Environmental Monitoring Plan* (DOE 1994c).

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1.1 Site Mission

R. L. Dirkes and D. G. Black

The Hanford Site was acquired by the federal government in 1943. For more than 25 years, Hanford Site facilities were dedicated primarily to the production of plutonium for national defense and management of the resulting wastes. In more recent years, programs at the Hanford Site have been diversified to include research and development for renewable energy technologies, waste disposal technologies, and cleanup of contamination from past practices.

The U.S. Department of Energy (DOE) has established a new mission for Hanford including:

- **Management of Stored Wastes** and the handling, storage, and disposal of radioactive, hazardous, mixed, or sanitary wastes from current operations
- **Environmental Restoration** of approximately 1,100 inactive radioactive, hazardous, and mixed waste disposal sites and about 100 surplus facilities
- **Research and Development** in energy, health, safety, environmental sciences, molecular sciences, environmental restoration, waste management, and national security
- **Development of New Technologies** for environmental restoration and waste management, including site characterization and assessment methods; waste minimization, treatment, and remediation technology.

The DOE has set a goal of cleaning up Hanford's waste sites and bringing its facilities into compliance with local, state, and federal environmental laws. In addition to supporting the environmental management mission, DOE is also supporting other special initiatives in accomplishing its national objective.

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1.2 Introduction to the Hanford Site

C. E. Cushing

The Hanford Site lies within the semiarid Pasco Basin of the Columbia Plateau in southeastern Washington State (Figure 1.2.1). The Site occupies an area of about 1,450 km^2 (approximately 560 km^2) north of the confluence of the Yakima river with the Columbia River. This land, with restricted public access, provides a buffer for the smaller areas historically used for production of nuclear materials, waste storage, and waste disposal; about 6% of the land area has been disturbed and is actively used. The Columbia River flows eastward through the northern part of the Hanford Site and then turns south, forming part of the eastern boundary. The Yakima River runs along part of the southern boundary and joins the Columbia River downstream from the city of Richland. Adjoining lands to the west, north, and east are principally range and agricultural lands in Benton, Grant, and Franklin counties. The cities of Richland, Kennewick, and Pasco (Tri-Cities) constitute the nearest population center and are located southeast of the Hanford Site.

Population estimates for 1994 by the Forecasting Division of the Office of Financial Management of the state of Washington place the totals for Benton, Franklin, and Grant counties at 127,000, 42,900, and 62,200, respectively. The 1994 estimates for the Tri-Cities populations are Richland, 35,430; Kennewick, 46,960; and Pasco, 22,170. The estimated populations of Benton City, Prosser, and West Richland totaled 11,985 in 1994. Estimates of the percent of the population exceeding 65 years of age are 9.72, 9.48, and 13.08 in Benton, Franklin, and Grant counties, respectively, in 1994. The census for 1990 (U.S. Bureau of the Census) revealed that the population of Benton and Franklin counties is young, with 56% of the total population under the age of 35, compared with 54% of the total state population. An examination of age groups in 5-year increments reveals that the largest age group in Benton and Franklin counties ranges from 5 to 9 years old, representing 9.3% of the total bi-county population; the largest age group in the state ranges from 30 to 34 years, which represents about 9% of the total state population.

The entire Hanford Site was designated a National Environmental Research Park (one of four nationally) by the former Energy Research and Development Administration, a precursor to DOE.

The major operational areas on the Site include the following:

- The 100 Areas, on the south shore of the Columbia River, are the sites of eight retired plutonium production reactors and the N Reactor, which has been permanently shut down since 1991. The 100 Areas occupy about 11 km^2 (4 mi^2).
- The 200-West and 200-East Areas are located on a plateau and are about 8 and 11 km (5 and 7 mi), respectively, south of the Columbia River. These areas historically have been dedicated to fuel reprocessing and waste management and disposal activities. The 200 Areas cover about 16 km^2 (6 mi^2).
- The 300 Area, located just north of the city of Richland, is the site of nuclear and non-nuclear research and development. This area covers 1.5 km^2 (0.6 mi^2).
- The 400 Area is about 8 km (5 mi) northwest of the 300 Area and is the site of the Fast Flux Test Facility (FFTF). Also included in this area is the Fuels and Materials Examination Facility.
- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas.

Support areas near the Site in north Richland include the 1100, 3000, and Richland North Areas. The 1100 Area includes Site support services such as general stores and transportation maintenance. The 3000 Area includes the facilities for ICF Kaiser Hanford Company. The Richland North Area includes the DOE and DOE contractor facilities located between the 300 Area and the city of Richland that are not in the 1100 and 3000 Areas.

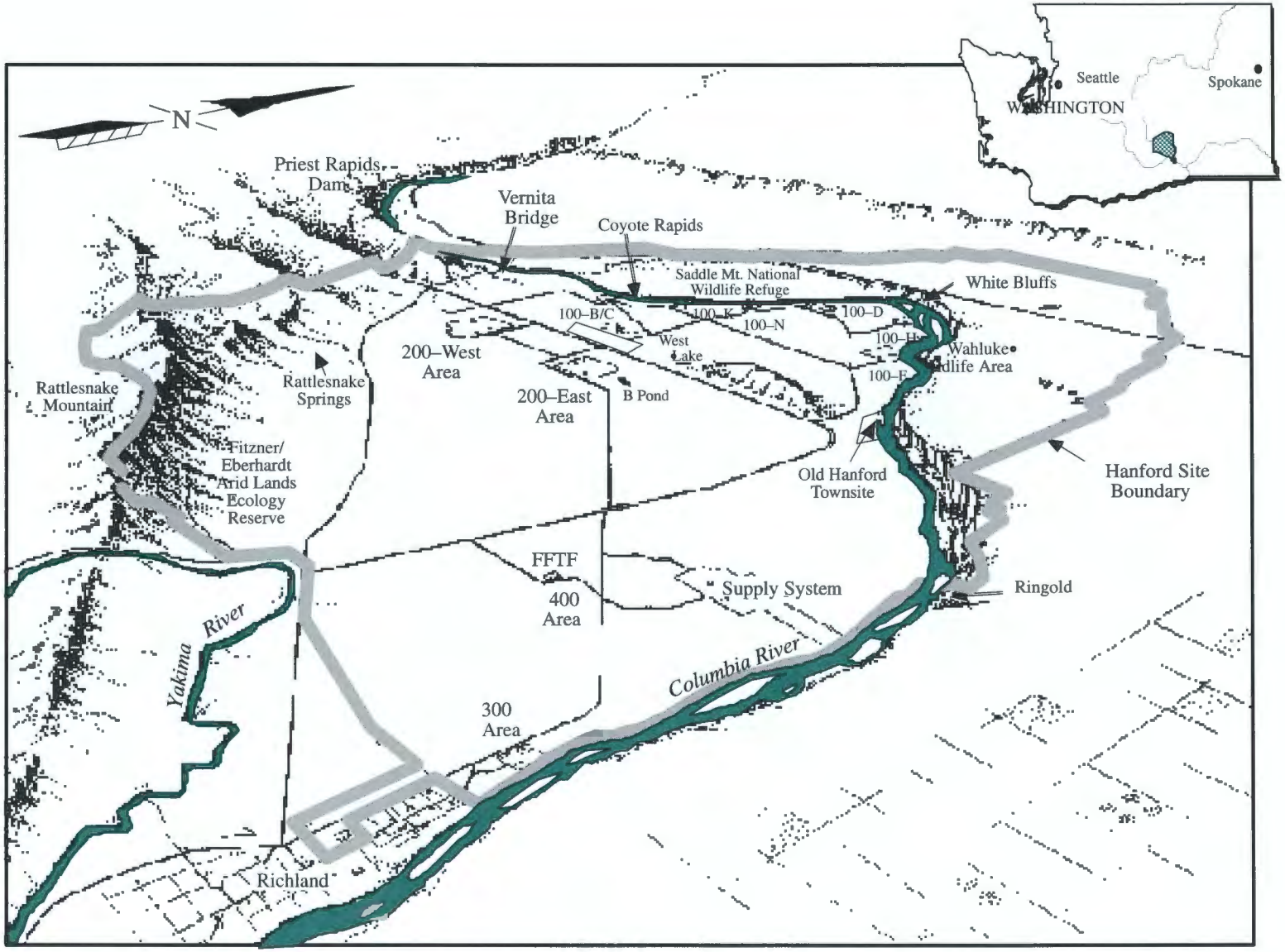

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Figure 1.2.1 DOE's Hanford Site and Surrounding Area

Other facilities are located in the Richland Central Area (located south of Saint Street and Highway 240 and north of the Yakima River), the Richland South Area (located between the Yakima River and Kennewick) and the Kennewick/Pasco area.

Several areas of the Site, totaling 665 km^2 (257 mi^2), have been designated as the Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve, the U.S. Fish and Wildlife Service Saddle Mountain National Wildlife Refuge, and the Washington State Department of Game Reserve Area (Wahluke Slope Wildlife Recreation Area) (DOE 1986). The ALE Reserve was established in 1967 by the Atomic Energy Commission, a precursor to DOE. In 1971, the reserve was classified a Research Natural Area as a result of a federal interagency cooperative agreement.

Land use in surrounding environs includes urban and industrial development, irrigated and dry-land farming, and grazing. In 1993, wheat represented the largest single crop in terms of area planted in Benton, Franklin, and Grant counties. Total acreage planted in the three counties was 207,890 ha (513,700 acres) and 24,120 ha (59,600 acres) for winter and spring wheat, respectively (Washington Agricultural Statistics Service 1994). Corn, alfalfa, potatoes, asparagus, apples, cherries, and grapes are other major crops in Benton, Franklin, and Grant counties. Several processors in Benton and Franklin counties produce food products including potato products, canned fruits and vegetables, wine, and animal feed.

Much of the above information is from Cushing (1994), where more detailed information can be found.

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1.3 Major Operations and Activities

D. G. Black

The primary DOE operations and activities on the Hanford Site in 1994 included Site management, waste management, environmental restoration, environmental corrective actions, and research and technology development. The majority of these activities were conducted under the Environmental Restoration and Waste Management Program.

Site Management

Hanford Site operations and activities are managed by the DOE Richland Operations Office through the following prime contractors and numerous subcontractors. Each contractor is responsible for safe, environmentally sound maintenance and management of its facilities and operations; for waste management; and for monitoring operations and effluents to ensure environmental compliance.

The principal contractors and their respective responsibilities include:

- Westinghouse Hanford Company, the operating and engineering contractor, which manages wastes, maintains the FFTF, PUREX, and other shutdown facilities, and provides support services such as fire protection, stores, and electrical power distribution. Site computer services are provided by Boeing Computer Services, a subcontractor to Westinghouse. In October 1993, administration of the ICF Kaiser Hanford Company contract was assigned to Westinghouse Hanford Company. ICF Kaiser is responsible for fabrication, custodial work, maintenance, design/drafting, and computer-aided mapping, and operates the utilities, railroad system, bus and van fleets, and roads.

- Battelle Memorial Institute, the research and development contractor, operates Pacific Northwest Laboratory for DOE, conducting research and development in environmental restoration and waste management, environmental science, molecular science, energy, health and safety, and national security.

- Bechtel Hanford, Inc. completed a four-month transition and became the Hanford environmental restoration contractor (ERC) in July 1994, with responsibility for remedial action at past-practice waste sites and D&D of facilities. The Bechtel ERC Team includes three preselected subcontractors: CH2M Hill, IT Corporation, and ThermoAnalytical, Inc.

- Hanford Environmental Health Foundation is the occupational and environmental health services contractor.

Non-DOE operations and activities on Hanford Site leased land include commercial power production by the Washington Public Power Supply System WNP-2 reactor, and operation of a commercial low-level radioactive waste burial site by US Ecology, Inc. Immediately adjacent to the southern boundary of the Hanford Site, Siemens Power Corporation operates a commercial nuclear fuel fabrication facility, and Allied Technology Group Corporation operates a low-level radioactive waste decontamination, super compaction, and packaging disposal facility. Kaiser Aluminum and Chemical Corporation is leasing the 313 Building in the 300 Area to use an extrusion press that was formerly DOE-owned. The National Science Foundation is building the Laser Interferometer Gravitational-Wave Observatory (LIGO) facility on the Hanford Site for gravitational wave studies.

Waste Management

Current waste management activities at the Site include the management of high- and low-activity defense wastes in the 200-East and 200-West Areas (Figure 1.2.1) and the storage of irradiated defense fuel in the 100-K Area. Key facilities include the waste storage tanks, Central Waste Complex, Low-Level Burial Grounds, 100-K Fuel Storage Basins, Plutonium Uranium Extraction (PUREX) Plant, Uranium-TriOxide Plant, Plutonium Finishing Plant, B Plant, T Plant, 616 Storage Facility, and 242-A Evaporator.

Waste management activities involving single-shell and double-shell tanks currently include ensuring

safe storage of wastes through surveillance and monitoring of the tanks, upgrading monitoring instrumentation, and imposing strict work controls during intrusive operations. Earlier, concerns had been raised about the potential for rapid exothermic reactions from ferrocyanide and/or organic fuels or hydrogen gas accumulation in the waste tanks. One safety issue stems from the fact that under conditions of sufficient chemical concentration, low moisture, and high temperature, ferrocyanide and/or organic materials combined with nitrates also present in the tanks could result in runaway chemical reactions that would release radioactive debris to the environment. The other issue is that in up to 25 tanks flammable hydrogen gases are generated in the waste and may be trapped, occasionally being released episodically. DOE and external oversight groups have concluded that there is no imminent danger to the public from either situation. The Tank Waste Remediation System Division has the responsibility to identify any hazards associated with the waste tanks and to implement the necessary actions to resolve or mitigate those hazards.

The aging, 40-year-old 100-K East and 100-K West Fuel Storage Basins are currently being used to store N Reactor irradiated fuel. In 1994, a strategy was implemented for near-term and interim fuel storage of the K Basin inventory. This strategy supports removal of the fuel and sludge from the K Basins before December 2002, as stipulated in the Tri-Party Agreement.

The PUREX Plant, located in the 200-East Area, formerly processed irradiated reactor fuel to extract plutonium and uranium. Plant operation was stopped in December 1988. From December 1989 through March 1990, the facility completed a stabilization run to process the fuel remaining in the plant. The PUREX Plant has not operated since the stabilization run. Solvent and nuclear materials remain, including nitric acid recovered from processing uranyl nitrate hexahydrate, spent fuel from Hanford production reactors, and organic solvents used in the PUREX process. After the stabilization run, the PUREX Plant began a transition to a "standby condition." In December 1992, DOE directed the facility to be deactivated and transitioned to "surveillance and maintenance" until final disposition.

The Uranium-TriOxide Plant, located in the 200-West Area, began preparations in 1992 to process the remaining liquid uranyl nitrate hexahydrate from the PUREX Plant. After completing an operational readiness review, the plant began operating in April 1993 and finished in June 1993. This stabilization campaign completed processing the last of the stored liquid that was converted into stable uranium trioxide. The final phase of the run produced almost 200 metric tons (180 tons) of uranium trioxide, which is stored in 45 steel storage containers at the plant. The stored product is now in its reusable powder form that DOE will make available for purchase by commercial power plants. The plant has been deactivated.

The Plutonium Finishing Plant, located in the 200-West Area, operated from 1951 until 1989 to produce plutonium metal and oxide for defense use and to recover plutonium from scrap materials. In 1993, the planned startup of a major process line, the Plutonium Reclamation Facility, was suspended pending completion of an environmental impact statement (EIS). A series of interim actions have been initiated to reduce safety risks in the facility while the EIS is prepared. As described in Section 2.3, sludge stabilization processing was initiated in November 1994, and 10-L container downloading and development testing will be initiated in early 1995.

While there are no production activities currently taking place at B Plant, several operating systems are required to accomplish the B Plant facility mission, which is to ensure safe storage and management of radiological inventories. Approximately 700 of 770 DOE-leased cesium capsules, manufactured during the late 1970s and early 1980s at the Waste Encapsulation Storage Facility adjacent to B Plant in the 200-East Area, have been safely returned and transferred to that facility. The capsules had been leased to commercial facilities in several states and were used for sterilizing medical products. DOE recalled all of the capsules as a precautionary measure after one leaked a very small amount of radioactive material at a Georgia facility in 1988. There will be about two shipments arriving monthly until approximately July 1995 when all the capsules will be returned. The capsules received to date have been inspected and are intact and free of leaks or deterioration. They are

currently stored under 4 m (13 ft) of water in the Waste Encapsulation Storage Facility storage pools. There are 33 cesium capsules stored in the 324 and 327 Buildings in the 300 Area, some of which are damaged and will require re-encapsulation in the future.

The 242-A Evaporator in the 200-East Area is used to reduce the volume of liquid wastes removed from double-shell tanks. The process condensate is currently being stored in liquid effluent retention basins until the Liquid Effluent Treatment Facility is complete. The concentrated waste from the evaporator will be returned to the double-shell tanks. The Liquid Effluent Treatment Facility is being constructed in the 200-East Area to remove regulated chemical constituents from the 242-A Evaporator process condensate.

The T Plant facility is used for radiological decontamination of equipment and repackaging of radioactive wastes. Many future facility upgrades are planned so the plant may continue to support decontamination needs at the Hanford Site.

Environmental Restoration

Environmental restoration includes activities to decontaminate and decommission facilities, clean up inactive waste sites, and prevent the spread of contamination. In 1994, the Hanford Site Environmental Restoration Project Plan (DOE 1994d) was completed, providing a program baseline that includes cost estimates for remedial design and remedial actions for the entire project and cost estimates for the decontamination and decommissioning of 170 facilities in the program.

The Decontamination and Decommissioning (D&D) Program conducts surveillance and maintenance of surplus facilities and performs cleanup and demolition of facilities. In 1994, approximately 170 facilities were included in the surveillance and maintenance program, and cleanup and demolition of 14 buildings was completed.

The 190-B Pumphouse complex, including the 190-B and 185-B Buildings, was demolished in 1994. Steel and other structural materials left from the demolition were reprocessed, and approximately 90% of the material was recycled. The D&D Program also completed the 105-B Reactor Museum Feasibility Study. The study showed that it would be feasible to turn the reactor into a museum for public education. Additionally, this would make about 240 ha (600 acres) of land near the 100-B/C Areas available for public use.

Other demolition included three support buildings in the 100-N Area, five buildings in the 100-D/DR Area, one building in the 100-F Area, three buildings in the 200-West Area associated with the former laundry facility, and a maintenance building in the 300 Area. The 107-C Retention Basins and four of the six 107-K Retention Basins, which received contaminated cooling water from the 100-C and 100-K reactors, were also dismantled and removed.

In other activities, the D&D Program initiated plutonium removal activities at the 232-Z facility and initiated the first phase of cleanout of the 233-S facility. Asbestos abatement was completed at 202-S (REDOX), 211-U, 271-U, and phase IIA of the 109-N facility. All of these facilities are in the 200-West Area except 109-N, which is in the 100-N Area.

The Environmental Restoration Remedial Action Program was established to clean up about 1,100 inactive waste sites. In 1994, cleanup activities on the North Slope and the Arid Lands Ecology Reserve were completed, making the land potentially available for other uses. In the 100 and 200 Areas, the program began test operations of five groundwater treatment systems that treated over $11,000\ m^3$ (3 million gal) of water, and continued a soil vapor extraction system that removed about 41,000 kg (90,000 lb) of carbon tetrachloride from the soil. An expedited response action was approved for the N Springs site and design and initial testing were started to reduce the flow of strontium-contaminated ground water to the river. These actions are described in more detail in Section 2.1, "Environmental Compliance and Cleanup".

Corrective Actions

Corrective actions consist of activities to comply with regulatory requirements or compliance agreements with federal, state, or local regulatory agencies. Corrective actions conducted in 1994 are addressed in Section 2.0, "Environmental Compliance Summary."

Research and Technology Development

Research and technology development activities on the Hanford Site are a relatively minor contributor to Site releases. Most of these activities are located in the 200, 300, 400, and North Richland Areas, and releases occur primarily from the operation of research laboratories and pilot facilities. Many of these activities are intended to improve the techniques and reduce the costs of waste management, environmental protection, and Site restoration.

DOE's Tank Waste Focus Area program is funding the development of a mobile robotic system called the Light Duty Utility Arm System. This new robotic arm technology will be used to support cleanup of Hanford's defense wastes and of other DOE sites such as the Waste Heel Removal Project at the Idaho National Engineering Laboratory and the Gunite and Associated Tanks Treatability Study at the Oak Ridge National Laboratory. At Hanford, the robotic arm will be used for surveillance, inspection, and retrieval applications in single-shell tanks. The robotic arm is capable of positioning a variety of scientific instruments, cameras, and small-scale retrieval devices within the tanks. These tools will help reveal the condition of the tank structures and also provide information about the nature of the waste materials inside. Hanford's Fuels and Materials Examination Facility in the 400 Area is being readied to test the robotic system before it is actually used in a single-shell tank. The Tank Waste Focus Area program is also supporting the Waste Dislodging and Conveyance Hydraulic Testbed. This is an integral part of a facility for testing in-tank hardware and integrated tank waste dislodging and conveyance systems with simulated wastes.

A remotely operated robotic system has been developed to vacuum sediment and debris from Hanford's 100-K Area spent nuclear fuel storage pools. The Remotely Operated Sediment Extraction Equipment is expected to be operational in the spring of 1995.

The Fast Flux Test Facility was put in standby in 1992 as a result of Congressional decisions to terminate the country's breeder reactor program. It remained in standby during most of 1993, pending Congressional authorization to fund future operations and determination of a new mission, as directed by DOE. In December 1993, DOE announced that a mission had not been identified that could justify continuing reactor operation. The Secretary of Energy ordered a phased process to place the Fast Flux Test Facility into a safe shutdown condition. It will take about 5 years to complete the shutdown process.

In 1994, the Environmental Restoration Program completed the construction of a prototype long-term surface barrier (prototype Hanford barrier) in the 200-East Area. The barrier, constructed of natural materials, will be an important tool in long-term isolation of waste sites at Hanford. Special instruments to measure the barrier's effectiveness in preventing rainwater from filtering through it were constructed at Hill Air Force Base in Utah.

During 1994, the Environmental Restoration Program completed the first of two horizontal boreholes. This first borehole was used to insert conductive fluid used to melt the soil under the in situ vitrification test located west of the 300 Area. The bore was drilled vertically for about 15 feet and then turned and bored horizontally for about 40 feet. Horizontal boreholes are expected to allow sampling and determining of subsurface contamination under substantially contaminated structures at a reduced cost and with reduced worker radiation exposure.

1.4 Site Environmental Programs

J. W. Schmidt and R. W. Hanf

It is the policy of DOE and Site contractors to conduct effluent monitoring and environmental surveillance programs that can determine whether the public and the environment are protected during Site operations and whether operations are in compliance with DOE and other federal, state, and local standards, regulations, and requirements. A number of environmental programs are conducted onsite. These programs monitor for impacts from operations in several areas. The first area consists of the point of possible release into the environment; this area is covered by the effluent monitoring programs operated by both PNL and WHC. The second area consists of possible contamination immediately adjacent to DOE facilities and is covered by the near-facility environmental monitoring program operated by WHC. The third area consists of contamination in the general environment both on and off the Site and is covered by the Site environmental surveillance program operated by PNL.

In addition, aspects of the environment are studied for reasons other than specific impacts from possible contamination. These aspects include climate, wildlife, and cultural resources. These studies are summarized in Section 4.0, "Environmental Program Information."

Effluent Monitoring and Waste Management and Chemical Inventory Programs

Liquid and airborne effluents and solid waste and chemical inventories are monitored or managed through effluent monitoring programs. The effluent programs are designed to measure effluents at their point of release into the environment, whenever possible. The waste management and chemical inventory programs document and report the quantities and types of solid waste disposed of at the Hanford Site and the hazardous chemicals stored across the Site. Results for the 1994 effluent monitoring and waste management and chemical inventory programs are summarized in Sections 3.1, "Facility Effluent Monitoring," and 3.3, "Waste Management and Chemical Inventories."

Near-Facility Environmental Monitoring Program

The near-facility environmental monitoring program provides facility-specific environmental monitoring immediately adjacent to facilities on the Site that are managed by WHC and BHI. This monitoring is conducted to ensure compliance with DOE and contract requirements and local, state, and federal environmental regulations. The program is also designed to evaluate the effectiveness of effluent treatments and controls, waste management and restoration activities, and to monitor emissions from diffuse/fugitive sources. Results for the 1994 program are summarized in Section 3.2, "Near-Facility Environmental Monitoring."

Sitewide Environmental Surveillance Program

The Sitewide environmental surveillance program is conducted by the PNL independent of facility specific monitoring programs conducted by other Site contractors. The program's main focus is on assessing the impacts of radiological and chemical contaminants on the environment and human health, and confirming compliance with pertinent environmental regulations and federal policies. Surveillance activities are conducted both on and off the Site and monitor contaminants from the entire Hanford Site, rather than from specific contractor-owned or managed facilities. Results for the 1994 Sitewide environmental surveillance program are summarized in Section 5.0, "Environmental Surveillance Information."

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Environmental Compliance Summary

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2.0 Environmental Compliance Summary

This section briefly describes how environmental compliance is being achieved for the Hanford Site. Included are subsections describing 1) the regulations and oversight of compliance at the Site, 2) the current status of the Site's compliance with the principal regulations, 3) issues and actions arising from these compliance efforts, and 4) environmentally significant unusual occurrences.

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2.1 Environmental Compliance and Cleanup

D. G. Black

Many entities have a role in DOE's new mission of environmental restoration and waste management. These include federal, state, and local regulatory agencies; environmental groups; regional communities; Indian tribes; and individual citizens. The following section describes the roles of the principal agencies, organizations, and public in environmental compliance and cleanup of the Hanford Site.

Regulatory Oversight

Several federal, state, and local government agencies are responsible for enforcing and overseeing environmental regulations at the Hanford Site. These agencies include the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), Washington State Department of Health (DOH), and the Benton County Clean Air Authority. These agencies issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable regulations. The DOE, through compliance audits and its directives to field offices, initiates and assesses actions for compliance with environmental requirements.

EPA is the principal federal environmental regulator. EPA develops, promulgates, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by Congress. In some instances, EPA has delegated environmental regulatory authority to the state or authorized the state program to operate in lieu of the federal program when the state's program meets or exceeds EPA's requirements. For instance, EPA has delegated or authorized enforcement authority to Ecology for air pollution control and many areas of hazardous waste management. In other activities, the state program is assigned direct oversight over federal agencies as provided by federal law. For example, the DOH has direct authority under the Clean Air Act to implement its state program for regulating radionuclide air emissions at the Hanford Site. Where regulatory authority is not delegated or authorized to the state, EPA Region 10 is responsible for reviewing and enforcing compliance with EPA regulations as they pertain to the Hanford Site.

Although the State of Oregon does not have a direct regulatory role at the Hanford Site, DOE recognizes its interest in Hanford Site cleanup because of Oregon's location downstream along the Columbia River and the potential for shipping radioactive wastes from the Hanford Site through Oregon by rail, truck, or barge. Oregon participates in the State and Tribal Government Working Group for the Hanford Site, which reviews the Site's cleanup plans.

The Hanford Federal Facility Agreement and Consent Order

The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) is an agreement among EPA, Ecology, and DOE for achieving environmental compliance at the Hanford Site with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) including the Superfund Amendments and Reauthorization Act (SARA) remedial action provisions, and with Resource Conservation and Recovery Act (RCRA) treatment, storage, and disposal unit regulation and corrective action provisions. The Tri-Party Agreement 1) defines RCRA and CERCLA cleanup commitments, 2) establishes responsibilities, 3) provides a basis for budgeting, and 4) reflects a concerted goal of achieving regulatory compliance and remediation with enforceable milestones in an aggressive manner. The Tri-Party Agreement was also established with input from the public.

Negotiations to make major changes to the Tri-Party Agreement were conducted in 1993, and a renegotiated agreement was signed by the three agencies in January 1994. Further significant changes were negotiated during 1994 with approval of these changes pending required public involvement activities. Copies of the agreement and Site Management System progress reports of activities are publicly available for inspection at the DOE Public Reading Room in Richland, Washington, and at

information repositories in Seattle and Spokane, Washington, and Portland, Oregon. To get on the mailing list to obtain Tri-Party Agreement information, contact the EPA or DOE directly, or call Ecology on 1-800-321-2008. Requests by mail can be sent to:

Hanford Mailing List: Informational Mailings
P.O. Box 1970 B3-35
Richland, WA 99352

or

Hanford Update
Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600

The Tri-Party Agreement consists of a legal agreement and an action plan. The legal agreement establishes jurisdictions, authorities, and other legal determinations among the parties. The five specific areas of involvement defined by the legal agreement are the following:

1. Identify RCRA treatment, storage, and disposal units that require permits and establish schedules to comply with interim and final status requirements. Where applicable, RCRA Part B permit applications will be completed, closures accomplished, and post-closure care implemented.

2. Identify interim-action alternatives appropriate to implement the final RCRA corrective and CERCLA remedial actions.

3. Establish requirements for performing investigations to determine the nature and extent of threats to public health or the environment caused by actual or possible releases, and perform studies to identify, evaluate, and select alternatives for controlling possible releases.

4. Identify the nature, objective, and schedule of response actions for cleanup of hazardous material spills.

5. Implement the selected interim and final RCRA corrective and CERCLA remedial actions.

The action plan implements the legal agreement by 1) defining how the parties will work together, 2) describing the processes and procedures to be followed, 3) defining the units to be addressed, and 4) scheduling the work. The action plan, through enforceable milestones, establishes a plan and schedule for bringing the Hanford Site into compliance with applicable requirements of RCRA and all remedial action requirements of CERCLA.

The Role of Indian Tribes

The Hanford Site is located on land ceded by treaties with the Yakama Indian Nation and the Confederated Tribes of the Umatilla Indian Reservation in 1855. The Nez Perce Tribe has treaty rights on the Columbia River. The tribes were guaranteed the right to fish "at all usual and accustomed places" and the privilege to hunt, gather roots and berries, and pasture horses and cattle on "open and unclaimed" land. The Wanapum people are not a federally recognized tribe, and are therefore ineligible for federal programs. However, they have historical ties to the Hanford Site and are routinely consulted regarding cultural and religious freedom issues.

In addition to treaties, other laws such as the American Indian Religious Freedom Act, the Archaeological Resources Protection Act, the National Historic Preservation Act, and the Native American Graves Protection and Repatriation Act provide a basis for the tribes' active participation in Hanford plans and activities.

The DOE provides financial assistance through cooperative agreements with the Yakama Indian Nation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce tribe to support their involvement in the environmental restoration and waste management activities at the Hanford Site.

In recognition of the government-to-government relationship established in federal policy, the DOE and each tribe interact and consult on a direct consultation basis. The tribes also participate in formal groups such as the State and Tribal Government Working Group, the Hanford Summit Steering Committee, and the Hanford Environmental Dose Reconstruction Project's Native American Working Group as well as informal groups such as the Hanford Cultural Resources Management Plan Team. The tribes have made presentations on treaty rights,

tribal sovereignty, the U.S. Government's trust responsibility, and the unique status of tribal governments for DOE and the contractors. Tribal members also made presentations at a variety of public forums and meetings.

CERCLA Natural Resource Damage Assessment Trustee Activities

CERCLA requires the President to appoint federal officials to act on behalf of the public as trustees for natural resources when natural resources may be injured, destroyed, lost, or threatened as a result of a release of hazardous substances. The President appointed the Secretary of Energy as the primary federal natural resource trustee for all natural resources located on, over, or under land administered by DOE.

The National Contingency Plan authorizes state governors to designate the appropriate state agencies to act as the state trustees for resources within or controlled by the state. The National Contingency Plan indicates that Tribal chairmen (or heads of governing bodies) of Indian tribes have essentially the same trusteeship over natural resources belonging to the tribe as state trustees have on behalf of state resources. In addition to DOE, organizations which have been designated as natural resource trustees for certain natural resources at or near Hanford include: the Yakama Indian Nation; the Confederated Tribes of the Umatilla; the Nez Perce Tribe; the state of Washington represented by Ecology and the Washington Department of Fish and Wildlife; the state of Oregon represented by the Oregon Department of Energy; the U.S. Department of Interior represented by the U.S. Fish and Wildlife Service and the Bureau of Land Management; and the U.S. Department of Commerce represented by the National Oceanic and Atmospheric Administration.

DOE has a duty to coordinate with the other natural resource trustees concerning the cleanup of a CERCLA release. DOE meets regularly with the trustees in an effort to meet this coordination requirement. According to the trustees, the objectives of these meetings include ensuring that natural resource values are fully integrated with Hanford decision-making, encouraging the development of sitewide natural resource management planning, and establishing good stewardship principles. The trustees are currently drafting a cooperative charter to formally establish the collaborative working group known as the Hanford Natural Resource Trustee Council.

Public Participation

Individual citizens of Washington State and neighboring states may influence Hanford Site cleanup decisions through public participation activities. The public is invited to share their input through many forums, including Hanford Advisory Board meetings (see Section 2.3), Tri-Party Agreement activities, National Environmental Policy Act meetings covering various environmental impact statements and environmental assessments, special forums to address specific Hanford decisions, and many less formal avenues.

A plan for community relations and public involvement is included in the Tri-Party Agreement. The community relations plan was developed and negotiated among DOE, Ecology, and EPA Region 10 with public comment and was jointly approved in 1990. The community relations plan was updated in June 1993 and will be updated on an as-needed basis.

While the Tri-Party Agreement covers cleanup and compliance decisions, many other Hanford decisions must be integrated with Tri-Party Agreement decisions. Many of the guidelines to improve interactions with the public established by the three parties have been adopted by other programs in conducting Hanford public involvement activities.

To apprise the public of upcoming opportunities for public participation, the *Hanford Update*, a synopsis of ongoing and upcoming public involvement activities, is published bimonthly. In addition, the *Hanford Happenings* calendar, which highlights all scheduled meetings and comment periods, is distributed each month.

Before each activity, the press is informed of the issues to be discussed, and notices are sent to elected officials, community leaders, and special interest groups. A mailing list of approximately 5,100 individuals who have indicated an interest in participating in Hanford decisions is maintained and kept current. The mailing list can also be used to

send topic-specific information to only those people who have requested it.

Most of Hanford's public resides in Washington, Oregon, and Idaho. To allow them better access to up-to-date Hanford information, four repositories have been established. They are located in Richland, Seattle, and Spokane, Washington, and Portland, Oregon. In addition, Ecology and EPA maintain administrative records in Seattle and Richland.

The three parties respond to questions that are received via a toll-free telephone line. By calling 1-800-321-2008, members of the public can request information about any public participation activity and receive a response from the appropriate agency.

2.2 Compliance Status

D. G. Black

This section summarizes the activities conducted to ensure that the Hanford Site is in compliance with federal environmental protection statutes and related Washington State and local environmental protection regulations and the status of Hanford's compliance with these requirements. Environmental permits required under the environmental protection regulations are discussed under the applicable statute.

Hanford Federal Facility Agreement and Consent Order

Originally signed in May 1989, the Tri-Party Agreement is an agreement among EPA, Ecology, and DOE to achieve environmental compliance for the Hanford Site with CERCLA remedial action provisions and with RCRA treatment, storage, and disposal unit regulations and corrective action provisions. At the end of 1994, a total of 378 enforceable milestones (including those from 1989 through 1994) had been completed on or ahead of schedule. The following are some of the more significant accomplishments for 1994:

- Completed construction and initiated operations of expanded laboratory hot cells in the 200-West Area for high-level radioactive mixed waste analysis
- Completed remediation of the entire ALE Reserve
- Completed remediation of the North Slope area
- Completed demolition of the 107-C and four of six 107-K Retention Basins and began removing steel panels from the 107-C Basin area
- Initiated full-scale operations of the 300 Area Treated Effluent Disposal Facility, ending discharges to the 300 Area process trenches
- Removed over 41,000 kg (90,000 lb) of carbon tetrachloride from the soil using a soil vapor extraction system in the 200-West Area
- Started five ground-water treatability tests in the 100 and 200 Areas and treated over 11 million L (3 million gal) of water to remove contaminants
- Initiated a field test installation of a barrier wall for the N Springs Expedited Response Action at the 100-N Area
- Implemented closed-loop cooling for buildings 291-Z, 234-5Z, and 236-Z. This reduced the discharge of cooling water to the 216-Z-20 crib
- Installed one additional RCRA monitoring well near the U-12 crib
- Completed construction of piping upgrades between the 234-5Z, 236-Z, and 241-Z tank systems
- Designed and fabricated a spare mixer pump for tank 241-SY-101
- Started emergency pumping (interim stabilization) of tank 241-T-111 (one of three tanks to be interim stabilized for fiscal year 1994)
- Demonstrated single-shell tank waste retrieval technology and completed scale-model testing
- Initiated operation of the low-level mixed waste laboratory near the 200-West Area
- Completed construction of the 242-A Evaporator/PUREX Condensate Treatment Facility
- Issued a compendium of Columbia River contaminant data. A series of workshops was held in Hood River, Oregon, and the Tri-Cities to familiarize the public with the assessment
- Began analyzing core samples from single-shell tanks.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

The CERCLA requires that specific procedures be implemented to assess inactive waste sites for

presence of hazardous substances. The process is divided into three tiers of activity: 1) preliminary assessments, 2) remedial investigation/feasibility studies, and 3) remedial actions. The EPA has established procedures to conduct the three-tiered process.

Preliminary assessments conducted for the Hanford Site revealed that there are approximately 1,100 known individual waste sites where hazardous substances may have been disposed. These 1,100 sites have been grouped into 62 operable units, which have been further grouped into four aggregate areas using identifiable geographic boundaries. The four aggregate areas have been placed on the EPA's National Priorities List, which requires a schedule and actions for the remediation of each area.

DOE is actively pursuing remedial investigation/feasibility studies at some operable units on the Hanford Site. The operable units currently being studied were selected as a result of Tri-Party Agreement negotiations. The Tri-Party Agreement provides the framework for meeting CERCLA cleanup requirements. All milestones related to the CERCLA process established for 1994 were achieved, and the Hanford Site was in compliance with these CERCLA requirements.

Expedited Response Actions

Expedited response actions are a method of hastening cleanup at sites to prevent further spread of contamination. These actions were first proposed in 1990 and have been ongoing at various sites since 1991. Six accelerated cleanup actions at the Hanford Site were proposed by the Secretary of Energy in 1992. Two of these actions were completed in 1993, and final reports were issued. Two others, remediation of the North Slope and the Riverland Areas, were completed in 1994. A fifth action, mitigation of the flow of contaminated ground water to the Columbia River from the N Springs, was initiated. The sixth action, identification and characterization of hazards in the soil in the burial grounds north of the 300 Area, was deleted as a potential expedited response action because of complexities found at the site. The status of currently active actions is described below.

Carbon Tetrachloride Vapor Extraction

Vapor extraction from the contaminated vadose zone beneath the 200-West Area began in 1992 and continued through 1994. This Expedited Response Action uses three vapor extraction systems to draw carbon tetrachloride out of the soil column and absorb it into granulated activated-charcoal. The charcoal is shipped offsite for treatment. In 1994, about 41,000 kg (90,000 lb) of carbon tetrachloride were removed from the soil. The system is expected to operate for several more years in meeting the response action goals.

N Springs

The DOE, EPA, and Ecology agreed to initiate an expedited response action at the N Springs, which is located in the 100-N Area. The objectives of the expedited response action are to substantially reduce the transport of strontium-90 into the Columbia River through ground water and to obtain data sufficient to establish final remedial actions. An engineering study was conducted in April 1993 for the N Springs. Based on the results of this study, an expedited response action proposal was developed and submitted to the EPA Region 10 and Ecology for review in January 1994, followed by submittal for public review. An action memorandum was issued by the agencies in September 1994 that required the design, construction, and operation of a ground-water treatment system in combination with a barrier wall. Test installations of the barrier wall began in December 1994. Due to installation problems, the barrier has been delayed while alternative barrier installation methods are being evaluated. Design of the ground-water treatment system was initiated in October 1994, and operation is expected to begin in September 1995.

North Slope

In April 1992, the North Slope was selected for an expedited response action by Ecology and EPA. The area covers approximately 36,000 ha (89,000 acres) and is located north of the Columbia River. The area contained potential environmental hazards such as the remains of three missile sites, seven anti-aircraft artillery sites, several homestead sites, ten military landfills, several disposal sites, and three oil-contaminated sites.

In March 1993, an agreement was signed by the DOE, Ecology, and EPA Region 10 to identify additional measures to accelerate Hanford Site cleanup. As part of the newly renegotiated Tri-Party Agreement, a new milestone was established focusing on removal of physical hazards and asbestos from the North Slope. This milestone required that the remediation of the North Slope be completed by October 1994.

Remedial actions were completed in September 1994. Remediation consisted of cleaning up 39 waste sites and decommissioning 16 wells. A record of decision is expected from the regulators in mid-1995. Hazardous waste removed from the North Slope included the following: 460 m^3 (600 yd^3) of DDT-contaminated soil, 230 m^3 (300 yd^3) of petroleum-contaminated soil, several hundred containers of various petroleum-based lubricants and solvents, and lead-acid battery plates. The soils were disposed of at waste facilities in Arlington, Oregon and Pasco, Washington. The other wastes were taken to the 100-N storage pad. Additionally, several of the water wells had been broken into and used for the disposal of waste motor oil. These wells were cleaned to Ecology standards before being decommissioned.

Fitzner/Eberhardt Arid Lands Ecology Reserve

A new Tri-Party Agreement milestone was established in January 1994 to accelerate the remediation of the 311 km^2 (120 mi^2) ALE Reserve by October 1994. The ALE Reserve contains 25 abandoned gas wells that predate Hanford Site activities, several abandoned lysimeter plots, two concrete cisterns, 32 waste sites, and other potential physical hazards. The 1100-IU-1 Operable Unit is also located within the ALE Reserve and contains an old NIKE missile launch site and control center. Remedial actions at the ALE Reserve were completed in September 1994. Thirty-two waste sites were cleaned up, 14 wells were decommissioned, three lysimeter plots were remediated, and 2000 mi^3 of DDT-contaminated soil were removed. Each waste stream was disposed of in accordance with Hanford Site procedures established under the Tri-Party Agreement.

Treatability Studies

Several treatability studies are identified in the Tri-Party Agreement. The purpose of the studies is to test cleanup technologies in the field to determine their effectiveness and provide better information on field conditions and probable costs. Three types of tests have been implemented, consisting of pump and treat systems, soil washing, and an excavation treatability study. More information on these studies is provided below.

Carbon Tetrachloride Ground-Water Plume

The carbon tetrachloride ground-water plume in the 200-West Area covers approximately 9 km^2 (3.5 mi^2). It resulted from historical discharges from processes at the Plutonium Finishing Plant. In early 1994, construction of a pilot-scale pump and treat system was completed and a treatability test was initiated, meeting Milestone M-13-04A. The pump and treat system is testing the removal of carbon tetrachloride, chloroform, and trichloroethylene from ground water using activated carbon. Approximately 4.2 million L (1.1 million gal) of water were treated in 1994. A proposed plan outlining a preferred alternative of scaling up the existing system as an interim remedial measure was issued to the public in October 1994. Once regulator and public comments are addressed, a record of decision will be issued.

Uranium/Technetium Ground-Water Plume

Another ground-water plume in the 200-West Area contains uranium and technetium-99. The contamination resulted from historical uranium recovery operations. A pump and treat system was designed to test removal of these contaminants using ion exchange. The treatability test treated over 7 million L (1.8 million gal) of water in 1994.

200-East Area Ground-Water Plumes

The contaminants in the two 200-East Area ground-water plumes include cesium-137, cobalt-60, plutonium, strontium-90, and technetium-99. They result from historical fuel reprocessing operations in the 200-East Area, including operation of the PUREX

Plant and B Plant. Two pump and treat systems, which began operations in 1994, are testing removal of these constituents from ground water using ion exchange and adsorbents. In 1994, approximately 200,000 L (53,000 gal) of water were treated.

Chromium Ground-Water Plume

Chromium-contaminated ground water that resulted from historical reactor operations underlies portions of the 100-D and 100-H Areas near the Columbia River. In 1994, a ground-water treatment system was designed, constructed, and began operation to test removal of the chromium using ion exchange. Through 1994, the system treated 1,930,000 L (511,000 gal) of ground water and removed 2,800 g (6.2 lb) of chromium. Essentially all of the chromium was hexavalent chromium, which has higher environmental and health risks. The system is continuing to operate in 1995.

Burial Ground Excavation Treatability Test

As part of historical operations, contaminated equipment and other solid wastes were buried in unlined excavations. The current condition of the buried wastes is uncertain. An excavation treatability test was undertaken at a large burial ground near the B and C Reactors to test the effectiveness of excavation techniques, analytical screening methods, and waste handling procedures. The objective was to excavate test pits to compare different excavation approaches, identify waste requiring special handling, and determine the feasibility of segregating different kinds of waste. The test was initiated in August 1994.

Emergency Planning and Community Right-To-Know Act and Pollution Prevention Act, Section 6607

The Emergency Planning and Community Right-To-Know Act of 1986 mandates that information about hazardous chemicals on the Site be provided to the public and establishes emergency planning and notification procedures to protect the public from a release. Subtitle A of the Act calls for creation of state emergency response commissions to guide planning for chemical release emergencies. State commissions have also created local emergency planning committees to ensure community participation and planning. Subtitle B contains requirements for periodic reporting on hazardous chemicals stored and/or used on the Site to provide the public with the basis for emergency planning.

The Hanford Site *1994 Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1995a) was issued to the State Emergency Response Commission, local emergency planning committees, and local fire departments in February 1995. The report contained information on hazardous materials stored in quantities at or above mandated threshold levels throughout the Hanford Site in 1994. The Hanford Site *1993 Toxic Chemical Release Inventory* (DOE 1994b) was issued to the EPA and the state in June 1994. Accordingly, the Hanford Site was in compliance with the reporting requirements contained in this Act.

EPA has issued two final rules expanding the list of toxic chemicals subject to reporting under Section 313 of the Emergency Planning and Community Right-To-Know Act and Section 6607 of the Pollution Prevention Act of 1990. The first expansion was effective for the 1994 reporting year and will be considered during preparation of the 1995 Toxic Chemical Release Inventory covering calendar year 1994. This expansion consists of 21 chemicals and two chemical categories that are listed wastes under RCRA, and 11 halogenated chlorofluorocarbons listed as ozone depleting substances under the Clean Air Act. An additional 286 chemicals, including six chemical categories, are added to the toxic chemical list, effective for the 1995 reporting year. These chemicals were added from lists of substances regulated under the Clean Water Act, Clean Air Act, RCRA, California's Proposition 65, and other sources.

Reporting and Pollution Prevention Program

As part of Section 313 of the Emergency Planning and Community Right-To-Know Act toxic chemical release inventory reporting program, a pollution prevention program has been established that requires an annual evaluation of the use and release of 17 specific priority chemicals. This program seeks to reduce releases of pollutants through avoidance or reduction in the generation of pollutants at their source.

The 17 priority chemicals targeted for reduction in this program are a subset of the chemicals listed in Section 313 of this Act. The thresholds listed in the Act are used to determine participation. DOE is committed to reducing the releases of these 17 priority chemicals by 50% (compared to the 1988 baseline) by 1995. Each DOE site annually evaluates its use and release of these 17 priority chemicals. The information is provided to DOE Headquarters, where it is aggregated for an annual progress report provided to the EPA.

Hanford did not exceed the reporting threshold for the use of any of the 17 priority chemicals during 1994.

The Hanford Site Pollution Prevention Program was designed to meet the requirements of DOE Orders 5400.1, and 5820.2A, the DOE Waste Minimization Cross Cut Plan (DOE 1994e) and EPA program guidance, and State of Washington Pollution Prevention Planning requirements. The major elements of the program were 1) establishment of management support, 2) identification and implementation of pollution prevention opportunities through an assessment process, 3) setting and measuring the progress of waste reduction goals, 4) development of waste generation baseline and tracking systems, 5) creation of employee awareness, training, and incentives programs, 6) championing sitewide pollution prevention initiatives, and 7) technology transfer, information exchange, and public outreach. The Pollution Prevention Opportunity Assessment is the cornerstone of the pollution prevention program and the primary mechanism used to identify and prioritize options to prevent pollution and reduce waste. These assessments are performed on waste-generating activities by a team of individuals selected for their process knowledge.

These assessments are a systematic approach to identify the materials entering, the pollutants and wastes exiting, and the activities that make up a waste-generating process. Potential pollution prevention opportunities are identified, evaluated, and prioritized according to environmental, health, safety, and economic criteria. Once pollution prevention opportunities are identified, schedules are developed, and the opportunities are implemented.

A methodology for pollution prevention opportunity assessments, specific to Hanford Site needs, was developed in 1992 and further refined in 1993. The baseline year established for waste generation was 1993. Significant waste streams for that year have been identified, prioritized, and scheduled for future assessment.

Resource Conservation and Recovery Act

Hanford Site Facility RCRA Permit

The Hanford Facility RCRA Permit was issued by Ecology and EPA in August 1994 and was in effect in late September 1994. The permit provides the foundation for all future RCRA permitting at Hanford in accordance with provisions of the Tri-Party Agreement.

RCRA/Dangerous Waste Permit Applications and Closure Plans

For purposes of RCRA and Ecology's Dangerous Waste Regulations, the Hanford Site is considered to be a single facility encompassing over 60 treatment, storage, and disposal units. The Tri-Party Agreement recognized that all of the treatment, storage, and disposal units cannot be permitted simultaneously and set up a schedule for submitting unit-specific Part B RCRA/dangerous waste permit applications and closure plans to Ecology and EPA. During 1994, 34 Part A Form 3's and three revised closure plans were submitted. A research, development, and demonstration permit for the Waste Water Pilot Plant was issued in May 1994 by Ecology and EPA and was effective in June 1994.

Management of Listed-Waste-Contaminated Soil

Part of RCRA consists of a "contained-in" policy. This policy states that any waste mixture containing a listed hazardous waste is considered a hazardous waste, regardless of what percentage of the mixture is composed of listed hazardous wastes.

To facilitate implementation of this policy, sampling and analysis plans are being developed for the tank farms. These sampling and analysis plans will de-

scribe the protocol necessary to properly characterize tank farm soil for contaminants.

RCRA Ground-Water Monitoring Project Management

Table 2.2.1 lists all the RCRA facilities and waste management areas and their ground-water monitoring program status. During fiscal year 1994, samples were collected from 311 wells. There was one RCRA compliant ground-water well constructed in 1994. The well was constructed at the 216-U-12 Crib to provide characterization required by the RCRA interim-status assessment program.

The 183-H Solar Evaporation Basins were included as part of the Sitewide RCRA Permit. Ground-water monitoring will be conducted in accordance with the final status regulations and is planned to be implemented in FY 1995.

Table 2.2.1 Status of Hanford Site RCRA Interim-Status Ground-Water Monitoring Projects as of December 31, 1994 (see Figure 5.46 for locations)

Project (Date Initiated)	Status: Background Monitoring	Status: Individual Parameter Evaluation	Status: Ground-Water Quality Assessment
100-D Ponds (4/92)		X	
183-H Solar Evaporation Basin (6/85)			X
1301-N Liquid Waste Disposal Facility (12/87)	X		
1324-N/NA Ponds (12/87)			X
1325-N Liquid Waste Disposal Facility (12/87)		X	
216-B-3 Pond (11/88)			X
216-A-29 Ditch (11/88)			X
216-A-36B Crib (5/88)		X	
216-A-10 Crib (11/88)		X	
216-B-63 Trench (8/91)		X	
216-S-10 Pond (8/91)		X	
216-U-12 Crib (9/91)			X
Liquid Effluent Retention Facility (7/91)		X	
2101-M Pond (8/88)		X	
Low-Level Burial Grounds Waste Management Area 1 (9/88)		X	
Low-Level Burial Grounds Waste Management Area 2 (9/88)		X	
Low-Level Burial Grounds Waste Management Area 3 (10/88)	X		
Low-Level Burial Grounds Waste Management Area 4 (10/88)		X	
Low-Level Burial Grounds Waste Management Area 5 (3/92)		X	
Single-Shell Tank Waste Management Area A-AX (2/90)		X	
Single-Shell Tank Waste Management Area B-BX-BY (2/90)		X	
Single-Shell Tank Waste Management Area C (2/90)		X	
Single-Shell Tank Waste Management Area S-SX (10/91)		X	
Single-Shell Tank Waste Management Area T (2/90)			X
Single-Shell Tank Waste Management Area TX-TY (10/91)			X
Single-Shell Tank Waste Management Area U (10/91)		X	
300 Area Process Trenches (6/85)			X
Nonradioactive Dangerous Waste Landfill (10/86)		X	

Three wells were constructed to support the ground-water monitoring network being established for the Environmental Restoration Disposal Facility. The facility is a CERCLA landfill but will follow RCRA monitoring requirements. This monitoring program will be conducted in accordance with 40 CFR 264 final status RCRA regulations.

Ground-Water Impact Assessments

As a part of the amended Tri-Party Agreement, DOE, Ecology, and EPA agreed that discharge of effluents from the processing of nuclear waste to the soil column will be stopped by June 1995 and that the impact to the subsurface will be determined by conducting ground-water impact assessments.

Two ground-water monitoring wells were installed to support ground-water impact assessments in fiscal year 1994. One well was drilled at each of the 216-T-1 and 216-T-4-2 Ditches. The wells were used to better define stratigraphy, ground-water flow direction and flow rates, and the nature and extent of any contamination. Three test pits were also excavated at each of the two ditches. These were used to determine the lateral extent of contamination within the vadose zone.

RCRA Waste Characterization Methods

Efforts continue to identify the scope of compliance with *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* (EPA 1986a) for highly radioactive laboratory analytical activities. To develop a methodology for choosing analytical procedures for highly radioactive wastes, documents such as the *Hanford Analytical Services Quality Assurance Plan* (DOE 1994f) have been prepared.

Underground Storage Tank Program

The Underground Storage Tank (UST) Program of RCRA regulates operation and closure of USTs. During 1994, the five remaining USTs were removed, finishing all fiscal year 1994 milestones.

Hanford Site Backlog Waste Program

In March 1993, Ecology issued Order Number 93NM-201 to the DOE Richland Operations Office and the Westinghouse Hanford Company for failure to properly designate as waste the contents of 2,276 containers. The Pollution Control Hearing Board modified the original Order (PCHB Number 93-64) such that designation of the backlog containers named in the Order was completed by September 1994.

In August 1994, the Richland Operations Office notified Ecology that waste designations for the contents of the 2,276 containers had been completed. The containers were processed according to the Waste Analysis Plan for Confirmation or Completion of Tank Farms Backlog Waste Designation. Copies of relevant portions of the Solid Waste Information and Tracking System database were provided to meet the requirement for a report detailing the final designation and selected waste management options for all containers identified in the Order. With the completion of these actions, all nine compliance actions of the Order have been completed.

RCRA Inspections

DOE and its Hanford contractors are working to resolve outstanding notices of violation and warning letters of noncompliance from Ecology that were received during 1994. Each of these notices lists specific violations. There were ten letters in total in 1994. Below is a brief summary of some of these noncompliance letters.

- Ecology issued an Order and Notice of Penalty against the U.S. Army Corps of Engineers (COE) for accidentally disposing of dangerous waste at the Richland Landfill, and against DOE for not providing adequate dangerous waste training to COE employees. Ecology assessed a penalty of $9,500 against DOE and a $6,000 penalty against COE. The dangerous waste resulted from cleanup activities on the North Slope. The incident occurred late in 1993. All compliance actions identified in the Order have been completed and Ecology considers this item closed.

- Ecology issued a compliance letter regarding noncompliance with personnel training requirements after an inspection was conducted at tank farms in March 1994, to determine compliance with generator requirements. The inspector stated that, at the time of the inspec-

tion, a random sample of training records was selected and approximately half of those were deficient.

In June 1994, the DOE Richland Operations Office notified Ecology that 95% of the tank farms personnel had completed the required training, and all remaining personnel would be limited to work that did not directly affect dangerous waste management activities until their training was completed. Ecology found the corrective actions satisfactory and considers this action closed.

- Ecology issued a compliance letter after an inspection was conducted in February 1994, to assess completion of Milestones 21, 22, and 23 of the Tri-Party Agreement. The compliance letter alleged seven violations of Washington Administrative Code (WAC) 173-303 dangerous waste regulations. Ecology's concerns were about RCRA interim status requirements being relaxed on the facilities that were inspected and are scheduled for closure or are undergoing a change in mission. Ecology was concerned that relaxed management of hazardous waste during these periods may cause a threat to human health or the environment. All violations have been corrected to Ecology's satisfaction except one, which is still being negotiated on an established timeline. This remaining violation concerns the adequacy of the barrier around the 100-D Ponds and public access to the ponds from the river.

- Ecology issued a compliance letter after a dangerous waste compliance assessment of the 325 Shielded Analytical Laboratory in April 1994. Four areas of noncompliance with WAC 173-303 were identified: 1) inadequate closure of a container in storage, 2) faulty facility recordkeeping, 3) interim status permit violations, and 4) absence of tracking dangerous waste volumes after small quantities of liquid wastes were mixed with large quantities of water in the radioactive mixed waste sewer. All corrective actions have been completed.

- Ecology issued a compliance letter after an inspection at the 204-AR Waste Transfer Facility in October 1994. This facility is operating as an interim status facility under a revised Part A permit. Three violations were noted: 1) emergency procedures were not in place, 2) the contingency plan was not adequate, and 3) transfer operations procedures were inadequate. Resolution of this item is ongoing.

- Ecology issued a compliance letter after a November 1994 inspection of dangerous waste generator facilities. Three facilities were inspected, and violations were identified at the 271-U 90-Day accumulation area. The violations are as follows: 1) the spill kit did not contain all the required equipment, 2) the waste inventory log sheet did not correspond to the labeling on the container, and 3) the weekly inspection log for the facility indicated no problems were found with any safety and emergency equipment; however, safety and emergency equipment were missing, damaged, or out of certification. All corrective actions have been completed and Ecology considers this item closed.

- Ecology issued a compliance letter after a November 1994 inspection of satellite accumulation areas in the 200-East and 200-West Areas. The letter alleged three violations: 1) the accumulation containers were not under the control of the operator or secured, 2) paint materials in the buckets at the area were left to air-dry, which constituted nonpermitted treatment and disposal, and 3) it appeared that spilled materials were not mitigated or prevented. The items in question were corrected, and other corrective actions were taken to prevent recurrence of similar deficiencies. Ecology was satisfied with the corrective actions and considers this action closed.

Clean Air Act

The DOH, Division of Radiation Protection, has promulgated regulatory controls for radioactive air emissions under Section 118 of the Clean Air Act. These controls are applicable to federal facilities such as the Hanford Site. Washington Administrative Code (WAC) 246-247 requires registration of all radioactive air emission point sources with the DOH. The Hanford Site received a state license for emissions based on this registration. The conditions

specified in the license will be incorporated into the upcoming Hanford air operating permit, required by Title V of the Clean Air Act and 1990 amendments.

EPA has retained authority in Washington State for regulating certain hazardous pollutants under the National Emission Standards for Hazardous Air Pollutants (NESHAP), in accordance with 40 CFR 61. These standards are designed to protect the public from hazardous air pollutants (for example, arsenic, asbestos, beryllium, mercury, radionuclides, and vinyl chloride).

Pursuant to this program within the Clean Air Act, the EPA has promulgated regulations specifically addressing asbestos emissions. These regulations apply at the Hanford Site in building demolition and/or disposal and waste disposal operations. Of the approximately 1,400 facilities on the Hanford Site, 456 facilities currently contain asbestos. During 1994, approximately 2,063 m^3 (72,860 ft^3) of asbestos were removed and disposed of in the Hanford Central Landfill in accordance with applicable regulations.

Revised Clean Air Act requirements for radioactive air emissions were issued in December 1989 under 40 CFR 61, Subpart H. Emissions from the Hanford Site are within the new EPA offsite emission standards of 10 mrem/yr (effective dose equivalent). The 1989 requirements for flow and emissions measurements, quality assurance, and sampling documentation are in the process of being implemented at all Hanford Site sources.

These specific reporting and monitoring requirements necessitate additional effort. The Richland Operations Office received a 2-year compliance extension for the Subpart H requirements until December 1991. During this extension period, evaluations were conducted to determine the need for any additional continuous sampling equipment and other actions to meet EPA criteria. Negotiations continued with the EPA in 1992 and 1993. In February 1993, the DOE Richland Operations Office received a Compliance Order and Information Request from EPA, Region 10. The Order required 1) evaluation of all radionuclide emission points on the Hanford Site to determine which are subject to continuous emission measurement requirements in 40 CFR Part 61, Subpart H, and 2) continuous measurement of radionuclide emissions in accordance with 40 CFR Part 61.93. DOE Richland Operations Office submitted a compliance plan to the EPA, Region 10, in April 1993. The compliance plan included, as one of its milestones, the requirement to develop a Federal Facility Compliance Agreement. In February 1994, the NESHAP Federal Facility Compliance Agreement for the Hanford Site was approved. This agreement was signed by the EPA, Region 10, and DOE Richland Operations Office. It provides a compliance plan and schedule to bring the Hanford Site into compliance with the Clean Air Act, as amended, and its implementing regulations in 40 CFR Part 61, NESHAP; Radionuclides.

Title VI of the Clean Air Act Amendments of 1990 requires regulation for the use and disposal of ozone-depleting substances through the requirements in 40 CFR Part 82. The Site operating and engineering contractor was assigned the lead by a DOE Richland Operations Office directive to coordinate the development of a sitewide plan to implement the Title VI requirements. Ozone-depleting substance management on the Hanford Site is administered through a sitewide implementation plan prepared and issued during 1994. This implementation plan will be updated periodically to reflect changing federal regulations.

The local air authority, Benton County Clean Air Authority, enforces Regulation 1, which pertains to detrimental effects, fugitive dust, incineration products, open burning, odor, opacity, asbestos disposal, and sulfur oxide emissions. They have been delegated the authority to enforce EPA asbestos regulations under NESHAP. In 1994, the Site was in compliance with the regulations.

During 1994, Hanford Site air emissions remained below all regulatory limits set for radioactive and other pollutants. Routine reports of air emissions were provided to each air quality agency in accordance with requirements.

Department of Health Enforcement Inspections

DOE and its Hanford contractors are working to resolve outstanding compliance findings from DOH inspections. Each of these notices lists specific

violations. There were five DOH notices in 1994. A brief summary of these inspection findings follows.

- DOH conducted a sitewide quality assurance (QA) audit in August 1994, which focused on the overall QA program of the DOE Richland Operations Office and its contractors. Four findings were identified. DOH stated in their letter that a new category of findings, finding level IVs, would be created to replace the former category of observations, that had not been responded to in the past, and that all formerly identified observations from past audits would be changed to finding level IVs. DOH also expects corrective actions for these former observations to be completed.
- DOH issued a compliance letter that followed an inspection at the 200-West Tank Farms in October 1994. Stack monitoring systems for five stacks in the 200-West tank farms were examined and three findings were identified.
- DOH conducted an audit of 200-East Area Tank Farms during March and April 1992, identifying 21 findings, 10 observations, and 9 best management practices related to radioactive emissions from the tank farms. Ten open findings remain. These ten findings were previously classified as "observations," so were originally not responded to (see first bullet, above).

Clean Water Act

The Clean Water Act applies to point discharges to waters of the United States. At the Hanford Site, the regulations are applied through National Pollutant Discharge Elimination System permits governing effluent discharges to the Columbia River.

The number of active outfalls operating within permit number WA-000374-3 has been reduced from eight to four over the past year. The active outfalls are located in the 100-K Area (outfall 004), the 100-N Area (N-Springs and outfall 009), and the 300 Area (outfall 003). A new permit, number WA-002591-7, was issued for the 300 Area Treated Effluent Disposal Facility, which became operational in December 1994. No instances of noncompliance occurred during 1994.

Liquid Effluent Consent Order

Washington State Department of Ecology Liquid Effluent Consent Order regulating Hanford Site liquid effluent discharges to the ground contains compliance milestones for Hanford Site liquid effluent streams designated as Phase I, Phase II, and Miscellaneous Streams. State waste discharge permit applications have been submitted to Ecology for all liquid effluent streams identified within the Consent Order. A total of ten permit applications have been submitted to the State. Currently, Ecology is in the process of preparing and issuing final permits for the 200 Area Treated Effluent Disposal Facility, 200 Area Effluent Treatment Facility, and the 400 Area Secondary Cooling Water Streams.

The Miscellaneous Streams Plan and Schedule was submitted to Ecology for approval, as required by the Consent Order, in December 1994. This plan and schedule addresses how and when the remaining miscellaneous streams will become compliant with State regulations. The Plan and Schedule proposed that four categorical permits be submitted over the next 4 years to ensure the efficient use of both state and federal resources in the permit development.

Lawsuits Filed

Heart of America Northwest et al., filed a lawsuit against both the Site operating and engineering contractor and DOE in early 1992. The suit alleged violations of the Clean Water Act resulting from discharges of pollutants without a permit and for failure to notify the appropriate agencies of releases of hazardous substances from high-level waste tanks. In April 1993, U.S. District Court granted a Motion to Dismiss and dismissed all claims made by the plaintiffs. The plaintiffs appealed to the Ninth District Circuit Court of Appeals in October 1993. The United States Court of Appeals for the Ninth Circuit dismissed this case in January 1995.

In July 1993, a class-action lawsuit was filed against the current Site operating and engineering contractor and Westinghouse Electric Corporation in Yakima Superior Court in Yakima, Washington. The plaintiffs are seeking damages to provide medical monitoring and an injunction against further discharges to the environment. The federal court has dismissed all claims against the current operating

and engineering contractor. DOE has consolidated the defenses for litigation purposes.

Safe Drinking Water Act

The National Primary Drinking Water Regulations of the Safe Drinking Water Act apply to the drinking water supplies at the Hanford Site. These regulations are enforced by the DOH. The Hanford Site water supplies are monitored for the contaminants listed in the rules and regulations of the DOE regarding public water systems. In 1994, all drinking water systems on the Site were in compliance with requirements and agreements. There are currently six Group A and six Group B water systems at Hanford. The Group A systems consist of five surface water systems and one ground water system; the Group B systems consist of two surface water systems and four ground water systems. A study is currently being performed that will validate the water's quality for the five Group A surface water systems onsite. The study will include measurements of chlorine concentration, temperature, and pH.

Toxic Substances Control Act

The application of Toxic Substances Control Act (TSCA) requirements to the Hanford Site essentially involves regulation of polychlorinated biphenyls (PCBs). Federal regulations for use, storage, and disposal of PCBs are found in 40 CFR 761. State of Washington dangerous waste regulations for managing PCB wastes are listed in WAC 173-303.

Various concentrations of PCBs are found in electrical equipment throughout the Hanford Site. The majority of transformers have been sampled and characterized. Nineteen PCB transformers (those with a PCB concentration greater than 500 ppm) remain in service. Schedules have been developed for removing these PCB transformers.

Defueled, decommissioned submarine reactor compartments shipped by the U.S. Navy to the Hanford Site for disposal contain small quantities of PCBs bound within the matrix of nonmetallic materials such as thermal insulation, electrical cables, and some synthetic rubber items. Because PCBs are present, the reactor compartments are regulated under this Act. A compliance agreement between EPA and DOE defines the process by which a chemical waste landfill approval under this Act will be issued for the disposal trench. The EPA Region 10 will grant a TSCA authorization for the disposal site after the State has issued a dangerous waste permit. The reactor compartments are currently stored in the trench without being covered by soil.

Nonradioactive PCB waste is stored and disposed of in accordance with the 40 CFR 761 requirements. Effective nationwide treatment and disposal capacity and technologies have not been developed for radioactive PCB waste. This waste remains in storage on the Site pending the development of adequate treatment and disposal technologies and capacities. A draft DOE-wide Federal Facilities Compliance Agreement allowing the storage of radioactive PCB wastes beyond the regulatory limit has been developed and is in the review cycle.

Federal Insecticide, Fungicide, and Rodenticide Act

The Washington State Department of Agriculture (WSDA) administers the Federal Insecticide, Fungicide, and Rodenticide Act of 1975 certification and storage requirements under authority granted by EPA. The Act and the Revised Code of Washington 17.21, Washington Pesticide Application Act, as implemented by WAC 16-228, "General Pesticides Regulations," apply to storage and use of pesticides. At the Hanford Site, pesticides are applied by personnel licensed by WSDA as commercial pesticide applicators. In 1994, the Hanford Site was in compliance with the Act's requirements and WAC 16-228 regulations pertaining to storage and application of pesticides.

Endangered Species Act

A few rare species of native plants and animals are known to occur on the Hanford Site. Two of these are listed by the U.S. Fish and Wildlife Service as endangered or threatened. Others are listed by the Washington State Department of Fish and Wildlife as endangered, threatened, or sensitive species (see Appendix G). The Site wildlife monitoring program is discussed in Section 4.2, "Wildlife."

Bald eagles, a threatened species, are seasonal visitors to the Hanford Site. Over the past years,

several bald eagles have begun nesting onsite. In compliance with the Bald Eagle Management Plan for the Hanford Site and Section 7 of the Endangered Species Act, access roads in the nesting areas are closed in the early spring to protect the nesting environment.

In 1993, the Richland Operations Office directed that an ecological review be conducted on all projects both on and off the Site that have the potential to affect the biological environment. The scope of the review includes evaluating whether any species protected by the Act occur in a proposed project area, quantifying any impacts that might result, and identifying mitigation to minimize or eliminate impacts. Reviews have been conducted on an ongoing basis. There were no additional compliance issues during 1994.

National Historic Preservation Act, Archaeological Resources Protection Act, Native American Graves Protection and Repatriation Act, and American Indian Religious Freedom Act

Cultural resources on the Hanford Site are subject to the provisions of these four Acts. Compliance with the applicable regulations is accomplished through an active management and monitoring program that includes a review of all proposed projects to assess potential impacts on cultural resources, periodic inspections of known archaeological and historical sites to determine their condition and eligibility for listing on the National Register of Historic Places, determination of the effects of land management policies on the sites, and management of a repository for federally owned archaeological collections. In 1994, 511 reviews and inspections were conducted on the Hanford Site.

The American Indian Religious Freedom Act requires federal agencies to help protect and preserve the rights of Native Americans to practice their traditional religions. The Richland Operations Office cooperates with Native Americans by providing Site access for organized religious activities.

There were no additional compliance issues during 1994.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires preparation of an Environmental Impact Statement (EIS) to review the effects and alternatives for any major federal action that has the potential to significantly impact the quality of the human environment. Other NEPA documents include the environmental assessment, which is prepared to determine if a proposed action has a potential to significantly impact the environment and therefore requires preparation of an EIS. NEPA documents are prepared and reviewed in accordance with the Council on Environmental Quality regulations (40 CFR 1500 to 1508), 10 CFR 1021, and DOE Order 5440.1E (dated November 1992).

Recently Approved Environmental Impact Statements

The final EIS, *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE 1992a) was recently approved. This EIS assessed potential environmental impacts of decommissioning eight water-cooled, graphite-moderated reactors on the Hanford Site. The EIS evaluated five alternatives including immediate one-piece removal, safe storage followed by deferred dismantlement, and in situ decommissioning. The scope of this EIS does not include decommissioning of the N Reactor.

The final EIS was issued as an addendum to the draft EIS in December 1992. The record of decision was published in the *Federal Register* in September 1993 (58 FR 48509). DOE has decided on safe storage followed by deferred one-piece removal of these eight surplus production reactors at the Hanford Site. DOE intends to complete this decommissioning action consistent with the proposed Hanford cleanup schedule for remedial actions included in the Tri-Party Agreement. Therefore, the safe storage period would be shorter than the 75 years outlined in the final EIS. Until decommissioning is initiated, DOE will continue to conduct routine maintenance, surveillance, and radiological monitoring activities to ensure continued protection of the public and the environment during the safe-storage period.

Environmental Impact Statements in Progress

Several related programmatic and site-specific EISs are in progress. One is the Programmatic Environmental Impact Statement, DOE Headquarters, Office of Environmental Restoration and Waste Management. The purpose of this EIS is to evaluate a broad range of alternatives for the configuration of new and expanded waste management facilities. It could include actions for remediations, compliance with RCRA and CERCLA, restoration, waste management, and repositories. The notice of intent was published in the *Federal Register* (55 FR 42633) in October 1990. DOE Headquarters issued an implementation plan for public comment in 1992 (DOE 1992a).

Another EIS in progress is the Weapons Complex Reconfiguration Modernization Programmatic Environmental Impact Statement, DOE Headquarters, Office of Defense Programs. The purpose of this programmatic EIS is to evaluate alternative approaches for reconfiguring the DOE defense program and its facilities, on both a programmatic and site-specific level. With the end of the Cold War, the U.S. is reducing its stockpile of nuclear weapons. This reduction requires DOE to reevaluate its earlier alternatives for reconfiguring the nuclear weapons complex. A revised notice of intent was published in the *Federal Register* in July 1993 (58 FR 39528). Significant changes include the addition of consolidated long-term storage facilities for plutonium and uranium, and consolidation of all weapons-complex functions at one site. The Nevada Test Site has been proposed as a new candidate site, and the Hanford Site was dropped from further consideration. The scope is continuing to be reviewed.

Another EIS is the DOE Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs EIS. The purpose of the programmatic part of this EIS is to evaluate alternatives for the management of spent nuclear fuel within the DOE complex. The EIS will evaluate the use of several sites, including Hanford, as potential sites for spent nuclear fuel storage. This EIS is on an accelerated schedule. The EIS will also evaluate environmental and waste management issues at the Idaho National Engineering Laboratory. In August 1993, Hanford was requested to support the preparation of this EIS. DOE issued the draft EIS in June 1994, and the final EIS in April 1995.

Site-Specific Environmental Impact Statements In Progress

The National Parks Service released a final EIS in June 1994 that covers options for the future management of the Hanford Reach of the Columbia River. The agency's proposed action is to make Hanford's North Slope a National Wildlife Refuge and to designate the Hanford Reach as a recreational river under the Wild and Scenic River system. This would transfer responsibility for the river, a 0.4 km (0.25 mi)-wide strip of land on both shores, and the North Slope, to the U.S. Fish and Wildlife Service. The Richland Operations Office would retain responsibility for remediation and Hanford Site security. A record of decision has not yet been issued.

The Tank Waste Remediation System EIS has its origin in two DOE decisions. The first was an October 1990 commitment by the Secretary of Energy to prepare a supplemental EIS to the Hanford Defense Waste EIS (DOE 1987a) to address tank management and safety issues. The second was a December 1991 decision by the Secretary of Energy to revise the entire tank safety/tank waste treatment and disposal program and to accelerate retrieval of single-shell tank wastes. This EIS combines the scope of the originally planned supplemental EIS and the tank safety mitigation/remediation issues EIS. The notice of intent (59 FR 4052) was published in the *Federal Register* in January 1994. Public scoping was conducted during February and March of 1994.

An EIS is also underway for a proposed Multifunction Waste Tank Facility. The EIS will review potential environmental impacts associated with the construction and operation of six new 3.8 million L (1 million gal) double-shell waste tanks. The notice of intent in January 1994 for the Tank Waste Remediation System EIS also included the new tanks. The new tanks will be addressed under NEPA by an interim action EIS. In July 1994, the implementation plan and the

draft EIS for the Safe Interim Storage of Hanford Tank Wastes were released for public review and comment.

Potential environmental impacts of CERCLA and RCRA past-practices remediation activities at the Hanford Site, particularly cumulative impacts, will be assessed in the Hanford Remedial Action EIS. This EIS will cover environmental restoration of past-practices liquid effluent disposal sites, buried solid low-level wastes, pre-1970 transuranic wastes, high-activity wastes associated with storage tanks and their piping, and miscellaneous dangerous and nondangerous waste sites. Additional NEPA documentation could be prepared, as needed, for specific remediation of individual operable units or construction of waste management facilities. The Hanford Remedial Action EIS will not make site-specific level-of-cleanup decisions. Instead, the final decision on this EIS may establish future site use objectives that in turn support the regulatory framework for establishing individual waste site cleanup levels. The scope of this EIS will be clear once the implementation plan is issued. The notice of intent was published in the *Federal Register* during August 1992. The final decision on this EIS is targeted for 1995.

Planned Environmental Impact Statements

Several EIS are currently being planned. An EIS addressing the proposed operation of the Plutonium Finishing Plant to stabilize reactive materials is being prepared. An environmental assessment was originally prepared regarding the proposed scope. However, the scope of the project was changed in 1993, resulting in an announcement of the preparation of an EIS for terminal cleanout. A notice of intent has been published. An interim action environmental assessment was published in 1994 for the Plutonium Reclamation Facility stabilization.

Another EIS is anticipated for spent nuclear fuel at the Hanford Site. The EIS would support implementation of the final decision that is expected to be made in the record of decision in June 1995 for the DOE programmatic spent nuclear fuel EIS.

2.3 Current Issues and Actions

D. G. Black

Progress has been made toward achieving full regulatory compliance at the Hanford Site. Ongoing compliance self-assessments, implementation of the Tri-Party Agreement, and public meetings continue to identify environmental compliance issues. These issues are discussed openly with the regulatory agencies and with the public to ensure that all environmental compliance issues are addressed.

Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement)

Eighty-six milestones scheduled for 1994 were completed. Included in these completed milestones were the activities below. The following were submitted to the regulators (Ecology and/or EPA):

- One closure plan for Hanford treatment, storage, and disposal facilities
- One remedial investigation report and plan
- Five limited field investigations
- Seven focused feasibility study reports
- Five interim remedial measures proposed plans
- 200 Area validated chemical and radiological data
- The 100-B Area burial ground test plan was submitted and field work was begun.

In 1994, the following activities were begun:

- Pilot-scale pump and treat operations for 100-HR-3 operable unit
- Analyses of core samples from single-shell tanks
- Operation of the 300 Area Treated Effluent Disposal Facility.

At the end of 1994, a total of 378 enforceable Tri-Party Agreement milestones (including 1989 through 1994) had been completed on or ahead of schedule. Two milestones were missed and two were completed later than scheduled.

Hanford Site cleanup began in 1989 with the signing of the Tri-Party Agreement. The Agreement laid out a blueprint for the cleanup of the Hanford Site over a 30-year period. Over the past 5 years, the Agreement has been changed as additional information has been acquired about the cleanup problems. The last major changes occurred in January 1994, and focused primarily on the waste tanks at Hanford. As part of those changes, the agencies agreed to take a comprehensive look at the environmental restoration program and the future of unused facilities at Hanford.

A package of new negotiated changes to the Tri-Party Agreement was developed in January 1995. The new requirements will establish 65 new enforceable milestones and 32 new unenforceable target dates.

A summary of the significant changes follows.

Environmental Restoration Proposed Changes

One of the strongest messages voiced by the public over the past several years has been to focus on cleanup efforts along the Columbia River. To do this, the agencies need to redirect resources and funding to waste sites near the Columbia River. The agencies are proposing to accelerate investigations and cleanup in the 100 and 300 Areas and defer investigation of many waste sites in the 200 Area. The 200 Area waste sites are located on the central plateau, which is farther from the Columbia River than the 100 and 300 Areas. The agencies will continue to address contaminated ground water throughout the Hanford Site.

In addition, the proposed changes seek to streamline regulatory processes at Hanford. Various waste sites in a given geographic area would be cleaned up by coordinating regulatory requirements instead of using multiple processes, which is the current method.

Specific Changes Proposed:

- Milestone M-13-00 requires the preparation and submittal of six remedial investigations/ feasibility studies each year. The sequence and types of submittals under this milestone will be modified to better coordinate regulatory requirements and support the application of resources to the 100 and 300 National Priorities List Areas.
- The 100-N Area will be used as a pilot project to ensure coordinated cleanup efforts. This cleanup will reduce current and potential near-term impacts to human health and the environment from 100-N Area facilities.
- The remedial investigation/feasibility study effort will be refocused to speed progress in achieving stakeholders values, which includes protecting the Columbia River, implementing aggressive remedial actions, and making land available for other uses.
- The completion of remediation of all operable units by September 2018 will be redefined to exclude the six tank farm operable units. Remediation of these six units will be completed in the year 2024. The remediation definition will be expanded to include the decontamination and decommissioning (final disposition) of all facilities and structures excluding the 100 Area reactor buildings.
- The requirement for Part B RCRA permit applications and closure plans for certain RCRA treatment, storage, or disposal units will be rewritten to optimize the efficiency of Site characterization and cleanup activities.

Facility Transition Proposed Changes

When a facility will no longer be used for its original purpose, it will be brought into a safe and secure condition that will minimize maintenance and surveillance expenses. This is facility transition. Transition is the first phase of a three-step process called facility decommissioning. Phase I, transition, will include the deactivation and stabilization of plant equipment and systems. Phase II, surveillance and maintenance, will be the bridge period. Phase III, disposition, will be final closure and disposal of a facility. Any time before disposition, a facility may be transferred to another useful purpose.

Until recently, the Tri-Party Agreement primarily addressed the cleanup of contaminated waste sites. In January 1994, DOE agreed to include in the Tri-Party Agreement the disposition of key production and other large Hanford facilities. The Tri-Party signatories began negotiations in July 1994 to set schedules and milestones for cleanup at the PUREX and Uranium-TriOxide plants and the FFTF. The negotiations also addressed the clean out of the Plutonium Finishing Plant and the 324 Building radiochemical engineering cells and vault tanks.

A tentative agreement between DOE, EPA, and Ecology to proceed with facility transition and cleanup actions under the Tri-Party Agreement was reached in January 1995 for all facilities except those in the 324 Building, which are still being negotiated.

Specific Changes Proposed:

- Establish a safe and environmentally secure configuration for the PUREX and Uranium-TriOxide plants to achieve necessary preclosure actions and transition the facilities to the surveillance and maintenance phase.
- Establish a safe and environmentally secure configuration for the Fast Flux Test Facility to achieve necessary preclosure actions and transition the facilities to the surveillance and maintenance phase.
- Stabilize the previous process areas within the Plutonium Finishing Plant, including the Plutonium Reclamation Facility and Remote Mechanical "C" Line. This will establish a safe and environmentally secure configuration in these areas of the facility.
- Revise the necessary permitting, closure, or preclosure actions related to transition efforts for the PUREX Plant, FFTF, and Plutonium Finishing Plant.

Other Proposed Modifications to the Tri-Party Agreement

Language will be added in Section 10 of the Tri-Party Agreement Action Plan that commits DOE to submit key documents to the involved Native

American tribes at the same time as they are submitted to Ecology and EPA. New language is proposed in Sections 3, 5, 6, 7, and 9 of the Action Plan to support integration of closure, past practice, and facility decommissioning activities. A number of terms will be added and other definitions modified under Appendix A, Definition of Terms.

A new section, 14, will be added to the Action Plan to detail the facility decommissioning process. It will include planning and action paths for all three decommissioning phases and will address regulatory integration.

Hanford Summit II

More than 700 people attended Hanford Summit II, which was held in Pasco, Washington in June 1994. The day-long event was a follow-up to the first Hanford Summit held in September 1993. The Secretary of Energy's response to the Summit II initiatives was issued after extensive consultation and dialogue with Summit participants.

Secretary of Energy Hazel O'Leary endorsed 26 Hanford Summit II initiatives to facilitate cleanup of the Hanford Site. The initiatives cover such areas as regulatory reform, openness, training, public involvement, and economic and technology development. The initiatives are also intended to create a sustainable economic future for the Mid-Columbia region. The centerpiece of the Secretary's endorsement is a "demonstration zone" to be established by the DOE, the EPA, and Ecology to integrate the various recommendations. Secretary O'Leary said that the demonstration zone "will help display new ideas, new ways of doing business, and new possibilities" for the nation's largest nuclear waste cleanup effort. Noting that the demonstration zone complements Hanford's designation as a "laboratory" for reinventing government, the Secretary encouraged the Richland Operations Office to begin implementation as soon as possible. Ideas proven to make cleanup better, faster, safer, and more cost-effective would be applied across the Hanford Site, throughout the DOE complex, and in some cases, to the commercial marketplace.

Other initiatives supported by the Secretary of Energy include:

- Streamlining regulations without compromising public safety, public involvement, or legal intent
- Maximizing public access to Hanford information
- Expediting declassification and release of documents from past DOE operations
- Continuing support of employee rights initiatives
- Working to increase stakeholder participation in the Hanford decision-making process
- Demonstrating and using new technologies
- Designing and constructing the Hazardous Materials Management and Emergency Response Center, subject to Congressional line item funding
- Developing partnerships and other innovative practices. For example, in addition to a recent $987,000 grant for an Entrepreneurship/Small Business Partnership, DOE will establish an Environmental Business Enterprise Center and an Entrepreneurs Advisory Board, as well as specific relationships for technology transfer. DOE endorsed school-to-work partnerships and other education initiatives, subject to funding by the states or private sector.

Hanford Advisory Board

The Hanford Advisory Board was created in January 1994 to advise DOE on major Hanford cleanup policy questions. The Board is one of 15 such advisory groups created by DOE at weapons production cleanup sites across the complex. The Board comprises 33 members that represent a broad cross section of interests: environmental, economic development, tribes and other governments, and the public. Each board member has at least one alternate. Merilyn Reeves, of Amity, Oregon, is the chairperson.

The Board has six committees: 1) Dollars and Sense, which deals with DOE budget issues, 2) Public Involvement, 3) Health, Safety, and Waste Management, 4) Environmental Restoration, 5) Cultural and Socioeconomic Impacts, and 6) the Board's internal budget committee. Committees study issues

and develop policy recommendations for Board action.

Early on, the Board adopted and affirmed values developed by two predecessor groups: The Hanford Future Site Use Working Group and the Tank Waste Task Force. The groups advised DOE and Hanford Site cleanup regulators to 1) protect the Columbia River and 2) get on with cleanup. Board members have submitted advice to DOE on a range of issues including budget priorities, environmental restoration, ground-water monitoring and remediation, releases to the Columbia River via the N Springs, worker health and safety, local economic transition issues, and public involvement.

Environmental and Molecular Science Laboratory

In 1994, ground was broken for the construction of the Environmental and Molecular Science Laboratory (EMSL). When finished, the 18,600 m^2 (200,000 ft^2) EMSL will accommodate up to 270 permanent staff, visiting scientists, postdoctoral researchers, and students who will work to develop the science and technology needed to clean up environmental problems at government and industrial sites across the country. Research conducted at this national user facility is also expected to lead to advancements in energy, new materials, health and medicine, and agriculture.

100-K Area Fuel Storage Basins

In February 1994, the Spent Nuclear Fuel Project was established. The project mission is to provide safe, economic, and environmentally sound management of Hanford spent nuclear fuel in a manner that stages it to final disposition.

The Hanford Site spent nuclear fuel inventory constitutes about 80% of the inventory currently stored in the DOE complex. The majority of Hanford's inventory consists of about 2,100 metric tons (2,300 tons) of irradiated N Reactor fuel stored in the 105 K-East and 105 K-West Fuel Storage Basins.

In 1994, working closely with stakeholders and local Native American tribes, decisions were made that support a strategy for near-term and interim fuel storage of the K Basin inventory. This strategy supports removal of the fuel and sludge from the K Basins before December 2002, as stipulated in the Tri-Party Agreement. The Spent Nuclear Fuel Project is now in the process of implementing the strategy for acceleration of fuel and sludge removal from the K Basins.

A project was started in 1994 to install isolation barriers in the basins. These barriers will isolate the spent fuel from a vulnerable construction joint in the discharge chute of the basins to prevent the shielding water from draining from the basins in the event of a major earthquake and releasing contaminated water to the ground and radioactive contamination to the air. The project is expected to be complete in April 1995.

Plutonium Uranium Extraction and Uranium-TriOxide Plants

The function of the PUREX Plant was to treat irradiated reactor fuel elements to recover uranium and plutonium-bearing solutions. In December 1992, DOE Headquarters directed the Richland Operations Office to proceed with deactivation of the PUREX Plant. In September 1993, PUREX Plant management submitted a project management plan to the Richland Operations Office for transition of the PUREX Plant to a minimum surveillance mode, awaiting final decontamination and decommissioning. The transition is expected to take approximately 5 years.

The Uranium-TriOxide Plant completed its final campaign in June 1993. During this campaign, 757,000 L (200,000 gal) of liquid uranyl nitrate hexahydrate that had been in storage at the PUREX and Uranium-TriOxide Plants were converted to approximately 199 metric tons (219 tons) of uranium-oxide powder. The powder is being stored at the plant pending transfer to a vendor. In July 1993, 378,000 L (100,000 gal) of recovered nitric acid were shipped back to the PUREX Plant. Flushing of residual process solutions from the Uranium-TriOxide Plant piping and tanks was completed as part of the transition to deactivation. This transition is expected to be complete by June 1995.

Plutonium Finishing Plant

The function of the Plutonium Finishing Plant (PFP) was to extract plutonium from plutonium-bearing chemical solutions and convert it into metal and oxide. The PFP was first used in 1951, and the production processes operated until May 1989. Although processing has ended, plutonium-bearing materials remain in the plant.

In July 1993, DOE started discussions with citizens groups about plans to operate the PFP processes. DOE intended to run processes within the PFP, the Plutonium Reclamation Facility, and portions of the Remote Mechanical "C" Line to stabilize some plutonium-bearing materials. The Plutonium Reclamation Facility would have purified plutonium solutions that would have been converted to plutonium dioxide in the Remote Mechanical "C" Line. That operation would have involved release of 28-37 kg (60-80 lb) per day of carbon tetrachloride to the air. DOE initiated efforts to prepare an environmental assessment to evaluate the action.

A series of public meetings regarding the proposed environmental assessment resulted in significant public comment, demands for an EIS, and consideration of alternate methods of plutonium stabilization. Based on these comments, DOE began preparing an EIS and approved a proposal to initiate several interim actions to reduce safety risks in the facility while waiting for the EIS. These interim actions were selected because they do not result in the production of a purified plutonium product, do not release carbon tetrachloride to the air or discharge liquids to the ground, and create a much smaller amount of waste to be sent to Hanford's double-shell tanks. Several of the interim actions have already been completed including downloading solutions from the Plutonium Reclamation Facility for disposal, decontaminating portions of the PFP, and removing plutonium-contaminated ducts and piping from the 232-Z incinerator building. Two interim actions are ongoing:

- Sludge Stabilization--Much of the plutonium-bearing sludge stored in PFP gloveboxes can be heated and converted to an impure stable solid and stored safely in PFP's vaults. An environmental assessment was prepared to review potential impacts from this operation. The process uses two new small laboratory furnaces to heat the sludge to about 1,000°C (1,800°F) over several hours. This process converts the plutonium compounds to plutonium oxide and drives off the moisture, resulting in a stable oxide powder. Other chemicals not driven off by the heating process remain as stable solids. Processing was initiated in November 1994.
- Solutions in Storage Containers known as "10-Ls"--Some storage containers contain plutonium-bearing chloride and fluoride solutions that pose special corrosion concerns. These solutions will be put in new, safe storage containers. Some or all of the solutions will be used in the development laboratory to test future processing options to support the EIS. Downloading these solutions is expected to start in early 1995.

Waste Vitrification

Approximately 215,000 m^3 (281,000 yd^3) of radioactive and hazardous wastes accumulated from over 40 years of plutonium production operations are stored in 149 underground single-shell tanks and 28 underground double-shell tanks. Current plans are to pretreat the waste and then solidify it into a glass matrix. Pretreatment will separate the waste into a low-radioactivity fraction, and a high-radioactivity and transuranic fraction. The bulk of the radionuclides will then be in the high-radioactivity and transuranic fraction. In separate facilities, both fractions will be vitrified, a process that will destroy or extract organic constituents, neutralize or deactivate dangerous waste characteristics, and immobilize toxic metals. The vitrified low-radioactivity fraction will be disposed of in a near-surface facility on the Hanford Site in a retrievable form. The vitrified high-radioactivity fraction will be stored onsite until a geologic repository is available offsite for permanent disposal. Tri-Party Agreement milestones specify December 2028 for completion of pretreatment and vitrification of the tank wastes.

Waste Receiving and Processing Facility

During 1994, construction was started on the first major solid waste processing facility associated with cleanup of the Hanford Site. Scheduled to

begin operations in March 1997, the Waste Receiving and Processing Facility Module 1 will be staffed to analyze, and prepare for disposal, drums and boxes of waste resulting from plutonium operations at Hanford. The Tri-Party Agreement mandates construction and operation of this module. Wastes destined for this module include Hanford's current inventory of more than 37,000 drums of stored waste, as well as materials generated by future site cleanup activities. Consisting primarily of clothing, gloves, face masks, small tools, and dirt suspected of being contaminated with plutonium, wastes in the 0.21 m^3 (55 gal) drums may also contain other radioactive materials and hazardous components. Some of the materials processed will qualify as low-level waste suitable for disposal directly at the Hanford Site. The remaining wastes will be certified and packaged for eventual shipment to the Waste Isolation Pilot Plant in New Mexico. Materials requiring further processing to meet disposal criteria will be retained at Hanford pending treatment.

The 4,831 m^2 (52,000 ft^2) facility will begin operations in 1997 near the Central Waste Complex in the 200-West Area. The 200-West Area is located on the central plateau that the public and Tri-Party agencies have designated for waste processing and long-term waste storage. The facility is designed to process 6,800 drums of waste annually for 30 years.

Waste Tank Safety Issues

The Waste Tank Safety Program (WTSP) was established in 1990 to address the hazards associated with storage of radioactive mixed waste in the 177 large underground storage tanks at the Hanford Site. The WTSP serves as the focal point for identification and resolution of selected high-priority waste tank safety issues, with resolution being completed in priority order. Tanks with the highest risk will be evaluated and mitigated first. The tasks to resolve the safety issue are planned and implemented in the following logic sequences: 1) evaluate and define the associated safety issue, 2) identify and close any associated unreviewed safety question (DOE 1991), 3) mitigate any hazardous condition to ensure safe storage of the waste, 4) store and monitor waste conditions, and 5) resolve the respective safety issue. Each of these steps has supporting functions of some combination of monitoring, mathematical analyses, laboratory studies, and in-tank sampling or testing. The path followed is ultimately a function of whether the waste requires treatment and where the treatment will take place.

The WTSP is currently focusing on resolution of ferrocyanide, flammable gas, organic, high-heat, noxious vapor, and criticality safety issues as described below. The tanks of concern are placed on a Watch List by safety issue. At the end of 1994, there were 54 tanks on the Watch List: 18 ferrocyanide tanks, 25 flammable gas tanks, 20 organic tanks, and one high-heat tank. Some of the tanks are included under more than one category. These tanks were identified in accordance with Public Law 101-510, Section 3137 (1990), *Safety Measures for Waste Tanks at Hanford Nuclear Reservation* (the Wyden Amendment).

Watch List Tanks

In 1990, all Hanford Site high-level waste tanks were evaluated and organized into four categories of watch list tanks to ensure increased attention and monitoring. Tanks were classified as ferrocyanide, flammable gas, high-heat, and organic watch list tanks. Two other safety concerns that involve some or all of the tanks include criticality and noxious vapor safety issues.

Ferrocyanide. The ferrocyanide safety issue involves the potential for uncontrolled exothermic reactions of ferrocyanide and nitrate/nitrite mixtures (Postma et al. 1994a). Laboratory studies show that temperatures must exceed 250°C for a reaction to propagate. The hottest ferrocyanide tank temperature is 530°C and decreasing. In October 1990, an unreviewed safety question was declared because safety was not adequately defined by then existing analyses. However, the unreviewed safety question was closed by DOE in March 1994, as a result of significant knowledge gained from simulant studies, conservative theoretical analyses, and analyses of actual waste samples that allowed bounding safety criteria to be defined and applied to each tank (Postma et al. 1994a). Of the original 24 ferrocyanide tanks, 18 are now on the watch list. Four were removed in 1993 and two were removed in 1994. The remaining tanks will be taken off the watch list as core samples are obtained and analytical analyses confirm that the ferrocyanide has decreased in fuel content from hydrolysis and radiolysis ("aging") to

acceptable low levels (Lilga et al. 1994, Meacham et al. 1995).

Flammable Gas. The flammable gas tanks safety issue involves the potential release of flammable gases from wastes in selected tanks. In prior years, work controls were instituted to prevent introduction of spark sources in these tanks, and evaluations were completed to ensure that installed equipment was intrinsically safe. The worst-case tank, 241-SY-101, was successfully mitigated in 1994 with the insertion of a mixing pump. The pump is operated up to three times a week to mix the waste and release gases that accumulate in the waste. Hydrogen monitors are being installed on all 25 flammable gas tanks. These monitors, called standard hydrogen monitoring systems, consist of a cabinet equipped with piping and instrumentation that support an on-line hydrogen detector and a "grab sampler." Documentation to close the unreviewed safety question in the 241-SY tank farm is being prepared and will be submitted to DOE early in 1995 for closure action.

High-Heat Tank. This safety issue concerns tank 241-C-106, a single-shell tank that requires water additions and forced ventilation for evaporative cooling. Without the water additions, which would be discontinued in the event of a tank leak, the tank could exceed structural temperature limits, resulting in potential concrete degradation and possible tank collapse. This tank is on an accelerated program for early retrieval and transfer of waste to a double-shell tank. Double-shell tanks are designed to handle heat-bearing materials better than single-shell tanks. A process test and considerable thermal analyses were completed in 1994 on tank 241-C-106 to evaluate alternative cooling approaches (Eyler 1994, Thurgood et al. 1995). The studies concluded that the tank could be adequately cooled using refrigerated air chillers.

Organic Tanks. The organic tanks safety issue involves the potential for uncontrolled exothermic reactions of organic chemicals and nitrates/nitrites and for vapors from semivolatile organics entrained in the waste to exceed the flammability limits. Recent laboratory tests showed that fuel concentrations and temperatures required to support propagating exothermic reactions are comparable to those for ferrocyanide. In addition, moisture levels above 20% will prevent reactions from propagating regardless of fuel concentrations.

Work controls were implemented in 1990 to prevent the introduction of ignition sources to these tanks. In May 1994, vapor sampling and safety analyses were completed that provided the technical basis for closing the unreviewed safety question on the flammability of the floating organic layer in tank 241-C-103 (Postma et al. 1994b). Ten tanks that contained organic complexants were added to the organic tanks watch list following a review of sampling data and waste transfer records (Hanlon 1994).

Other work indicates that aging processes have also destroyed or significantly lowered the energy content of the organic tanks (Ashby et al. 1994). In addition, work by Barney (1994) shows that the more energetic complexants and the primary degradation products of tributyl phosphate (TBP) are water soluble in saturated nitrate-nitrite salt solutions. Thus, a high percentage of organic chemicals were removed from the single-shell tanks when their pumpable liquid supernatant was pumped out as part of the interim stabilization process for the single-shell tanks.

Criticality. The unreviewed safety question on the potential for criticality in the high-level waste tanks was closed in 1994 by completing additional analyses, strengthening tank criticality prevention controls, and improving administrative procedures and training (Braun and Szendre 1994). The analyses showed that criticality is highly unlikely during storage. All of the single- and double-shell tanks at the Hanford Site contain sufficient neutron absorbers to ensure safe storage; however, additional sampling and controls will be required for retrieval and pretreatment-related activities.

Noxious Vapor. Some of the Hanford Site tanks contain chemicals that release toxic vapors to the environment. These vapors pose a potential health risk to Hanford Site employees who work in the tank farms. The safety issue stems from an insufficient understanding of the causes of reported exposures of personnel to unacceptable levels of noxious vapors and the concern that, until the vapors in the tanks are well characterized, the risks to worker health and safety cannot be determined or controlled (Osborne 1994, Huckaby and Babad 1994).

In prior years, worker protection controls were instituted to prevent worker exposures, and a program was implemented for routine workspace air monitoring and personnel dosimetry.

In-tank vapor sampling equipment was developed and tested in 1994. Two methods are now used to collect vapor samples from the waste tanks (Huckaby 1994). The primary method involves drawing air, gases, and vapors out of the waste tanks. This method was designed to collect representative samples from warm, moist tanks, even if a fog exists in the tank headspace. A second method employs in situ sampling. Rather than transferring the air, gases, and vapors to be sampled to a remote location, the sampling devices themselves (specifically, sorbent traps) are lowered into the tank headspace. Through 1994, 18 high-level waste tanks were vapor sampled using these two methods.

Waste Tank Status

The status of the 177 waste tanks as of December 1994 is reported in WHC-EP-0182-81, *Waste Tank Summary for Month Ending December 31, 1994* (Hanlon 1995). This report is published monthly; the December report provided the following:

- Number of waste tanks
  - 149 single-shell tanks
  - 28 double-shell tanks
- Number of tanks listed as "assumed leaker" tanks
  - 67 single-shell tanks
  - 0 double-shell tanks
- Chronology of single–shell tank leaks
  - 1956: First tank reported as suspected of leaking (Tank 241-U-104)
  - 1973: Largest estimated leak reported (Tank 241-T-106; 435,000 L [115,000 gal])
  - 1988: Tanks 241-AX-102, -C-201, -C-202, -C-204, and -SX-104 reported as confirmed leakers
  - 1992: Latest tank (241-T-101) added to assumed leaker list, bringing total to 67 single-shell tanks
  - 1994: Tank 241-T-111 declared an assumed re-leaker
- Number of ferrocyanide tanks on watch list
  - 18 single-shell tanks[(a)] (two tanks [241-BX-102 and -BX-106] were removed from the watch list in December 1994)
- Number of flammable gas tanks on watch list
  - 19 single-shell tanks[(b)]
  - 6 double-shell tanks
- Number of organic tanks on watch list
  - 20 single-shell tanks

So far, 106 single-shell tanks have been stabilized, with the program to be completed in 2000. At the end of 1994, 98 single-shell tanks had intrusion prevention devices completed, and 51 single-shell tanks were partial interim isolated.

The total estimated volume of radioactive waste leakage from single-shell tanks is 2,270,000 to 3,410,000 L (600,000 to 900,000 gal).

During 1994, two single-shell tanks identified as assumed re-leaker tanks were pumped as discussed below.

Tank 241-BX-111. This tank was declared an assumed re-leaker in April 1993. Pumping of the tank commenced in October 1993, and was completed in April 1994. Pumping was restarted in May to remove additional pumpable liquid after review of in-tank photos. A total of 436,000 L (115,000 gal) were pumped from the tank in 1994 with completion of interim stabilization expected in 1995.

Tank 241-T-111. The surface level showed a steady decrease after the automatic waste surface

(a) Two ferrocyanide tanks are also listed as organic tanks.
(b) Eight flammable gas tanks are also listed as organic tanks.

level measurement device was repaired in August 1993. The surface level measurement after the repair was 4.11 m (13.5 ft) and continued to decrease to 4.09 m (13.4 ft) through January 1994. An off-normal occurrence report was issued in February 1994, and the tank was declared an assumed re-leaker. Pumping began in May 1994, completing a Tri-Party Agreement milestone for the start of emergency pumping. A total of 29,900 L (7,900 gal) was pumped from the tank in 1994 with completion of interim stabilization expected in 1995.

During 1994, pumping occurred in eight single-shell tanks. In addition to the two tanks listed above, tanks 241-BX-110, 241-BY-102, 241-BY-109, 241-C-102, 241-C-107, and 241-C-110 were also pumped. In 1994, the total liquid volume removed from the eight tanks was 490,000 L (129,000 gal).

Pollution Prevention Program

The Hanford Site Pollution Prevention Program (formerly Waste Minimization) is an organized, comprehensive, and continual effort to systematically reduce the quantity and toxicity of hazardous, radioactive, mixed, and sanitary wastes; conserve resources and energy; reduce hazardous substance use; and prevent or minimize pollutant releases to all environmental media from all operations and Site cleanup activities.

It is designed to satisfy DOE requirements, recent presidential executive orders, and other state and federal regulations and requirements. In accordance with sound environmental management, preventing pollution through source reduction is the first priority in the Hanford Site's Pollution Prevention Program, and the second priority is environmentally safe recycling. Waste treatment to reduce the quantity, toxicity, or mobility (or a combination of these) will be considered only when prevention or recycling are not possible or practical. Environmentally safe disposal is the last option.

By incorporating this hierarchy into Hanford environmental management activities, the following successes in minimizing waste were accomplished:

- Hanford Site pollution prevention efforts in 1994 helped to prevent the generation of 1,270 m^3 (1,660 yd^3) of radioactive mixed waste, 133 metric tons (147 tons) of RCRA waste, and 17,700 metric tons (19,500 tons) of sanitary waste with a cost savings of approximately $4 million.
- Two separate modifications in liquid scintillation measurement techniques accounted for a 5.4 m^3 (190 ft^3) reduction in radioactive mixed waste. The use of a microscintillation counter allowed a 99% reduction in materials used for some sample measurements, and the substitution of a nonregulated scintillation cocktail reduced the waste classification from radioactive mixed to low-level radioactive waste.
- The Hazardous Materials Reduction Initiative avoided the purchase of 900 kg (2000 lb) of hazardous products, recycled more than 10 metric tons (11 tons) of surplus materials, and eliminated the use of more than 2.5 metric tons (1.7 tons) of products containing Class I ozone depleting substances.
- During 1994, the Hanford Site recycled offsite 610 metric tons (670 tons) of office paper; 1,800 metric tons (2000 tons) of scrap metal; 59 metric tons (65 tons) of lead; 9,500 toner cartridges for computer printers, and 8,300 L (2200 gal) and 50 metric tons (55 tons) of surplus chemical products.

Besides these sitewide programs, numerous generator-specific initiatives were put into place. These initiatives are specific to a particular area or process and, in most cases, were thought of and implemented by the onsite people who handle the waste daily. To celebrate these pollution prevention activities, the "Pollution Prevention Accomplishments Book" (Betsch 1994) was published in October covering activities in 1994. This book outlines 33 significant initiatives that were implemented and are now in use at locations throughout the Hanford Site. A few of these initiatives are:

- Replaced alkaline and NiCd batteries with rechargeable alkaline batteries

- Avoided mixed waste by diverting rainwater away from areas where it would become contaminated
- Eliminated custodial services' use of all hazardous cleaning products, thereby avoiding the resulting regulated waste
- Recycled radiological signs into plastic pipe.

These activities, plus 29 others, resulted in significant reductions in hazardous waste, radioactive waste, and solid sanitary waste, and promoted resource conservation and technology transfer. Most of the ideas were simple improvements in processes enacted by changing the methods of remediation or disposal. The focus was on generating less waste in the first place and reusing or recycling the waste that was generated.

Although not all the waste savings from these generator-specific ideas were quantifiable, those that were resulted in the following reductions:

- 8,730 million L (2,310 million gal) of bulk liquid
- 1,070 m^3 (1,400 yd^3) of solid waste
- 7.12 x 10^{10} kilojoules (1.98 x 10^7 kilowatt-hours) of energy.

These reductions are estimated for all of 1994. In addition to these and the nonquantifiable waste reductions, numerous other benefits were realized, including significant cost savings of more than $43 million, reduced worker exposure, improved public relations, and an overall improvement in quality of operations.

242-A Evaporator Status

The 242-A Evaporator was restarted as scheduled in April 1994 and completed two waste reduction campaigns. Each campaign processed the low-level mixed waste contents of six double-shell tanks. The evaporator process resulted in an average waste reduction of 85% in tank waste volume. The process condensate from the evaporator operation is stored in the Liquid Effluent Retention Facility and is awaiting final disposal through the 200 Area Effluent Treatment Facility. Future campaigns have been scheduled for 1995 and 1996.

Liquid Effluent Activities

Liquid Effluent Retention Facility

The start-up activities for the Liquid Effluent Retention Facility were completed on time to support the 242-A Evaporator campaigns in 1994. As a result of these campaigns, 25,000,000 L (6,600,000 gal) of evaporator process condensate are stored in the Liquid Effluent Retention Basins awaiting final processing through the 200 Area Effluent Treatment Facility. The Liquid Effluent Retention Facilities consist of three separate 24,600 m^3 (32,200 yd^3) storage basins (surface impoundments). Two are used for normal operation, and the third is used as a contingency in the event a leak should develop in an operational basin.

Ecology requested that the 242-A Evaporator, the Liquid Effluent Retention Facility, and the 200 Area Effluent Treatment Facility RCRA Part B permit applications be integrated into one permit application. The Richland Operations Office concurred with Ecology's request.

200 Area Effluent Treatment Facility, Project C-018H

The 242-A Evaporator/PUREX Plant Process Condensate Treatment Facility (200 Area Effluent Treatment Facility) is being constructed to provide effluent treatment and disposal capability required to restart the 242-A Evaporator. The facility will provide for effluent collection, a treatment system to reduce the concentration of radioactive and hazardous waste constituents in the effluent streams to acceptable levels, tanks to allow verification of treated effluent characteristics before discharge, and a state-approved land disposal structure for effluents.

Secondary waste generated by the treatment facility will be concentrated and packaged to meet state requirements for storage and/or disposal of solid waste.

Acceptance testing of the facility began in late 1994 and is expected to be completed in March 1995. The facility is expected to begin operations in October 1995. All regulatory permit applications required for the facility and disposal site have been submitted to the regulators as required in the

Tri-Party Agreement and Ecology Liquid Effluent Consent Order (No. DE 91NM-177). Because process condensate was not available for waste characterization, the Federal Delisting Petition, the State Waste-water Discharge Permit, and the RCRA Dangerous Waste Permit applications were based on a surrogate solution. This surrogate was developed and tested under pilot-scale conditions to determine a list of constituents that the facility can successfully treat.

200 Area Treated Effluent Disposal Facility, Project W-049H

The 200 Area Treated Effluent Disposal Facility will be a permitted system for the collection, sampling, and disposal of 13 effluent streams in the 200-East and 200-West Areas. Based on data derived in preparing the Washington Administrative Code 173-240-130 Engineering Report required by the State Waste-Water Discharge Permit program, it has been determined that the best available technology and all known and reasonable methods of prevention, control, and treatment will be implemented at each waste-water generating facility. Effluents will meet the requirements of best available technology before being discharged to the collection and disposal system. The construction of the collection system began in April 1993 and is now complete: final testing of the system is ongoing. The disposal facility design is complete.

300 Area Treated Effluent Disposal Facility

The 300 Area Treated Effluent Disposal Facility was completed and in operation in December 1994, ahead of schedule and under budget. It satisfied Tri-Party Agreement milestone M-17-09 for ceasing the discharge of untreated 300 Area process sewer effluent to the soil column at the 300 Area Process Trenches. A National Pollutant Discharge Elimination System permit has been issued by EPA Region 10 that allows the facility to discharge treated effluents to the Columbia River. The permit contains a reopener clause such that, after one year of operation, permit conditions may be renegotiated.

The 300 Area Treated Effluent Disposal Facility has a 1200 L/min (320 gal/min) treatment capacity. The facility, operated 24 hrs, is largely computer automated, with the capability for full manual operation. After its collection, the process waste water is treated for metals, suspended solids, residual mercury and heavy metals, organics, nitrite, sulfides, cyanide, and pH before discharge via a subsurface river diffuser in the Columbia River near Johnson Island. Sludge from the process is packaged in drums, and disposed of in a landfill.

340 Facility

The 340 Facility collects radionuclides and mixed wastes from the 300 Area for transportation to tank farms via rail car. Radioactive mixed liquid wastes that are collected originate at PNL laboratories and are critical to tank waste safety, tank characterization, and Site remediation. The 340 Facility tanks are currently operated as less than 90-day accumulation tanks under the requirements of the Dangerous Waste Regulations, WAC 173-303.

Phase II Effluent Streams

As part of the October 1991 negotiations to supplement the Tri-Party Agreement and to create the Consent Order (No. DE 91NM-177), the Richland Operations Office committed by October 1997, to implement the best available technology and all known and reasonable methods of prevention, control, and treatment (BAT/AKART) for the remaining nine Phase II streams, and to permit the streams under the WAC 173-216 State Waste-Water Discharge Permit Program. A WAC 173-240-130 Engineering Report was submitted to Ecology in September 1992.

One stream, the 241-AY/AZ Steam Condensate, is discharged to the Tank Farms and is not planned for discharge to the ground. Another stream, the 183-D Filter Backwash, was eliminated in June 1994. A State Waste-Water Discharge Permit application for 400 Area Secondary Cooling Water was submitted to Ecology in December 1992. The permit is expected to be issued in 1995.

The scope of the BAT/AKART for the 200 Area Phase II Streams is to eliminate, minimize, or treat effluents currently being discharged to the 216-B-3 Expansion Ponds. The facilities involved include the 241-A Tank, the 242-A Evaporator, the 244-AR Vault, B Plant, and the 284-E Powerhouse. The conceptual design report was completed in June 1993. Advanced conceptual design was completed

in January 1995, with definitive design starting in February 1995. A State Waste-Water Discharge Permit application for these streams was submitted to Ecology in December 1993.

Miscellaneous Streams

In accordance with Ecology Consent Order (No. DE 91NM-177), the DOE Richland Operations Office committed to submit State Waste-Water Discharge Permit applications for eleven miscellaneous streams. A decision was made to instead obtain a National Pollutant Discharge Elimination System permit for two of these streams for discharge to the Columbia River (300 Area Powerhouse Ash Waste Water, and Filter Backwash). Other changes included the decision to connect the 300 Area Sanitary Sewer to the City of Richland Publically Owned Treatment Works, and the decision to connect the 234-5Z Ventilation Steam Condensate/Dry Air Compressor Cooling Water to the 200 Area Treated Effluent Disposal Facility. The 209-E Building Steam Condensate stream was eliminated. State Waste-Water Discharge Permit applications were submitted to Ecology in June 1994 for the remaining six miscellaneous streams.

The DOE Richland Operations Office also agreed to inventory the remaining miscellaneous streams and to develop a plan and schedule for the disposition of those streams. An inventory of all effluent streams was developed that identified more than 500 small discharges. These discharges were evaluated against criteria developed to determine if they had any potential to cause harm to the environment or ground water. This inventory and these criteria were used to develop the final overall plan and schedule for regulatory compliance, which was submitted to Ecology in December 1994.

Submarine Reactor Compartments

Eight defueled submarine reactor compartment disposal packages were received and placed in Trench 94 in the 200-East Area during 1994. This brings the total number received to 43.

The reactor compartment disposal packages are being regulated by Ecology as dangerous waste because of the presence of lead used as shielding and by EPA because of the presence of small amounts of PCBs bound within the matrix of nonmetallic materials such as thermal insulation, electrical cables, and some synthetic rubber items.

Revegetation

The U.S. Army Corps of Engineers is currently working with the Natural Resources Trustee Council, PNL, and the Nature Conservancy on the preparation of a habitat/revegetation plan for the Hanford Site. Revegetation of selected sites is expected to occur in 1995.

Self-Assessments

During 1994, 249 environmental compliance self-assessments were completed by WHC. Approximately a third of these self-assessments identified compliance deficiencies such as deficiencies with hazardous waste management and effluent monitoring. Corrective actions for each of these deficiencies were also identified for completion.

PNL completed 36 environmental compliance self-assessments in 1994. Unsatisfactory conditions were identified in 14 of the assessments. The conditions all dealt with hazardous waste management issues. The majority of the conditions have been rectified, and corrective action is in progress for the remainder.

2.4 Environmental Occurrences

D. G. Black

Onsite and offsite environmental releases of radioactive and regulated materials during 1994 were reported to DOE and to federal and state agencies as required by law. The specific agencies notified depended on the type, amount, and location of the individual occurrences. In some cases an occurrence may be under continuing observation and evaluation. During 1994, all unusual and off-normal occurrences at the Hanford Site were reported to the Hanford Site Occurrence Notification Center. This Center is responsible for maintaining both a computer database and a hard copy file of event descriptions and corrective actions. Copies of occurrence reports are made available for public review in the DOE Public Reading Room located on the Washington State University Tri-Cities campus in Richland, Washington.

As defined in DOE Order 5000.3B, emergency occurrences "are the most serious occurrences and require an increased alert status for onsite personnel and, in some specified cases, for offsite authorities." There were no emergency occurrence reports filed in 1994.

Unusual occurrences are defined as nonemergency occurrences that may have a "significant impact or potential for impact on safety, environment, and health." There were 33 unusual occurrence reports filed during 1994 for Site contractors. The only unusual occurrences of environmental significance are summarized below.

Off-normal environmental occurrences are referred to as "abnormal or unplanned events or conditions that adversely affect, potentially affect, or are indicative of degradation in, the safety, environmental or health protection performance or operation of a facility." There were 16 off-normal environmental release-related occurrence reports filed at the Hanford Site during the year most of which involved releases of various types of oil. DOE contractors submitted these reports to the DOE reporting database, Occurrence Reporting and Processing System during calendar year 1994. The "Nature of Occurrence" for these occurrences was determined to be either "Hazardous Substances/Regulated Pollutants/ Oils" or "Hazardous Material Contamination". The more significant of these off-normal occurrences are summarized below.

Unusual Occurrences

Diesel Tank Leak at the 6652-L Building

After an underground diesel oil storage tank was removed, soil sample results indicated the soil under the tank was contaminated with oil. Soil samples were collected and tested and the analyses were submitted to Ecology. Based on Ecology's decisions, the site was cleaned up.

Disturbance of Native American Burial Ground

During excavation of an area south of the 300 Area for construction of the EMSL, an apparent Native American burial site was uncovered. The Hanford Cultural Resources Laboratory representative who was monitoring the excavation made the discovery and halted the work. Representatives of the tribes were notified immediately, and meetings were held with DOE to discuss stabilization and restoration needs. The tribes assumed responsibility for directing the restoration with funding provided by DOE. The planned building and facilities were relocated to avoid further disturbance.

Tank 241-C-110 Saltwell Diluted Waste Spill

In December 1994, while flushing a transfer line at the C-110 Saltwell in the 200-East Area, an operator noticed a quick disconnect that was leaking diluted waste onto a concrete pad and adjacent soil. Samples of the waste were taken to determine the what radiological contaminants were present. In addition to radiological contaminants in the diluted waste, hexavalent chromium was found at a concentration of 27.6 ppm, which exceeded the regulatory limit of 5.0 mg/l (5 ppm). The spilled liquid was therefore determined to be a dangerous waste exhibiting the toxicity characteristic for chromium. The total quantity spilled was calculated to be 4.540 kg (10.008 lb) containing 0.102 g (2.25×10^{-4} lb) of

chromium. This spill was upgraded to an unusual occurrence upon detection of the presence of the dangerous waste and the determination of the reportable quantity. The spill was cleaned up.

Off-Normal Occurrences

Oil Leaks in the 183-KW Transformer Yard

In March 1994, during maintenance surveillance of the 183-KW transformer yard, maintenance personnel noticed one transformer (Number D42719F) had leaked approximately 38 L (10 gal) of oil onto the ground. Substation maintenance was contacted for a spill assessment. During inspection of the transformer yard with substation maintenance, another transformer (Number D42718F) was discovered that had also leaked at least 38 L (10 gal) of oil to the ground. Both transformers were clearly labeled "Non-PCB-Contaminated Oil." Substation maintenance notified the spill office, electrical utilities, and the K Basins maintenance manager. Further investigation with electrical utilities produced documentation that each transformer had been retrofilled and contained PCB concentrations of between 5 ppm and 6 ppm, which meets EPA qualifications for non-PCB contaminated oils (less than 50 ppm). The spills were cleaned up.

384 Powerhouse Tank Removal Discovery of Contaminated Soil

In May 1994, while removing one empty diesel and one empty unleaded fuel tank, an offsite contractor discovered fuel-contaminated soil under the tanks. Approximately 300 m^3 (400 yd^3) of contaminated soil were excavated. The leaks appeared to be around the fuel line fittings and not from the tanks themselves. Maximum soil concentrations were 4300 ppm and 660 ppm for diesel and gasoline, respectively.

384 Powerhouse Release of Number 6 Fuel Oil

In May 1994, during ongoing efforts to locate and repair an existing leak in the Number 6 fuel oil transfer line, employees performing excavation work were unable to prevent accumulated oil from leaking to the ground. Approximately 38 L (10 gal) of the oil leaked from a containment tray inside a heat retention encasement that also holds the transfer line. The oil was cleaned up.

224-U Building Instrument Air Compressor Oil Leak

In June 1994, water was noticed coming from the Number 2 Joy air compressor cabinet, a backup instrument air compressor located on the third floor of the 224-U Building. When the unit's doors were opened, water was observed exiting the air inlet of the unit. Plant maintenance was called to shut-off electrical power to the unit. The Number 2 Joy air compressor was not in operation but in stand-by mode. According to a work package procedure, the plant millwright removed the lid from the oil sump and noticed that water was present, indicating that the unit's oil had been displaced. Further troubleshooting determined that approximately 94.6 L (25 gal) of lubricating oil had been displaced from the unit. Investigations determined that the oil/water had drained into the nearby floor drain that leads to the 207-U Diversion Basin situated approximately 0.4 km (0.25 mi) west of the Uranium-TriOxide Plant. (The Material Safety Data Sheet for the lubricating oil notes that the product is not regulated.)

Vehicle Accident - Overturned Water Truck

In September 1994, a contractor for ICF Kaiser Hanford Company overturned a water truck at the intersection of Route 4S and the entrance road to the 400 Area, Route 40, while attempting to make a left turn. The Hanford Fire Department, Benton County Sheriff, and Hanford Hazardous Materials Group responded to the accident. The driver was transported to Kadlec Hospital for observation and was released. The water truck released 38 to 57 L (10 to 15 gal) of gasoline and approximately 11,000 L (2,900 gal) of water to the soil. Environmental remediation activities to clean up the gasoline spill were completed according to procedure.

1171 Building Oil Release to Environment

In November 1994, during excavation of an in-ground vehicle floor hoist, work crews discovered oil-saturated soil beneath the leaking hoist. Initial evaluation determined the accumulation of oil over time to be in excess of 38 L (10 gal) of hydraulic oil. The release was cleaned up.

CERCLA and WAC Reportable Releases

There were 33 releases reported under the CERCLA-reportable quantity and WAC requirements by Hanford Site contractors in 1994. Twenty two of these were ethylene glycol released from motor vehicles or equipment, none of which were of any notable concern. The EPA Administrator has proposed an upward adjustment in the threshold level reportable quantity by regulation for ethylene glycol. The final rule should be published sometime in early 1995. An upward adjustment would have a major effect on the number of reportable ethylene glycol releases by eliminating the 0.454 kg (1 lb) threshold reportable quantity criteria.

There were nine release reports filed in accordance with the requirements of Underground Storage Tank Regulations, WAC 173-360. Eight releases were from underground storage tanks undergoing remediation under the Hanford Infrastructure Underground Storage Tank L-044 Project. One release was from an underground storage tank that was unearthed during excavation at the EMSL construction project. All releases were remediated with Ecology concurrence, per regulatory cleanup standards.

Other Releases:

1. On May 18, 1994, 38 L (10 gal) of Number 6 fuel oil was discovered to have leaked to the soil from the bulk storage tank piping system at the 300 Area 384 Powerhouse. The release was remediated and the piping system was repaired and put back into operation.

2. On December 12, 1994, 27.6 mg (6×10^{-5} lb) of hexavalent chromium were released to the top of a concrete pad and a small amount was released to the soil during a flushing operation at the tank farm area, Tank C-110 Saltwell Pump Pit. A detailed description of this release can be found under "Unusual Occurrences" in this section.

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Effluent Monitoring Information

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3.0 Effluent Monitoring, Waste Management, and Chemical Inventory Information

Monitoring effluents and managing waste and chemical inventories at Hanford Site facilities are essential to determine the effects these materials may have on the public, workers at the Site, and the surrounding environment. Hanford Site contractors have programs to monitor liquid and airborne effluents and manage solid waste and chemical inventories. Facility effluent monitoring programs are designed to measure effluents at their point of release into the environment, whenever possible. The effectiveness of effluent treatment and control and waste management practices are evaluated through near-facility monitoring. Types, quantities, and locations of chemicals are also tracked. This section summarizes the data collected in 1994 by these programs. More detailed program, sampling, and waste management information is contained in the volumes, *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1994* (Schmidt et al. 1995), *Westinghouse Hanford Company Operational Groundwater Status Report* (Johnson 1994), *1994 Hanford Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1995a), the *Hanford Site Annual Dangerous Waste Report for Calendar Year 1994* (DOE 1995c) and *Summary of Radioactive Solid Waste Received in the 200 Areas During Calendar Year 1994* (Anderson and Hagel 1995).

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3.1 Facility Effluent Monitoring

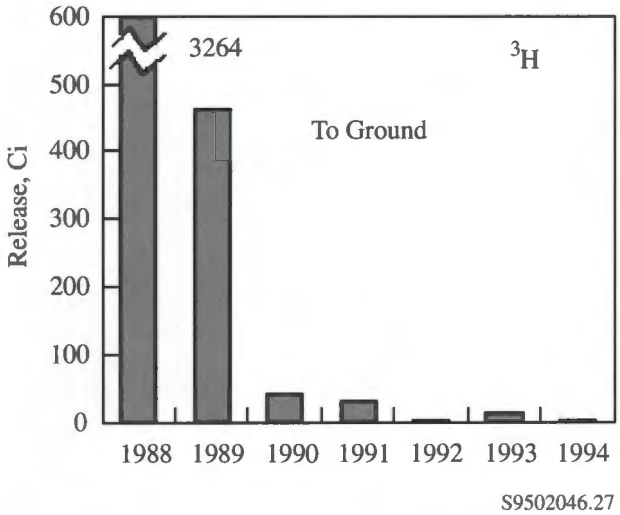
B. P. Gleckler

Liquid and airborne effluents that may contain radioactive or hazardous constituents are continually monitored when released to the environment at the Hanford Site. Facility operators perform the monitoring mainly through analyzing samples collected near points of release into the environment. Effluent monitoring data are evaluated to determine the degree of regulatory compliance for each facility or the entire Site, as appropriate. The evaluations are also useful in assessing the effectiveness of effluent treatment and control systems and management practices. Major facilities have their own individual effluent monitoring plans, which are part of *Environmental Monitoring Plan United States Department of Energy Richland Operations Office* (DOE 1994c), the comprehensive Site environmental monitoring plan required by DOE.

Measuring devices quantify most facility effluent flows, but some flows are calculated using process information. Effluent sampling methods include continuous sampling for most radioactive air emissions and proportional or "grab" sampling for most liquid effluents. Liquid and airborne effluents with a potential to contain radioactive materials at prescribed threshold levels are measured for total alpha and total beta activity and, as warranted, specific radionuclides. Nonradioactive constituents are also either monitored or sampled, as applicable.

Small quantities of the radionuclides americium-241, antimony-125, cesium-134, cesium-137, cobalt-60, europium-154, europium-155, iodine-129, krypton-85, plutonium-238, plutonium-239,240, ruthenium-106, strontium-90, tin-113, tritium, uranium, zinc-65, and zirconium-95 continue to be released to the environment. However, most radionuclides in effluents at the Site are approaching levels indistinguishable from background concentrations. A new Site mission of environmental restoration, replacing nuclear materials production, is largely responsible for the improved trend in radioactive emissions. This decreasing trend results in significantly smaller offsite radiation doses to the maximally exposed individual that are attributable to Site activities. Figures 3.1.1 and 3.1.2 depict quantities of several long-lived prominent dose-contributing radionuclides released from the Site over the past 7 years. In 1994, releases of radioactive and nonradioactive constituents in effluents were less than applicable standards.

Effluent release data are also documented in several other publicly available reports. For instance, the Richland Operations Office annually submits to



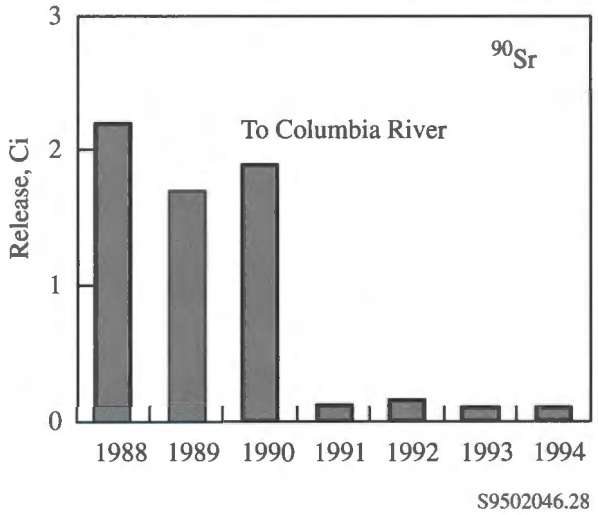


Figure 3.1.1 Liquid Releases of Selected Radionuclides from Site Facilities, 1988 Through 1994

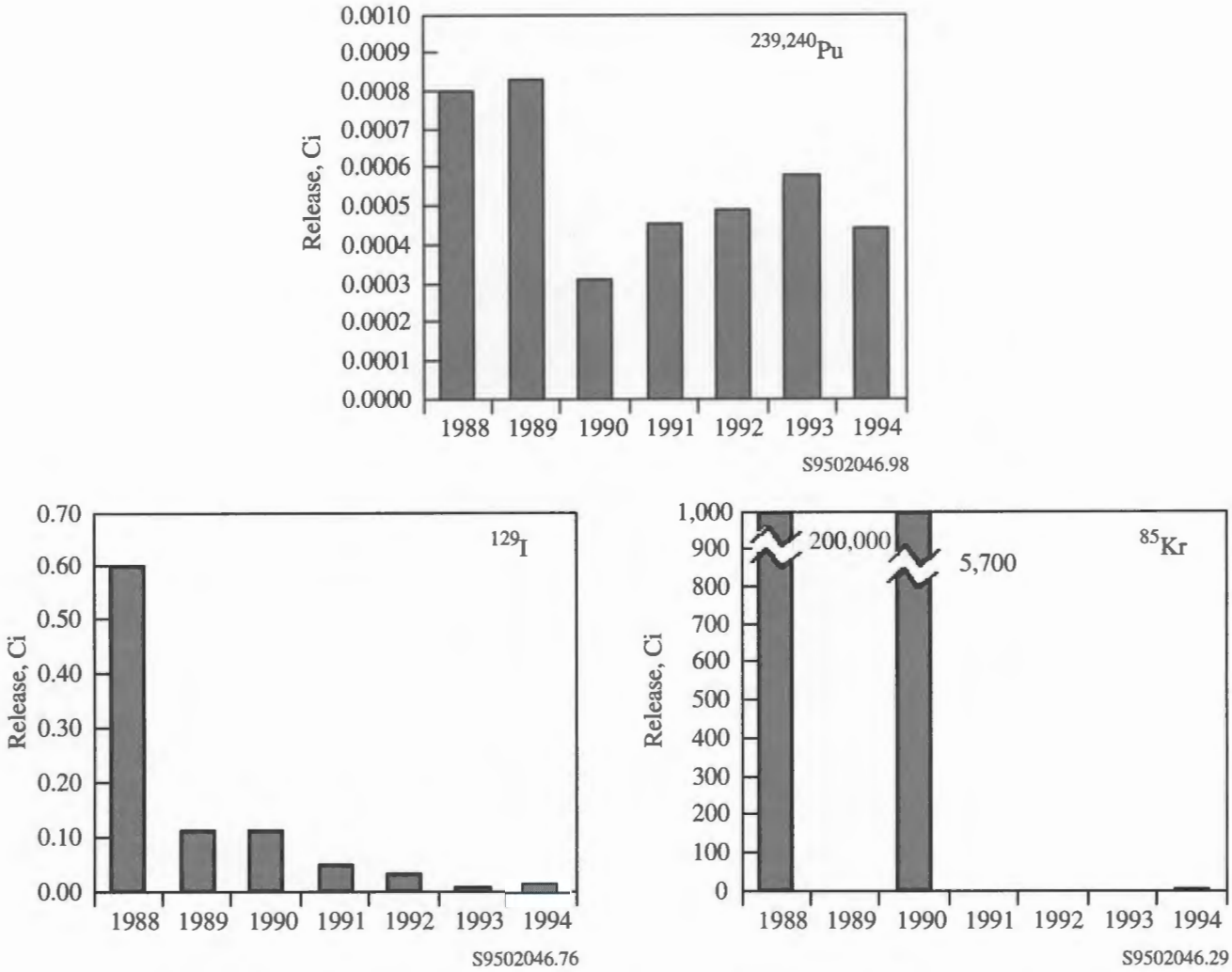


Figure 3.1.2 Airborne Releases of Selected Radionuclides from Site Facilities, 1988 Through 1994

EPA a report of radioactive airborne emissions from the Site, in compliance with *National Emission Standards for Hazardous Air Pollutants* (DOE 1994g). Data quantifying radioactive liquid and airborne effluents discharged from WHC facilities and activities are reported to DOE annually in the *Environmental Releases Report* (WHC 1995b). Monitoring results for liquid streams regulated by the National Pollutant Discharge Elimination System permit are reported monthly to EPA. Yearly data on nonradioactive emissions from fossil-fuel boilers are reported to Ecology.

Airborne Emissions

Radioactive Airborne Emissions

Radioactive airborne emissions from Site activities contain at least one of these forms of radionuclides: particles, noble gases, and volatile elements. Emissions having the potential to exceed 1% of the 10-mrem/yr standard for offsite doses are continuously monitored.

The continuous monitoring of radioactive emissions involves analyzing samples collected at points of

discharge to the environment, usually from a stack or vent. Samples are analyzed for total alpha and total beta activity and selected radionuclides. The selection of the specific radionuclides that are sampled, analyzed, and reported is based on 1) an evaluation of maximum potential unmitigated emissions expected from known radionuclide inventories in a facility or activity area, 2) sampling criteria given in contractor environmental compliance manuals, and 3) the potential each radionuclide has to contribute to the offsite public dose. Continuous air monitoring systems with alarms are also used at selected discharge points when a potential exists for radioactive emissions to exceed normal operating ranges by levels requiring immediate personnel alert.

Radioactive emission discharge points are located in the 100, 200, 300, 400, and 600 Areas. The sources for these emissions are summarized below:

- In the 100 Areas, emissions originate from the shutdown N Reactor, the two 100-K Area water-filled storage basins containing irradiated fuel, a recirculation facility that filters radioactive water from the N Reactor basin, which was used for storage of irradiated fuel, a room used for cleaning contaminated tools and equipment, and a radiochemistry laboratory. Seven radioactive emission points were active in the 100 Areas during 1994.
- The 200 Areas contain facilities for nuclear-fuel chemical separations and reprocessing, waste-handling and disposal, and steam generation using fossil fuels. Primary sources of radionuclide emissions are the PUREX Plant, the Uranium-TriOxide Plant, the Plutonium Finishing Plant, T Plant, the 222-S Analytical Laboratory, underground tanks for storage of high-level radioactive waste, and waste evaporators. During 1994, 57 radioactive emission discharge points were active in the 200 Areas.
- The 300 Area primarily contains laboratories, research facilities, and a fossil-fuel-powered steam plant. Primary sources of radionuclide emissions are the 324 Waste Technology Engineering Laboratory, the 325 Applied Chemistry Laboratory, the 327 Post-Irradiation Laboratory, and the 340 Vault and Tanks. Radioactive emissions arise from research and development and waste-handling activities. During 1994, 37 radioactive emission discharge points were active in the 300 Area.
- The 400 Area contains the FFTF, the Maintenance and Storage Facility, and the Fuels and Materials Examination Facility. Operations and support activities at FFTF and the Maintenance and Storage Facility released small quantities of radioactive material to the environment, even though the reactor did not operate in 1994. The 400 Area had four active radioactive emission discharge points during 1994.
- The 600 Area encompasses the remaining portions of the Hanford Site not assigned to other areas. One minor radioactive emission point was active during 1994 (the 6652-H Ecology Laboratory on the ALE Reserve).

Radioactive emissions at the Hanford Site in 1994 are summarized in Table 3.1.1.

Table 3.1.1 Radionuclides Discharged to the Atmosphere, 1994

		Release, Ci[a]				
Radionuclide	Half-Life	100 Areas	200-East Area	200-West Area	300 Area	400 Area
^{3}H (as HTO)[b]	12.3 yr	NM	NM	NM	1.7	NM
^{3}H (as HT)[c]	12.3 yr	NM	NM	NM	10.0	NM
^{60}Co	5.3 yr	6.3×10^{-6}	ND	ND	8.6×10^{-8}	NM
^{65}Zn	244.4 d	ND	ND	ND	7.1×10^{-7}	NM
^{85}Kr	10.7 yr	NM	NM	NM	4.1	NM
^{90}Sr[d]	29.1 yr	4.7×10^{-5}	6.5×10^{-5}	7.5×10^{-5}	1.6×10^{-5}	6.7×10^{-8}
$^{95}ZrNb$	64.02 d	ND	ND	ND	1.1×10^{-6}	NM
^{106}Ru	368 d	1.4×10^{-5}	ND	NM	2.4×10^{-6}	NM

Table 3.1.1 Radionuclides Discharged to the Atmosphere, 1994 (contd)

Radionuclide	Half-Life	Release, Ci[a]				
		100 Areas	200-East Area	200-West Area	300 Area	400 Area
^{113}Sn	115.1 d	ND	2.2×10^{-6}	NM	NM	NM
^{125}Sb	2.77 yr	1.6×10^{-6}	ND	NM	NM	NM
^{129}I	1.6×10^{7} yr	NM	1.4×10^{-2}	NM	NM	NM
^{134}Cs	2.1 yr	3.2×10^{-7}	ND	ND	ND	NM
^{137}Cs[e]	30 yr	1.0×10^{-4}	2.9×10^{-4}	2.7×10^{-4}	7.2×10^{-6}	7.0×10^{-6}
^{147}Pm	2.6 yr	ND	ND	ND	NM	NM
^{154}Eu	8.8 yr	1.7×10^{-6}	ND	ND	2.7×10^{-7}	NM
^{155}Eu	5 yr	4.7×10^{-6}	ND	ND	NM	NM
^{220}Rn	56 s	NM	NM	NM	160.0	NM
^{222}Rn	3.8 d	NM	NM	NM	1.2	NM
Uranium, recycled[f]	$> 2.445 \times 10^{5}$ yr	NM	NM	6.8×10^{-7}	3.7×10^{-9}	NM
Uranium, depleted[g]	$> 2.445 \times 10^{5}$ yr	NM	NM	NM	2.6×10^{-8}	NM
^{238}Pu	87.7 yr	1.2×10^{-6}	ND	1.5×10^{-5}	2.1×10^{-8}	NM
$^{239,240}Pu$[h]	2.4×10^{4} yr	7.8×10^{-6}	3.2×10^{-5}	3.9×10^{-4}	3.6×10^{-6}	2.4×10^{-6}
^{241}Pu	14.4 yr	NM	1.8×10^{-4}	2.0×10^{-3}	NM	NM
^{241}Am	432 yr	5.6×10^{-6}	1.2×10^{-5}	6.6×10^{-5}	6.7×10^{-8}	NM

(a) 1 Ci = 3.7×10^{10} Bq; NM = not measured; ND = none detected.
(b) HTO = tritiated water vapor.
(c) HT = elemental tritium.
(d) ^{90}Sr values in the 200, 300, and 400 Areas include total beta measurements from emission sources which are not analyzed for ^{90}Sr. The 400 Area ^{90}Sr value includes the total beta measurement from a single emission point in the 600 Area.
(e) The 400 Area's ^{137}Cs value is derived fully from total beta measurements.
(f) 200-West Area value determined by total uranium chemical analysis. 300 Area value determined from total alpha measurements. Assumed to be recycled uranium consisting of 34.614 Ci% ^{238}U, 2.059 Ci% ^{235}U, 58.551 Ci% ^{234}U, and 4.776 Ci% ^{236}U (99.008 Wt% ^{238}U, 0.912 Wt% ^{235}U, 0.009 Wt% ^{234}U, and 0.071 Wt% ^{236}U).
(g) Determined from total alpha measurements. Assumed to be depleted uranium consisting of 63.478 Ci% ^{238}U, 0.821 Ci% ^{235}U, and 35.701 Ci% ^{234}U (99.797 Wt% ^{238}U, 0.200 Wt% ^{235}U, and 0.003 Wt% ^{234}U).
(h) $^{239,240}Pu$ values in the 200, 300, and 400 Areas include total alpha measurements from emission sources which are not analyzed for $^{239,240}Pu$. The 400 Area $^{239,240}Pu$ value includes the total alpha measurement from a single emission point in the 600 Area.

Nonradioactive Airborne Emissions

Nonradioactive air pollutants emitted from power-generating and chemical-processing facilities are monitored when activities at a facility are known to potentially generate pollutants of concern.

In past years, gaseous ammonia has been emitted from the PUREX Plant, 242-A Evaporator, 241-AP Tank Farm, and 241-AW Tank Farms. Ammonia emissions are monitored only when activities at these facilities are capable of generating them. In 1994, the 242-A Evaporator operated during April, May, June, September, October, and November producing reportable ammonia emissions. The 241-AP and 241-AW Tank Farms also produced reportable ammonia emissions in 1994. The ammonia releases from the 242-A Evaporator, 241-AP and 241-AW Tank Farms are summarized in Table 3.1.2.

Table 3.1.2 Nonradioactive Constituents Discharged to the Atmosphere, 1994[a]

Constituent	Release, kg		
	200-East Area	200-West Area	300 Area
Particulate matter	7.43×10^2	1.77×10^3	1.21×10^4
Nitrogen oxides	7.71×10^4	1.84×10^5	4.97×10^4
Sulfur oxides	1.13×10^5	2.68×10^5	2.48×10^5
Carbon monoxide	2.82×10^4	6.72×10^4	4.97×10^3
Lead	7.23×10^1	1.72×10^2	2.68×10^1
Volatile organic compounds[b]	2.82×10^2	6.72×10^2	2.53×10^2
Ammonia	2.26	NM	NM
Antimony	NM	NM	6.35
Arsenic	7.73×10^1	1.84×10^2	1.58×10^1
Beryllium	1.04×10^1	2.48×10^1	0.58
Cadmium	6.13	1.46×10^1	2.92×10^1
Carbon tetrachloride[c]	NM	ND	NM
Chromium	2.24×10^2	5.34×10^2	1.77×10^1
Cobalt	NM	NM	1.67×10^1
Copper	1.41×10^2	3.36×10^2	3.84×10^1
Formaldehyde	3.15×10^1	7.52×10^1	5.60×10^1
Manganese	3.09×10^2	7.38×10^2	1.02×10^1
Mercury	2.28	5.44	4.42
Nickel	1.84×10^2	4.39×10^2	3.22×10^2
Polycyclic organic matter	NM	NM	7.59×10^3
Selenium	2.79×10^1	6.67×10^1	5.25
Vanadium	1.93×10^1	4.59×10^1	4.18×10^2

(a) The estimate of volatile organic compound emissions do not include emissions from certain laboratory operations; NM = not measured; ND = not detected.
(b) Produced from fossil fuel burning for steam generation.
(c) Plutonium Reclamation Facility did not operate in 1994.

The Uranium-TriOxide Plant operated during May 1994 and for the final time in June 1994. Emissions from the Uranium-TriOxide Plant were continuously monitored for nitrogen oxides, as required by the Prevention of Significant Deterioration permit (No. PSD-X80-14).

Operating powerhouses on the Site emit particulate matter, sulfur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide, and lead. The total annual releases of these constituents is reported in accordance with the air quality standards established by Ecology. Powerhouse emissions are calculated from the quantities of fossil fuel consumed, using EPA-approved formulas.

Should activities lead to chemical emissions that exceed quantities reportable under CERCLA, the release totals are reported immediately to EPA. If the emissions remain stable at predicted levels, they may be reported annually with EPA's permission. Table 3.1.2 summarizes 1994 emissions of nonradioactive constituents (the 100, 400, and 600 Areas have no nonradioactive emission sources of concern).

Liquid Effluents

Radioactive Liquid Effluents

Liquid effluents are discharged from facilities in all areas of the Hanford Site. Effluents that normally

or potentially contain radionuclides include cooling water, steam condensates, process condensates, and waste water from laboratories and chemical sewers. These waste-water streams are sampled and analyzed for total alpha and total beta activity and selected radionuclides.

Radioactive liquid effluents discharged to ground disposal facilities in 1994 are summarized in Table 3.1.3. Table 3.1.4 summarizes data on radionuclides released from the 100 Areas to the Columbia River. Releases entering the river via ground water are not measured directly but are assessed through the environmental surveillance of river water (see Section 5.3). These measurements are used with the direct effluent measurements to determine potential public doses.

Table 3.1.3 Radionuclides in Liquid Effluents Discharged to Ground Disposal Facilities, 1994

Radionuclide	Half-Life	Release, Ci[(a)]	
		200 Area	300 Area
^{3}H	12.3 yr	5.6	NM
^{90}Sr	29.1 yr	3.3×10^{-1}	1.6×10^{-3}[(b)]
^{99}Tc	2.1×10^{5} yr	2.7×10^{-2}	NM
^{137}Cs	30 yr	5.7×10^{-2}	NM
Uranium, recycled[(c)]	$> 2.445 \times 10^{5}$ yr	3.4×10^{-2}	NM
Uranium, natural[(d)]	$> 2.445 \times 10^{5}$ yr	NM	1.1×10^{-3}
^{238}Pu	87.7 yr	4.8×10^{-4}	NM
$^{239,240}Pu$	2.4×10^{4} yr	3.1×10^{-2}	NM
^{241}Pu	14.4 yr	4.3×10^{-3}	NM
^{241}Am	432 yr	1.1×10^{-1}	NM

(a) 1 Ci = 3.7×10^{10} Bq; NM = not measured; ND = none detected.
(b) ^{90}Sr value is determined from total beta measurements.
(c) Recycled uranium value is determined from total uranium chemical analyses.
(d) Natural uranium value is determined from total alpha measurements.

Table 3.1.4 Radionuclides in Liquid Effluents Discharged to the Columbia River from the 100 Areas, 1994

Radionuclide	Half-Life	Release, Ci[(a)]
^{3}H	12.3 yr	2.7×10^{-1}
^{60}Co	5.3 yr	1.1×10^{-4}
^{90}Sr	29.1 yr	1.1×10^{-1}
^{106}Ru	368 d	7.1×10^{-4}
^{125}Sb	2.8 yr	4.9×10^{-5}
^{134}Cs	2.1 yr	2.2×10^{-5}
^{137}Cs	30 yr	1.5×10^{-5}
^{238}Pu	87.7 yr	1.4×10^{-8}
$^{239,240}Pu$	2.4×10^{4}	2.5×10^{-7}

(a) 1 Ci = 3.7×10^{10} Bq.

Nonradioactive Hazardous Materials in Liquid Effluents

Nonradioactive hazardous materials in liquid effluents are monitored in the 100, 200, 300, and 400 Areas. These effluents are typically discharged to cribs, ponds, ditches, trenches, and the Columbia River. Effluents entering the Columbia River at designated discharge points are sampled and analyzed to determine compliance with the National Pollutant Discharge Elimination System permit for the Site. Should chemicals in liquid effluents exceed quantities reportable under CERCLA, the release totals are reported immediately to EPA. If emissions remain stable at predicted levels, they may be reported annually with EPA's permission.

Liquid effluents containing both radioactive and hazardous constituents are stored at the 200 Areas

in underground waste storage tanks or monitored interim-storage facilities. Activities in the 600 and 1100 Areas generate neither radioactive nor nonradioactive hazardous liquid effluents.

Chemical Releases

Chemical releases are hazardous chemicals discharged directly to the environment, rather than through a liquid effluent stream. These releases consist almost entirely of accidental spills. Releases of hazardous substances exceeding specified quantities that are continuous and stable in quantity and rate must be reported as required by Section 103(f)(2) of the CERCLA as amended. Table 3.1.5 contains a synopsis of 1994 CERCLA reportable spills.

Table 3.1.5 CERCLA Reportable Spills, 1994

Material	Occurrences	Unit	Quantity
Ethylene Glycol	21	kg	593.39
Number 6 Fuel Oil	1	L	37.85
Oil	1	L	7.50
Hexavalent Chromium	1	mg	27.60
Diesel Fuel	5	L	Undetermined[a]
Diesel/Gasohol	1	L	Undetermined[b]
Waste Oil	2	L	Undetermined[c]

(a) Three of the five spills were found while removing underground fuel storage tanks.
(b) This spill was found while removing three underground fuel storage tanks.
(c) Both spills were found while removing underground storage tanks.

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3.2 Near-Facility Environmental Monitoring

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Several types of environmental media are sampled near nuclear facilities to monitor the effectiveness of waste management and restoration activities, and effluent treatment and control practices. These media include air, surface water and springs, surface contamination, soil and vegetation, investigative sampling (which can include wildlife), and external radiation. Sampling and analysis information and analytical results for 1994 for each of these media are summarized below. Additional data and more detailed information may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1994* (Schmidt et al. 1995).

Near-Facility Environmental Monitoring at Hanford

Near-facility environmental monitoring is defined as routine monitoring near facilities that have potential to discharge or have discharged, stored, or disposed of radioactive or hazardous contaminants. Monitoring locations are associated mostly with major nuclear facilities, such as the PUREX Plant and N Reactor, and waste storage or disposal facilities such as burial grounds, tank farms, ponds, cribs, trenches, and ditches.

Much of the monitoring program consists of collecting and analyzing environmental samples and methodically surveying areas near waste sites and facilities releasing effluents and waste streams. The program also evaluates acquired analytical data, determines the effectiveness of facility effluent monitoring and controls, measures the adequacy of containment at waste disposal units, and detects and monitors unusual conditions. The program implements applicable portions of DOE Orders 5400.1, 5484.1, 5400.5, and 5820.2A.

Monitoring activities routinely include sampling and monitoring ambient air, water from surface-water disposal units, external radiation dose, soil, sediment, vegetation, and animals. Some of the parameters typically monitored are pH, radionuclide concentrations, radiation exposure levels, and concentrations of some hazardous chemical constituents. Samples are collected from known or expected effluent pathways. These pathways are generally downwind of potential or actual airborne releases and downgradient of liquid discharges. The annual routine activities of near-facility monitoring are summarized in Table 3.2.1, which shows the type, quantity, and location of samples collected. A detailed discussion of results for ground-water wells used specifically to monitor operating facilities may be found in Schmidt et al. (1995).

Waste disposal sites and the terrain surrounding them are surveyed to detect and characterize any radioactive surface contamination. Routine survey locations include cribs, trenches, retention basin perimeters, pond perimeters, ditch banks, solid waste disposal sites (for example, burial grounds, trenches), unplanned release sites, tank farm perimeters, stabilized waste disposal sites, roads, and firebreaks in and around the Site operational areas.

Air Monitoring

Near-facility air sampling monitors the effectiveness of waste management and effluent treatment and controls in reducing liquid effluents and air emissions; these systems also monitor diffuse source emissions.

Table 3.2.1 Near-Facility Routine Environmental Samples and Locations, 1994

Sample Type	Total Number of Samples	100 Areas	200 Areas	300/400 Areas
Air	41	8	32[a]	1
Surface water	21	9	12	0
External radiation	292	213[b]	58	21
Soil	86	12	57	17
Vegetation	74	20	37	17

(a) Includes one station located at the Wye Barricade.
(b) Forty-one thermoluminescent dosimeters and 172 survey points.

Sample Collection and Analysis

Radioactivity in air was sampled by a network of continuously operating samplers at 41 locations near nuclear facilities: four were located in the 100-N Area, four were in the 100-K Area, 31 were in the 200 Areas, one was located near the 300 Area Treated Effluent Disposal Facility, and one station was collocated with samplers operated by the Surface Environmental Surveillance Project and the DOH at the Wye Barricade. To avoid duplication of sampling, the near-facility environmental monitoring program used existing Surface Environmental Surveillance Project air samplers in the 300 and 400 Areas. Results for these areas are reported in Section 5.2, "Air Surveillance," and are not discussed here. Air samplers were primarily located at or near (within approximately 500 m [1500 ft]) sites and/or facilities having the potential for, or history of, environmental releases, with an emphasis on the prevailing downwind directions.

Samples were collected according to a schedule established before the monitoring year (Schmidt 1993). Airborne particles were sampled at each of these stations by drawing air through a glass-fiber filter. The filters were collected biweekly, field-surveyed for gross radioactivity to detect any unusual trends or off-normal occurrences, held for at least 7 days, and then analyzed for total alpha and beta activity. The 7-day holding period was necessary to allow for the decay of naturally occurring radionuclides that would otherwise obscure detection of longer-lived radionuclides associated with emissions from nuclear facilities. The total radioactivity measurements were used to indicate changes in trends in the near-facility environment.

For most radionuclides, the amount of radioactive material collected on a single filter during a 2-week sampling period was too small to be measured accurately. The accuracy of the sample analysis was increased by compositing the samples into one biannual sample for each location. Each biannual composite sample was then sent to International Technology Corporation, Inc. (Richland, Washington), to be analyzed for plutonium-238, plutonium-239,240, strontium-90, uranium-234, -235, -238, and gamma-emitting (e.g., cesium-137, cobalt-60) radionuclides.

Results

Of the radionuclide analyses performed, cesium-137, plutonium-239,240, strontium-90, and uranium were consistently detectable in the 200 Areas and cobalt-60 was detectable in the 100-N Area. Air concentrations for these radionuclides were elevated near facilities compared to the concentrations measured offsite. Figure 3.2.1 shows average values for 1994 and the preceding 5 years for selected radionuclides compared to Derived Concentration Guides and the background air concentration as measured by the Surface Environmental Surveillance Project. The Derived Concentration Guides are reference values that are used as indices of performance. The data indicate a large degree of variability. In general, samples collected from air samplers located at or directly adjacent to nuclear facilities had significantly higher concentrations than did those samples collected farther away. The data also show, as expected, that concentrations

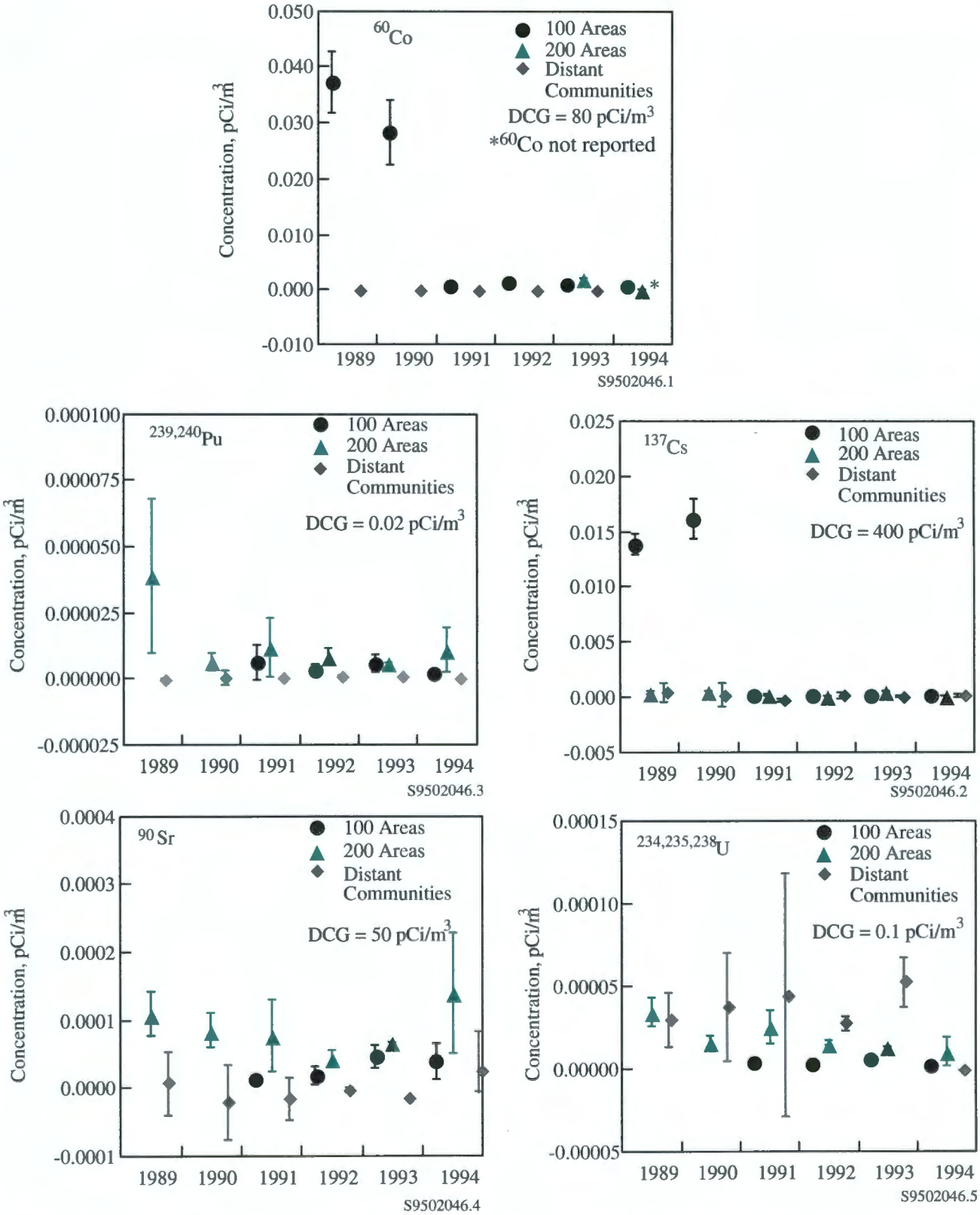

Figure 3.2.1 Concentrations (± 2 standard error of the mean) of Selected Radionuclides in Near-Facility Air Samples Compared to Those in Distant Communities, 1989 Through 1994. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols.

of certain radionuclides were higher within different operational areas. Generally, the predominant radionuclides are activation products (i.e., gamma emitters) in the 100 Areas and fission products in the 200 Areas. A more detailed data summary is provided in Schmidt et al. (1995).

100-N Area

Analytical results from air samples taken in the 100-N Area continued to be at or near background for most radionuclides as a result of facility shutdowns, improved effluent controls and waste management practices. These levels were much less than the Derived Concentration Guides; however, they were greater than levels measured offsite.

100-K Area

Analytical results from air samples taken in the 100-K East Area showed radionuclide concentrations at or near minimum detection levels. This was the first year for environmental air sampling at the 100-K East Area, thus trend analysis was not possible.

200 Areas

Analytical results from air samples taken in the 200 Areas were on a downward trend for most radionuclides as a result of facility shutdowns, better effluent controls, and improved waste management practices. These levels, although much less than the Derived Concentration Guides, were greater than levels measured offsite and were higher for plutonium-239,240, strontium-90, and uranium than levels measured in the 100-N Area.

Surface-Water Disposal Units and Springs Monitoring

Surface-water disposal units (open ponds and ditches) used by the operating facilities and springs along the 100-N Area Columbia River shoreline are monitored to assess the effectiveness of effluent and contamination controls. Surface water disposal units have declined from a maximum of 12 to 4 during 1994. A more detailed description may be found in Schmidt et al. (1995).

Sample Collection and Analysis

Samples from surface-water disposal units and Columbia River shoreline springs were collected from various locations in the operational areas. A more detailed description of sampling locations is given in Schmidt et al. (1995). Samples collected from surface-water disposal units included water, sediment, and aquatic vegetation. Only water samples were taken at river shoreline springs. The sampling methods are discussed in detail in *Operational Environmental Monitoring* (WHC 1991b). To avoid duplication of sampling, the near-facility environmental monitoring program used surface-water sample data collected by the Surface Environmental Surveillance Project for the 400 Area. Results for the 400 Area sampling are reported in Section 5.3, "Surface-Water Surveillance," and are not discussed here.

Radiological analyses of water samples from surface-water disposal units included plutonium-239,240, total alpha, total beta, tritium, and gamma-emitting radionuclides. Total alpha and beta measurements provided a general indication of radionuclide contamination. Radiological analyses of sediment and aquatic vegetation samples were performed for plutonium-239,240, strontium-90, uranium, and gamma-emitting radionuclides. Nonradiological analyses were performed for pH, temperature, and nitrates. Analytes of interest were selected based on their presence in effluent discharges and their importance in verifying effluent control and determining compliance with applicable effluent discharge standards. Surface-water disposal units that received potentially radioactively contaminated effluents were within posted radiological control areas.

Radiological Results

Surface-Water Disposal Units

Radiological analytical results for individual surface-water disposal units (ponds and ditches) located in the 200 Areas are summarized in Table 3.2.2. In all cases, radionuclide concentrations in surface-water disposal units were less than the Derived Concentration Guides and in most cases were equal to or less than the analytical detection limit. One location had an elevated reading for tritium of 106,000 pCi/L. The sample was the last collected from 216-U-14 Ditch before it was stabilized and is believed to be a result of sample collection practices or laboratory

Table 3.2.2 Radiological Results for Liquid Samples from Surface-Water Disposal Units (pCi/L), 200 Areas, 1994

Sample Locations[a]	No. of Samples		Total Alpha	Total Beta	^{3}H	^{90}Sr	^{137}Cs
200-West Area Ditches	25	Mean	0.46	22.3	6,579	6.17	57.9
		Maximum	3.32	228.0	106,000	10.90	192.0
200-West Area Ponds	27	Mean	0.28	2.04	706	4.63	52.6
		Maximum	1.40	4.63	2,290	8.25	60.2
200-East Area Ditch	16	Mean	0.27	2.49	450[b]	5.21	52.3
		Maximum	0.61	4.95	450	9.28	60.5
200-East Area Ponds	23	Mean	0.36	2.76	1,762	5.48	51.6
		Maximum	0.68	6.01	10,600	12.10	77.2
		DCG[c]	30[d]	1,000[e]	2,000,000	1,000	3,000

(a) 200-West Area Ditches: 216-T-1, 216-T-4, 216-U-14.
200-West Area Ponds: Powerhouse Pond, 216-Z-21 Basin.
200-East Area Ditch: 216-B-3-3, Powerhouse Ditch.
200-East Area Ponds: 216-B-3 (East), 216-B-3 (South), 216-B-3A (Outflow), 216-B-3C, 216-B-3A (Input).
(b) The detection limit for ^{3}H is 450 pCi/L.
(c) DCG = Derived Concentration Guide (see Appendix C).
(d) Using ^{239}Pu for comparison.
(e) Using ^{90}Sr for comparison.

analyses practices. There were no other samples collected from this location due to cease of discharge to the site.

Radiological analytical results for aquatic vegetation and sediment samples taken from surface-water disposal units located in the 200 Areas are summarized in Tables 3.2.3 and 3.2.4, respectively. Although there were some elevated levels in both aquatic vegetation and sediment, in all cases the radiological analytical results were much less than the WHC standards used for radiological control.

A more detailed data summary for samples taken to monitor surface-water disposal units is provided in Schmidt et al. (1995).

Springs

In the past, radioactive effluent streams sent to the 1301-N and 1325-N Liquid Waste Disposal Facilities in the 100-N Area contributed to the release of radionuclides to the Columbia River through their migration with the ground water. Radionuclides enter the Columbia River along the riverbank region known as the N Springs. Releases into the river are calculated based on analysis of weekly samples collected from a monitoring well located near the shoreline. A more detailed discussion of the release calculations may be found in the report, *Environmental Releases for Calendar Year 1994* (Gleckler 1995).

Ground-water springs along the 100-N Area shoreline are sampled annually to verify that the reported radionuclide releases to the Columbia River are conservative (i.e., not under reported). Release reporting utilizes conservatively high radionuclide concentrations in samples collected from the facility effluent monitoring well, multiplied by the estimated ground-water discharge into the river. The N Springs ground-water flow rate was estimated using a computer model developed by Gilmore et al. (1992). The estimated ground-water flow rate used to calculate 1994 releases from N Springs was 10 gallons per minute (38 L/min). By characterizing the radionuclide concentrations in the springs along the shoreline, these results can then be compared to the concentrations measured in the facility effluent monitoring well ensuring that the effluent monitoring well is located in the ground-water migration route that contains the highest concentrations of radionuclides.

Table 3.2.3 Radiological Results for Aquatic Vegetation Samples from Surface-Water Disposal Units (pCi/g), 200 Areas, 1994

Sample Locations[a]	No. of Samples		^{90}Sr[b]	^{137}Cs[c]	$^{239,240}Pu$[b]	U total (g/g)
200-West Area Ditches	2	Mean	1.2	2.2	1.6	9.0×10^{-9}
		Maximum	1.5	2.4	1.6	1.0×10^{-8}
200-West Area Ponds	2	Mean	1.2	2.2	2.3	2.7×10^{-8}
		Maximum	1.2	2.2	2.5	4.5×10^{-8}
200-East Area Ditch	1	Maximum	1.0	1.8×10^{-8}	1.7	2.8×10^{-8}
200-East Area Pond	1	Maximum	1.2	4.3×10^{-7}	3.5	1.3×10^{-8}

(a) 200-West Area Ditches: 216-T-4, 216-U-14.
200-West Area Ponds: 216-Z-21 Basin, Powerhouse Pond.
200-East Area Ditch: Powerhouse Ditch.
200-East Area Pond: 216-B-3C.
(b) Strontium-90 and $^{239,240}Pu$ samples were analyzed using dry weights.
(c) Cesium-137 samples were analyzed using wet weights.

Table 3.2.4 Radiological Results for Sediment Samples from Surface-Water Disposal Units (pCi/g), 200 Areas, 1994

Sample Locations[a]	No. of Samples		^{90}Sr[b]	^{137}Cs[c]	$^{239,240}Pu$[b]	U total (g/g)
200-West Area Ditches	2	Mean	2.5	.00017	1.2	2.3×10^{-7}
		Maximum	4.5	.00019	2.0	4.5×10^{-7}
200-West Area Ponds	2	Mean	0.66	0.83	0.46	2.8×10^{-7}
		Maximum	0.76	1.7	0.49	3.3×10^{-7}
200-East Area Ditch	1	Maximum	0.63	0.45	0.59	7.9×10^{-7}
200-East Area Pond	1	Maximum	2.7	7.0	0.49	2.5×10^{-7}

(a) 200-West Area Ditches: 216-T-4, 216-U-14.
200-West Area Ponds: 216-Z-21 Basin, Powerhouse Pond.
200-East Area Ditches: Powerhouse Ditch.
200-East Area Ponds: 216-B-3C.
(b) Strontium-90 and $^{239,240}Pu$ samples are analyzed using dry weights.
(c) Cesium-137 samples are analyzed using wet weights.

In 1994, the concentrations detected in the springs samples were highest in springs nearest the facility effluent monitoring well, although springs concentrations were considerably lower than concentrations measured in the well. The data from springs sampling are summarized in Table 3.2.5. A more detailed data summary is provided in Schmidt et al. (1995).

Nonradiological Results for Surface-Water Disposal Units

Nonradiological analytical results for water samples taken from surface-water disposal units located in the 200 Areas are summarized in Table 3.2.6. The results for pH were well within the pH standard of 2.0 to 12.5 for liquid effluent discharges based on the discharge limits listed in RCRA. The analytical results for nitrates were all less than the detection limit of 1.4 mg/L and less than the 45-mg/L Drinking Water Standard for public water supplies.

Table 3.2.5 Concentrations (pCi/L) of Radionuclides in 100-N Area Columbia River Shoreline Springs, 1994

Radionuclide	Facility Effluent Monitoring Well (09/08/94)	Springs		
		Maximum	Mean	DCG[a]
^{3}H	26,000	450	178	2,000,000
^{60}Co	17	3.1	<-0.17	5,000
^{90}Sr	6,600	120	37	1,000

(a) DCG = Derived Concentration Guide (see Appendix C).

Table 3.2.6 Nonradiological Results for Liquid Samples from Surface-Water Disposal Units, 200 Areas, 1994

Sample Locations[a]	pH				Nitrate (NO_3), mg/L		
	No. of Samples	Mean	Maximum	Minimum	No. of Samples	Mean	Maximum
200-West Area Ditches	110	7.68	9.08	6.10	11	<1.4	<1.4
200-West Area Ponds	120	8.32	9.76	6.94	10	<1.4	<1.4
200-East Area Ditches	72	7.87	10.45	6.70	6	<1.4	<1.4
200-East Area Ponds	98	7.82	8.75	6.66	12	<1.4	<1.4

(a) 200-West Area Ditches: 216-T-4-1, 216-T-4-2, 216-U-14.
200-West Area Ponds: Powerhouse Pond, 216-Z-21 Basin.
200-East Area Ditches: 216-B-3-3, Powerhouse Ditch.
200-East Area Ponds: 216-B-3 (East), 216-B-3 (South), 216-B-3A (Outflow), 216-B-3C, 216-B-3A (Input).

Radiological Surveys

Radiological surveys are used to monitor and detect radiological contamination on the Hanford Site. There are two types of posted radiological controlled areas: one designating underground radioactive materials and the other for surface/soil contamination.

Underground radioactive material areas are posted areas where contamination is contained below the surface soil. These areas are typically "stabilized" cribs; burial grounds; and covered ponds, trenches, and ditches. Barriers over the contamination sources are used to inhibit radionuclide transport to the surface environs. These areas are routinely surveyed (at least annually) to document the current radiological status.

Surface/soil contamination areas may or may not have been associated with an underground radioactive material structure. A breech in the barrier of an underground radioactive materials area may have resulted in the growth of contaminated vegetation. Insects or animals could have burrowed into an underground radioactive materials area and brought contamination to the surface. Vent pipes or risers from an underground structure could have been a source of speck contamination. Fallout from stacks, or unplanned releases from previously operating facilities, may have caused an area of surface contamination that was not related to a subsurface structure. All types of surface contamination areas are susceptible to contamination migration. Surface contamination areas are routinely surveyed (at least annually) to document the current radiological status.

In 1994, there were approximately 2,756 ha (6,364 acres) of posted outdoor surface contamination areas and 981 ha (2,423 acres) of posted

underground radioactive materials areas not including active facilities at the Hanford Site. The number of ha (acres) of surface contamination areas is approximately three times larger than the underground radioactive materials areas. This is primarily because of the BC Controlled Area located south of the 200-East Area. This site was posted as a Radiologically Controlled Area in 1959 due to widespread speck contamination and currently encompasses approximately 1,000 ha (2,500 acres). Table 3.2.7 contains the acreage for surface contamination areas and underground radioactive material areas, showing the net change from 1993 to 1994. The large change in reported area from 1993 to 1994 is due to the inclusion of the tank farms and the use of a global positioning system to enhance accuracy. In past years, the sizes of the contaminated areas were based on visual estimates and unconfirmed estimates in other documents. Area measurements for 1994 have been entered into the Hanford Geographical Information System, maintained by the Environmental Restoration Contractor. Table 3.2.8 summarizes the number of contaminated ha (acres) that changed status in 1994.

Table 3.2.7 Outdoor Contamination Status, 1994. Approximate Surface Area Reported in Hectares (acres)

Hanford Site Area	Surface Contamination[a]	Net Change[b]	Underground Radioactive Material[c]	Net Change
100-B/C	8 (20)	0	39 (96)	0
100-KE/KW	11 (26)	-10 (25)	52 (129)	10 (25)
100-N	29 (73)	0	0.3 (1)	0
100 D/DR	6 (15)	0	33 (81)	0
100-H	0.4 (1)	-2 (5)	13 (33)	2 (5)
100-F	8 (20)	-2 (5)	30 (74)	2 (5)
200-East[d]	2,270 (5,608)	-34 (85)	139 (343)	34 (85)
200-West[e]	222 (549)	-1 (2)	656 (1,621)	1 (2)
300	21 (52)	0	13 (31)	0
400	0	0	0	0
600	0	0	6 (14)	0
Totals	2,756 (6,364)	-49 (122)	981 (2,423)	49 (122)

(a) Includes areas posted as "surface/soil contamination" or as "Radiologically Controlled" and areas that had both underground and surface/soil contamination.
(b) - = decreases as compared to 1993.
(c) Includes areas with only underground contamination. Does not include areas that had surface as well as underground radioactive material.
(d) Includes tank farms, BC controlled zone, and waste disposal facilities outside the 200-E boundary which received waste from 200-E facilities (i.e., 216-A-25, 216-B-3-3, etc.).
(e) Includes tank farms and waste disposal facilities outside the 200-W boundary which received waste from 200-W facilities (i.e., 216-S-19, 216-U-11, etc.).

Table 3.2.8 Zone Status Change by Area, 1994. Area Reported in Hectares (acres).

Location	Zone Change[a]	Area
100 Areas	SCA to URM	14 (35)
200 East Area	SCA to URM	34 (85)
200 West Area	SCA to URM	1 (2)
300 Area	SCA to URM	0
400 Area	SCA to URM	0
600 Area	SCA to URM	0

(a) SCA = Surface Contamination Area.
URM = Underground Radioactive Materials.

The area of posted surface contamination varies between years because of an ongoing effort to clean, stabilize, and remediate areas of known contamination. During this time, new areas of contamination are also being identified. Table 3.2.8 indicates the changes resulting from stabilization activities during 1994. Approximately 49 ha (122 acres) were reclassified from surface/soil contamination areas to underground radioactive material areas. Newly identified areas may have resulted from contamination migration or an increased effort to investigate outdoor areas for radiological contamination. Vehicles equipped with radiation detection devices and an ultrasonic ranging and data system identified areas of contamination that were previously undetected.

It was estimated that the external dose rate at 80% of the identified outdoor surface contamination areas was less than 1 mrem/h, although direct dose rate readings from isolated radioactive specks (a diameter less than 0.6 cm [0.25 in.]) could have been considerably higher. Contamination levels of this magnitude would not have added significantly to dose rates for the public or Hanford Site workers in 1994.

Soil and Vegetation Sampling from Operational Areas

Soil and vegetation samples were collected on or adjacent to waste disposal units and from locations downwind and near or within the boundaries of the operating facilities. Samples were collected to detect potential migration and deposition of facility effluents. Migration can occur as the result of resuspension from radioactively contaminated surface areas, absorption of radionuclides by the roots of vegetation growing on or near underground and surface-water disposal units, or by waste site intrusion by animals. In 1994, routine annual soil and vegetation sampling was eliminated in the 100 Areas except for the 100-N Area. Historical data indicated that the 100 Area sites previously monitored exhibited no signs of contamination migration and continued monitoring would not be cost-effective. Special samples were also taken where physical or biological transport problems were identified. The results of the sampling effort are discussed below. Soil sampling in the 200 Areas was modified to be more cost effective to collect 55 soil samples at alternating locations each year.

Sample Collection and Analysis

The sampling methods and locations used are discussed in detail in the manual *Operational Environmental Monitoring* (WHC 1991b). Radiological analyses of soil and vegetation samples included plutonium-239,240, strontium-90, uranium, and gamma-emitting radionuclides.

Soil Results

Of the radionuclide analyses performed, cesium-137, cobalt-60, plutonium-239,240, strontium-90, and uranium were consistently detectable. Soil concentrations for these radionuclides were elevated near and within facility boundaries when compared to the concentrations measured offsite. Figure 3.2.2 shows average values for 1994 and the preceding 5 years. The concentrations show a large degree of variability. In general, concentrations in

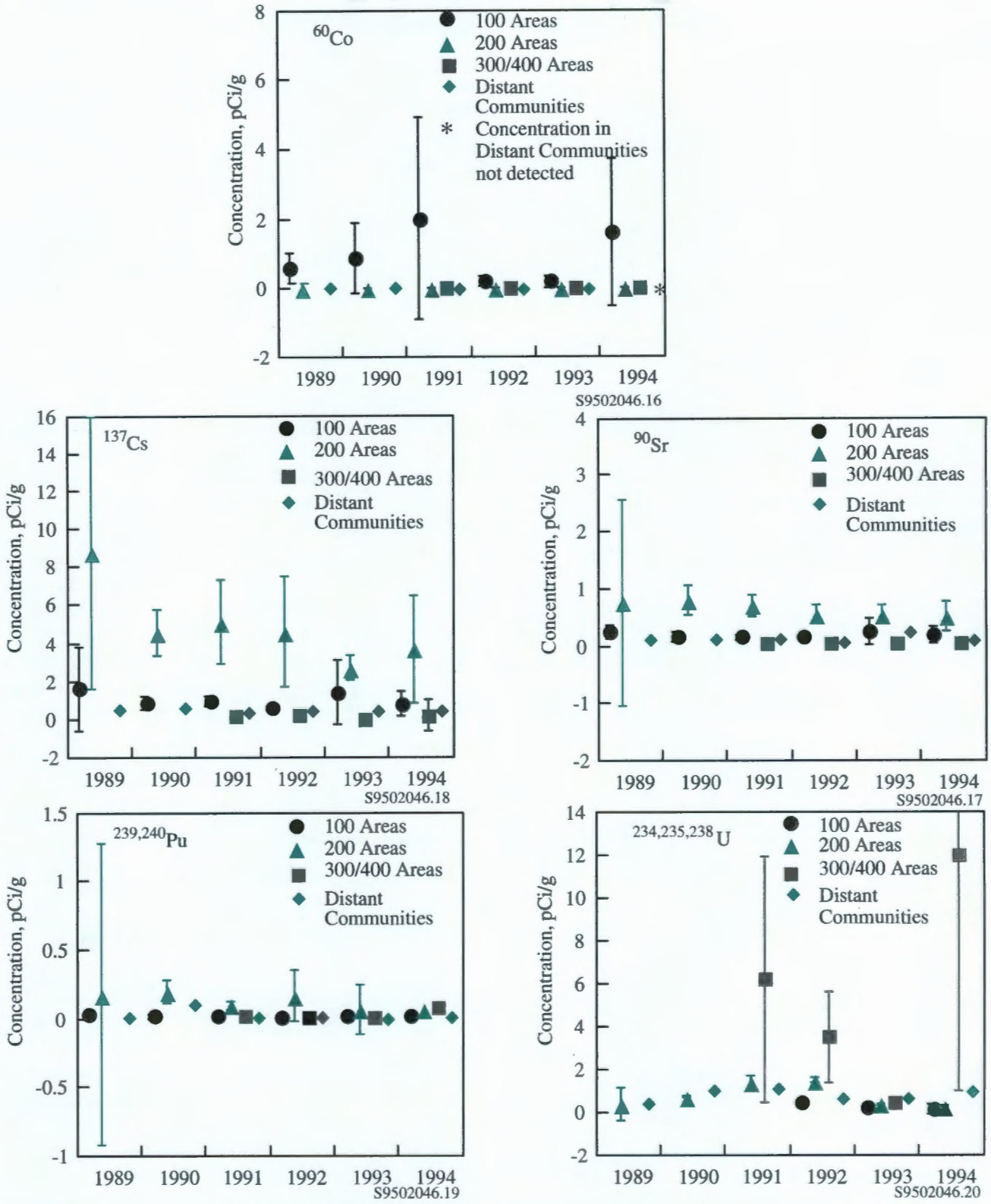

Figure 3.2.2 Concentrations (± 2 standard error of the mean) of Selected Radionuclides in Near-Facility Soil Samples Compared to Those in Distant Communities, 1989 Through 1994. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols. The 1994 100 Area data includes the 100-N Area only.

samples collected on or directly adjacent to waste disposal facilities were significantly higher than concentrations in samples collected farther away. The data also show, as expected, that concentrations of certain radionuclides were higher within different operational areas. Generally, the predominant radionuclides were activation products and strontium-90 in the 100-N Area, fission products in the 200 Areas, and uranium in the 300 Area. A more detailed data summary is provided in Schmidt et al. (1995).

100-N Area

Analytical results from soil samples collected in the 100-N Area in 1994 generally exhibit concentrations at or near background levels, as a result of the shutdown of the 105-N Reactor, and associated facilities, and the implementation of more effective effluent controls. However, contamination levels were still greater than those measured offsite, and the concentrations of cobalt-60 were greater than those measured in the 200 and 300/400 Areas. The cobalt-60 in the 100-N Area soils resulted from past discharges to waste disposal structures, primarily the 1301-N Liquid Waste Disposal Facility.

200 Areas

Analytical results from soil samples taken in the 200 Areas were on a downward trend for most radionuclides as a result of facility shutdowns, improved effluent controls, and waste management practices. However, these levels were greater than those measured offsite and were shown to be higher for cesium-137, plutonium-239,240, and strontium-90 when compared to values from the 100 and 300/400 Areas.

300/400 Areas

This was the fourth sampling year for the 300/400 Areas' Near-Facility Environmental Monitoring Program. The data for these areas were compared to results for other operational areas and to those measured offsite. The levels of uranium for the 300/400 Area were higher than those measured from the 100 Area and the 200 Areas and higher than previous years. This radionuclide was expected because the uranium is the result of past fuel fabrication operations conducted in the 300 Area.

Vegetation Results

Of the radionuclide analyses performed, cesium-137, cobalt-60, plutonium-239,240, strontium-90, and uranium were consistently detectable. Concentrations of these radionuclides in vegetation were elevated near and within facility boundaries compared to the concentrations measured offsite. Figure 3.2.3 shows average values for 1994 and the preceding 5 years. The concentrations show a large degree of variability. In general, concentrations in samples collected on or directly adjacent to the waste disposal facilities were significantly higher than concentrations in samples collected farther away. As with the soil samples, the data show that certain radionuclides were found in higher concentrations in vegetation within different operational areas. Except for strontium-90 (a fission product) detected in vegetation from the N Springs, generally the predominant radionuclides are activation products in the 100 Areas, fission products in the 200 Areas, and uranium in the 300 Area. A more detailed data summary is provided in Schmidt et al. (1995).

100-N Area

Analytical results from vegetation samples collected in the 100-N Area in 1994 were generally higher than those seen in 1993. The maximum values observed were for strontium-90 in samples collected near the N Springs. Significant increases in radionuclide concentrations in vegetation samples collected nearest the 1301-N Liquid Waste Disposal Facility were observed in 1994. This is likely attributable to uptake of the contaminants by this deep-rooted vegetation. The 1994 levels were also greater than those measured offsite and levels for cobalt-60 and strontium-90 were higher compared to the 200 and 300/400 Areas.

200 Areas

Analytical results from vegetation samples taken in the 200 Areas were on a downward trend for most radionuclides as a result of facility shutdowns, better effluent controls, and improved waste management practices. Before 1992, radionuclide levels in these areas were greater than those measured offsite and were higher for cesium-137 and plutonium-239,240 compared to the 100 and 300/400 Areas. During 1994, the average concentrations for cesium-137 and plutonium-239,240 were similar

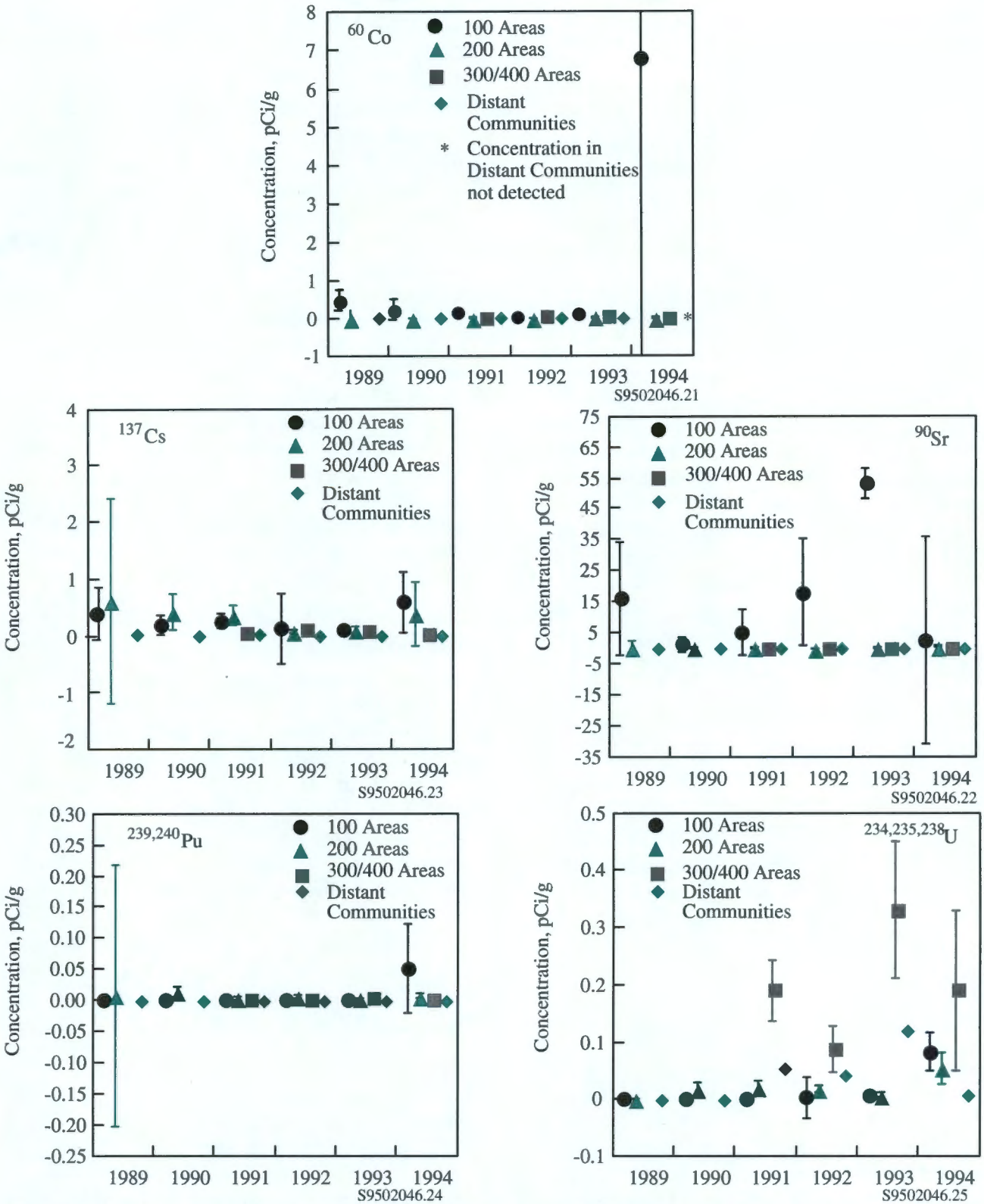

Figure 3.2.3 Concentrations (± 2 standard error of the mean) of Selected Radionuclides in Near-Facility Vegetation Compared to Those in Distant Communities, 1989 Through 1994. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols. The 1994 100 Area data includes the 100-N Area only.

onsite, offsite, and within the various operational areas.

300/400 Areas

Generally, the levels of most radionuclides measured in the 300 Area were greater than those measured offsite and levels for uranium were higher compared to the 100 Area and the 200 Areas. This difference was expected because uranium was released during past fuel fabrication operations conducted in the 300 Area. The levels measured in the 400 Area were at or near those measured offsite.

External Radiation

External radiation fields were measured near facilities and waste handling, storage, and disposal sites to measure, assess, and control the impacts of operations.

Field Measurements and Analysis

Two methods were used for measuring external radiation fields. Hand-held microroentgen (μR) meters were used at individual points of interest to give real-time radiation field assessments. Thermoluminescent dosimeters were used at numerous fixed locations to absorb radiation energy over longer periods of time and can be read later by thermal excitation of the detector. TLD sample results can be averaged to determine dose rates of an area throughout the sampling period. The measurement methods used for external radiation measurements and descriptions of sampling locations are discussed in the manual *Operational Environmental Monitoring* (WHC 1991b).

Results

Radiation Measurements

Hand-held μR meters were used to survey points near and within three waste disposal locations in the 100-N Area: the N Springs area, the 1301-N Liquid Waste Disposal Facility, and the 1325-N Liquid Waste Disposal Facility. These radiation measurements were taken at a height of approximately 1 m (3.28 ft) and are not necessarily a true measurement of exposure rates but provide a sensitive and practical method to evaluate exposure rate trends in this area. The hand-held μR meters are known to overrespond to low-energy gamma radiation. The radiation levels measured along the 100-N Area shoreline in 1994 were comparable to 1993 levels (Figure 3.2.4). The radiation measurements taken at the 1301-N and 1325-N Liquid Waste Disposal Facilities in 1994 continued to drop due to the decay of cobalt-60 (Table 3.2.9). A more detailed summary is provided in Schmidt et al. (1995).

Table 3.2.9 100-N Liquid Waste Disposal Facilities (LWDF) Direct Radiation Measurements (μR/h), 1993 and 1994

LWDF	1993 Average	1994 Average
1301-N	1,600	1,300
1325-N	730	550

TLDs

100 Areas. TLDs in the 100 Areas were located in the 100-N and 100-K Areas; results are presented in Table 3.2.10. The 1994 TLD results indicate that direct radiation levels were highest near facilities that had contained or received liquid effluent from the N Reactor. These facilities primarily include the 1301-N Liquid Waste Disposal Facility and 1325-N Liquid Waste Disposal Facility. While the results for these two facilities were noticeably higher than those for other 100-N Area TLD locations, they were approximately 5% lower than exposure levels measured at these locations in 1993. An historical summary of the dose rates measured around the Liquid Waste Disposal Facilities may be found in Schmidt et al. (1995). Decreases are the result of decay of the radionuclide inventories in the facilities. Increases are due to loss of shielding and decreased attenuation factors as the facilities "dried up" after their shutdown.

In 1993, 11 TLDs were relocated from the 100-N Area and placed at the 100-K Area, surrounding the 105-K East and 105-K West reactor buildings. Elevated readings in the 100-K Area were due to the sporadic outdoor storage of radiologically contaminated materials such as internally contaminated ion-exchange modules used in maintaining water quality in the nearby 105-KE fuel storage basin. A more detailed data summary and description is provided in Schmidt et al. (1995).

200 Areas. Thirty-three (33) TLD monitoring sites were eliminated and thirty-five (35) new TLD

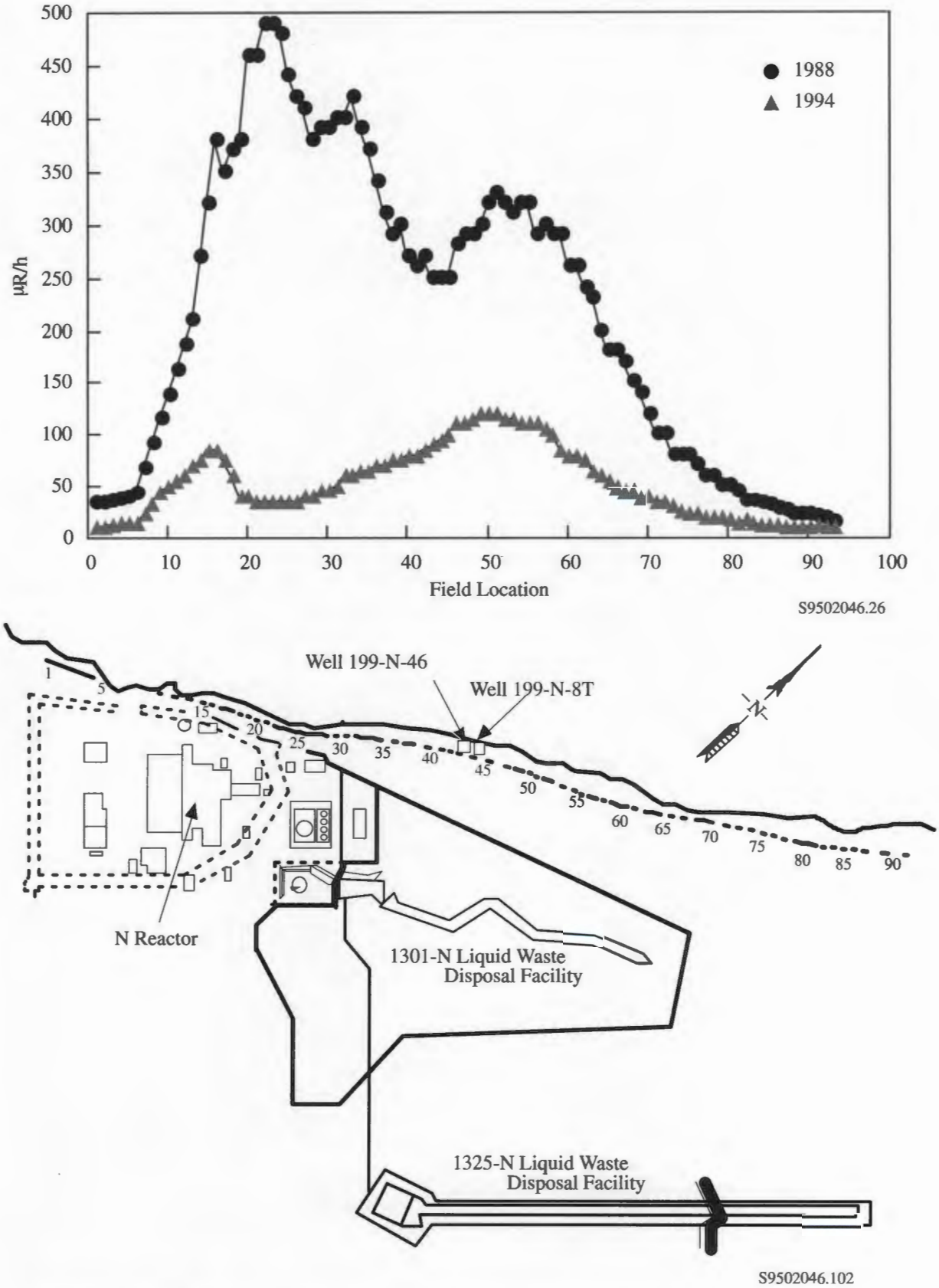

Figure 3.2.4 Radiation Survey Measurements Along the 100-N Area Shoreline, 1988 and 1994

monitoring sites were established in the 200 Area network to better evaluate the remaining operational facilities and to begin monitoring new facilities constructed to treat effluents and solid waste, and to fulfill the environmental restoration mission. Table 3.2.11 summarizes the results for the 24 TLD locations which were not repositioned between 1993 and 1994. The highest dose rates were measured near waste-handling facilities such as tank farms. The highest dose rate was measured at the 241-A Tank Farm complex located in the 200-East Area. The average annual dose rate measured in 1994 by TLDs was 160 mrem/yr, which was a decrease of 6% over the average dose rate of 170 mrem/yr measured in 1993. A more detailed data summary is provided in Schmidt et al. (1995).

300/400 Areas. Table 3.2.11 compares 1994 TLD results to those of 1993 for the 300/400 Areas. Six new TLD locations were established to monitor dose rates around the new 300 Area Treated Effluent Disposal Facility. The highest dose rates in the 300 Area were measured near waste-handling facilities such as the 340 Waste Handling Facility. The average annual dose rate measured in the 300 Area in 1994 was 170 mrem/yr. This represents a decrease of 15% when compared to the average dose rate of 200 mrem/yr measured in 1993. This comparison does not include the six new TLD locations established around the 300 Area Treated Effluent Disposal Facility. The average annual dose rate measured in the 400 Area in 1994 was 115 mrem/yr, which represents an increase of 15% when compared to the average dose rate of 100 mrem/yr measured in 1993. This increase is due to the staging of railroad cars which transport radioactive material near the 437 Building.

Investigative Sampling

An important part of the near-facility monitoring program, investigative sampling was conducted in the operations areas to confirm the absence of, or to detect the presence of, radioactive or hazardous contaminants. Investigative sampling took place near facilities such as storage and disposal sites for at least one of the following reasons:

- to follow-up radiological surface surveys which had indicated that radioactive contamination was present
- to quantify the radiological hazardous condition at a site before facility construction or operation
- to quantify the radiological condition of a site before remediation
- to determine if biotic intrusion (e.g., animal burrows or deep-rooted vegetation) had created a potential for the spread of contaminants
- to determine the integrity of waste containment systems.

Table 3.2.10 Investigative Samples Collected from the Operations Areas, 1994

Sample Type	Collection Area (Number of Samples)	Elevated Radionuclides	Maximum Concentration
Water	200 Areas (2)	^{90}Sr	520 pCi/L[a]
		^{137}Cs	130 pCi/L
		$^{239/240}Pu$	0.45 pCi/L
Soil	200 Areas (28)	^{90}Sr	4,800 pCi/g[b]
		^{137}Cs	80,000 pCi/g
		TotalU	380,000 pCi/g[c]
		$^{239/240}Pu$	4,000,000 pCi/g
		^{241}Am	8,800 pCi/g
Inactive Transfer Line Scraping	200-East Area (1)	^{90}Sr	160 pCi/g
		^{137}Cs	330 pCi/g
		^{210}Pb	4,800 pCi/g
		TotalU	410 pCi/g
		$^{239/240}Pu$	3,700 pCi/g
		^{241}Am	530 pCi/g

Table 3.2.10 Investigative Samples Collected from the Operations Areas, 1994 (contd)

Sample Type	Collection Area (Number of Samples)	Elevated Radionuclides	Maximum Concentration
Vegetation	200 Areas (2)	^{90}Sr	3.1 pCi/g
		^{99}Tc	8.6 pCi/g
		^{137}Cs	3.6 pCi/g
		TotalU	7.3 pCi/g
		$^{239/240}Pu$	<1.4 pCi/g
Mollusks	200-East Area (2)	^{90}Sr	8.3 pCi/g
		^{99}Tc	<160 pCi/g
		^{137}Cs	16 pCi/g
		$^{239/240}Pu$	<2.2 pCi/g
Rattlesnake	100-N (1)	^{60}Co	16,000 pCi/g
		^{90}Sr	55 pCi/g
		^{137}Cs	1,100 pCi/g
		TotalU	0.41 pCi/g
		$^{239/240}Pu$	680 pCi/g
		^{241}Am	92 pCi/g
Gopher Snake	200 Areas (3)	^{90}Sr	780 pCi/g
		^{137}Cs	1,700 pCi/g
		TotalU	0.11 pCi/g
		$^{239/240}Pu$	<0.63 pCi/g
		^{241}Am	<25 pCi/g
Western Kingbird	100-K (1)	^{60}Co	0.97 pCi/g
		^{90}Sr	8.4 pCi/g
		^{137}Cs	34 pCi/g
		TotalU	0.004 pCi/g
		$^{239/240}Pu$	1.7 pCi/g
Western Kingbird (cont)	200 Areas (1)	^{90}Sr	14 pCi/g
		^{137}Cs	5.2 pCi/g
		TotalU	0.11 pCi/g
Cliff Swallow	200-West Area (1)	^{60}Co	0.46 pCi/g
		^{90}Sr	21 pCi/g
		^{137}Cs	20 pCi/g
		TotalU	0.002 pCi/g
		$^{239/240}Pu$	<0.87 pCi/g
Deer Mouse	200 Areas (15)	^{90}Sr	90,000 pCi/g
		^{137}Cs	250,000 pCi/g
		TotalU	0.12 pCi/g
		$^{239/240}Pu$	<16 pCi/g
Coyote Feces	200 Areas (2)	^{90}Sr	0.64 pCi/g
		^{137}Cs	<0.21 pCi/g
		TotalU	0.002 pCi/g
		$^{239/240}Pu$	<0.68 pCi/g
	600 Area (1)		

(a) Picocuries per liter.
(b) Picocuries per gram.
(c) Suspect result - did not correlate with field instrument readings.

Table 3.2.11 Thermoluminescent Dosimeter (TLD) Results for Waste-Handling Facilities in the Operations Areas (mrem/yr, based on 24 hours/day), 1993 and 1994

Area	No. of Sites, 1994	1993 Annual Average		1994 Annual Average		% Change[a]
		Maximum	Mean	Maximum	Mean	
100-K	11	13,800	820	14,700	1,100	34
100-N	30	14,640	1,700	15,500	1,560	-8
200/600	60 (24)[b]	1,100	170	770	160	-6
300	8	830	200	540	170	-15
300 TEDF[c]	6	NS[d]	NS[d]	120	110	NA
400	7	130	100	210	115	15

(a) Numbers indicate a decrease (-) or increase from 1993. NA = not applicable.
(b) Indicates 24 of 60 data points were applicable to this table.
(c) TEDF = Treated Effluent Disposal Facility.
(d) NS = not sampled.

These data include the maximum concentrations of radioactive materials from analytical results of investigative samples and field instrument readings in counts per minute (cpm) or millirad per hour (mrad/h). Complete data results are listed in Schmidt et al. (1995).

Generally, the predominant radionuclides discovered during these efforts were activation products and strontium-90 in the 100 Areas, fission products in the 200 Areas, and uranium in the 300 Area. Hazardous chemicals have generally not been identified above background levels in preoperational environmental monitoring samples.

Sample Collection and Analysis

The types of investigative samples collected previously have included air, water, snow, sediments, soil, vegetation such as grasses, tumbleweeds (i.e., Russian thistle), sagebrush, trees, and fruits, and various organisms such as spiders, termites, ants, fish, toads, snakes, birds, mice, rabbits, coyotes, and bobcats.

Investigative samples in 1994 included air, water, soil (including sediment and radioactive specks), two types of vegetation (i.e., cattail and watercress), freshwater clams, gopher snake, western rattlesnake, western kingbird, cliff swallow nest, deer mouse, and coyote feces (Table 3.2.10).

Methods for collecting or otherwise obtaining investigative samples are found in the manual *Operational Environmental Monitoring* (WHC 1991b). Field monitoring was conducted to detect radioactivity before samples were collected. Field monitoring results were expressed as cpm when a Geiger-Mueller detector was used or as mrads/h when an ion chamber was used. Laboratory sample analysis results were expressed in pCi/g. Maximum concentrations of radionuclides, rather than averages, are presented in this subsection.

Results

Investigative samples were collected where known or suspected radioactive contamination was present, or to verify radiological conditions at project sites. In 1994, 52 such samples were analyzed for radionuclides, and 23 showed some level of contamination. An additional 42 contamination incidents were discovered and disposed without isotopic analyses during cleanup operations. A more detailed data summary is provided in Schmidt et al. (1995).

Air

Investigative air samples collected in 1994 were used to determine the fugitive and diffuse air emissions from four waste treatment, storage, or disposal sites. These sites included the Plutonium Finishing Plant in the 200 West Area, the 241-BY Tank Farm in the 200 East Area, the 1301-N Liquid Effluent Trench in the 100-N Area, and the Process Ponds

and Trenches in the 300 Area. Air monitoring was initiated at the 118-B-1 Burial Ground near 100 B/C Area to monitor possible fugitive emissions during exhumation operations. Radionuclides monitored included cesium-137, cobalt-60, strontium-90, plutonium-239,240, and total uranium. All analytical results for these nuclides were well below the Derived Concentration Guide values (Table 3.2.9).

Soil

In 1994, 19 investigative soil samples were taken. The radionuclides of highest concentration were cesium-137 (80,000 pCi/g) near 241-A Tank Farm; plutonium-239,240 (4,000,000 pCi/g) near the 241-A Tank Farm; strontium-90 (4,800 pCi/g) also near 241-A Tank Farm; and total uranium (380,000 pCi/g) from 216-B-3A Pond sediment. In addition, 75 incidents of contaminated specks were found during cleanup operations and disposed of in low-level burial grounds.

In 1994, the number of contamination incidents, radioactivity levels, and range of radionuclide concentrations were generally within historical ranges, with the exception of the high uranium value from 216-B-3A Pond sediment. This pond would not be expected to have received effluents that would produce samples with concentrations of this magnitude. Of 11 other samples from this pond, no concentrations approached this value. A laboratory reporting error is suspected. Areas of special soil sampling that were outside radiological control areas and had radiation levels greater than WHC radiological control limits (WHC 1991a) were posted as surface contamination areas.

Vegetation

In 1994, there were two vegetation samples (i.e., cattails and watercress) analyzed for radionuclide concentrations (Table 3.2.10). Analytical results were well below WHC radiological control limits (WHC 1991a). In addition, 36 instances of contaminated tumbleweed and two of big sagebrush were recorded in operational areas in 1994. This vegetation was found during remedial operations, surveyed with field instruments, and disposed of to low-level burial grounds. In 1994 field-instrument readings ranged from less than 1 mrad/h (100 cpm) to 75 mrad/h, which were within the ranges reported for the past few years. The number of samples found to be contaminated was within normal parameters. In the past, the greatest number of contaminated vegetation samples (42) were submitted for analyses in 1978.

Wildlife

Animals were collected either as part of a pest control program designed to limit the exposure and potential contamination of animals to radioactive material or as a result of finding a radiologically contaminated animal. Animals were collected directly from or near facilities to identify problems with preventative measures designed to inhibit animal intrusion. Surveys were performed after collection to determine whether an animal was radioactively contaminated. If a live animal was found free of contamination, it was taken to a suitable habitat area and released. If an animal was contaminated, a decision based on the level of contamination, sampling facility, and frequency of occurrence was made to collect the animal as a sample or dispose of the animal to a low-level burial ground.

One noteworthy biotic contamination incident occurred near the 105-N Building in the 100-N Area when a contaminated western rattlesnake was caught digesting prey. Radioanalysis indicated 16,000 pCi/g concentration of cobalt-60. Dissection of the snake did not allow identification of the prey, but the size and mass was indicative of a mouse. Other notable incidents were deer mice at the 200-East Garage, at 241-A Lift Station/200-East Area, and at the 241-C Tank Farm/200-East Area.

The radionuclides found at the maximum concentrations were cesium-137 (250,000 pCi/g) in a deer mouse from 200 East Garage, cobalt-60 (15,550 pCi/g) in a western rattlesnake from 105-N/100-N Area, and strontium-90 (90,000 pCi/g) in a deer mouse from 244-A Lift Station/200-East Area (see Table 3.2.10). There were 11 cases of contaminated animals or feces found during cleanup operations, which were disposed of without being analyzed. The total number of animals found to be contaminated with radioactivity, the radioactivity levels, and the range of radionuclides concentrations was within historical limits.

There were 27 special animal (including nests and feces) samples analyzed in 1994, of which 16 showed detectable levels of contamination. The number of incidents decreased in 1994 compared to

32 in 1993; and 26 incidents in 1992. The greatest number of contaminated animals submitted for analysis occurred in 1982 (44, mostly pigeons).

The practical results of these data, in addition to those mentioned previously were to identify locations where pest control, waste containment, or biotic barriers needed to be improved or added. Benefits derived from this sampling improved worker health and safety, reduced potential exposures, and reduced cleanup costs by early identification of loss of contaminant control.

Special Characterization Sampling

Special characterization projects were conducted to verify the radiological, and in some cases hazardous chemical, status of several operations. These included the following:

- Ambient air monitoring to determine the levels of fugitive diffuse air emissions at the Plutonium Finishing Plant in the 200 West Area, at the 241-BY Tank Farm in the 200 East Area, at the 1301-N Liquid Effluent Trench in the 100-N Area, and at the Process Ponds and Trenches in the 300 Area
- Ambient air sampling at the Transuranic Waste Retrieval trenches (218-W-4c) in the 200 West Area to detect potential diffuse emissions during transuranic waste retrieval
- Soil and sediment sampling during decontamination and decommissioning of the 216-B-3 Ditch and Pond
- Ambient air sampling and installation of TLDs at the 300 Area Treated Effluent Disposal Facility
- Biota sampling at the 244-A Lift Station and the 241-C Tank Farm to determine the extent of radionuclide contamination and transport by animals
- Completed preoperational monitoring for the 200 Areas effluent treatment facility and associated facilities (Project C-018H)
- Continued preoperational monitoring for the 200 Areas Cross-site Transfer Line Replacement, and the 200 Areas Effluent Treatment Facility and associated facilities
- New preoperational monitoring at the three main projects of the Solid Waste Operations Complex in 200 West.

Diffuse emissions measured at 107-C Retention Basins and 118-B-1 Burial Ground near 100 B/C Area, at 107-KE/KW Basins in 100-K Area, at 1301-N Trench in the 100 Area, at PFP in the 200-West Area, at 241-BY Tank in the 200-East Area, and at the process ponds in the 300 Area were collected during typical meteorological conditions and were sometimes measurable but not significant. Detailed results of the fugitive diffuse emissions study can be found in *Final Report of Fugitive and Diffuse Emissions Evaluations at the Hanford Site, CY 1994* (WHC 1995c).

Ambient air monitoring at 218-W-4C Burial Grounds during transuranic waste retrieval did not indicate increased diffuse radionuclide emissions.

The 216-B-3-3 Ditch and 216-B-3A Pond were decommissioned in 1994. The values for radionuclides in samples of sediment soil, surface soil (dried-out pond sediment), watercress, and freshwater clams were near background levels for radionuclides, and only occasionally measurable by laboratory analyses (Table 3.2.10). A single uranium concentration of 380,500 pCi/g in a surface soil sample from 216-B-3A Pond is considered to be a laboratory reporting error because 11 other samples in this area did not verify the results.

Construction was completed in the 300 Area Treated Effluent Disposal Facility in 1994. An ambient air sampler and four TLDs began collecting baseline environmental data before startup.

Biotic contamination in the environs of the 216-C Tank Farm and the 244-A Lift Station received special attention in 1994 to document the extent and levels of contamination because Pest Control Operations activities had repeatedly discovered contaminated mice. Significant levels of contamination were identified in five deer mouse samples. Contamination, as measured by field instruments, ranged from 5,000 cpm beta/gamma, to greater than 100,000 cpm (6 mrads/h). Laboratory analyses indicated the maximum strontium-90 contamination at 90,090 pCi/g and maximum cesium-137 levels at 2,730 pCi/g. Maximum concentrations are listed in Table 3.2.9.

In 1994, additional preoperational monitoring and characterization samples of soil and vegetation were

collected from the 200 Areas Cross-Site Transfer Line Replacement Project and near the 200 Areas Effluent Treatment Facility and Pipeline. Samples were analyzed for both radioactive and chemical contaminants. Both radionuclide and chemical concentrations at these sites were near background levels. Detailed results of the preoperational environmental monitoring for this project can be found in the final report *Preoperational Environmental Survey Report: 200 Areas Cross-site Transfer Line Replacement (W-058)* (WHC 1995d).

Final results of preoperational monitoring for Project C-018-H can be found in the report *Preoperational Environmental Survey Report: 200 Areas Effluent Treatment Facility (ETF) and State-approved Land Disposal Structure (SALDS), and Liquid Effluent Treatment Facility (C-018H)* (WHC 1995e). Preoperational monitoring for the Solid Waste Operations Complex will be published in a final report to be issued in 1996.

3.3 Waste Management and Chemical Inventories

B. P. Gleckler

Waste Management

Waste produced at the Hanford Site is classified as either radioactive, nonradioactive, or mixed waste. Radioactive waste is categorized as transuranic, high-level, and low-level. Mixed waste has both radioactive and hazardous nonradioactive substances. Hazardous waste contains dangerous wastes or extremely hazardous wastes or both, as defined in Ecology's Dangerous Waste Regulations.

Radioactive and mixed waste are currently handled in several ways. High-level waste is stored in single- and double-shell tanks. Low-level waste is stored in double-shell tanks, on storage pads, or is buried. The method used to manage low-level waste is dependent on the source, composition, and concentration of the waste. Transuranic waste is stored in vaults or on underground storage pads from which it can be retrieved.

Approximately 200 Hanford Site facilities have the capacity to generate dangerous waste. An annual report lists the dangerous wastes and extremely hazardous wastes generated, treated, stored, and disposed of onsite and offsite (DOE 1995b). Dangerous wastes are treated, stored, and prepared for disposal at several Hanford Site facilities or are shipped offsite for disposal, destruction, or recycling.

Nondangerous wastes generated at the Hanford Site are buried in the Solid Waste Landfill, located in the 200 Areas. These wastes originate at a number of areas across the Site. Examples of these wastes are construction debris, office trash, cafeteria waste, and packaging materials. Other materials and items classified as waste include solidified filter backwash and sludge from the treatment of river water, failed and broken equipment and tools, air filters, uncontaminated used gloves and other clothing, and certain chemical precipitates such as oxalates. Nonradioactive friable asbestos is buried in designated areas at the Solid Waste Landfill. Ash generated at powerhouses in the 200-East and 200-West Areas is buried in designated sites near those powerhouses. Demolition waste from 100 Areas decommissioning projects is buried in situ or in designated sites in the 100 Areas.

Annual reports document the quantities and types of solid waste generated onsite, received, shipped offsite, and disposed of at the Hanford Site (WHC 1995b). Solid waste program activities are regulated by the RCRA and TSCA, discussed in Section 2.0, "Environmental Compliance Summary." Solid waste quantities generated onsite, received from offsite sources, shipped offsite, and disposed of at the Hanford Site annually from 1989 through 1994 are shown in Tables 3.3.1 through 3.3.4.

The quantities of liquid wastes generated in 1994 and stored in underground storage tanks are included in the annual dangerous waste report (DOE 1995b). Table 3.3.5 is a summary of the liquid waste generated from 1989 through 1994, which are stored in underground storage tanks.

Chemical Inventories

Emergency Planning and Community Right-To-Know Act

Title III of the Superfund Amendments and Reauthorization Act is a free-standing law, called the Emergency Planning and Community Right-To-Know Act. This Act requires that the public be given information about hazardous chemicals in their communities. It also established emergency planning and notification procedures to protect the public in the event of a hazardous chemical release.

Subtitle B of the Act contains requirements for reporting information to local communities on hazardous materials existing in or released from a facility near those communities. The Hanford Site was in compliance with the reporting and notification requirements of the Act in 1994. The *1994 Hanford Tier-Two Emergency and Hazardous Chemical Inventory* (DOE 1995a) report will be issued in 1995 to the State Emergency Response Commission, local county emergency management committees, and the local fire departments. This report contains information on hazardous materials stored across the Hanford Site. Table 3.3.6 summarizes the information reported, listing the 10 chemicals stored in greatest quantity on the Hanford Site.

Table 3.3.1 Quantities of Solid Waste[a] Generated on the Hanford Site, kg

Waste Category	1989	1990	1991	1992	1993	1994
Mixed	670,457	1,025,084	475,370	48,641	150,012	567,670
Radioactive	7,798,182	1,325,045	1,069,703	682,684	1,116,616	1,390,647

(a) Solid waste includes containerized liquid waste.

Table 3.3.2 Quantities of Solid Waste[a] Received from Offsite, kg

Waste Category	1989	1990	1991	1992	1993	1994
Mixed	815,655	0	23,605	40,897	207,905	96,409
Radioactive	585,064	239,669	629,686	1,010,439	1,587,884	1,355,653

(a) Solid waste includes containerized liquid waste. Solid waste quantities do not include naval reactor submarine compartments.

Table 3.3.3 Quantities of Hazardous Waste[a] Shipped Offsite, kg

Waste Category	1990	1991	1992	1993	1994
Containerized	92,811	89,354	181,305	123,754	428,219
Bulk Solids		0	433,330	250,235	2,872,661
Bulk Liquids		331,905	11,089	94,065	87,056
Totals	92,811	421,259	625,724[b]	468,054[c]	3,387,936[d]

(a) Does not include Toxic Substances Control Act wastes.
(b) Includes 418,676 kg from demolition of 2727-S Building.
(c) Includes 250,235 kg from demolition of 190-B Building.
(d) Includes 2,658,788 kg from North Slope cleanup and 160,883 kg from carbon tetrachloride soil extraction.

Table 3.3.4 Radioactive Solid Waste Disposed of in 1994[a]

Constituent	Units	Low-Level	Low-Level Mixed	Low-Level Plus[b]	Low-Level Mixed Plus[c]	Transuranic	Transuranic Mixed
Americium	g	3.1×10^{-1}	0.0	0.0	1.5×10^{-4}	0.0	0.0
Cesium	Ci	0.0	0.0	0.0	0.0	0.0	0.0
Europium	Ci	6.7×10^{-1}	0.0	0.0	0.0	0.0	0.0
Plutonium	g	2.8×10^{1}	0.0	0.0	7.0×10^{-4}	0.0	0.0
Strontium	Ci	5.0×10^{3}	0.0	0.0	5.6×10^{-2}	0.0	0.0
Thorium	g	1.0×10^{5}	0.0	0.0	0.0	0.0	0.0
Uranium	g	2.3×10^{6}	0.0	0.0	0.0	0.0	0.0
Other fission and activation products	Ci	3.6×10^{-1}	0.0	0.0	0.0	0.0	0.0

(a) Values provided include only waste buried or permanently disposed of. This table does not include inventories of waste contained in temporary storage facilities. The "Mixed" category identifies wastes that are regulated under the RCRA. The "Plus" category identifies waste that are regulated under the TSCA (e.g., polychlorinated biphenyls).
(b) Low-level with polychlorinated biphenyls.
(c) Low-level mixed with polychlorinated biphenyls. All quantities in this category are from the naval reactor compartments disposed of at the Hanford Site.

Table 3.3.5 Quantities of Bulk Liquid Waste[a] Generated on the Hanford Site, kg

1989	1990	1991	1992	1993	1994
8,642,497	10,988,821	4,094,802	3,330,246	5,859,059	2,833,896

(a) Bulk liquid waste is defined as liquid waste sent to double-shell underground storage tanks. This does not include containerized waste (e.g., barreled), which are included in the solid waste category.

Table 3.3.6 Average Balance of Ten Chemicals Stored in Greatest Quantity, 1994

Hazardous Material	Average Daily Balance, kg
Coal	2.9×10^{7}
Mineral oil	2.0×10^{6}
Sodium	1.3×10^{6}
Diesel fuel	6.0×10^{5}
#6 Fuel oil	5.9×10^{5}
Nitric acid	4.8×10^{5}
Ethylene glycol	2.8×10^{5}
Argon	1.4×10^{5}
Unleaded gasoline	1.1×10^{5}
Nitrogen	9.2×10^{4}

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Environmental Program Information

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4.0 Environmental Program Information

It is DOE's policy to conduct its operations in an environmentally responsible manner and comply with applicable environmental standards. At the Hanford Site, a variety of environmental activities are performed to comply with laws and regulations, enhance environmental quality, and monitor the impact of environmental pollutants from Site operations.

This section summarizes significant activities conducted in 1994 to monitor the meteorology and climatology of the Site, assess the status of wildlife and cultural resources, and conduct special environmental programs.

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4.1 Climate and Meteorology

D. J. Hoitink

Meteorological measurements are taken to support 1) Hanford Site emergency preparedness and response, 2) Hanford Site operations, and 3) atmospheric dispersion calculations. Support is provided through weather forecasting and the maintenance and distribution of climatological data. Forecasting is provided to help manage weather-dependent operations. Climatological data are provided to help plan weather-dependent activities and are used as a resource to assess the environmental effects of Hanford Site operations.

The Cascade Mountains to the west of Yakima greatly influence the climate of the Hanford Site. These mountains create a rain shadow effect and also serve as a source of cold air drainage, which significantly effects the wind regime.

The Hanford Meteorology Station is located on the 200 Area Plateau, where the prevailing wind direction is from the northwest during all months of the year. The secondary wind direction is from the southwest. Summaries of wind direction indicate that winds from the northwest quadrant occur most often during the winter and summer. During the spring and fall, the frequency of southwesterly winds increases, with a corresponding decrease in the northwesterly flow. Monthly average wind speeds are lowest during the winter months, averaging 10 to 11 km/h (6 to 7 mph), and highest during the summer, averaging 13 to 15 km/h (8 to 9 mph). Wind speeds that are well above average are usually associated with southwesterly winds. However, the summertime drainage winds are generally northwesterly and frequently reach 50 km/h (30 mph). These winds are most prevalent over the northern portion of the Site.

Daily and monthly averages and extremes of temperature, dew point temperature, and relative humidity for the years 1945 through 1993 are given by Hoitink et al. (1994). From 1945 through 1994, the record maximum temperature was 45° C (113° F), and the record minimum temperature was − 30.6° C (2° F) below normal, had the largest negative departure.

Precipitation for 1994 totaled 15.6 cm (6.1 in.), 98% of normal (15.9 cm [6.3 in.]), with 13.2 cm (5.2 in.) of snow (compared to an annual normal snowfall of 35.1 cm [13.8 in.]).

The average wind speed for 1994 was 11.8 km/h (7.3 mph), which was 0.6 km/h (0.4 mph) below normal, and the peak gust for the year was 84 km/h (52 mph) on February 13. Figure 4.1.1 shows the 1994 wind roses (diagrams showing direction and frequencies of wind) at 10 m for meteorological monitoring stations on and around the Hanford Site.

Table 4.1.1 provides monthly climatological data from the Hanford Meteorology Station for 1994.

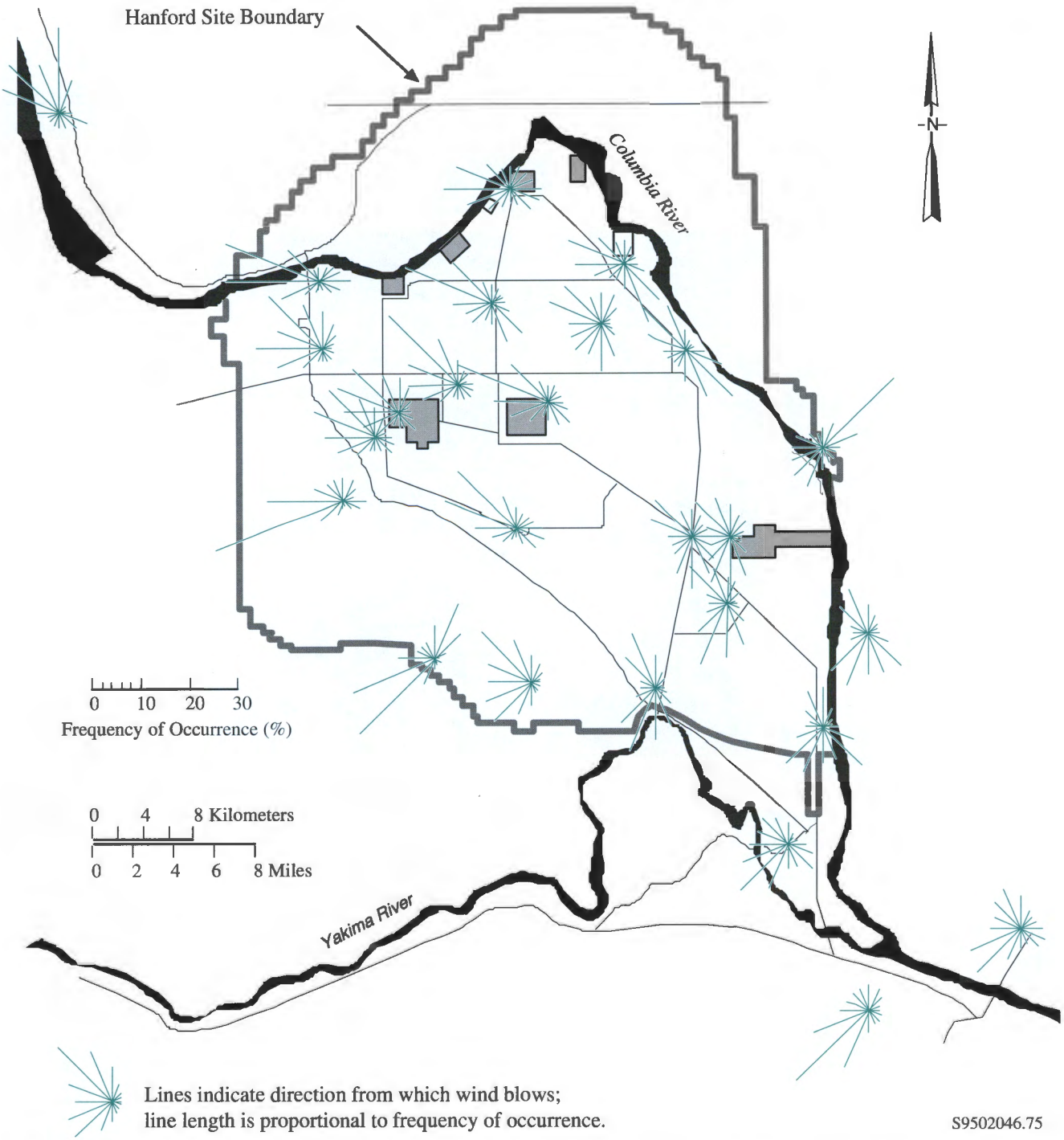

Figure 4.1.1 Hanford Meterological Monitoring Network Wind Roses (at 10 m), 1994. Individual lines indicate direction from which wind blows. Length of line is proportional to frequency of occurrence from a particular direction.

Table 4.1.1 Monthly Climatological Data from the Hanford Meteorology Station, 1994 Hanford Meteorology Station, 40 km N.W. of Richland, Washington Latitude 46° 34'N, Longitude 119° 35'W, Elevation 223 m (733 ft)

	Temperatures, °C								Precipitation (cm)				Relative Humidity (%)		15–m Wind[a]				
	Averages				Extremes						Snowfall						Peak Gusts		
Month	Daily Max	Daily Min	Monthly	Depart.[b]	Highest	Date	Lowest	Date	Total	Depart.[b]	Total	Depart.[b]	Average	Depart.[b]	Average Speed, km/h	Depart.[b]	Speed, km/h	Direction	Date
J	8.1	–0.7	3.7	4.1	16.1	13	–6.7	31	1.1	–0.9	0	–9.9	85.5	9.1	7.1	–3.4	64	SW	4
F	7.0	–2.6	2.2	–1.1	17.2	28	–15.0	8	0.3	–1.3	2.3	–2.8	66.2	–4.1	9.5	–2.1	84	SSW	13
M	17.4	1.7	9.6	2.0	26.1	28	–7.2	22	0.1	–1.1	0	–0.8	46.0	–9.9	11.4	–1.9	74	SW	17
A	21.8	7.3	14.6	3.1	31.1	18+[c]	–1.7	1	1.6	0.5	0	–T[d]	47.6	0.4	12.6	–1.9	61	WNW	24+ [c]
M	25.7	10.9	18.3	2.0	35.0	8	2.2	3	3.2	1.9	—[e]	—	43.0	0.3	12.2	–2.4	72	SW	29
J	29.2	12.8	21.0	0.1	38.3	22	6.7	2	1.0	0	—	—	36.5	–2.3	13.7	–1.1	74	WSW	13
J	36.4	18.1	27.2	2.7	43.9	22	10.0	3	0.4	–0.1	—	—	29.3	–4.2	12.6	–1.6	82	WSW	24
A	33.5	16.1	24.8	0.8	41.1	2	11.7	9	0.2	–0.5	—	—	33.5	–2.3	13.8	1.1	64	NW	28
S	30.1	12.7	21.4	2.7	34.4	20+[c]	8.3	23	0.2	–0.6	—	—	39.8	–2.9	11.4	–0.5	61	WSW	3
O	19.5	5.4	12.4	0.8	28.9	1	–1.1	30	2.4	1.4	0	–0.3	56.3	1.1	12.7	2.2	79	SSW	26
N	9.0	–0.6	4.2	–0.3	16.7	30	–7.2	22	1.7	–0.6	0.3	–4.3	72.9	–0.5	13.0	2.7	80	SSW	30
D	5.5	–2.1	1.7	2.1	17.8	20	–13.3	4	3.4	0.8	10.7	–3.8	78.2	–2.1	11.4	1.9	72	S	8
Y[f]	20.3	6.6	13.4	1.6	43.9	Jul 22	–15.0	Feb 8	15.6	–0.4	13.2	–21.8	52.9	–1.4	11.8	–0.6	84	SSW	Feb 13

(a) Measured on a tower 15 m (50 ft) above the ground.
(b) Departure columns indicate positive or negative departure of meteorological parameters from 30–year (1961–1990) climatological normals.
(c) + after date indicates latest of several occurrences.
(d) Trace.
(e) — means no record of any snowfall during these months.
(f) Yearly averages, extremes, and totals.

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4.2 Wildlife

L. L. Cadwell and M. A. Simmons

The Hanford Site is a relatively large, undisturbed area of shrub-steppe that contains numerous plant and animal species adapted to the region's semiarid environment. The vegetation mosaic of the Site consists of ten major plant communities: 1) sagebrush/bluebunch wheatgrass, 2) sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass, 3) sagebrush-bitterbrush/cheatgrass, 4) grease wood/cheatgrass-saltgrass, 5) winterfat/Sandberg's bluegrass, 6) thyme buckwheat/Sandberg's bluegrass, 7) cheatgrass-tumble mustard, 8) willow or riparian, 9) spiny hopsage, and 10) sand dunes (Cushing 1994). Nearly 600 species of plants have been identified on the Hanford Site (Sackschewsky et al. 1992). Cheatgrass is the dominant plant on old fields that were cultivated approximately 50 years ago.

More than 300 species of terrestrial and aquatic insects, 12 species of reptiles and amphibians, 44 species of fish, 187 species of birds, and 39 species of mammals have been found on the Hanford Site (Cushing 1994). Deer and elk are the major large mammals on the Site; coyotes are plentiful, and the Great Basin pocket mouse is the most abundant mammal. Waterfowl are numerous on the Columbia River, and the bald eagle is a regular winter visitor along the river. Salmon and steelhead are the fish species of most interest to sport fishermen and Native American tribal members.

There are two types of natural aquatic habitats on the Hanford Site; one is the Columbia River, and the other is provided by the small spring-streams and seeps located mainly on the ALE Reserve in the Rattlesnake Hills. These include Rattlesnake Springs, Dry Creek, Snively Springs, and West Lake, a small, natural pond near the 200 Areas. Several artificial water bodies, both ponds and ditches, have been formed as a result of waste-water disposal practices associated with the operation of the reactors and separation facilities; these water bodies form established aquatic ecosystems complete with representative flora and fauna (Emery and McShane 1980).

The Hanford Site contains no plant species listed on the federal list of threatened and endangered species. The federal government lists the peregrine falcon as endangered and the bald eagle and Aleutian Canada goose as threatened. The peregrine falcon and Aleutian Canada goose are migrants through the Hanford Site, and the bald eagle is a common winter resident. Several plant species, mammals, birds, molluscs, reptiles, and invertebrates occurring on the Hanford Site are currently candidates for formal listing under the Endangered Species Act. Appendix G lists special-status species that could occur on the Hanford Site.

Results for Wildlife Resource Monitoring, 1994

Wildlife populations inhabiting the Hanford Site are monitored to measure the status and condition of the populations and assess effects of Hanford operations. Particular attention is paid to species that are rare, threatened, or endangered nationally or statewide and those species that are of commercial, recreational, or aesthetic importance statewide or locally. These species include the bald eagle, chinook salmon, Canada goose, ferruginous hawk, Rocky Mountain elk, mule deer, loggerhead shrike, and other bird species.

Fluctuations in wildlife and plant species on the Hanford Site appear to be a result of natural ecological factors and management of the Columbia River system. The establishment and management of the Hanford Site has helped to maintain wildlife populations and overall biological diversity relative to probable alternative uses of the Site.

Bald Eagle

The bald eagle is listed as a federally threatened species and also a Washington state threatened species. Historically, bald eagles have wintered along the Hanford Reach of the Columbia River. However, when monitoring began in the early 1960s, numbers were very low (Figure 4.2.1). Following the passage of the Endangered Species Act in 1973, the

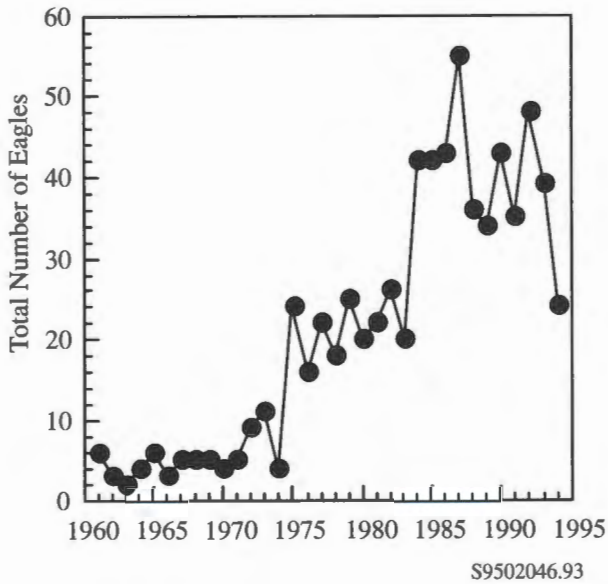

Figure 4.2.1 Bald Eagles Observed Along the Hanford Reach, Fall and Winter Months, 1961 Through 1994

number of wintering bald eagles increased. Possible reasons for the observed increase are the added protection of bald eagles at nesting locations off the Hanford Site and the nationwide elimination of dichlorodiphenyltrichloroethane (DDT) as an agricultural pesticide in 1972. On a local scale, changes in the number of eagles on the Hanford Site generally correspond to changes in the number of salmon, a major fall and winter food source for eagles. The recent decline in numbers is probably attributable to the recent decline in salmon in the area. Most of the eagles using the Hanford Reach are concentrated in the section between the old Hanford Townsite and the 100-K Area.

The Hanford Reach is expected to continue providing wintering habitat as long as critical resources such as food, perches, and relative freedom from human activities are maintained. Limited nest building by bald eagles has been observed at the Hanford Site in recent years although none of the attempts has been successful.

Chinook Salmon

Chinook salmon are an important resource to the citizens of the Pacific Northwest. Salmon are caught commercially and for recreation. The commercial and recreational catch is carefully managed to sustain the resource. Today the most important natural spawning area in the mainstream Columbia River for the fall chinook salmon is found in the free-flowing Hanford Reach. In the early years of the Hanford Site, there were few spawning nests (redds) in the Hanford Reach (Figure 4.2.2). Between 1943 and 1971, a number of dams were constructed on the Columbia River. The reservoirs created behind the dams eliminated most mainstem spawning areas and increased salmon spawning in the Hanford Reach. Fisheries management strategies aimed at maintaining spawning populations in the mainstem Columbia River have also contributed to the observed increases. In recent years, numbers of fall chinook salmon spawning in the Hanford Reach have declined, consistent with reduced run sizes returning to the Columbia River. The larger 1994 redd count was partly the result of harvest restrictions directed at protecting Snake River stocks of fall chinook salmon under the Endangered Species Act. Also, for most of the surveys conditions were excellent for observing the redds. Additionally, low daytime discharges from Priest Rapids Dam contributed to generally low water as far downstream as Ringold. Redds were visible in the lower part of the Reach for the first time in many years. The Hanford Reach under existing management practices continues to provide valuable salmon spawning habitat.

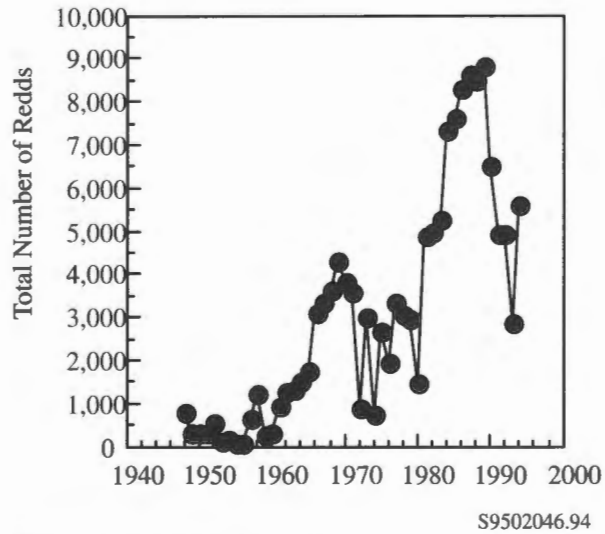

Figure 4.2.2 Chinook Salmon Spawning Redds in the Hanford Reach, 1948 Through 1994

Canada Goose

Nesting Canada geese are valuable recreational and aesthetic resources along the Snake and Columbia rivers in eastern Washington. Goose nesting surveys began in the 1950s to monitor changes in response to reactor operations (Figure 4.2.3). The gradual decline observed in the late 1960s and early 1970s is attributed to persistent coyote predation, mostly on the Columbia River islands upstream from the old Hanford Townsite. Since the 1970s, the center of the nesting population has shifted from upstream to downstream islands near Richland, which in recent years have been relatively free from coyote predation. The lower nest count in 1994 can be attributed to extensive coyote predation on Island 12 (a downstream island). In 1993, there were 60 nests on Island 12 while no nests were found in 1994.

Canada goose populations are successful on the Hanford Reach because the islands are restricted from human uses during the nesting period and because shoreline habitats provide adequate food and cover for broods (Eberhardt et al. 1989).

Hawks

The undeveloped land of the semiarid areas of the Hanford Site provides nest sites and food for three species of migratory buteo hawks: Swainson's, red-tailed, and ferruginous. Under natural conditions, these hawks nest in trees, on cliffs, or on the ground. Powerline towers and poles also can serve as nest sites, and these structures are well used by nesting hawks on the Hanford Site because of the relative scarcity of trees and cliffs. The ferruginous hawk is a U.S. Fish and Wildlife Service candidate species for listing as threatened and/or endangered. In recent years, the number of ferruginous hawks nesting on the Hanford Site has increased (Figure 4.2.4). The Site continues to provide hawk nesting habitats administratively protected from human intrusions, as well as providing suitable foraging areas. The sharp declines in red-tailed and Swainson's hawk nests in the late 1980s are probably not a result of Hanford Site activities because the number of nests for the very sensitive ferruginous hawk did not decline (Figure 4.2.4). Decreases in nesting red-tailed and Swainson's hawks may have been related to impacts that occurred during their migration and/or while they were on their wintering grounds. Nesting pairs of red-tailed hawks increased in 1991 and 1992 to approximately 25, which represents a high for the species. Since 1993, no complete survey data are available for either red-tailed and Swainson's hawks.

Rocky Mountain Elk

Rocky Mountain elk did not inhabit the Hanford Site when it was established in 1943. Elk appeared

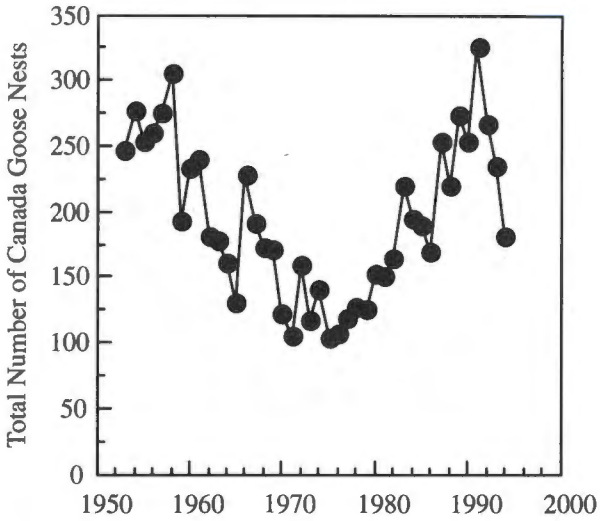

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Figure 4.2.3 Canada Goose Nests on Islands in the Hanford Reach, 1952 Through 1994

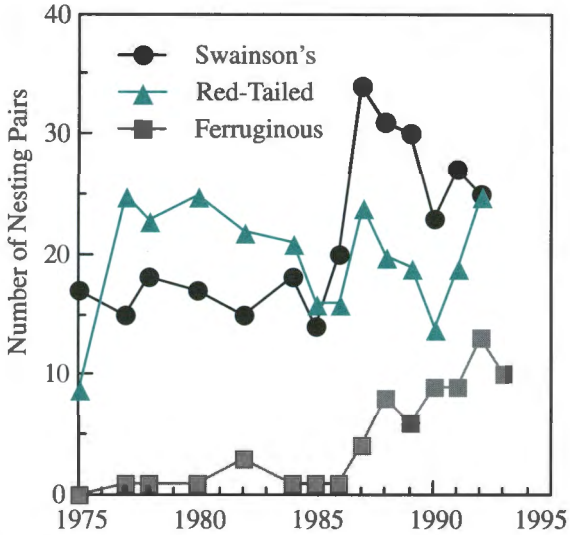

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Figure 4.2.4 Red-Tailed, Swainson's, and Ferruginous Hawks on the Hanford Site, 1975 Through 1994

on the ALE Reserve in the winter of 1972. A few animals stayed and reproduced. Over 300 elk were recorded in 1994 before the offsite hunting season (Figure 4.2.5). With a regulated hunting season on private lands adjoining the ALE Reserve, the elk population appeared to be holding at less than 100 animals until the spring of 1990. During the 1994 hunting season, more than 40 elk were estimated to have been harvested.

Elk are successful on the ALE Reserve because of 1) available forage without competition from domestic livestock; 2) unrestricted access to drinking water at springs located on the ALE Reserve; 3) relatively mild winters; 4) ability to accommodate extreme summer temperatures, even in the absence of shade; and 5) absence of hunting on the Site.

Mule Deer

Mule deer are a common resident of the Hanford Site and are important because of the recreational (offsite hunting) and aesthetic values they provide. Because mule deer have been protected from hunting on the Hanford Site for approximately 50 years, the herd has developed a number of unique

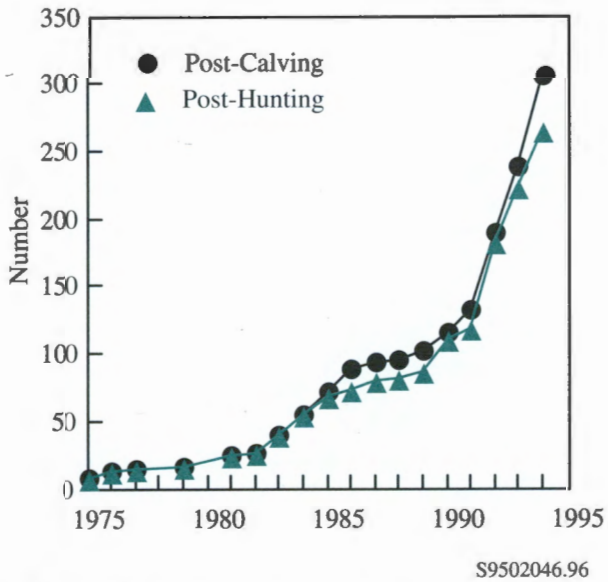

Figure 4.2.5 Elk on the Hanford Site Counted by Aerial Surveillance During the Post-Calving Period, August Through September, and the Post-Hunting Period, December Through January, 1975 Through 1994

population characteristics that are in contrast to most other herds in the semiarid region of the Northwest. These characteristics include a large proportion of old-age animals (older than 5 years) and large-antlered males. This herd provides a unique opportunity for comparison to other more heavily harvested herds in this region.

Because of the unique nature of the herd and high degree of public interest, a study was initiated in 1990 to 1) obtain estimates of the number of deer on the Hanford Site, 2) determine the extent and frequency of offsite movements by Hanford Site deer, and 3) evaluate the level of strontium-90 in deer from the 100 Areas (see Section 5.5, "Wildlife Surveillance"). Additional work was initiated in 1993 to identify possible causes for abnormal antler development and reduced testicle size observed in some mule deer residing along the Columbia River corridor. The condition was recently observed in old buck deer.

Offsite movement of deer was monitored by radiocollaring 53 animals (15 bucks and 38 does). Frequent movements across the river or onto islands were made by some deer, particularly during the breeding (October-December) and fawning (May-July) season. Twenty-four of the 53 radiocollared animals were located at least once either across the river or on the islands. The most frequently visited locations offsite locations are the riparian areas along the Columbia River and adjacent to the Hanford Site.

A total of 38 deer antlers was analyzed in 1994 for strontium-90 concentrations. Fourteen of the antler samples came from animals captured near the 100 Area reactor sites, 14 were collected from animals near or south of the old Hanford Townsite and 10 were collected from a reference site near Silver Lake, Oregon. Analysis of the antlers revealed that the mean concentration from 100 Area deer was 0.41 pCi/g, the mean concentration from old Hanford Townsite deer was 0.19 pCi/g, and the mean concentration in antlers collected near Silver Lake was 2.09 pCi/g. The elevated concentrations from Silver Lake samples are attributed to higher amounts of fallout-derived strontium-90 scavenged from the atmosphere by precipitation, which is greater in the mountainous regions of Oregon.

A total of 25 deer (5 in 1993 and 20 in 1994) have been examined for testicular atrophy and abnormal antler development. All affected animals (n=12) were over 4 years old; 10 were between 8 and 12 years old. Age for the unaffected animals was between 1 and 6 years. Blood tests revealed no parasitic cause for the testicular atrophy and there were no endocrine abnormalities. PNL is currently conducting movement analysis of the normal and affected animals to examine areas of use for the two groups. We are also observing seasonal forage patterns and collecting fecal samples to identify diet.

Monitoring Northern Oriole Populations

During the 1980s, scientists noted declines in the number of North American migratory song birds. Habitat loss and degradation is partly responsible. Habitat needed for food and shelter is disappearing in the neotropics. In the United States, there is not enough suitable nesting habitat to sustain populations of some species. In some cases, populations have diminished to the point where special protection is required to sustain them. Federal agencies are required to monitor numbers of threatened and endangered species and to devise and implement management plans.

The northern oriole (*Icterus galbula*) is one of the 120 species of migratory song birds that nest in Washington and Oregon. On the Hanford Site, northern orioles nest in deciduous trees. The nests are difficult to locate during spring, when trees are in full foliage, but are more conspicuous after leaf fall in autumn. The old Hanford Townsite was selected for monitoring in 1994 because it has more trees than other places on the Site. Forty nests were located in seven tree groups (Figure 4.2.6).

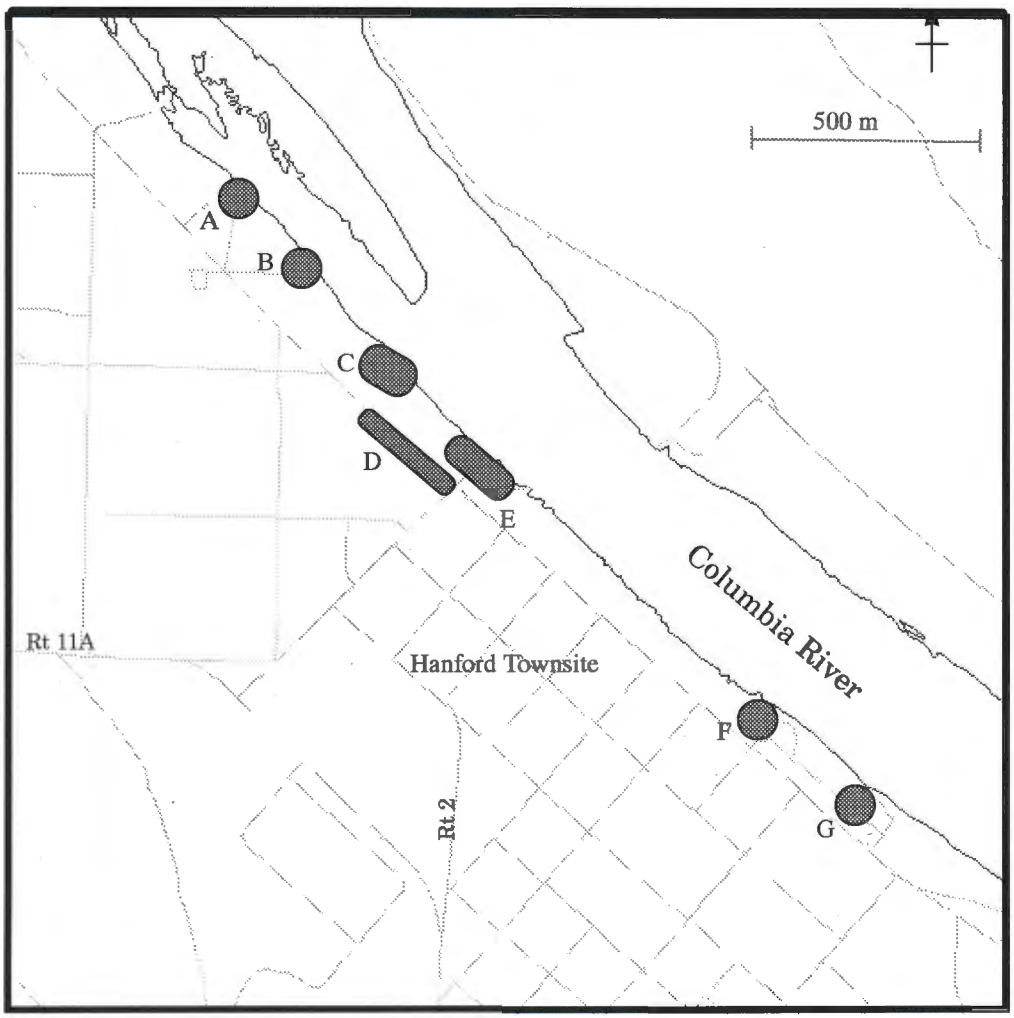

Figure 4.2.6 Oriole Nesting Sites at the old Hanford Townsite, 1994

Counting nests appears to be an efficient way to monitor breeding populations of northern orioles. These data will provide the basis for judging the impacts of land use changes at the old Hanford Townsite as the land is converted to other purposes in the future.

Special Plants

In 1994, The Nature Conservancy along with botanists from PNL initiated a survey of the Hanford Site for rare plant species. A total of 55 new populations were found of 10 plant taxa listed in Washington as Endangered, Threatened or Sensitive. These taxa are *Astragalus columbianus* (Columbia milkvetch), *Astragalus geyeri* (Geyer's milkvetch), *Camissonia pygmaea* (dwarf evening-primrose), *Cryptantha leucophaea* (gray cryptantha), *Cyperus bipartitus* (shining flatsedge), *Erigeron piperianus* (Piper's daisy), *Limosella acaulis* (southern mudwort), *Lindernia dubia* var. *anagallidea* (false-pimpernel), *Oenothera caespitosa* subsp. *caespitosa* (desert evening-primrose), and *Rorippa columbiae* (persistentsepal yellowcress).

Wildlife Monitoring on Non-DOE Managed Hanford Site Land

DOE property north of the Columbia River is managed for wildlife and recreation by two separate agencies. The Saddle Mountain National Wildlife Refuge is the westernmost portion of the North Slope area and is managed by the U.S. Fish and Wildlife Service through the Columbia National Wildlife Refuge Office located in Othello, Washington. The Wahluke Wildlife Area, which lies generally east and north of the Saddle Mountain refuge, is managed by the Washington Department of Fish and Wildlife as an outdoor recreation area. A third agency, the U.S. Army Corps of Engineers, was involved during 1994 in activities to clean-up any residual contamination on all of the lands north of the Columbia River in anticipation of DOE's final decision to disposition those properties. That activity has commonly been referred to as North Slope cleanup.

The Saddle Mountain refuge is managed as a natural preserve with relatively little resources dedicated to habitat management. This management approach is being used because the refuge is deemed to be temporary as a result of the 30-day revocation clause in the U.S. Fish and Wildlife permit from DOE. Habitat management will likely be given a higher priority if Saddle Mountain becomes a permanent part of the refuge system.

Land management activities conducted on the Wahluke Wildlife Area by the Washington Department of Fish and Wildlife in 1994 included inspection of North Slope cleanup areas and participation in rehabilitation planning, assisting The Nature Conservancy with plant and bird inventories, assisting the U.S. Bureau of Reclamation contractor with White Bluffs road closure, spraying about 45 acres of noxious weeds on Wahluke units, and planting 7 acres of wildlife food crops at Ringold (volunteers planted an additional 15 acres at Ringold). Other activities included investigating low water in WB-10 ponds and searching the ponds and wasteway for Salt cedar and Purple loosestrife infestations. Two grazing permits and three agricultural leases were evaluated for the Wahluke units. The Washington Department of Fish and Wildlife also evaluated four fires including the 1500-acre Savage Island fire, seeded about 10 acres of fire breaks with winter wheat cover crop, and maintained eight winter feeders and one guzzler for upland birds. Maintenance activity included removing litter and replacing damaged and deteriorating signs. The only wildlife management activity was counting duck pairs which was done twice in May 1994 in Section 27, T14N, R27E and Section 9, T12N, R28E.

4.3 Hanford Cultural Resources Laboratory

M. K. Wright

The Hanford Cultural Resources Laboratory (HCRL) was established by the Richland Operations Office in 1987 as part of PNL. The HCRL provides support for managing the archaeological, historical, and traditional cultural resources of the Hanford Site in a manner consistent with the National Historic Preservation Act, the Native American Graves Protection and Repatriation Act, the Archaeological Resources Protection Act, and the American Indian Religious Freedom Act.

Pursuant to Section 106 of the National Historic Preservation Act, cultural resource reviews must be conducted before each proposed ground disturbance or building alteration/demolition project on the Hanford Site. During 1994, Hanford contractors requested 511 such reviews, 26 of which required archaeological surveys. The surveys covered a total of 10.09 km^2 (3.9 mi^2) and resulted in the discovery of 11 prehistoric archaeological sites, 27 historic archaeological sites, and two archaeological sites with historic and prehistoric components. The cultural affiliation of one site could not be determined on the basis of existing data. Sixty buildings and/or structures were also inventoried and added to the HCRL database.

Three large projects were undertaken in 1994: the Tank Waste Remediation Systems Complex, the Environmental Restoration Disposal Facility Site and the Proposed Basalt Quarry Sites. Four sites and 21 isolated finds were recorded during fieldwork conducted for these three projects. Most of the sites recorded are historic in nature and contain information ranging from lifeways of early settlers in the Hanford area to military installations of the 1950s. In addition to these efforts, the HCRL was involved in the environmental assessment of the EMSL relocation.

Section 110 of the National Historic Preservation Act requires that federal agencies undertake a program to identify historic properties, maintain and manage cultural resource information, consider the effects of proposed undertakings on properties that are eligible or potentially eligible for listing on the National Register of Historic Places early in the planning process, consider the use and re-use of historic properties, and seek opportunities for cooperative efforts with others in the preservation and use of historic properties. A Historic American Engineering Record documentation process was initiated for a multibuilding complex and two individual buildings that were determined eligible for the National Register of Historic Places during this period.

The archaeological site-monitoring program is designed to document the current condition of cultural resources and thus to determine whether cultural resource management and protection policies are effective. Site monitoring activities for FY 1993 were completed and reported early in FY 1994. Natural erosive and human processes are the most significant factors impacting the majority of sites. These impacts could be reduced by site revegetation and increased surveillance. Sites with public access received the heaviest impacts from looting and vandalism. Sites inside and outside the security perimeter are also impacted by wind erosion, which is intensified by off-road vehicle use. Site evaluation is also an important aspect of Section 110 of the National Historic Preservation Act. In 1994, five archaeological sites, the White Bluffs Road, and the McGee Ranch/Cold Creek Valley District were evaluated. All but one historic archaeological site was found to be eligible for listing on the National Register of Historic Places.

Compliance activities falling under the American Indian Religious Freedom Act and the Native American Graves Protection and Repatriation Act included the acquisition and curation of cultural materials, completion of a Native American Graves Protection and Repatriation Act summary report, and the discovery of human remains at the original EMSL construction site and selection of a new EMSL site.

Educational activities associated with the cultural resources program included presenting lectures to groups of all ages and developing a series of displays to be used in Hanford Site facilities for worker education. Lectures were presented to

groups ranging from primary school rock hounds to civic groups. In April, the HCRL participated in a multimedia news conference to discuss events associated with the discovery of human remains at the original EMSL construction site.

The HCRL participated in the Teacher Research Associate and Northwest College and University Association for Science programs. One Teacher Research Associate was involved in researching past stream conditions on and off the Hanford Site using archaeological shell samples; another Teacher Research Associate provided preliminary faunal analysis of one archaeological collection from the Hanford Site. Three Associated Western Universities, Inc., Northwest Division student interns were also involved in field and laboratory work with HCRL staff.

Ongoing research activities were continued, when possible, as part of compliance work. Research in the field of archaeology and history focused on several general areas of interest: interaction between prehistoric inhabitants and their plant and animal resources, the cultural interface between Native Americans and early settlers, early settlement patterns of Euro-Americans, the private-to-public land transfers that took place during the early 1940s for the Manhattan Project, and the built environment of the Manhattan Project and the Cold War period.

4.4 Community-Operated Environmental Surveillance Program

Since 1991, citizens living near the Hanford Site have been participating in Hanford Site environmental surveillance activities. Local teachers have been managing and operating three special radiological air sampling stations located in Richland, Basin City, and Franklin County, Washington (see Figure 5.2.1 in Section 5.2). Each station is similar in design and consists of equipment for collecting air samples and monitoring ambient radiation levels. Each station also includes a large, lighted, and covered informational display containing real-time meteorological and radiological information (Figure 4.4.1). All areas of the stations are publicly accessible, and stations have been designed and outfitted to stimulate public interest. Station displays provide the public with general information on station equipment, sample types, and analyses. The station manager's name and phone number are provided for anyone desiring additional information. Brochure boxes containing a variety of free pamphlets and brochures discussing Hanford environmental programs have also been installed on each display panel.

Figure 4.4.1 Community Members Can See Environmental Surveillance in Action at Three Local Community-Operated Environmental Surveillance Stations

Two teachers working in schools close to the stations were selected to operate each station. The teachers are responsible for collecting a variety of air samples, preparing the samples and collection records for submission to a radioanalytical laboratory, monitoring the performance of station equipment, performing minor station maintenance, and participating in scheduled training. They also serve as spokespersons for the Community-Operated Environmental Surveillance Program and function as points-of-contact for local citizens. Surface Environmental Surveillance project staff work closely with the teachers to maintain station equipment and displays and to coordinate sampling and analytical efforts with other Hanford environmental surveillance activities. Analytical results for samples collected at these stations in 1994 are discussed in Section 5.2, "Air Surveillance."

In 1994, an expansion of the Community-Operated Environmental Surveillance Program was initiated at the request of DOE. A 5-year expansion plan was prepared, and teachers were selected and trained to operate two routine air-monitoring stations in Pasco and Kennewick, Washington (see Figure 5.2.1 in Section 5.2). These two stations differ from the original three citizen-operated stations in that they have not been modified to attract public attention. However, the air sampling station in Pasco was moved a short distance to the campus of Columbia Basin College (a local community college) to be more conveniently located and to benefit students in the school's radiological sciences program.

Also in 1994, construction was started on a fourth special air-monitoring station on the campus of Heritage College in Toppenish, Washington. This station is being built by the college with money from a DOE grant and will be used by both PNL and the college for their individual needs. Most of the equipment at the station will be supplied and maintained by PNL. However, some equipment will be purchased by the school with grant monies and will be used to enhance their fledgling environmental sciences program.

Additionally, public participation in crop sampling continued in 1994. Leafy vegetables were obtained from the Bailie Memorial Youth Ranch in the east Wahluke sampling area and the Country Haven Academy in the Sagemoor sampling area (see Figure 5.3.17 in Section 5.3). Both of these areas are considered to be downwind of the Site and could potentially be impacted by Site emissions. Analytical results for these samples are reported in Section 5.4, "Food and Farm Product Surveillance."

The long-range goal for the expansion of the Community-Operated Environmental Surveillance Program is to select and train enough teachers by 1999 to do most of the offsite sampling for the Surface Environmental Surveillance Project. Environmental sampling on and around the Hanford Site has been conducted by Site personnel for almost 50 years so this represents a major change in DOE's approach to accomplishing its Sitewide monitoring objectives. However, this kind of program change is commensurate with other changes currently ongoing at all DOE sites and should help to bolster public acceptance of the data and increase public understanding of the reported results. In the near future, if the budget permits, expansion efforts will allow increased citizen involvement in offsite air sampling, some involvement in offsite water sampling, and increased involvement in food and farm product sampling.

Environmental Surveillance Information

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5.0 Environmental Surveillance Information

Environmental monitoring of the Hanford Site consists of effluent monitoring and environmental surveillance. Effluent monitoring is conducted at or near facilities on the Site and is discussed in this report in Section 3.0, "Effluent Monitoring Information." Environmental surveillance activities are conducted routinely both on and off the Site with the intent of detecting and quantifying radiological and nonradiological contaminants and assessing their environmental and human health significance. Sections 5.2 through 5.8 describe the results of the Hanford Site environmental and ground-water surveillance programs for 1994 and include, where applicable, information on both radiological and nonradiological monitoring. Radiological doses associated with the surveillance results are discussed in Section 6.0, "Potential Radiation Doses from 1994 Hanford Operations," and the quality assurance and quality control programs developed for ensuring the value of surveillance data are described in Section 7.0, "Quality Assurance."

Many samples are collected and analyzed for the Hanford Site environmental surveillance program, and data obtained from the analytical laboratory are compiled in large computer databases. As it is not practical or desirable to include a listing of individual results in this report, the following sections include summary information emphasizing those radionuclides or chemicals of Hanford origin that are important to environmental or human health concerns. Supplemental data for some sections can be found in Appendix A of this report. More detailed results for specific surface environmental surveillance sampling locations are contained in the volume, *Hanford Site Environmental Data 1994 Surface and Columbia River* (Bisping 1995). Additional information on Hanford Site ground-water monitoring can be found in the annual Hanford Site ground-water monitoring report (e.g., Dresel et al. 1994). The intent of the following summaries is to provide the reader with the most current surveillance data, compare the 1994 data to past data and to existing and accepted standards so that concentrations can be viewed in perspective, and present a general overview of Hanford Site surveillance activities.

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5.1 Environmental and Ground-Water Surveillance at Hanford

R. L. Dirkes and S. P. Luttrell

Environmental and ground-water surveillance of the Hanford Site and surrounding region is conducted to demonstrate compliance with environmental regulations, confirm adherence to DOE environmental protection policies, support DOE environmental management decisions, and provide information to the public. Surveillance is conducted as an independent program under DOE Orders 5400.1, "General Environmental Protection Program," and 5400.5, "Radiation Protection of the Public and Environment," and the guidance in *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991). The objectives, criteria, design, and description of the program are summarized below and provided in detail in the *Environmental Monitoring Plan* (DOE 1991c).

Ground-water surveillance is designed to meet the ground-water monitoring program objectives stated in DOE Order 5400.1 and described in DOE (1991). The objectives, rationale and design criteria for monitoring radiological and chemical contaminants in ground water are summarized in this section. Ground-water surveillance at Hanford is an integral part of the Hanford Site Ground-Water Protection Management Program (DOE 1994g) but is conducted independently of the operating contractor's programs. A brief description of the program is included below and provided in detail in the *Hanford Site Ground-Water Protection Management Plan* (DOE 1994g).

Environmental Surveillance

Environmental surveillance encompasses sampling and analyzing for potential radiological and nonradiological chemical (hereinafter referred to as chemical) contaminants on and off the Hanford Site. Emphasis is placed on surveillance of exposure pathways and chemical constituents that present the greatest potential risk to humans and the environment. Exposure is defined as the interaction of an organism with a physical or chemical agent of interest. Thus, exposure can be quantified as the amount of chemical or physical agent available for absorption at the organism's exchange boundaries (i.e., dermal contact, lungs, gut, etc.). An exposure pathway is identified based upon 1) examination of the types, location, and sources (contaminated soil, raw effluent, etc.) of contaminants occurring onsite; 2) the principal release mechanisms; 3) the probable environmental fate and transport (including persistence, partitioning, and intermediate transfer) of contaminants of interest; and, most importantly, 4) the location and activities of the potentially exposed populations. Mechanisms that influence the fate and transport of a chemical through the environment and that are the determining factor influencing the amount of exposure one might receive at various receptor locations are listed below.

Once a radionuclide or chemical is released into the environment it may be:

- transported (e.g., migrate downstream in solution or on suspended sediment, or travel through the atmosphere)
- physically or chemically transformed (e.g., deposition, precipitation, volatilization, photolysis, oxidation, reduction, hydrolysis; if radionuclide it may decay)
- biologically transformed (e.g., biodegradation)
- accumulated in the receiving media (e.g., an environmental sink, such as a chemical sorbed strongly in the soil column).

The Environmental surveillance program has always been focused on radionuclides and nonradiological water quality parameters. In the last few years, however, surveillance for hazardous chemicals has been initiated. In 1994, a detailed nonradiological chemical pathway and exposure analysis was completed. This type of analysis helps to ensure that the selection of nonradiological surveillance parameters such as environmental media, sampling location, and chemical constituents are chosen in a manner that is scientifically sound and

cost efficient. The chemical (nonradiological) pathway analysis is based upon source-term data reported in the literature through February 1994, and the use of the Multimedia Environmental Pollutant Assessment System (MEPAS) code, version 3.0 (Droppo et al. 1989, 1991). A report will be published in summer 1995 (Blanton et al, 1995)

Each year a radiological pathway analysis and exposure assessment is also performed. The radionuclide pathway analysis is based on 1994 source-term data and on the comprehensive pathway and dose assessment methodology included in the GENII computer code (Napier et al. 1988a, 1988b, 1988c) used for estimating the radiation doses to the public from Hanford operations. The pathway analysis is also based on the CRITR computer code (Baker and Soldat 1992) used to calculate doses to animals, and on hand calculations for those doses not addressed in the computer codes.

The environmental surveillance program focuses on routine releases from DOE facilities on the Hanford Site; however, the program is also responsive to unplanned releases and releases from non-DOE operations on and near the Site. Surveillance results are provided annually through this report series. In addition, unusual results or trends are reported to DOE and the appropriate facility managers when they occur. Whereas effluent and near-facility environmental monitoring are conducted by the facility operating contractor, environmental surveillance is conducted under an independent program that reports directly to the DOE Quality, Safety, and Health Programs Division.

Objectives

Key surveillance objectives in 1994 included verifying compliance with DOE and EPA radiological dose standards for public protection, independently assessing the adequacy of facility pollution controls, assessing the environmental and public health impacts of Hanford operations, identifying and quantifying potential environmental quality problems, and providing information to DOE for environmental management of the Site, to the public, and to regulatory agencies.

Criteria

The criteria for environmental surveillance are derived from DOE Order 5400.1, guidance published for DOE sites (DOE 1991a), and the above-stated objectives. These criteria, pathway analyses to determine the radionuclides and media contributing to the dose to humans, and local needs and interests have been used in establishing the surveillance program. Experience gained from environmental surveillance activities and studies conducted at the Hanford Site for more than 45 years have provided valuable technical background for planning and data interpretation.

Surveillance Design

Environmental surveillance at Hanford is designed to meet the previously listed objectives, considering the environmental characteristics of the Site and the potential and actual releases from Site activities. The main focus is on determining environmental impacts and compliance with public health standards, as well as environmental standards or protection guides, rather than on detailed radiological and chemical characterization.

The primary pathways for movement of radioactive materials and chemicals from the Site to the public are the atmosphere, surface water, and ground water. Figure 5.1.1 illustrates these potential primary routes and the possible exposure pathways to humans.

The significance of each pathway is determined from measurements and calculations that estimate the amount of radioactive material or chemical transported along each pathway and by comparing the concentrations or doses to environmental and public health protection standards or guides. Pathways are also evaluated based on prior studies and observations of radionuclide and chemical movement through the environment and food chains. Calculations based on effluent data show the expected concentrations off the Hanford Site to be low for all radionuclides and chemicals and generally below the level that can be detected by monitoring technology. To ensure that radiological and chemical analyses of samples are sufficiently sensitive, minimum detectable concentrations of key radionuclides and chemicals in air, water, and food are

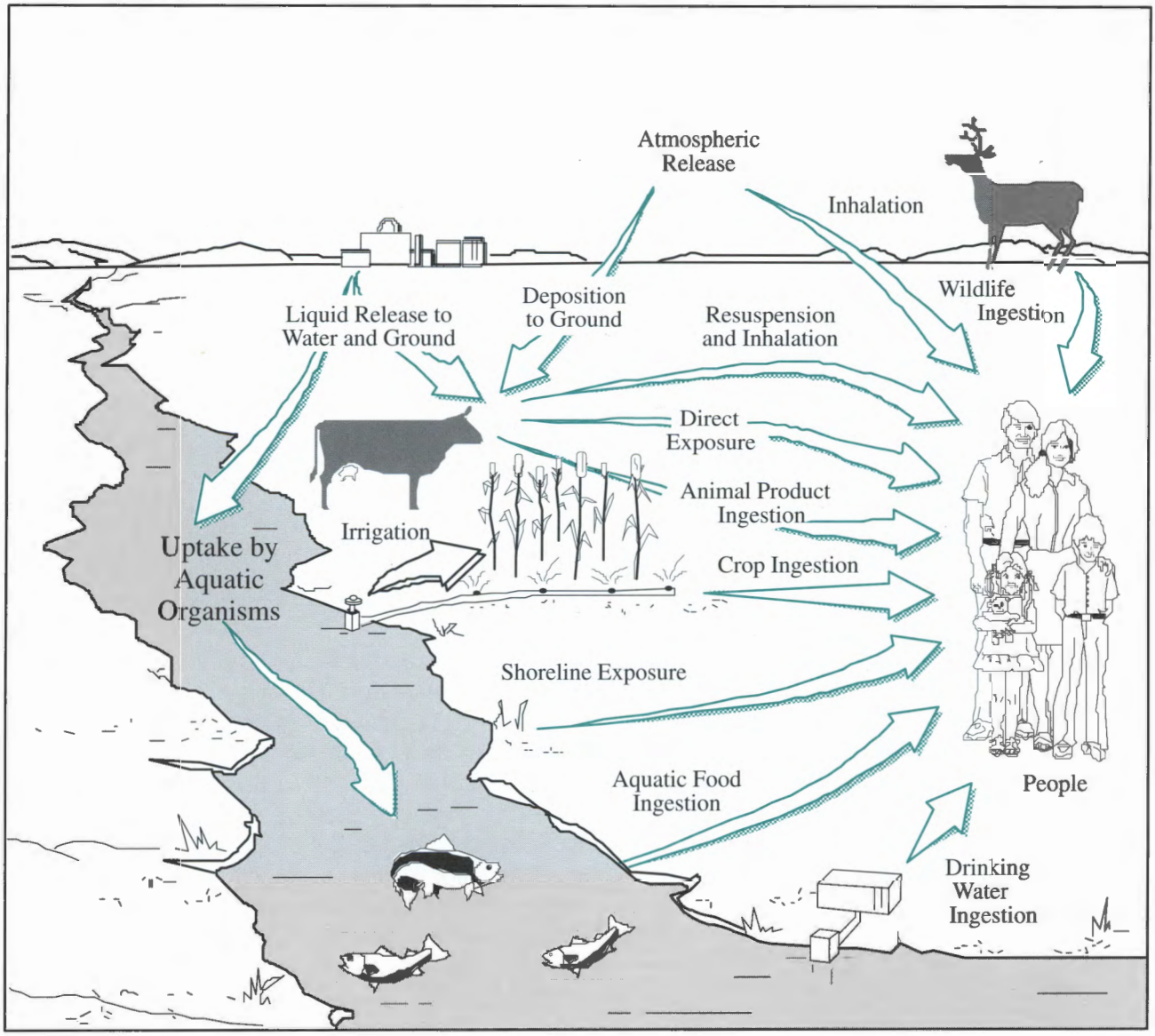

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Figure 5.1.1 Primary Exposure Pathways

established at levels well below the levels that correspond to the applicable health standards.

Environmental and food-chain pathways are monitored near the facilities releasing effluents and at potential offsite receptor locations. The surveillance design at Hanford uses a stratified sampling approach to monitor these pathways. Samples are collected and radiation or chemical concentrations are measured in three general surveillance zones that extend from onsite operational areas to the offsite environs.

The first zone extends from near the operational areas to the Site perimeter. The environmental concentrations of releases from facilities and fugitive sources (those released from other than monitored sources such as contaminated soils) will generally be the highest, and therefore most easily detected, in this zone. The second surveillance zone consists of a series of perimeter sampling stations positioned near or just inside the Site boundary. Exposures at these locations are typically the maximum that any member of the public could receive. The third surveillance zone consists of nearby and distant community locations within an 80-km (50-mi) radius of the Site. Surveillance is conducted in communities to provide measurements at locations where a large number of people may

potentially be exposed to Hanford releases and to provide assurance to the communities that contaminant levels are well below standards established to protect public health.

Background concentrations are measured at distant locations and compared with concentrations measured onsite and at perimeter and community locations. Background locations are locations that are essentially unaffected by Hanford operations, i.e., locations that can be used to measure ambient environmental levels of chemicals and radionuclides. Comparing background concentrations to concentrations measured on or near the Site provides an indication of the impact of Hanford operations.

To the extent possible, radiation dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations in environmental media. However, the amounts of most radioactive materials released from Hanford operations in recent years have generally been too small to be measured directly once dispersed in the offsite environment. For the measurable radionuclides, it is often not possible to distinguish levels resulting from worldwide fallout and natural sources from those associated from Hanford releases. Therefore, offsite doses in 1994 were estimated using the following methods:

- Doses from controlled effluents were estimated by applying environmental transport and dose calculation models to measured effluent monitoring data and selected environmental measurements.
- Doses from fugitive air emissions (for example, from contaminated soils) were estimated from measured airborne concentrations at Site perimeter locations.
- Doses from fugitive liquid releases (for example, ground water seeping into the Columbia River) were estimated based on differences in measured concentrations upstream and downstream from the Hanford Site.

Program Description

In the first surveillance zone, between the operational areas and the Site perimeter, air monitoring stations were located near operational areas (see Figure 5.2.1) because air transport is a potential key pathway for movement of radioactive materials off the Site. Surface-water ponds, potentially accessible to wildlife, and drinking water sources were also sampled (see Figure 5.3.1). Ground water was sampled from wells located near operating areas and along potential transport pathways (see Figures 5.8.8-5.8.10). In addition to air and water surveillance, samples of soil, native vegetation, and wildlife were collected (see Figures 5.5.1 and 5.6.1). Direct radiation dose rates were also measured (Figures 5.7.1-5.7.3).

In the second or perimeter zone, air monitoring stations, radiation measurement locations, and groundwater surveillance wells were located near or just inside the Site boundary. Agriculture is an important industry near the Site; therefore, milk, crops, soil, and native vegetation are monitored (see Figures 5.4.1 and 5.6.1) to detect any influence from Hanford on locally produced food and farm products. The Columbia River is included in the second zone. River water is monitored upstream from the Site at Priest Rapids Dam and downstream at Richland, Washington, where it is used for public drinking water. Water pumped from the Columbia River for irrigation is also monitored.

Surveillance in the third zone, consisting of nearby and distant communities, includes air, soil, water supplies, vegetation, and food products sampling, and direct radiation dose rate measurements. Table 5.1.2 summarizes the geographic distribution of measurement locations.

Table 5.1.2 Environmental Surveillance Sample Types and Measurement Locations, 1994

		Sample Locations							
							Columbia River		
	Total Number	Onsite[a]	Site Perimeter[b]	Nearby Locations[c]	Distant Locations[c]	COES Stations[c,d]	Upstream[c]	Hanford Reach[b]	Downstream[c]
Air	39	20	10	4	2	3			
Ground water[e]	528	528[f]							
Springs	7							7	
Columbia River	7						2	4	1
Irrigation water	1		1						
Drinking water	13	8[g]	5[h]						
Columbia River sediments	9						1	6	2
Ponds	3	3							
Foodstuffs	11		7	1	3				
Wildlife	14[i]	5			4			5	
Soil	20	15	4		1				
Vegetation	9	4	4		1				
TLDs[j]	69	26	33[k]	5	2	3			
Shoreline surveys	16		16						

(a) Surveillance Zone 1.
(b) Surveillance Zone 2.
(c) Surveillance Zone 3.
(d) COES = community-operated environmental surveillance.
(e) Approximately 806 wells were sampled for all ground-water monitoring programs onsite.
(f) Some onsite wells along the Columbia River are referred to as perimeter locations in the text.
(g) Data are reported by Hanford Environmental Health Foundation (e.g., HEHF 1994).
(h) Includes four offsite water supplies.
(i) Does not include roadkill deer.
(j) TLDs = thermoluminescent dosimeters.
(k) Includes locations along the Columbia River.

Surveillance is conducted using established quality assurance plans (see Section 7.0, "Quality Assurance") and written procedures (PNL 1992a, 1993). Sample scheduling, accountability, data storage, and data screening were managed and controlled by computerized systems. Laboratory analyses of samples for radioactivity and chemicals were conducted principally by International Technology Corporation and PNL, both in Richland, Washington. Selected river water quality and chemistry analyses, and temperature and flow measurements were performed by the U.S. Geological Survey, Denver, Colorado.

Ground-Water Surveillance

Ground-water surveillance at the Hanford Site is conducted to assess radiological and hazardous chemical impacts of Hanford activities on ground water, to provide an integrated assessment of

ground-water quality on the Hanford Site, and to evaluate potential offsite impacts. In addition to the sitewide monitoring activities performed for environmental surveillance, near-field ground-water monitoring evaluates the effects of operations in and around specific waste-disposal facilities for compliance with DOE Orders (Johnson 1993) and compliance with 40 CFR 265 and WAC 173-303 and -304 (DOE 1995a and c). The results from these operational and compliance monitoring programs contribute information useful in determining the total impact of Hanford Site operations on ground water and are used in meeting DOE's environmental surveillance responsibilities.

Objectives

Ground-water surveillance objectives include verifying compliance with applicable environmental laws and regulations; verifying compliance with environmental commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official DOE documents; characterizing and defining trends in the physical, chemical, and biological condition of environmental media; establishing environmental quality baselines; providing a continuing assessment of pollution abatement programs; and identifying and quantifying new or existing environmental quality problems.

Criteria

The Ground-water Surveillance Project is designed to monitor the effects of DOE activities at the Hanford Site on ground water to meet the ground-water monitoring program objectives stated in DOE Order 5400.1 and the specific project objectives stated above. The Ground-Water Surveillance Project, or predecessor projects, have monitored ground water at Hanford for more than 45 years. Hydrogeologic characterization and ground-water modeling are conducted to adequately design the monitoring network and to evaluate potential impacts of Hanford Site ground-water contamination on water users offsite and onsite.

Design

The selection of radionuclides and chemicals for analysis at particular wells is based on waste materials previously disposed of at Hanford (Stenner et al. 1988), ongoing waste disposal activities (Diediker and Rokkan 1993), and chemical contaminants observed in the past in neighboring wells (Dresel et al. 1994). The information contained in these documents is used to identify radionuclide and chemical sources and to develop a monitoring network that includes a study of chemicals and radionuclides important in terms of dose to humans and understanding of contaminant distributions and movement. Monitoring wells to be sampled and their sampling frequency are identified each year in the *Environmental Surveillance Master Sampling Schedule* (Bisping 1994). Ground-water surveillance is conducted using established quality assurance plans (see Section 7.0) and written procedures (PNL 1992). Computerized database management systems are used to schedule sampling activities; generate sample labels and chain-of-custody forms; track sample status; and load, store, report, and evaluate data.

Ground-water samples are collected from wells completed in the unconfined and upper-confined aquifers. The unconfined aquifer is monitored extensively because it has been contaminated from Hanford operations (Dresel et al. 1994) and provides a pathway for contaminants to reach points of human exposure (e.g., water supply wells, Columbia River). The upper-confined aquifer is monitored, although less extensively than the unconfined aquifer, because it also provides a potential pathway for contaminants to migrate off the Hanford Site. Wells are also used for detecting the presence of potential contaminants at the request of DOH.

Contaminant source areas are monitored to characterize and define trends in the chemical condition of the ground water and to identify and quantify existing, emerging or potential ground water quality problems. Source areas include regions with active waste disposal facilities or with facilities that have generated or received waste in the past. These include the 100, 200 and 300 Areas on the Site as well as the central landfill. Ground-water monitoring in these areas is performed primarily by the RCRA compliance or operational monitoring programs conducted by the Site operating contractor. Additional sampling is conducted by the Environmental Restoration Contractor-Team as part of CERCLA activities on the Hanford Site. The

Ground-Water Surveillance Project will supplement these monitoring activities if it is required to meet the needs of the DOE.

Wells located within known contaminant plumes continue to be monitored to characterize and define trends in the concentrations of the associated radiological or chemical constituents. These wells are also monitored to quantify existing ground water quality problems and to provide a baseline of environmental conditions against which future changes can be assessed.

Water supplies on and near the Site potentially provide the most direct route for human exposure to contaminants in ground water. Three water supplies exist onsite. One is for staff and visitors at the FFTF, one is at the Yakima Barricade guard house, and one is at the Hanford Patrol shooting range. Water supply wells for the City of Richland are adjacent to Hanford's southern boundary. Wells near these water systems are monitored to identify any potential water quality problems long before regulatory limits are reached.

Wells are monitored to assess the quality of ground water at the Site perimeter. Wells in a region about 2-km-wide along the boundary of the Site have been identified for monitoring. Data gathered from wells in this region help address a number of the objectives of the program including the identification and quantification of existing, emerging or potential ground water quality problems, and the assessment of the potential for contaminants to migrate off the Hanford Site through the ground-water pathway.

To determine the impact of Hanford operations on the environment, the background conditions, or the quality of water on the Hanford Site unaffected by operations, must be known. Data on the concentration of contaminants of concern in ground water before Hanford operations are not available; therefore, concentrations of naturally occurring chemical and radiological constituents in ground water sampled from wells located in areas unaffected by Hanford operations, including upgradient locations, provide the best estimate of pre-Hanford operations ground-water quality.

Samples are collected at various frequencies depending on the historical trends of constituent data, regulatory or compliance requirements, and characterization requirements. Sampling frequencies range from monthly to annually; some constituents are monitored less frequently than annually in some wells.

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5.2 Air Surveillance

G. W. Patton

Atmospheric releases of pollutants from Hanford to the surrounding region are a potential source of human exposure. For that reason, both radioactive and nonradioactive materials in air are monitored at a number of locations. The influence of Hanford emissions on local radionuclide concentrations was evaluated by comparing concentrations measured at distant locations within the region to concentrations measured at the Site perimeter. This section discusses sample collection, analytical methods, and the results of the Hanford air surveillance program. A complete listing of all analytical results summarized in this section is reported separately by Bisping (1995).

Sample Collection and Analysis

Radiological Air Sampling

Airborne radionuclides were sampled by a network of 39 continuously operating samplers: 20 on the Hanford Site, 10 near the Site perimeter, 4 in nearby communities, 2 in distant communities, and 3 community-operated environmental surveillance stations that were managed and operated by local school teachers (Figure 5.2.1 and Table 5.2.1). Air samplers on the Hanford Site were located primarily around major operational areas to maximize the ability to detect contaminants resulting from Site operations. Perimeter samplers were located around the Site, with emphasis on the prevailing downwind directions to the south and east of the Site. Continuous samplers located in Benton City, Richland, Kennewick, Mattawa, and Pasco provided concentrations at the nearest population centers. Samplers at the distant communities of Sunnyside and Yakima provided background data from communities essentially unaffected by Site operations.

Samples were collected according to a schedule established before the monitoring year (Bisping 1994). Air sampling locations are listed in Table 5.2.1, along with specific analyses for each location. Airborne particles were sampled at each of these locations by continuously drawing air through a high-efficiency glass-fiber filter. The filters were collected every 2 weeks, field surveyed with hand-held instruments for total radioactivity to detect for unusual occurrences, and stored for at least 7 days at the analytical laboratory. The storage period was necessary to allow for the decay of short-lived, naturally occurring radionuclides (e.g., radon gas decay products) that would otherwise obscure detection of longer-lived radionuclides potentially present from Hanford emissions. The filters were then analyzed for total beta radioactivity and most filters were also analyzed for total alpha radioactivity. Field measurements of radioactivity in samples are used to monitor changes in environmental conditions that could warrant attention before the more detailed and sensitive laboratory analyses are completed.

For most radionuclides, the amount of radioactive material collected on the filter during the 2-week period was too small to be readily measured. The sensitivity and accuracy of sample analysis was increased by combining biweekly samples for nearby locations (or in some cases a single location) into quarterly composite samples. The quarterly composite samples were analyzed for numerous specific gamma-emitting radionuclides (Appendix F). The quarterly composite samples were then combined to form annual composite samples (Table 5.2.1). Annual composites were analyzed for strontium and plutonium isotopes, and selected annual composites were also analyzed for uranium and americium isotopes.

Gaseous iodine-131 was sampled at four locations by drawing air through a cartridge containing chemically treated activated charcoal. These cartridges were exchanged biweekly and were located downstream of a particle filter. Iodine-131 has a short half-life (8 days) and is potentially present in the environment only around active nuclear reactors.

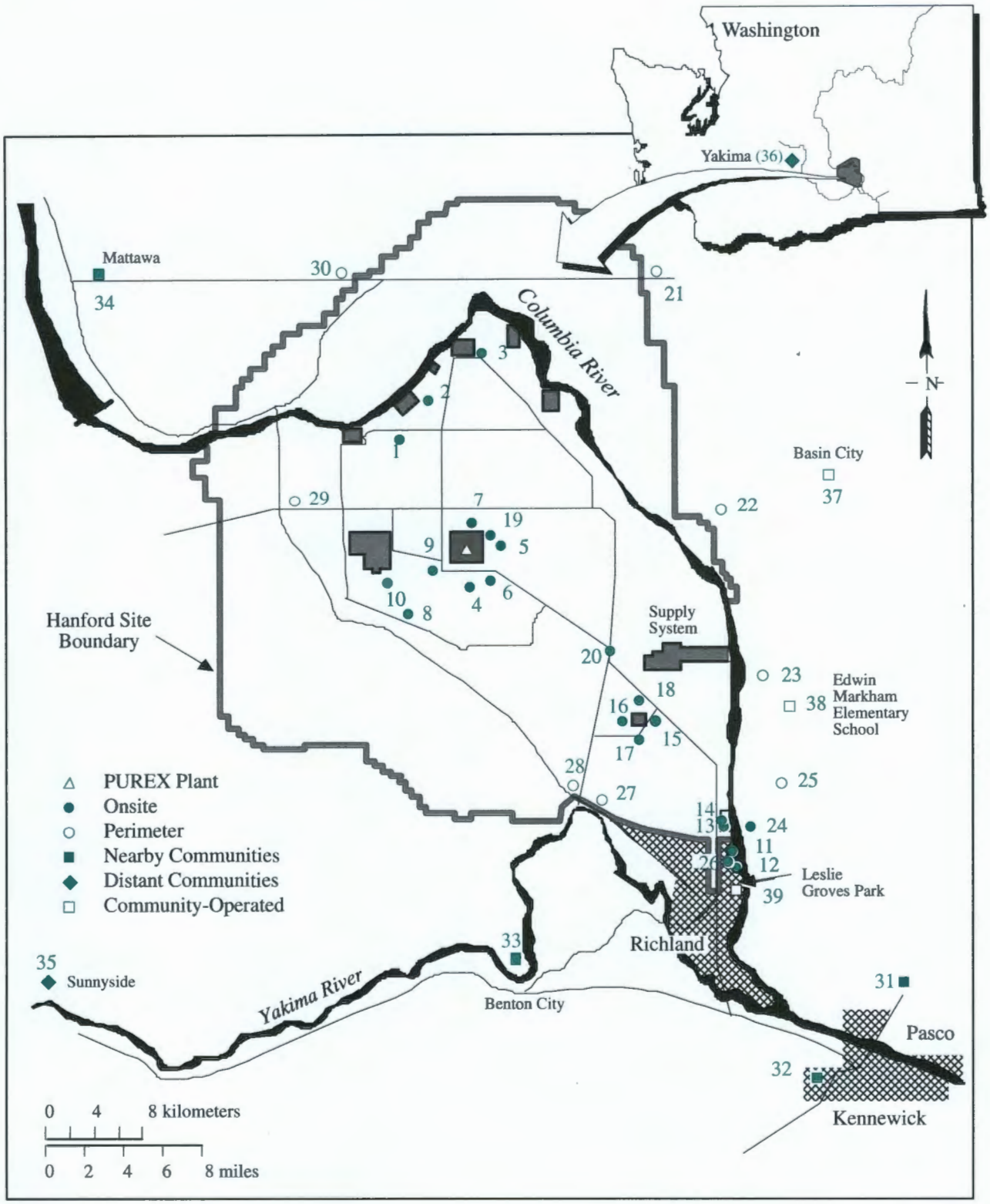

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Figure 5.2.1 Air Sampling Locations, 1994

Table 5.2.1 Air Sampling Locations, Sample Composite Groups, and Analyses, 1994

Location[a]	Sampling Location	Analyses[b]	Composite Group	Analyses[c]
Onsite				
1	100-K	Beta, alpha, ^{3}H	100 Areas	Gamma, Sr, Pu
2	100-N, 1325 Crib	Beta, alpha, ^{3}H		
3	100-D	Beta, alpha		
4	S of 200-East	Beta, alpha	200 East	Gamma, Sr, Pu, U, Am
5	E of 200-East	Beta, alpha		
6	200-East SE	Beta, alpha, ^{3}H, ^{129}I		
7	N of 200-East	NRA[d]		
8	Army Loop Camp	Beta, alpha	200-West, South, and East	Gamma, Sr, Pu, U
9	GTE Building	Beta, alpha, ^{3}H		
10	200-West SE	Beta, alpha, VOC[e]	200-West	Gamma, Sr, Pu, U
11	300 Water intake	Beta	300 Area	Gamma, Sr, Pu, U
12	300-South Gate	Beta, alpha, ^{3}H		
13	300 NE	Beta, alpha, ^{3}H, VOC	300 NE	Gamma, Sr, Pu, U
14	300 Trench	Beta, alpha, ^{3}H		
15	400-East	Beta, alpha, ^{3}H	400 Area	Gamma, Sr, Pu
16	400-West	Beta, alpha		
17	400-South	Beta, alpha		
18	400-North	Beta, alpha		
19	B Pond	Beta, alpha	B Pond	Gamma, Sr, Pu, U
20	Wye Barricade	Beta, alpha	Wye Barricade	Gamma, Sr, Pu, U, Am
Perimeter				
21	Berg Ranch	NRA		
22	Ringold Met. Tower	Beta, alpha, ^{3}H, ^{129}I, ^{131}I	Ringold Met. Tower	Gamma, Sr, Pu
23	W End of Fir Road	Beta, alpha	W End of Fir Road	Gamma, Sr, Pu, U, Am
24	Byers Landing	Beta, alpha, ^{3}H, ^{129}I, ^{131}I	Byers Landing	Gamma, Sr, Pu, U, Am
25	Dogwood Met. Tower	Beta, alpha, ^{3}H	Dogwood Met. Tower	Gamma, Sr, Pu, U, Am

Table 5.2.1 Air Sampling Locations, Sample Composite Groups, and Analyses, 1994 (contd)

Location[a]	Sampling Location	Analyses[b]	Composite Group	Analyses[c]
26	Battelle Complex	NRA		
27	Horn Rapids Road Substation	Beta, alpha	Prosser Barricade	Gamma, Sr, Pu, U
28	Prosser Barricade	Beta, alpha, ^{3}H		
29	Yakima Barricade	Beta, alpha, VOC[f]	Yakima Barricade	Gamma, Sr, Pu
30	Wahluke Slope	Beta, alpha, ^{3}H	Wahluke Slope	Gamma, Sr, Pu
Nearby Communities				
31	Pasco	Beta	Tri-Cities	Gamma, Sr, Pu
32	Kennewick	Beta, alpha		
33	Benton City	NRA		
34	Mattawa	NRA		
Distant Communities				
35	Sunnyside	Beta, alpha, ^{3}H	Sunnyside	Gamma, Sr, Pu, U
36	Yakima	Beta, alpha, ^{3}H, ^{129}I, ^{131}I	Yakima	Gamma, Sr, Pu, U, Am
Community-Operated Environmental Stations				
37	Basin City	Beta, alpha, ^{3}H	Basin City Elem. School	Gamma, Sr, Pu, U
38	North Franklin County	Beta, alpha, ^{3}H, ^{131}I	Edwin Markham Elem. School	Gamma, Sr, Pu, U, Am
39	Richland	Beta, alpha, ^{3}H	Leslie Groves Park	Gamma, Sr, Pu, U

(a) See Figure 5.2.1.
(b) Beta, alpha, and ^{131}I samples are collected biweekly (every 2 weeks), ^{3}H samples are collected monthly (every 4 weeks), and ^{129}I samples are collected monthly (every 4 weeks) and combined into a quarterly composite sample for each location (see Sample Collection and Analysis in this section).
(c) Gamma scans are performed on quarterly composite samples; Sr, Pu, U, and Am analyses are performed on annual composite samples (see Sample Collection and Analysis in this section).
(d) NRA = not routinely analyzed.
(e) VOC = Volatile organic compounds.
(f) The volatile organic compounds samples were collected at Rattlesnake Springs.

With the shutdown of all DOE nuclear reactors on the Hanford Site, there is no active DOE source of this radioisotope, any iodine-131 released to the environment from past operations would have decayed to undetectable amounts. Therefore, sampling for iodine-131 on the Hanford Site was discontinued in 1993. Iodine-131 was sampled at four locations offsite to maintain field sampling and analytical capability.

Iodine-129 (16,000,000-year half-life) was sampled using a similar technique as that used to collect iodine-131; however, a special low-background petroleum-charcoal cartridge was used for increased sensitivity. Samples were collected monthly at four locations and combined to form quarterly composite samples for each location.

Atmospheric water vapor was collected for tritium analysis at 18 locations by continuously passing air through cartridges containing silica gel, which were exchanged every 4 weeks. The collected water was distilled from the silica gel and analyzed for its tritium content.

A detailed description of all radiological sampling and analytical techniques is provided in the *Hanford Site Environmental Monitoring Plan* (DOE 1991b). Air samples were collected, but not routinely analyzed, at Benton City, the Battelle complex, Berg Ranch, Mattawa, and north of the 200-East Area. Samples from these locations were stored in an archive facility in the event that later analysis would be required in case of an unusual occurrence on the Site.

A portion of the environmental surveillance air samples was collected at three community-operated environmental surveillance stations located at Basin City Elementary School in Basin City, Edwin Markham Elementary School in North Franklin County, and Leslie Groves Park in Richland (see Figure 5.2.1 and Table 5.2.1). These samples were collected by local teachers using the same equipment, procedures, and analytical laboratory as the routine surveillance program. This work is part of an ongoing DOE-sponsored program to promote public awareness of Hanford environmental monitoring programs and the effects of Site operations.

Nonradiological Air Sampling

Samples for volatile organic compounds in air were collected downwind of the 300 Area Process Trenches (Table 5.2.1, location #13), at the southeast corner of the 200-West Area (Table 5.2.1, location #10), and at a background location near Rattlesnake Springs (Table 5.2.1, near location #29). Air samples for volatile organic compounds were collected using EPA Method TO-2 (EPA 1988), which uses low-volume air samplers with adsorbent (carbon molecular sieve) traps. Air samples were analyzed by the Hanford Environmental Health Foundation using thermal desorption techniques and gas chromatography-mass spectrometry.

Results

Radiological Results

Radiological air sampling results for onsite, Site perimeter, nearby communities, distant communities, and community-operated stations for total beta, total alpha, and specific radionuclides are summarized in Table 5.2.2. Numerous specific radionuclides (Appendix F) were identified in the quarterly composite gamma-scan analyses, but none of Hanford origin was detected consistently.

Total beta concentrations in air for 1994, as shown in Figure 5.2.2, peaked during the winter, repeating a pattern of natural annual radioactivity fluctuations (Eisenbud 1987). As shown in Table 5.2.2, the average total beta concentrations were about the same onsite as at the Site perimeter and in nearby and distant communities, indicating that the observed levels were predominantly a result of natural sources and worldwide radioactive fallout.

The concentrations of total alpha radioactivity in air for 1994 are given in Table 5.2.2. The average concentration of total alpha radioactivity at the Site perimeter and nearby communities in 1994 was elevated compared to the concentrations measured at the distant stations; however, the concentrations were not beyond the range of 1992 to 1993 measurements as shown in Figure 5.2.3.

The airborne concentration of tritium from 1989 to 1994 is given in Table 5.2.3. Table 5.2.3 provides a consistent treatment of the historical data because previous Hanford Site reports used differing methods to report suspect tritium results. As shown in Table 5.2.3, tritium concentrations measured in 1994 were similar to the values reported from 1989 and 1990 and did not show the highly elevated concentrations and widely variable results reported for 1991 and 1992 (Woodruff et al. 1993). The 1991 and 1992 results are highly suspect and are likely the results of cross-contamination because even the concentrations at the distant locations were high and variable. Tritium concentrations for two individual samples for 1994 were elevated (two of 231 samples were $\geq$ 100 pCi/m^3) and were also suspected as resulting from cross-contamination; however, no sampling

Table 5.2.2 Airborne Radionuclide Concentrations in the Hanford Environs, 1994 Compared to Values from the Previous 5 Years

Radionuclide	Location Group[a]	1994 No. of Samples	1994 Maximum[b]	1994 Average[c]	1989–1993 No. of Samples	1989–1993 Maximum[b]	1989–1993 Average[c]	1994 Concentration Guide[d]
			pCi/m^3	pCi/m^3		pCi/m^3	pCi/m^3	pCi/m^3
Total Beta	Onsite	469	0.047 ± 0.0063	0.017 ± 0.00072	2487	0.13 ± 0.012	0.020 ± 0.00052	
	Perimeter	180	0.041 ± 0.0046	0.016 ± 0.0011	1471	0.15 ± 0.014	0.019 ± 0.00065	
	Nearby Communities	52	0.050 ± 0.0052	0.018 ± 0.0026	767	0.10 ± 0.0098	0.019 ± 0.00091	
	Distant Communities	51	0.095 ± 0.0099	0.016 ± 0.0037	492	0.12 ± 0.013	0.017 ± 0.00099	
	COES Stations[e]	78	0.038 ± 0.0054	0.016 ± 0.0019	212	0.079 ± 0.0082	0.019 ± 0.0017	
			aCi/m^3	aCi/m^3		aCi/m^3	aCi/m^3	aCi/m^3
^{90}Sr	Onsite	9	14 ± 58	–14 ± 14	116	4200 ± 810	83 ± 98	9,000,000
	Perimeter	7	29 ± 78	–21 ± 24	73	2300 ± 430	130 ± 110	
	Nearby Communities	1	–32 ± 50	–32 ± 50	47	6300 ± 1200	210 ± 290	
	Distant Communities	2	68 ± 120	46 ± 44	44	52 ± 33	–6.5 ± 5.8	
	COES Stations	3	5.1 ± 54	–7.7 ± 17	15	64 ± 39	–1.3 ± 14	
^{106}Ru	Onsite	36	3200 ± 2400	–290 ± 520	284	14,000 ± 9500	–210 ± 500	30,000,000
	Perimeter	28	7400 ± 4500	–110 ± 890	208	17,000 ± 19,000	180 ± 580	
	Nearby Communities	4	980 ± 2600	–970 ± 2000	133	12,000 ± 11,000	–260 ± 940	
	Distant Communities	8	5000 ± 3500	280 ± 2100	121	20,000 ± 16,000	160 ± 970	
	COES Stations	12	5300 ± 4100	730 ± 1200	33	2400 ± 3400	–370 ± 500	

Table 5.2.2 Airborne Radionuclide Concentrations in the Hanford Environs, 1994 Compared to Values from the Previous 5 Years (contd)

Radionuclide	Location Group[a]	1994 No. of Samples	1994 Maximum[b]	1994 Average[c]	1989–1993 No. of Samples	1989–1993 Maximum[b]	1989–1993 Average[c]	1994 Concentration Guide[d]
			aCi/m^3	aCi/m^3		aCi/m^3	aCi/m^3	aCi/m^3
^{129}I	Onsite	4	43 ± 4.3	37 ± 9.3	20	110 ± 11	55 ± 12	70,000,000
	Perimeter	8	2.2 ± 0.18	1.2 ± 0.37	40	5.2 ± 0.39	1.7 ± 0.31	
	Distant Communities	4	0.085 ± 0.0065	0.065 ± 0.014	20	0.40 ± 0.046	0.13 ± 0.042	
^{131}I	Perimeter	51	5700 ± 4100	550 ± 540	406	13,000 ± 11,000	–260 ± 260	400,000,000
	Distant Communities	24	4500 ± 3300	160 ± 1200	187	7200 ± 8900	2.1 ± 270	
	COES Stations	25	6700 ± 5700	340 ± 1000	164	28,000 ± 19,000	430 ± 500	
^{137}Cs	Onsite	36	360 ± 300	51 ± 59	284	1200 ± 880	53 ± 47	400,000,000
	Perimeter	28	380 ± 250	30 ± 77	208	1400 ± 1100	–24 ± 64	
	Nearby Communities	4	340 ± 210	100 ± 190	133	1600 ± 1100	38 ± 91	
	Distant Communities	8	360 ± 400	80 ± 130	121	1300 ± 1200	40 ± 90	
	COES Stations	12	340 ± 260	–41 ± 150	33	390 ± 280	21 ± 48	
U Total[f]	Onsite	7	190 ± 280	66 ± 44	85	6200 ± 400	200 ± 160	100,000
	Perimeter	4	62 ± 13	51 ± 13	30	120 ± 20	68 ± 8.6	
	Distant Communities	2	52 ± 8.7	37 ± 31	29	250 ± 30	58 ± 17	
	COES Stations	3	73 ± 21	60 ± 16	15	87 ± 17	56 ± 9.1	

Table 5.2.2 Airborne Radionuclide Concentrations in the Hanford Environs, 1994 Compared to Values from the Previous 5 Years (contd)

		1994			1989–1993			1994
Radionuclide	Location Group[a]	No. of Samples	Maximum[b]	Average[c]	No. of Samples	Maximum[b]	Average[c]	Concentration Guide[d]
			aCi/m^3	aCi/m^3		aCi/m^3	aCi/m^3	aCi/m^3
^{238}Pu	Onsite	9	0.68 ± 2.2	–0.44 ± 0.43	116	2.7 ± 2.1	0.36 ± 0.13	30,000
	Perimeter	7	3.1 ± 4.1	–0.19 ± 1.2	72	3.0 ± 2.5	0.043 ± 0.15	
	Nearby Communities	1	–0.0076 ± 0.90	–0.0076 ± 0.90	47	0.84 ± 1.3	–0.069 ± 0.097	
	Distant Communities	2	0.86 ± 3.5	0.84 ± 0.039	44	5.3 ± 3.1	0.34 ± 0.33	
	COES Stations	3	0.76 ± 3.3	–0.32 ± 1.2	15	1.8 ± 1.6	0.29 ± 0.26	
$^{239/240}$Pu	Onsite	9	3.0 ± 3.1	1.2 ± 0.76	116	86 ± 14	2.5 ± 1.7	20,000
	Perimeter	7	1.1 ± 2.5	0.30 ± 0.38	72	2.5 ± 2.0	0.65 ± 0.18	
	Nearby Communities	1	0.24 ± 1.7	0.24 ± 1.7	47	2.2 ± 1.6	0.48 ± 0.20	
	Distant Communities	2	–0.14 ± 1.5	–0.22 ± 0.15	44	3.9 ± 1.3	0.41 ± 0.31	
	COES Stations	3	1.3 ± 3.1	–0.20 ± 1.5	15	3.3 ± 1.5	1.3 ± 0.48	
^{241}Am[g]	Onsite	2	0.50 ± 1.5	0.46 ± 0.077	2	0.90 ± 1.2	0.41 ± 0.98	20,000
	Perimeter	3	–0.078 ± 3.2	–0.64 ± 0.72	2	0.43 ± 1.2	0.28 ± 0.31	
	Distant Communities	1	–1.1 ± 3.4	–1.1 ± 3.4	1	–0.47 ± 1.1	–0.47 ± 1.1	
	COES Stations	1	–0.64 ± 3.4	–0.64 ± 3.4	1	–0.32 ± 0.76	–0.32 ± 0.76	

Table 5.2.2 Airborne Radionuclide Concentrations in the Hanford Environs, 1994 Compared to Values from the Previous 5 Years (contd)

Radionuclide	Location Group[a]	1994 No. of Samples	1994 Maximum[b]	1994 Average[c]	1989–1993 No. of Samples	1989–1993 Maximum[b]	1989–1993 Average[c]	1994 Concentration Guide[d]
			aCi/m^3	aCi/m^3		aCi/m^3	aCi/m^3	aCi/m^3
Total alpha[h]	Onsite	447	2000 ± 560	520 ± 25	930	8700 ± 1600	570 ± 39	
	Perimeter	181	2100 ± 570	530 ± 48	411	6800 ± 1400	600 ± 67	
	Nearby Communities	26	1100 ± 420	590 ± 100	55	1600 ± 540	680 ± 87	
	Distant Communities	49[i]	1100 ± 410	410 ± 60	103	8300 ± 1500	790 ± 240	
	COES Stations	78	1200 ± 460	490 ± 54	150	4800 ± 990	570 ± 82	

(a) Location groups are identified in Table 5.2.1.
(b) Maximum single sample result ±2 total propagated analytical uncertainty. Negative concentration values are explained in the section, "Helpful Information."
(c) Average of all samples ±2 times the standard error of the mean.
(d) From DOE Derived Concentration Guide (see Appendix C).
(e) COES = community–operated environmental surveillance (station).
(f) Summation of Uranium–234, –235, and –238.
(g) Americium–241 sampling was initiated in 1993.
(h) Total alpha values for 1991 and 1992 were not included in Table 5.2.3 because extended storage of these samples before analysis likely resulted in anomolously high concentrations through the ingrowth of alpha–emitting radon and thoron decay products (Sheets and Thompson 1992).
(i) Two results from the distant communities were excluded as anomolous values through the use of a Q–test (26,000 ± 3,400 aCi/m^3 at Yakima and 8,000 ± 1,000 aCi/m^3 at Sunnyside) (Skoog and West 1980).

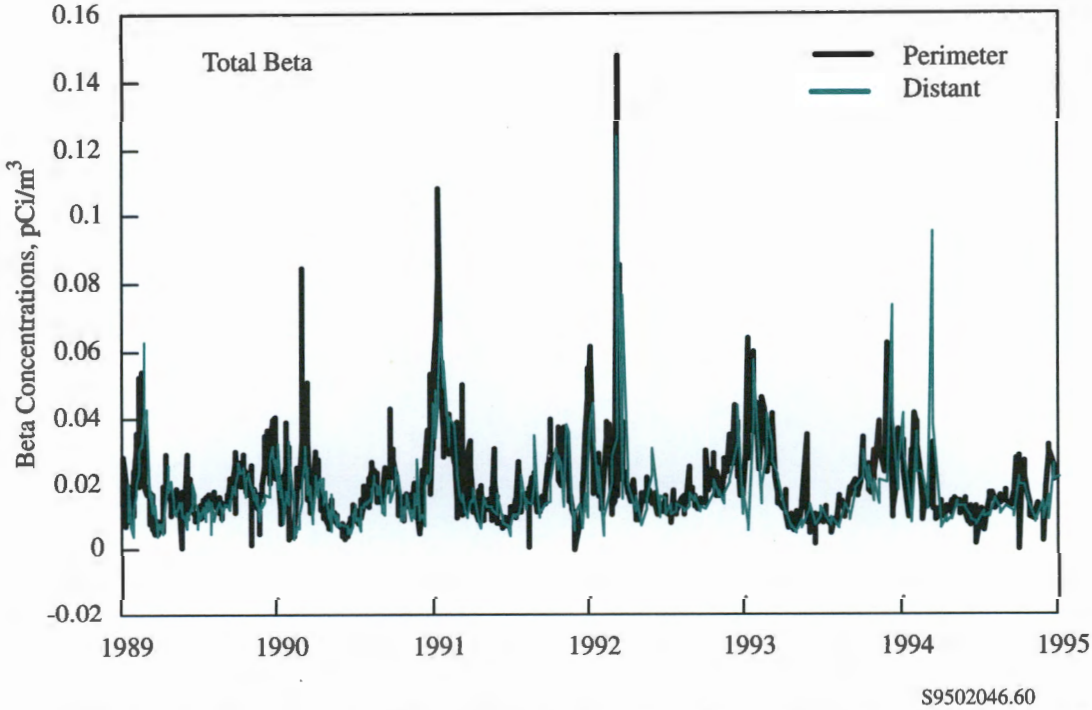

Figure 5.2.2 Total Beta Radioactivity in Airborne Particulate Samples, 1989 Through 1994

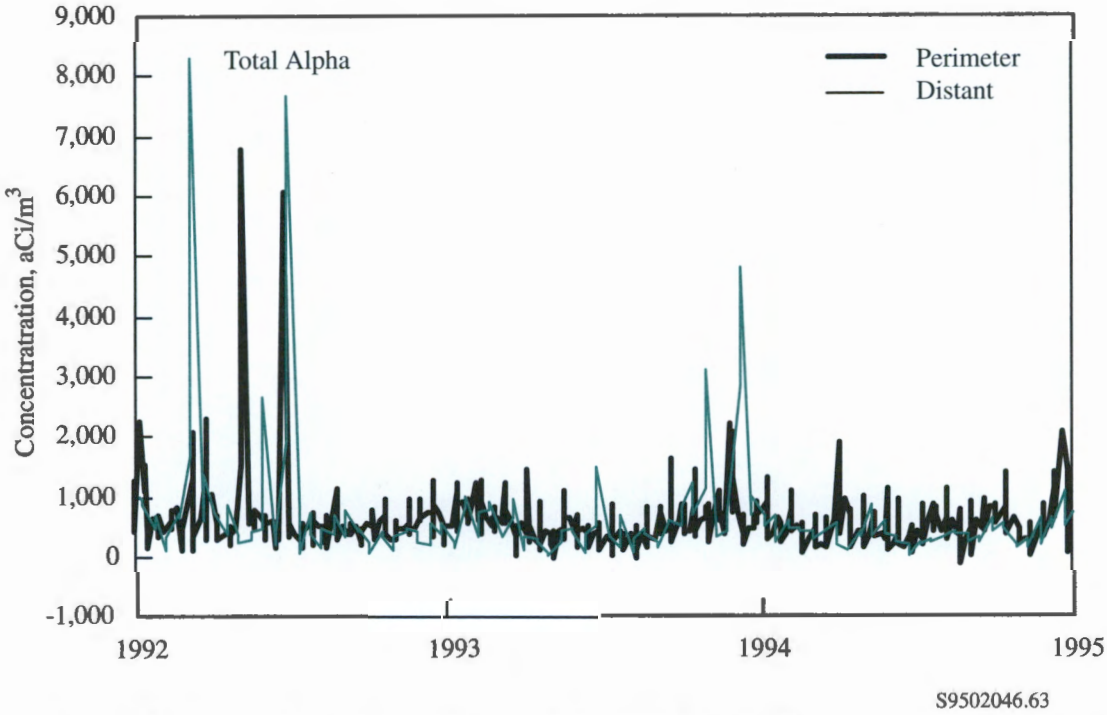

Figure 5.2.3 Total Alpha Radioactivity in Airborne Particulate Samples, 1992 Through 1994

station measured consistently elevated concentrations. Even the highest individual concentration reported for 1994 (530 ± 46 pCi/m^3 [300 NE location]) was only 0.5% of the 100,000 pCi/m^3 Derived Concentration Guide. For 1994, the annual average tritium concentration measured at the Site perimeter

Table 5.2.3 Airborne Concentrations[a] of Tritium in the Hanford Environs (pCi/m^3), 1989 to 1994

Location Group[b]	No. of Samples	Maximum[c]	Average (All Data)[d]	No. of Samples	Average Excluding Data ≥ 100 pCi/m^3[e]
1989					
Onsite	77	4.5 ± 1.3	1.4 ± 0.20	77	1.4 ± 0.20
Perimeter	100	2.9 ± 1.2	0.90 ± 0.16	100	0.90 ± 0.16
Distant Comm.	26	2.4 ± 1.3	0.81 ± 0.32	26	0.81 ± 0.32
1990					
Onsite	48	71 ± 2.3	3.1 ± 1.5	48	3.1 ± 1.5
Perimeter	96	12 ± 1.3	1.5 ± 0.21	96	1.5 ± 0.21
Distant Comm.	24	3.4 ± 1.4	1.3 ± 0.22	24	1.3 ± 0.22
1991[f]					
Onsite	91	2,900 ± 250	59 ± 71	85	2.8 ± 1.4
Perimeter	68	4,700 ± 400	140 ± 200	66	2.1 ± 1.1
Distant Comm.	29	350 ± 31	18 ± 25	27	2.2 ± 2.2
COES Stations	30	4,900 ± 420	210 ± 340	28	1.9 ± 0.86
1992[g]					
Onsite	90	770 ± 6.0	53 ± 30	78	5.0 ± 1.8
Perimeter	63	1,600 ± 9.4	82 ± 64	54	4.8 ± 2.2
Distant Comm.	26	380 ± 5.4	43 ± 43	23	5.0 ± 6.0
COES Stations	40	1,600 ± 8.4	120 ± 100	31	6.0 ± 5.6
1993[h]					
Onsite	91	600 ± 4.2	12 ± 14	89	3.4 ± 2.2
Perimeter	64	9.9 ± 1.2	0.90 ± 0.40	64	0.90 ± 0.40
Distant Comm.	26	3.8 ± 4.1	0.83 ± 0.52	26	0.83 ± 0.51
COES Stations	34	120 ± 3.6	4.5 ± 7.2	33	0.95 ± 0.40
1994[h]					
Onsite	101	530 ± 46	7.8 ± 11	99	1.3 ± 0.90
Perimeter	65	3.0 ± 2.8	0.59 ± 0.17	65	0.59 ± 0.18
Distant Comm.	26	2.2 ± 1.5	0.54 ± 0.29	26	0.54 ± 0.29
COES Stations	39	21 ± 2.2	1.2 ± 1.1	39	1.2 ± 1.1

(a) 1994 Derived Concentration Guide = 100,000 pCi/m^3.
(b) Onsite, Site perimeter, distant communities, and community–operated environmental surveillance stations are identified in Figure 5.2.1 and Table 5.2.1.
(c) Maximum single sample result ±2 total propagated analytical uncertainty.
(d) Average of samples ±2 times the standard error of the mean.
(e) Average was calculated by excluding results greater than 100 pCi/m^3 to produce a more representative mean that was not influenced by highly suspect results.
(f) 1991 results reported in this table include some values that were excluded from the 1991 Hanford Site Environmental Report because of suspected laboratory contamination. These results are still considered highly suspect but have been included to provide a consistent treatment of the monitoring data. The suspect results were presented in the 1991 data summary (Bisping and Woodruff 1992).
(g) These results contain values that are suspect and may be the result of laboratory contamination (Woodruff et al. 1993). The results differ from the 1992 Hanford Site Environmental Report (Woodruff et al. 1993) to provide a consistent treatment of the data for this table.
(h) These results contain some values that are suspect and may be the result of laboratory contamination.

(0.59 ± 0.17 pCi/m^3) was similar to the annual average value at the distant locations (0.54 ± 0.29 pCi/m^3). The annual average tritium concentration at the Site perimeter in 1994 was 0.0006% of the Derived Concentration Guide.

All strontium-90 results (Table 5.2.2) for air samples for 1994 were below a nominal detection limit of 98 aCi/m^3. The concentration at the detectable limit would only be 0.001% of the 9,000,000 aCi/m^3 Derived Concentration Guide.

Iodine-129 was sampled downwind of the PUREX Plant (200-East southeast location), at two downwind perimeter locations, and at a distant location (Yakima) in 1994 (Figure 5.2.4). Onsite concentrations in 1994 were elevated compared to those measured at the Site perimeter, and perimeter concentrations were higher than those measured at Yakima (Table 5.2.2). Iodine-129 concentration differences between these locations were statistically significant (two-tailed t-test, 5% significance level) and showed a measurable Hanford source. Onsite and Site perimeter air concentrations decreased in 1989 compared to previous years (Patton and Cooper 1993) in response to reduced PUREX Plant operations and have remained at their respective levels from 1990 to 1994 (Table 5.2.4). Onsite air concentrations of iodine-129 were influenced by minor emissions (0.014 Ci, Table 3.1.1) from the PUREX Plant and possible releases from the storage of dissolved fuel rod solutions in waste storage tanks and cribs. The annual average iodine-129 concentration at the downwind perimeter in 1994 (1.2 ± 0.37 aCi/m^3) was 0.000002% of the 70,000,000 aCi/m^3 Derived Concentration Guide.

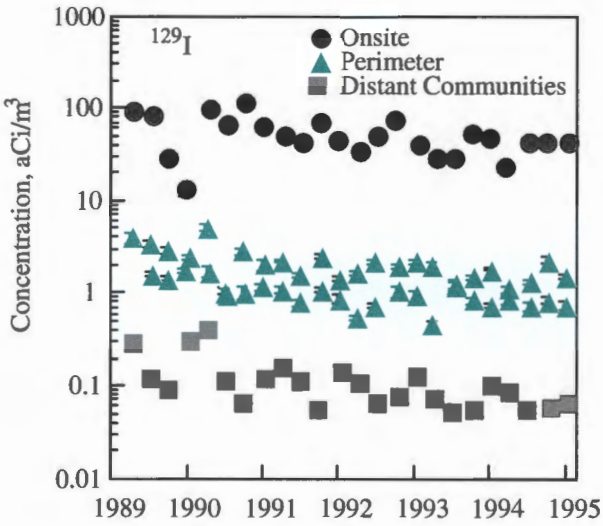

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Figure 5.2.4 Concentration ($\pm$ 2 standard error of the mean) of Iodine-129 in Air, 1989 Through 1994. As a result of figure scale, some uncertainties are concealed by point symbol.

Plutonium-238 was not detected in any air samples for 1994 with a detection limit of 3.5 aCi/m^3. This detection limit represents 0.01% of the 30,000 aCi/m^3 Derived Concentration Guide for plutonium-238. Plutonium-239,240 was not detected in any onsite or offsite samples for 1994 with a nominal detection limit of 3.3 aCi/m^3. This detection limit for plutonium-239,240 represents 0.02% of the 20,000 aCi/m^3 Derived Concentration Guide. Figure 5.2.5 shows the average plutonium-239,240 concentrations in air for 1989 to 1994.

Uranium concentrations (uranium-234, -235, and -238) in airborne particulate matter in 1994 were similar at the Site perimeter and at distant communities (Table 5.2.2 and Figure 5.2.6). The 1994 annual average concentration for the Site perimeter was 61 ± 13 aCi/m^3, which was 0.05% of the 100,000 aCi/m^3 Derived Concentration Guide.

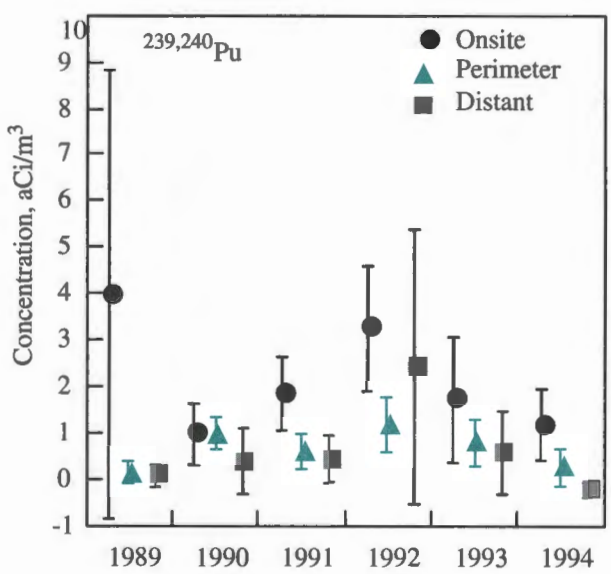

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Figure 5.2.5 Annual Average Concentrations ($\pm$ 2 standard error of the mean) of Plutonium-239, 240 in Air, 1989 Through 1994. As a result of figure scale, some uncertainties are concealed by point symbol.

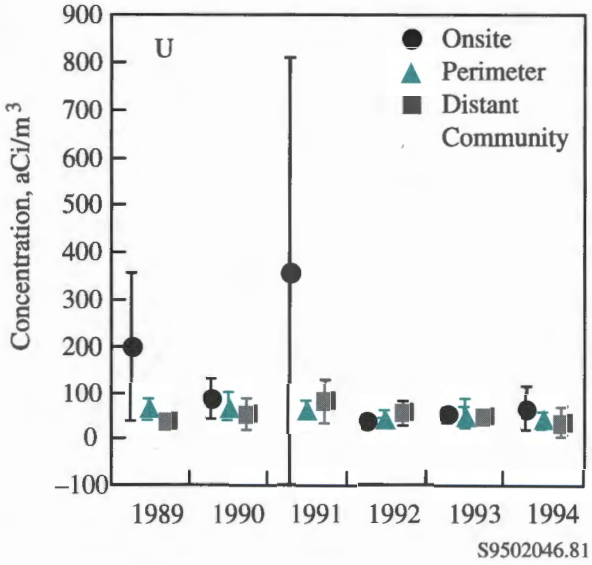

Figure 5.2.6 Annual Average Concentrations (± 2 standard error of the mean) of Uranium in Air, 1989 Through 1994. As a result of figure scale, some uncertainties are concealed by point symbol.

Seven annual air composite samples were analyzed for americium-241 in 1994 and all results (Table 5.2.2) were below a nominal detection limit of 3.2 aCi/m^3. This concentration represents 0.02% of the 20,000 aCi/m^3 Derived Concentration Guide. Americium-241 was added to the sampling schedule in 1993 to estimate the regional background air concentrations before large-scale remediation work at Hanford.

Cesium-137 and ruthenium-106 associated with airborne particulate matter, and iodine-131 collected on charcoal cartridges, were routinely monitored through gamma-scan analyses. Results were generally below detectable concentrations both on and off the Hanford Site (only 12 of 88 cesium-137 samples, 6 of 100 iodine-131 samples, and 7 of 88 ruthenium-106 samples) had concentrations above the detection limit). The results obtained for 1994 samples are included in Table 5.2.2. Even the maximum individual measurements for these radionuclides were less than 0.02% of their Derived Concentration Guide.

Nonradiological Results

Ten air samples were collected on the Hanford Site and analyzed for volatile organic compounds during 1994. The samples were analyzed for halogenated alkanes and alkenes, benzene, and alkylbenzenes. These compounds are widely used by modern society and are ubiquitous environmental contaminants. The results are given in Table 5.2.4, along with ambient air level goals (AALG) and occupational maximum allowable concentrations. All measured volatile organic compound concentrations were well below occupational maximum allowable

Table 5.2.4 Average Concentrations (ng/L ± 2 standard deviation) of Selected Volatile Organic Compounds in Air on the Hanford Site, 1994

Compound	No. of Samples	300 Area	No. of Samples	200–West Area	No. of Samples	Rattlesnake Springs	MAC[a]	AALG[b]
dichloromethane	2	0.065 ± 0.014	2	0.13 ± 0.0057	0	NA[c]	1,800	0.12
1,1,1, – trichloroethane	3	0.64 ± 0.27	4	0.64 ± 0.84	2	0.97 ± 0.34	1,900	36,400
benzene	4	0.55 ± 0.72	4	0.48 ± 0.95	2	0.45 ± 0.97	5	0.096
carbon tetrachloride	3	0.46 ± 0.37	4	0.60 ± 0.89	2	0.78 ± 0.045	12.6	0.053
toluene	4	0.79 ± 1.0	4	0.43 ± 0.88	2	0.64 ± 0.24	375	1,400
m,p–xylene	3	0.77 ± 0.69	4	0.14 ± 0.31	2	0.21 ± 0.065	435	57
o–xylene	3	0.29 ± 0.33	3	0.059 ± 0.088	2	0.088 ± 0.034	435	290

(a) MAC = maximum allowable concentrations; time–weighted average (8–h day, 40–h work week); from 29 CFR 1910, January 1989.
(b) AALG = ambient air level goal (Calabrese and Kenyon 1991).
(c) NA = not available.

concentration values. The AALG are nonregulatory, nonbinding values that were developed by Calabrese and Kenyon (1991) for use as health-based guidelines for risk assessments and are somewhat analogous to the EPA's maximum contaminant level goals for water. The AALG values are used as a comparative tool in this report because no regulatory standards for ambient air concentrations have been established for these compounds.

Compounds that routinely approached or exceeded the AALG values were dichloromethane (methylene chloride), tetrachloromethane (carbon tetrachloride), and benzene. The concentrations of these and other compounds at the 300 Area, 200-West Area, and Rattlesnake Spring locations are shown in Figure 5.2.7. Xylene concentrations at the 300 Area were slightly elevated relative to those at the background site at Rattlesnake Springs; however, the 300 Area concentrations are influenced by sources both on the Site and in the nearby communities. Benzene concentrations in air were similar for all locations. Carbon tetrachloride was used for past Site operations and is routinely detected in ground-water monitoring wells in the 200-West Area (see Section 5.8). However, there was little difference between average air concentrations of carbon tetrachloride measured onsite and at the background location. Dichloromethane concentrations in air were similar for both the 200-West and 300 Area locations. Overall air concentrations of volatile organic components for 1994 were within the range of values reported from previous studies (Patton et al.1994).

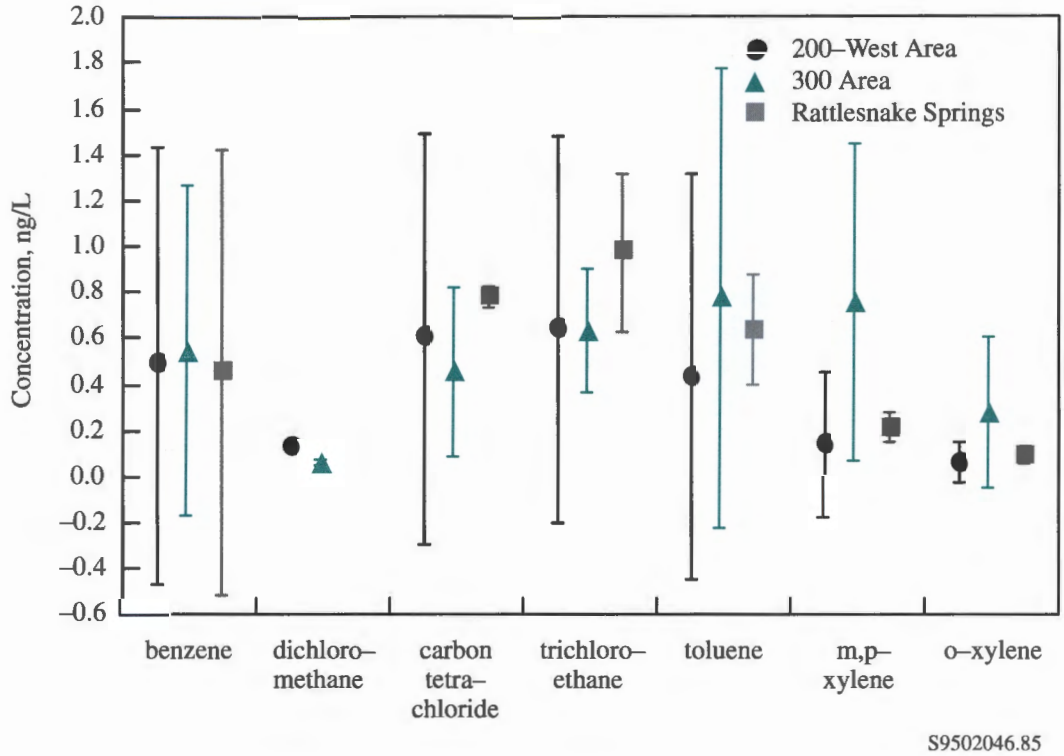

Figure 5.2.7 Annual Average Concentrations (± 2 standard error of the mean) of Volatile Organic Compounds in Air on the Hanford Site

5.3 Surface-Water Surveillance

K. A. Saldi, R. L. Dirkes, and M. L. Blanton

Surface water on and near the Hanford Site is monitored to determine the potential effects of Hanford operations. Surface water at Hanford includes the Columbia River, riverbank springs, ponds located on the Hanford Site, and offsite water systems directly east and across the Columbia River from the Hanford Site. Columbia River sediments are also included in this discussion. Tables 5.3.1 and 5.3.2 summarize the sampling locations, sample types, sampling frequencies, and sample analyses included in surface-water surveillance activities during 1994. Sample locations are also identified in Figure 5.3.1. This section describes the surveillance effort and summarizes the results for these aquatic environments. Detailed analytical results are reported by Bisping (1995).

Columbia River Water

The Columbia River, which flows through the northern portion and forms part of the eastern boundary of the Hanford Site, is the dominant surface-water body on the Site. The river is used as a source of drinking water for onsite facilities and by communities located downstream from the Hanford Site. In addition, the Hanford Reach of the Columbia River is used for a variety of recreational activities, including hunting, fishing, boating, water-skiing, and swimming. Water from the Columbia River downstream from the Site is also used extensively for crop irrigation.

Originating in the mountains of eastern British Columbia, Canada, the Columbia River drains a total area of approximately 70,800 km^2 (27,300 mi^2) en route to the Pacific Ocean. Flow of the Columbia River is regulated by 11 dams within the United States, seven upstream and four downstream from the Site. Priest Rapids is the nearest dam upstream, and McNary is the nearest dam downstream from the Site. The Hanford Reach of the Columbia River extends from Priest Rapids Dam to the head of Lake Wallula (created by McNary Dam), near Richland. This Reach is the last stretch of the Columbia River in the United States above Bonneville Dam that remains unimpounded. The width of the river varies from approximately 300 m (984 ft) to 1,000 m (3,281 ft) within the Hanford Site. The Hanford Reach is currently under consideration for designation as a National Wild and Scenic River as a result of congressional action in 1988.

Pollutants, both radiological and nonradiological, are known to enter the river along the Hanford Site. In addition to direct discharges of liquid effluents from Hanford facilities, contaminants in ground water from past discharges to the ground are known to seep into the river (Dirkes 1990, DOE 1992c, McCormack and Carlile 1984, Peterson 1992). Effluents from each direct discharge point are routinely monitored and reported by the responsible operating contractor; they are summarized in Section 3.1, "Facility Effluent Monitoring." Direct discharges are identified and regulated for nonradiological constituents under the National Pollutant Discharge Elimination System. The National Pollutant Discharge Elimination System-permitted discharges at Hanford and the regulated parameters are listed in Appendix C, Table C.7.

The state of Washington has classified the stretch of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, as Class A, Excellent (Ecology 1992). Water quality criteria and water use guidelines have been established in conjunction with this designation (Appendix C, Table C.1). The state of Washington and EPA Drinking Water Standards used in evaluating radionuclide concentrations in Columbia River water are provided in Appendix C, Table C.2.

Sample Collection and Analysis

Samples of Columbia River water were collected throughout 1994 by the Surface Environmental Surveillance Project at the locations shown in Figure 5.3.1. Samples were collected upstream from Hanford facilities at Priest Rapids Dam and near the Vernita Bridge to provide background data from locations unaffected by Site operations. Samples were collected from the Richland Pumphouse to identify any increase in contaminant concentrations

Table 5.3.1 Surface-Water Surveillance, 1994

Location	Sample Type	Frequency[a]	Analyses
Columbia River - Radiological			
Priest Rapids Dam and Richland	Cumulative	M Comp[b]	Alpha, beta, lo ^{3}H[c], gamma scan, ^{90}Sr, ^{99}Tc, U[d]
Priest Rapids Dam and Richland	Particulate (filter)	M Q Comp	Gamma scan Pu[e]
Priest Rapids Dam and Richland	Soluble (resin)	M Q Comp	Gamma scan 129I, Pu(e)
Vernita Bridge and Richland	Grab (transects)	Q	lo ^{3}H, ^{90}Sr, U[d]
100-F and 300 Area	Grab (transects)	A	lo ^{3}H, ^{90}Sr, U[d]
100-N	Grab (transects)	A	Alpha, beta, lo ^{3}H, ^{90}Sr, ^{99}Tc, U[d], gamma scan
Hanford Townsite	Grab (transects)	A	lo ^{3}H, ^{90}Sr, ^{99}Tc, U[d]
Columbia River - Nonradiological			
Vernita and Richland	Grab	Q[f]	WQ-NASQAN, temperature, dissolved oxygen, turbidity, pH, fecal coliforms, suspended solids, dissolved solids, conductivity, hardness as $CaCO_3$, P, Cr, N-Kjeldahl, dissolved oxygen content, Fe, NH_3
Vernita and Richland	Grab (transects)	Q	ICP[g] metals, anions, volatile organics
100-N, 100-F, Hanford Townsite, and 300 Area	Grab (transects)	A	ICP metals, anions, volatile organics
Onsite Ponds			
West Lake	Grab	Q	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U[d], gamma scan
B Pond	Grab	Q	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, gamma scan
FFTF Pond	Grab	Q	Alpha, beta, ^{3}H, gamma scan
Offsite Water			
Ringold Hatchery, Mathews Corner, White Bluffs shallow, White Bluffs deep, and Alexander Farm	Grab	A	Alpha, beta, ^{3}H, U[d], gamma scan
Riverview Canal	Grab	3[h]	Alpha, beta, ^{3}H, ^{90}Sr, U[d], gamma scan
Riverbank Springs			
100-B, 100-K, 100-N, 100-D, and 100-H	Grab	2[i]	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U[d], gamma scan, ICP metals, anions, volatile organics
Hanford Townsite, 300 Area	Grab	2[i]	Alpha, beta, ^{3}H, ^{129}I, ^{90}Sr, ^{99}Tc, U[d], gamma scan, ICP metals, anions, volatile organics

(a) A = annually; M = monthly; Q = quarterly; Comp = composite.
(b) M Comp is collected weekly and composited for monthly analysis.
(c) lo ^{3}H = low-level tritium analysis.
(d) Isotopic uranium.
(e) Isotopic plutonium.
(f) Numerous water quality analyses are performed by the U.S. Geological Survey (USGS) in conjunction with the National Stream Quality Accounting Network (NASQAN) Program. Thermograph stations are operated and maintained by the USGS.
(g) ICP = inductively coupled plasma analysis method.
(h) Three samples during irrigation season.
(i) Two samples during period of low river flow (August-September).

Table 5.3.2 Sediment Surveillance, 1994

Location[a]	Frequency	Analyses
River		
McNary Dam		
Oregon shore	A[b]	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
1/3 from Oregon shore	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
2/3 from Oregon shore	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
Washington shore	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
Priest Rapids Dam		
Grant County shore	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
1/3 from Grant County shore	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
2/3 from Grant County shore	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
Yakima County shore	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
White Bluffs Slough	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
100-F Slough	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
Hanford Slough	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
Richland	A	Gamma scan, ^{90}Sr, U[c], Pu[d], ICP[e] Metals
Springs		
100-N Spring 8-13	A	Gamma scan, ^{90}Sr, U[c], ICP Metals
Hanford Spring 28-2	A	Gamma scan, ^{90}Sr, U[c], ICP Metals
300 Area Spring 42-2	A	Gamma scan, ^{90}Sr, U[c], ICP Metals

(a) See Figure 5.8.
(b) A = annually
(c) Includes ^{235}U and ^{238}U analyzed by low-energy photon analysis.
(d) Isotopic plutonium.
(e) Inductively coupled plasma analysis method.

at this location attributable to Hanford operations. The Richland Pumphouse is the first downstream point of river water withdrawal for a public drinking water supply. The river sampling locations and the methods used for sample collection are discussed in detail in the *Hanford Site Environmental Monitoring Plan* (DOE 1994c). In addition to the routine single-point intake, fixed-location monitoring stations described in the environmental monitoring plan, routine sampling was performed along cross sections of the Columbia River at the Vernita Bridge, 100-N Area, 100-F Area, old Hanford Townsite, 300 Area, and the Richland Pumphouse. The transect sampling was initiated as a result of findings of a special study conducted during 1987 and 1988 (Dirkes 1993). This study concluded that under certain flow conditions contaminants entering the river from Hanford are not completely mixed at routine Surface Environmental Surveillance Project river monitoring stations. Incomplete mixing results in a slight conservative bias in the data generated using the routine single-point sampling systems at the 300 Area and the Richland Pumphouse. The cross sections at Vernita Bridge and the Richland Pumphouse were sampled quarterly during 1994. Annual transect sampling was conducted at the 100-N Area, 100-F Area, old Hanford Townsite, and 300 Area sampling locations.

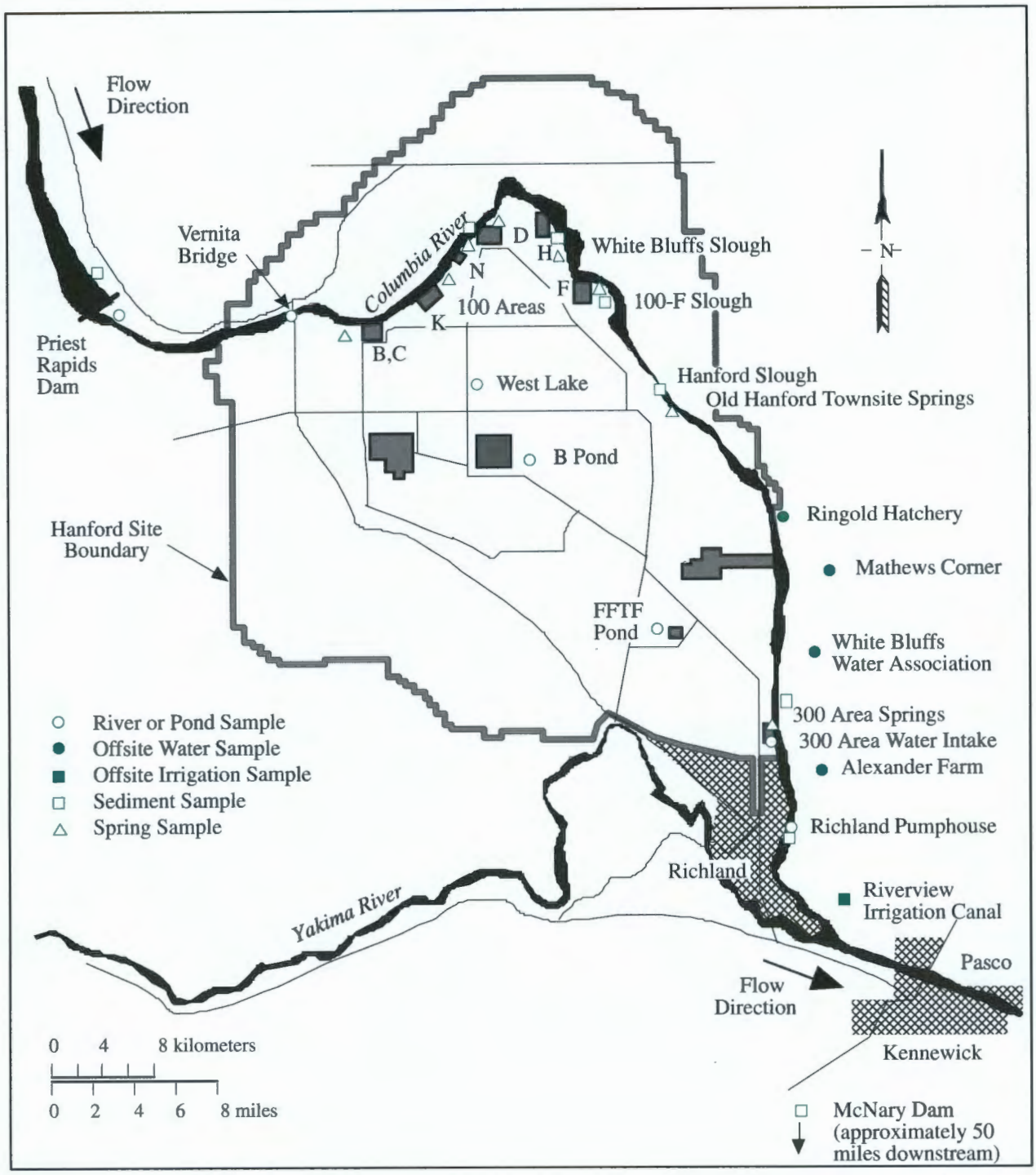

Figure 5.3.1 Water and Sediment Sampling Locations, 1994

Radiological analyses of water samples collected from the Priest Rapids Dam and Richland Pumphouse monitoring stations included gamma scan, iodine-129, plutonium-238, plutonium-239,240, strontium-90, technetium-99, total alpha, total beta, tritium, uranium-234, -235, and -238. Analyses of cumulative river samples (Table 5.3.1) were performed on unfiltered samples. Analyses of filters and resins were performed on particulate and soluble fractions of Columbia River water, respectively. Alpha and beta measurements provided a general indication of the radioactive contamination.

Gamma scans provided the ability to detect numerous specific radionuclides (Appendix F). Sensitive radiochemical analyses and, in some cases, special sampling techniques were used to determine the concentrations of iodine-129, plutonium-238, plutonium-239,240, strontium-90, technetium-99, tritium, uranium-234, -235, and -238 in river water during the year. Radionuclides of interest were selected based on their presence in effluent discharges or ground water near the river, and their importance in determining water quality, verifying effluent control and effluent monitoring systems, and determining compliance with applicable standards. Columbia River transect samples collected in 1994 were analyzed for both radiological and chemical contaminants (Table 5.3.1). Metals, anions, and volatile organics of interest, listed in DOE (1994c), were determined from reviews of existing surface- and ground-water data, various Remedial Investigation/ Feasibility Study work plans, and preliminary Hanford Site risk assessments (Dirkes et al. 1993, DOE 1992b, Evans et al. 1992). All radiological and chemical analyses of transect samples were performed on unfiltered samples.

In addition to Columbia River monitoring conducted by the Surface Environmental Surveillance Project, nonradiological water quality monitoring was also performed by the U.S. Geological Survey (USGS) at the Vernita Bridge and the Richland Pumphouse. During 1994, USGS samples were collected along cross sections every 2 months at the Vernita Bridge and quarterly at the Richland Pumphouse. Sample analyses were performed at the USGS laboratory in Denver, Colorado for numerous physical, biological, and chemical constituents. Results of USGS monitoring activities are documented in Bisping (1995).

Radiological Results for River Water

Results of the radiological analyses of Columbia River water samples collected by the Surface Environmental Surveillance Project at Priest Rapids Dam and the Richland Pumphouse during 1994 are reported by Bisping (1995) and summarized in Appendix A, Tables A.1 and A.2. Samples of Columbia River water were also collected by the Drinking Water Monitoring Program in 1994 at the 300 Area water intake. The 300 Area monitoring results are reported by the Hanford Environmental Health Foundation and are summarized in Appendix A, Table A.3. Tables A.1 through A.3 list the maximum and mean concentrations of select radionuclides observed in 1994 and during the previous 5 years. All radiological contaminant concentrations measured in the Columbia River in 1994 were less than DOE Derived Concentration Guides and state of Washington and EPA Drinking Water Standards (Appendix C, Tables C.6. and C.2., respectively). Significant results are discussed and illustrated below, and comparisons to previous years are provided.

Levels of radionuclides monitored in Columbia River water were extremely low throughout the year. Radionuclides consistently detected in river water collected from monitoring stations during 1994 at concentrations greater than their 2 sigma total propagated analytical uncertainty included iodine-129, plutonium-239,240, strontium-90, tritium, uranium-234, and -238. The concentrations of all other measured radionuclides were less than their respective 2 total propagated analytical uncertainties in over 75% of samples collected. Iodine-129, plutonium-239,240, strontium-90, and tritium exist in worldwide fallout, as well as in effluents from Hanford facilities. Tritium and uranium occur naturally in the environment in addition to being present in Hanford effluents.

Total alpha and total beta measurements are useful indicators of the general radiological quality of the river and provide an early indication of changes in the levels of radioactive contamination because results are obtained quickly. Figures 5.3.2 and 5.3.3 illustrate the average annual total alpha and total beta concentrations, respectively, at Priest Rapids Dam and the Richland Pumphouse during the past 6 years. The 1994 average total alpha and total beta concentrations were similar to those observed during recent years. Monthly total alpha concentrations measured at the Richland Pumphouse in 1994 were not significantly different (paired sample comparison and t-test of differences, 5% significance level) from those measured at Priest Rapids Dam. Monthly total beta concentrations, however, were significantly lower at the Richland Pumphouse. The 1994 total alpha and beta concentrations in Columbia River water at Priest Rapids Dam and the Richland Pumphouse were less than 10% of the

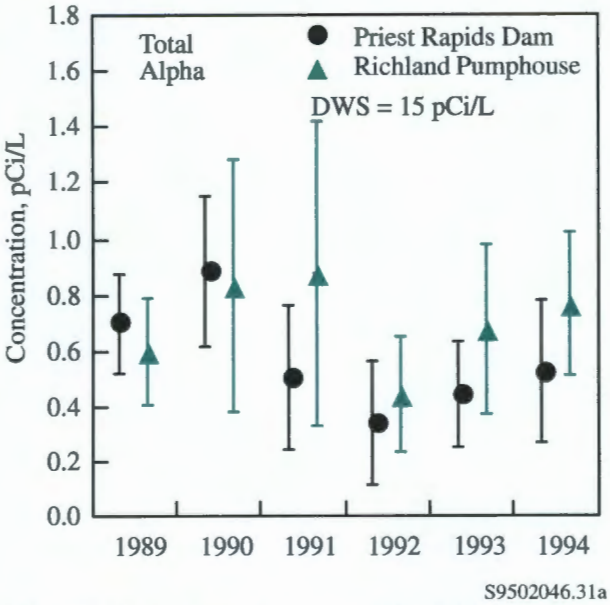

Figure 5.3.2 Annual Average Total Alpha Concentrations (± 2 standard error of the mean) in Columbia River Water, 1989 Through 1994

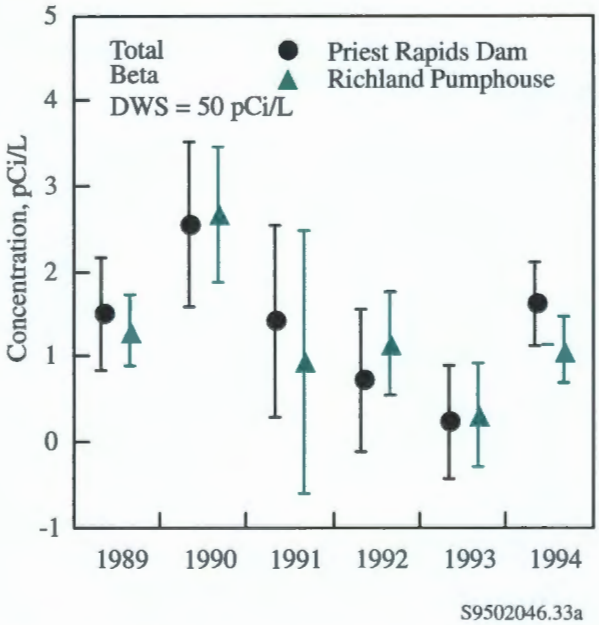

Figure 5.3.3 Annual Average Total Beta Concentrations (± 2 standard error of the mean) in Columbia River Water, 1989 Through 1994

applicable Drinking Water Standards of 15 and 50 pCi/L, respectively.

Figure 5.3.4 compares the average annual tritium concentrations at Priest Rapids Dam and the Richland Pumphouse from 1989 through 1994. The

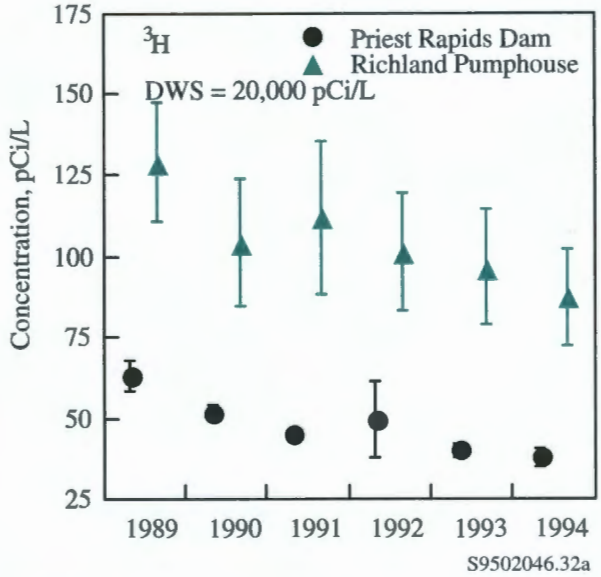

Figure 5.3.4 Annual Average Tritium Concentrations (± 2 standard error of the mean) in Columbia River Water, 1989 Through 1994. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

general decline in tritium concentrations in river water noted during the late 1980s remains evident at both locations. Statistical analysis (paired sample comparison, t-test of differences, 5% significance level) indicated that monthly tritium concentrations in river water at the Richland Pumphouse were significantly higher than those at Priest Rapids Dam. Onsite sources of tritium entering the river include ground-water seepage and direct discharge from outfalls located in the 100 Area (see Section 3.1, "Facility Effluent Monitoring," and Section 5.8, "Ground-Water Protection and Monitoring Program"). Tritium concentrations measured at the Richland Pumphouse, while representative of the Columbia River source of City of Richland drinking water, tend to overestimate the average concentrations of tritium in the river at this location (Dirkes 1993). This bias is attributable to the contaminated 200 Area ground-water plume entering the river along the portion of shoreline extending from the old Hanford Townsite to below the 300 Area, which is relatively close to the Richland sample intake. This plume is not completely mixed within the river at the Richland Pumphouse. Sampling along a cross section at the Richland Pumphouse during 1994 confirmed the existence of a concentration

gradient in the river under certain flow conditions and is discussed in subsequent sections of this report. The extent to which samples taken from the Richland Pumphouse overestimate the average tritium concentrations in the Columbia River at this location is highly variable and appears to be related to the flow rate of the river just before and during sample collection. All tritium concentrations were less than 1% of the state of Washington and EPA Drinking Water Standard of 20,000 pCi/L.

The annual average strontium-90 concentrations at Priest Rapids Dam and the Richland Pumphouse during 1994 was 0.09 ± 0.01 pCi/L at both locations. Figure 5.3.5 shows the average annual strontium-90 concentrations at these locations from 1989 through 1994. Concentrations observed in 1994 were similar to those seen in recent years. The differences between monthly strontium-90 concentrations at Priest Rapids Dam and the Richland Pumphouse observed in 1994 were not significant (paired sample comparison, t-test of differences, 5% significance level). The primary source of strontium-90 entering the Columbia River and attributable to Hanford has been the 100-N Area liquid waste disposal facilities, which are known to discharge to the river via ground water. Average strontium-90 concentrations in Columbia River water collected from Priest Rapids Dam and the Richland Pumphouse during 1994 remained less than 2% of the State of Washington and EPA Drinking Water Standard of 8 pCi/L.

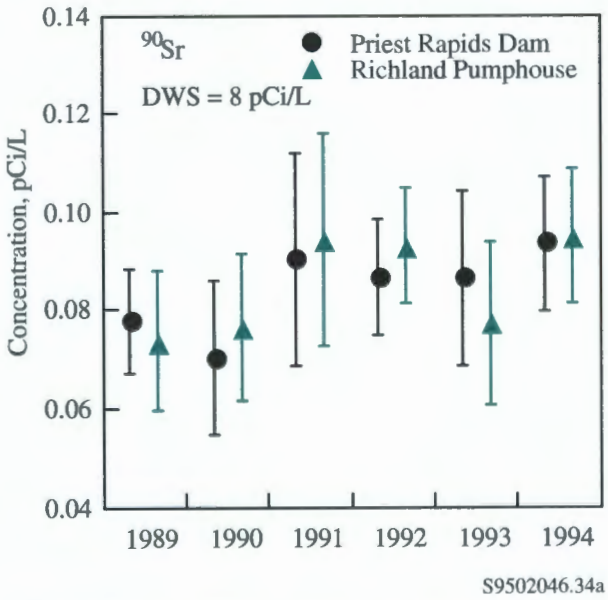

Figure 5.3.5 Annual Average Strontium-90 Concentrations (± 2 standard error of the mean) in Columbia River Water, 1989 Through 1994

Average annual total uranium concentrations (i.e., the sum of uranium-234, -235, and -238 concentrations) at the Richland Pumphouse and Priest Rapids Dam for 1989 through 1994 are shown in Figure 5.3.6. Total uranium concentrations observed in 1994 were similar to those observed during recent years. The larger 2 standard error of the mean associated with 1994 results was attributed to an unusually low concentration found in the December sample of each location. Although there is no direct discharge of uranium to the river, uranium is present in the ground water beneath the 300 Area as a result of past Hanford operations (see Section 5.8, "Ground-Water Protection and Monitoring Program") and has been detected at elevated levels in riverbank springs in this area (see Riverbank Springs subsection). Naturally occurring uranium is also known to enter the river across from Hanford via seepage from extensive irrigation east of the river and via irrigation canal outfalls (Dirkes 1990). Though monthly total uranium concentrations measured at the Richland Pumphouse in 1994 were slightly higher than those measured at Priest Rapids

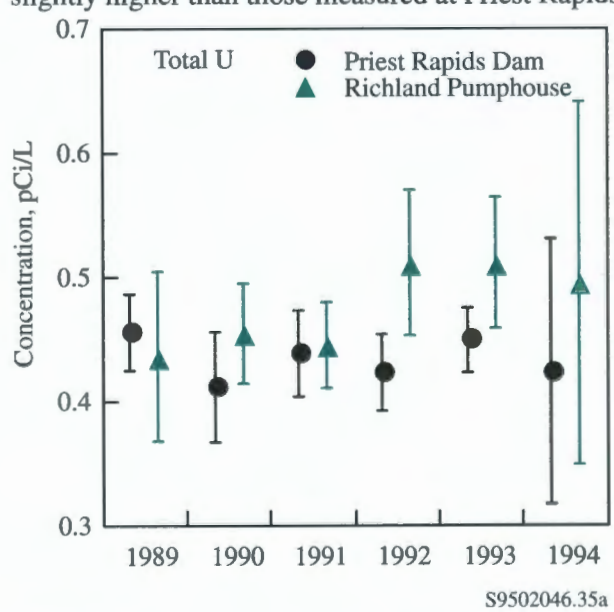

Figure 5.3.6 Annual Average Uranium (Uranium-234 + Uranium-235 + Uranium-238) Concentrations (± 2 standard error of the mean) in Columbia River Water, 1989 Through 1994

Dam, the differences were not statistically significant (paired sample comparison, t-test of differences, 5% significance level). There is currently no Drinking Water Standard directly applicable to uranium. However, total uranium concentrations in the river during 1994 were well below the proposed EPA Drinking Water Standard of 20 µg/L (30 pCi/L).

Figure 5.3.7 presents the average annual iodine-129 concentrations (aCi/L units) for Priest Rapids Dam and the Richland Pumphouse for 1989 through 1994. The average concentration of iodine-129 in Columbia River water was extremely low during 1994 (less than one-tenth of 1% of the Drinking Water Standard of 1 pCi/L [1,000,000 aCi/L]) and similar to levels observed during recent years. The onsite source of iodine-129 to the Columbia River in 1994 was the discharge of contaminated ground water along the portion of shoreline extending from the old Hanford Townsite to below the 300 Area. The iodine-129 plume originated in the 200 Area from past waste disposal practices. Unlike past findings, average concentrations of iodine-129 measured at the Priest Rapids Dam (43.1 ± 59.0 aCi/L) and the Richland Pumphouse 76.5 ± 26.6 aCi/L) in 1994 were not statistically significant (paired sample comparison and t-test of differences, 5% significance level). The lack of significance is attributable to third quarter results for which the iodine-129 concentration was higher at Priest Rapids Dam than at the Richland Pumphouse. The unusually high concentration observed at Priest Rapids Dam is reflected in the 2 standard error of the mean (Figure 5.3.7).

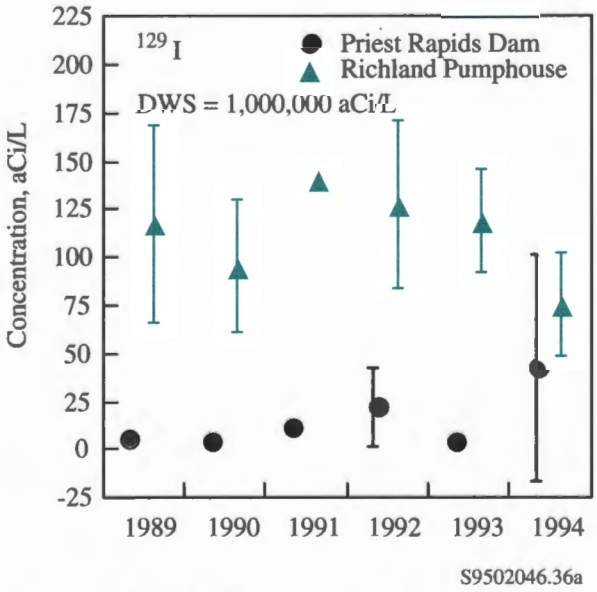

Figure 5.3.7 Annual Average Iodine-129 Concentrations (± 2 standard error of the mean) in Columbia River Water, 1989 Through 1994. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

During 1994, average plutonium-239,240 concentrations at Priest Rapids Dam and the Richland Pumphouse were 4.47 ± 120 aCi/L and 74.7 ± 40.4 aCi/L, respectively. No Washington State or EPA Drinking Water Standard currently exists for plutonium-239 or plutonium-240; however, if the Derived Concentration Guides (Appendix C, Table C.6.), which are based on a 100-mrem dose standard, are converted to a 4-mrem dose equivalent used to develop the Drinking Water Standards, 1.2 pCi/L (1,200,000 aCi/L) would be the relevant guideline for both plutonium-239 and plutonium-240. Concentrations of plutonium-239,240 at Priest Rapids Dam were not statistically different from those observed at the Richland Pumphouse during 1994 (paired sample comparison, t-test of differences, 5% significance level).

Radiological results of samples collected along cross sections of the Columbia River established at the Vernita Bridge, 100-N Area, 100-F Area, old Hanford Townsite, 300 Area, and the Richland Pumphouse during 1994 are presented in Appendix A, Table A.4 and in Bisping (1995). Constituents that were consistently detected (in greater than 50% of river transect samples) at concentrations greater than their associated 2 total propagated analytical uncertainty included strontium-90, tritium, uranium-234, and -238. All measured radionuclide concentrations were less than applicable Washington State and federal Drinking Water Standards.

Mean strontium-90 and tritium concentrations measured along cross sections of the Columbia River during 1994 are depicted in Figures 5.3.8 and 5.3.9, respectively. The reported result is plotted for those transects that were sampled only once in 1994. The transects are displayed such that the observer's view is downstream. Vernita Bridge is the most upstream transect. Stations 1 and 10 are located along the

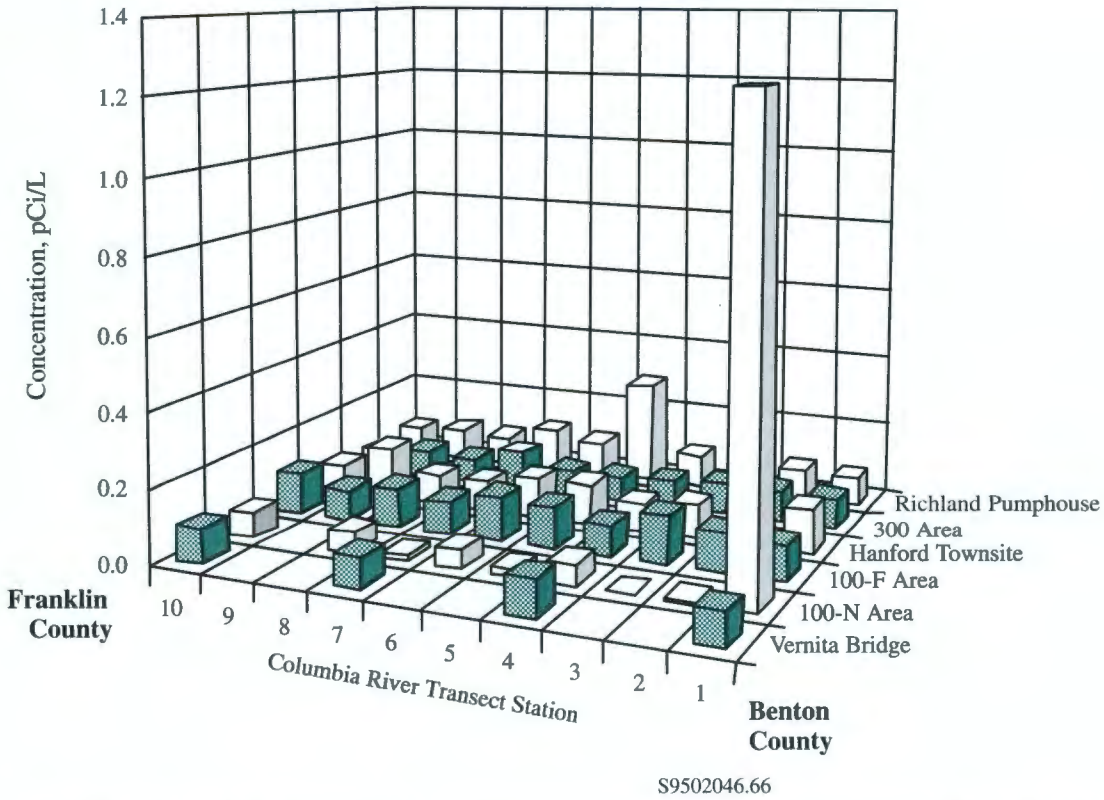

Figure 5.3.8 Mean Strontium-90 Concentrations in Columbia River Transects During 1994

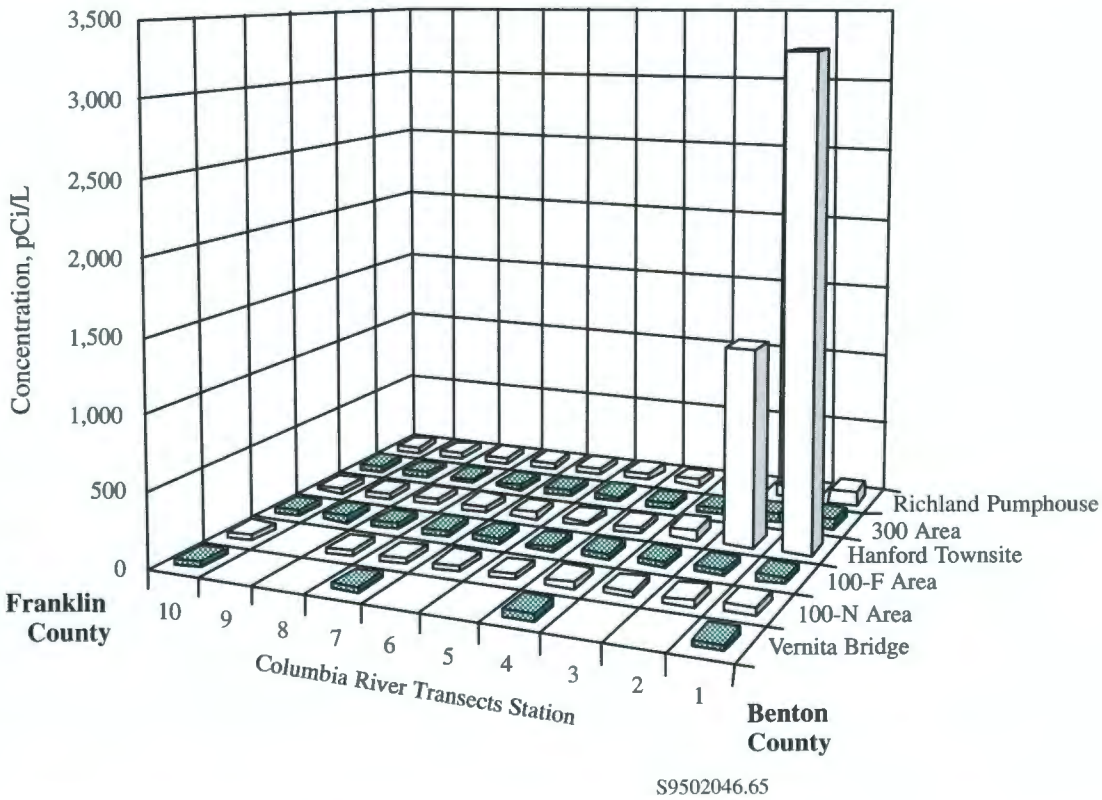

Figure 5.3.9 Mean Tritium Concentrations in Columbia River Transects During 1994

Benton County and Franklin County shorelines, respectively.

Strontium-90 levels in 1994 transect samples (Figure 5.3.8) were elevated along the 100-N Area shoreline. This observation concurred with recent Hanford ground-water reports (Dresel et al. 1994) indicating that the highest shoreline concentrations of strontium-90 existed in the 100-N Area. With the exception of the 100-N Area transect, strontium-90 concentrations were fairly uniform across the width of the river. The mean concentration of strontium-90 found during cross-sectional sampling at the Richland Pumphouse was similar to that obtained from the routine single-intake automatic composite sampler used at that location.

The highest tritium concentrations observed in 1994 river transect water (Figure 5.3.9) were detected along the shoreline of the old Hanford Townsite where ground water containing tritium concentrations in excess of the Drinking Water Standard of 20,000 pCi/L is known to discharge to the river (Dresel et al. 1994). Elevated levels of tritium were also evident near the Hanford shoreline at the 100-N Area, 300 Area, and Richland Pumphouse transect locations. The presence of a tritium concentration gradient in the Columbia River at the Richland Pumphouse supports previous conclusions made by Backman (1962) and Dirkes (1993) that contaminants in the 200 Area ground-water plume entering the river at and upstream of the 300 Area are not completely mixed at the Richland Pumphouse. The mean concentration of tritium measured along the cross section established at the Richland Pumphouse was less than that measured using the single-intake sampler located near the western shoreline of the river.

Total uranium concentrations in 1994 were elevated along both the Benton and Franklin County shorelines of the 300 Area and Richland Pumphouse transects. The highest total uranium concentration was measured near the Franklin County shoreline of the 300 Area transect and likely resulted from irrigation returns. The mean concentration of total uranium across the Richland Pumphouse transect was similar to that obtained from the routine single-intake automatic composite sampler used at that location.

Nonradiological Results for River Water

Nonradiological water quality data were compiled by the Surface Environmental Surveillance Project and the USGS during 1994. A number of the parameters measured have no regulatory limits; however, they are useful as indicators of water quality and/or Hanford-origin contaminants. Potential sources of pollutants not associated with Hanford include irrigation return water and ground-water seepage associated with extensive irrigation north and east of the Columbia River.

Figure 5.3.10 shows the Vernita Bridge and the Richland Pumphouse USGS results for 1989 through 1994 for several water quality parameters with respect to the applicable standards. In accordance with Washington State Water Quality Standards (Appendix C, Table C.1.), fecal coliform results are presented as annual geometric means (i.e., the antilogarithm of the arithmetic mean of the logarithms of the individual sample values). Turbidity and dissolved oxygen results are presented as annual arithmetic means. The complete list of results obtained through the USGS national water quality network are summarized in Appendix A, Table A.5. The 1994 USGS results were comparable to those reported during the previous 5 years. Applicable standards for a Class A-designated surface-water body were met. During 1994, there was no indication of any deterioration of water quality resulting from Hanford operations along the Hanford Reach of the Columbia River.

Results of nonradiological sampling conducted by the Surface Environmental Surveillance Project along cross sections of the Columbia River at the Vernita Bridge, 100-N Area, 100-F Area, old Hanford Townsite, 300 Area, and the Richland Pumphouse are provided by Bisping (1995). The concentrations of volatile organics, metals, and anions observed in river water in 1994 were similar to those observed in the past (Dirkes et al. 1993). Volatile organic compounds were not routinely detected; those that were detected in 1994 included acetone (in one of a total of 94 samples collected) and methylene chloride. Average annual concentrations of both compounds were higher at the Vernita Bridge than at the Richland Pumphouse. Neither compound displayed elevated concentrations along the Hanford shoreline of the Columbia River.

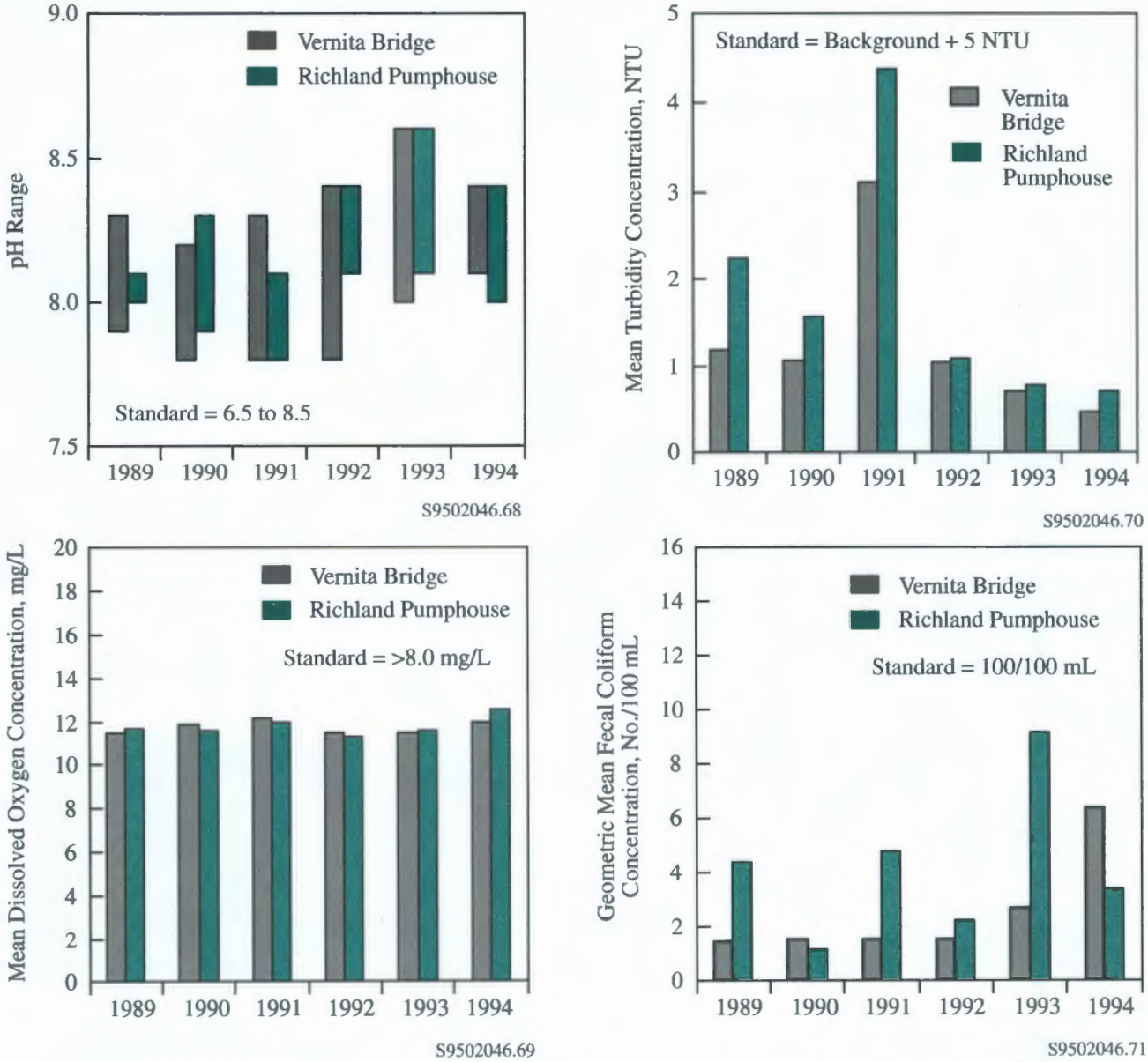

Figure 5.3.10 USGS Columbia River Water Quality Measurements, 1989 Through 1994

Several metals and anions were detected both upstream and downstream of the Hanford Site at levels comparable to those reported by the USGS as part of their ongoing national water quality monitoring network. With the exception of magnesium and manganese, whose average quarterly concentrations were highest at the Richland Pumphouse, no consistent differences were found between average quarterly contaminant concentrations in the Vernita Bridge and Richland Pumphouse samples. All metal and anion concentrations in river water were less than primary Washington State and federal Drinking Water Standards (Appendix C, Table C.3).

However, aluminum and iron concentrations in Columbia River water collected along the Hanford shoreline at the 300 Area exceeded their respective secondary Drinking Water Standards. Secondary Drinking Water Standards are based on factors other than health effects. Elevated concentrations of aluminum and iron were also observed in Columbia River springs in the 300 Area during 1994 (see Riverbank Springs subsection). Other contaminants with elevated concentrations measured near the Hanford shoreline included manganese in the 300 Area transect and nitrate in the old Hanford Townsite transect. The highest nitrate concentrations,

however, were measured on the Franklin County shoreline and likely resulted from irrigation returns.

The annual average flow rate of the Columbia River at Priest Rapids Dam was 2,673 m^3/s (94,400 cfs) during 1994, similar to that reported in recent years. The monthly average flow rates at Priest Rapids Dam are shown in Figure 5.3.11. The peak monthly average flow rate occurred during June (4,288 m^3/s [151,430 cfs]), and the lowest monthly average flow rate occurred during September (1,700 m^3/s [60,050 cfs]). Daily average flow rates varied from 1,045 to 5,097 m^3/s (36,900 to 180,000 cfs) during 1994.

Columbia River Sediment

In 1994, numerous studies were conducted on various aspects of sediment contamination in the Columbia River. This section will discuss the results of 1994 sediment surveillance activities. In addition, special studies or activities in 1994 that are pertinent to the evaluation of Columbia River sediment contamination will also be discussed.

Sample Collection and Analysis

Samples of Columbia River surface sediments (1-5 cm) were collected at 12 stations from six annual monitoring sites (shown in Figure 5.3.1 and summarized in Table 5.3.2) during 1994. Monitoring sites located at McNary and Priest Rapids Dams consisted of a transect with four stations established

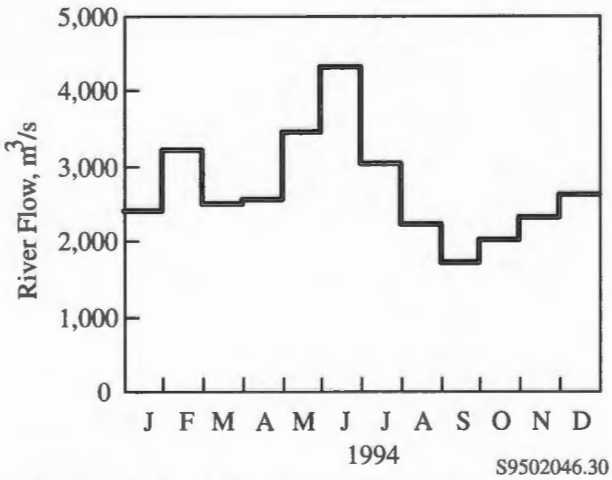

Figure 5.3.11 Mean Monthly Columbia River Flow Rates During 1994 (measured at Priest Rapids Dam)

across the river at approximately equal distances. At the Hanford Reach sampling locations (White Bluffs Slough, 100-F Slough, Hanford Slough, and Richland Pumphouse), a single near-shore grab sample (Hanford Site shoreline) was collected. A sample was taken at each sampling point using a Petite Ponar Grab sampler with a 235-cm^2 opening. Sediment samples were analyzed for gamma emitters (see Appendix F), plutonium-238, plutonium-239, plutonium-240, strontium-90, uranium-235, -238, and ICP metals (DOE 1994c). The sampling locations and methods used are discussed in detail in the *Environmental Monitoring Plan* (DOE 1994c).

Sediment Monitoring Results and Discussion

Sediments in the Columbia River contain low levels of radionuclides and metals of Hanford origin and radionuclides from nuclear weapons testing fallout (Beasley et al. 1981, Robertson and Fix 1977, Woodruff et al. 1992, Blanton et al. 1995). Hanford Site-derived pollutants are transported in surface waters in particulate or dissolved form. In fluvial systems, particulate transport is based on particle size, particle density, and water velocity. Contaminants associated with minerals are transported and deposited differently than contaminants associated with organic carbon. Organic carbon content of sediments is associated with the finer grained size fractions. Thus, areas where water velocity is reduced (slack water) will have a higher composition of fine-grained sediment and organic carbon content. Sediment grain size and total organic carbon content varied greatly among sediment monitoring site locations (Blanton et al. 1995). Consequently, concentrations of contaminants in sediments can vary significantly depending on sediment makeup and particle size distribution. Therefore, direct comparisons between bulk sediment contaminant concentrations among monitoring stations at Priest Rapids Dam, the Hanford Reach, and McNary Dam must consider the effects of grain size and total organic carbon content on sediment contaminant sorption. These factors were considered in the following discussion of the 1994 sediment monitoring results. The results and discussion are presented for both individual monitoring sites and regional means. Regional means include the sampling stations in the Priest Rapids and McNary Dams transects as well as the Hanford Reach stations of

White Bluffs, 100-F Area and Hanford Sloughs, and the Richland Pumphouse. All 1994 data collected for both radionuclides and chemicals (metals, inorganics) in sediments is reported in Bisping (1995). For more detailed information on sediment grain size and contaminant associations see Blanton et al. (1995).

In general, radiological analytical results for surface sediment samples collected during 1994 (Appendix A, Table A.6) were very low or below the minimum detection levels at all sites sampled. Appendix A, Table A.6 summarizes data for 1989 through 1993. The McNary Dam site had the highest concentrations of radionuclides during 1994. However, no appreciable differences existed between the Priest Rapids Dam reference site and the Hanford Reach or McNary Dam stations (Figure 5.3.12). Radionuclide concentration measured during 1994 were similar to those in sediment samples collected during the previous 5 years. The downriver trend in radionuclide concentration described above was expected based on examination of the grain size distribution and total organic carbon content of sediment collected from each monitoring site location (Blanton et al. 1995).

A summary of 1994 metal (and other inorganics) results is provided in Appendix A, Table A.7. All metal concentrations analyzed were detected above the minimum detection level. In general, mean metal concentrations along the Hanford Reach and at McNary Dam were not significantly different (based on the standard error of the mean) than those found at Priest Rapids Dam. (Figure 5.3.13). Mean chromium concentrations in sediment along the Hanford Reach appeared to be slightly elevated when compared to Priest Rapids and McNary Dams. A single elevated result at 100-F Slough (100 mg/kg) accounts for the increase in the mean chemical concentration. Generally, concentrations of metals at monitoring locations support the grain size and total organic carbon data reported in Blanton et al. 1995.

Review of 1994 Special Studies on Columbia River Sediments

Factors Controlling Sediment Contaminant Sorption

A special sediment monitoring study was conducted in 1994 to investigate the difference in sediment grain size composition and total organic carbon content at established monitoring sites. The study also determined if associations exist between sediment contaminant burden, grain size composition and total organic carbon content. During this study, sediments at the six Columbia River monitoring locations (Figure 5.3.1) were analyzed for grain size, total organic carbon content, radionuclides, metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and pesticides (Blanton et al. 1995). Sediment grain size and total organic carbon influence contaminant fate and transport. In general, river sediments with higher total organic carbon and finer grain size distribution can have higher contaminant burdens than sediments with less total organic carbon and more coarse–grained sediments. Physicochemical sediment characteristics were found to be highly variable among monitoring sites along the Columbia River. Again, sediment grain size and total organic carbon content should be considered in interpretations of sediment monitoring data. Additional detailed information on specific grain size and total organic carbon characteristics for individual monitoring sites is provided in Blanton et al. (1995).

Columbia River Comprehensive Impact Assessment: Distribution of Sediment Contamination

In 1994, the Surface Environmental Surveillance Program, in conjunction with the Columbia River Comprehensive Impact Assessment Program, analyzed sediment samples taken at 29 different locations along the Columbia River, from Priest Rapids Dam downstream to river mile 170 near Hood River, Oregon. In addition, samples were taken from the Yakima and Walla Walla Rivers, and two samples were taken from the Snake River near the Columbia River confluence. During this special study, samples were analyzed for various radionuclides, metals, organics, grain size distribution and

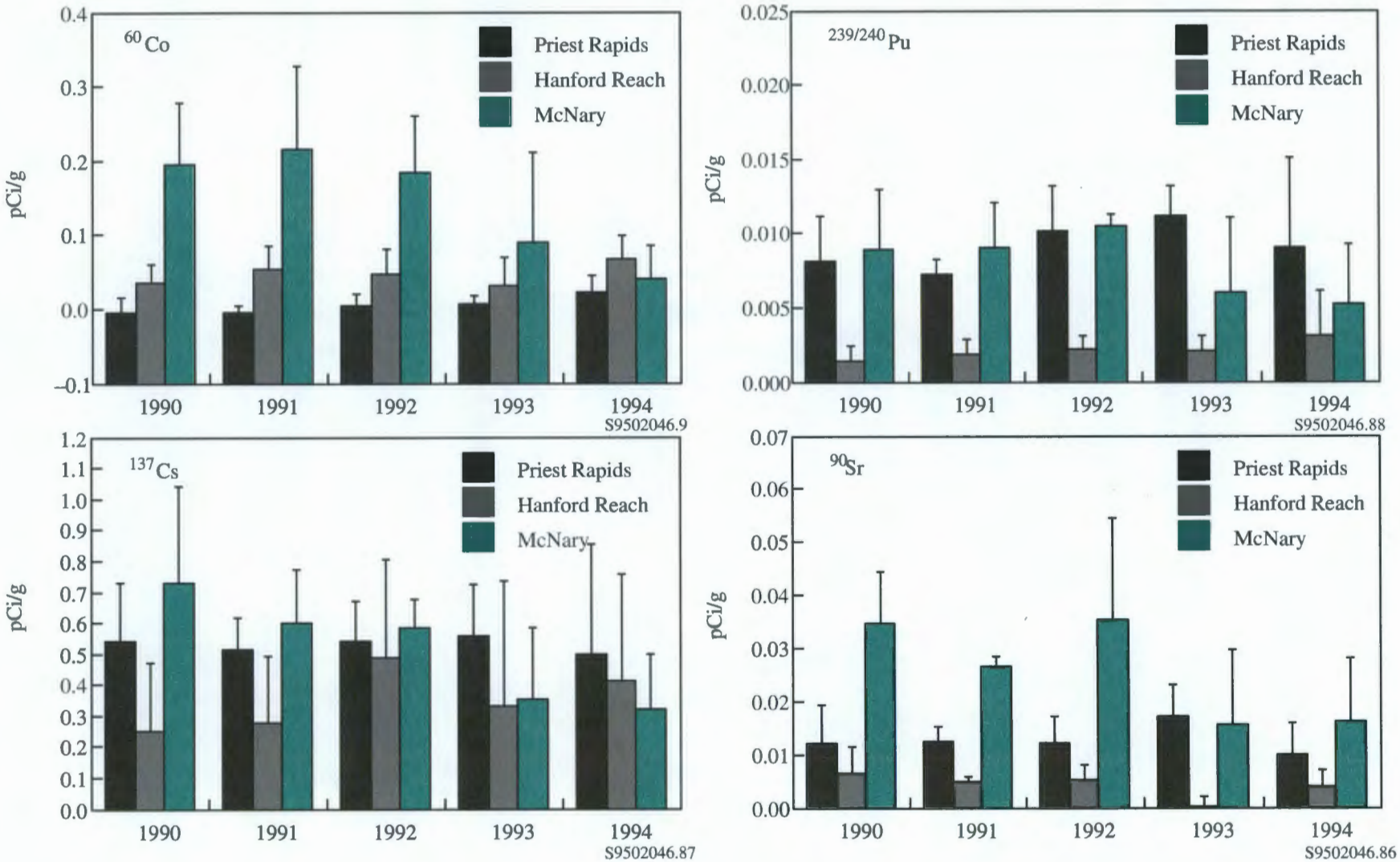

Figure 5.3.12 Regional Mean Radionuclide Concentrations for Cobalt-60, Cesium-137, Plutonium-239/240, and Strontium-90 Occuring in Columbia River Sediments at Priest Rapids Dam, Hanford Reach, and McNary Dam, 1989–1994. Error bars are ±2 standard error of the mean. Regional mean concentrations for Priest Rapids and McNary Dams are an average of four transects. The Hanford Reach regional mean is an average of four different sampling stations (100-F, White Bluffs, Hanford Slough, and Richland Pumphouse).

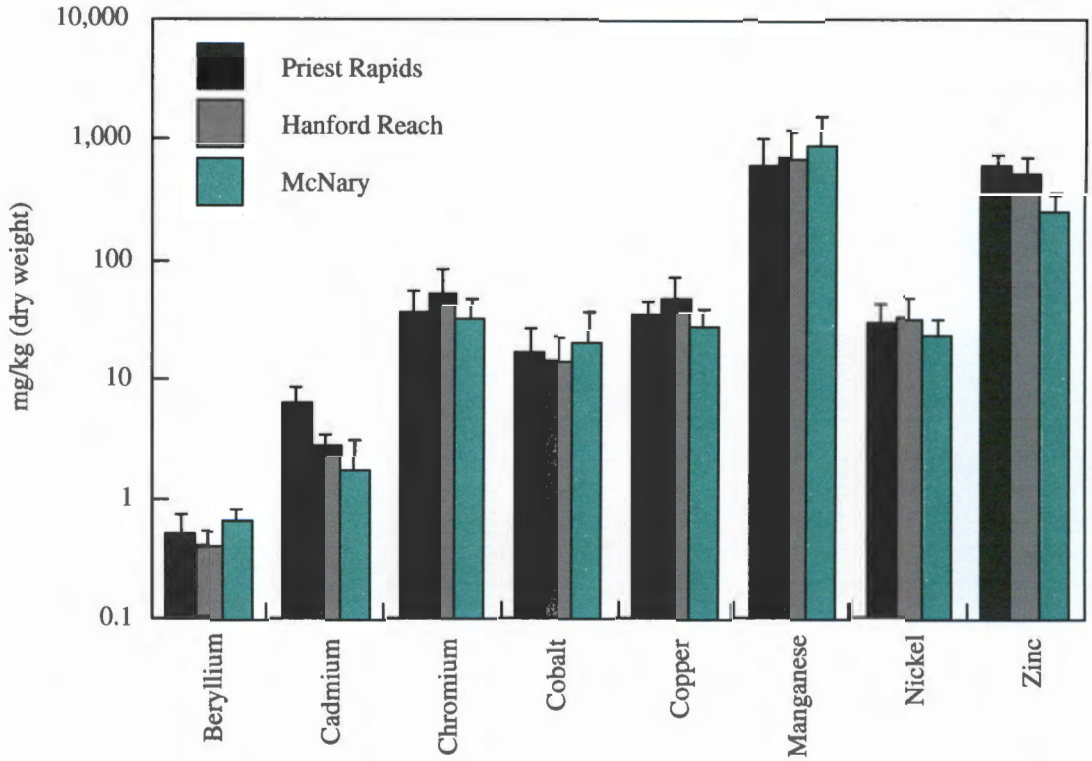

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Figure 5.3.13 Regional Mean Sediment Concentrations for Surface Environmental Surveillance Project 1994 Monitoring Data. Error bars represent ± 2 standard error of the mean. Regional mean concentrations for Priest Rapids and McNary Dams are an average of four transects. The Hanford Reach regional mean is an average of four different sampling stations (100-F, White Bluffs, Hanford Slough, and Richland Pumphouse).

total organic carbon content. A Columbia River Comprehensive Impact Assessment Program report documenting the findings from this study is in preparation; selected data results for radionuclides and metals are provided in Appendix A, Table A.8. The organic and chemical (CPAHs, pesticides, etc.) results for this study were very low at all sites sampled, and most concentrations were below the minimum detection limit. A table containing analytical organic data results is presented in Appendix A, Table A.9. In general, concentrations of radionuclides and metals in Columbia River sediment obtained in this study are similar to those previously reported by the Surface Environmental Surveillance Project monitoring program.

Washington Department of Health, Special Report on Sediments in the Columbia River

In March 1994, DOH issued a special report that evaluated radioactivity in Columbia River sediments and their associated health effects (Wells 1994). In that report, dose estimates were made for the maximally exposed individual using maximum measured concentrations of artificial radioactivity in surface sediments of the Columbia River. The report calculated doses from surface and buried sediments in addition to other scenarios. In the DOH report, the maximally exposed individual dose was reported to be 0.13 mrem/yr for surface sediments, which is less than 1% of the natural background

exposure dose. From this dose assessment study, DOH concluded that "calculated doses and attendant risks (to humans) from exposure to artificial radioactivity in Columbia River sediments are small for every section of the river." The concentration of radionuclides used in the DOH dose calculations were higher than the concentrations measured by PNL in 1994, at times by orders of magnitude. The 1994 PNL monitoring results support the DOH conclusions that radionuclide concentrations in Columbia River sediments are low and are not a public health concern.

CH2M HILL Special Study: Chromium in Interstitial Pore Water, Effects on Salmon Redds

During 1994, CH2M HILL conducted a strategic planning assessment for an experimental design to investigate the potential impacts in salmon redds from chromium-contaminated groundwater upwelling along the Hanford Reach. Data collection and analysis is scheduled for 1995. A report documenting the results of this study is in preparation.

Riverbank Springs

The Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site (Dirkes et al. 1994). Ground water thus provides a means for transporting Hanford-associated contaminants, which have leached into ground water from past waste disposal practices, to the Columbia River. Contaminated ground water enters the Columbia River via surface and subsurface discharge. Discharge zones located above the water level of the river are identified in this report as riverbank springs. Routine monitoring of riverbank springs offers the opportunity to characterize the quality of ground water being discharged to the river and to assess the potential human and ecological risk associated with the spring water.

Riverbank springs discharges were documented along the Hanford Reach long before the start-up of Hanford operations (Jenkins 1922). These relatively small springs flow intermittently and are influenced primarily by changes in the river level. Hanford-origin contaminants associated with these ground-water discharges have been documented to enter the river along the Hanford Reach (Dirkes 1990, DOE 1992c, McCormack and Carlile 1984, Peterson 1992).

Sample Collection and Analysis

Routine riverbank springs sampling began in 1988 at the 100-N Area, the old Hanford Townsite, and the 300-Area. In 1993, the monitoring plan was expanded to include the 100-B, 100-K, 100-D, and 100-H Areas. The 100-F Area spring was added in 1994. The locations of all riverbank springs sampled in 1994 are identified in Figure 5.3.1.

From 1988 through 1992, riverbank springs sampling was conducted annually during the period of low river flow (August through September). After 1992, sampling frequency was increased to twice during the low river flow season. Sample collection methods are described in the *Environmental Monitoring Plan* (DOE 1994c).

Sample analyses were selected based on findings of previous riverbank springs investigations, reviews of contaminant concentrations observed in nearby groundwater monitoring wells, and results of preliminary risk assessments. At a minimum, riverbank springs samples collected during 1994 were analyzed for gamma-emitting radionuclides, strontium-90, technetium-99, total alpha, total beta, tritium, uranium-234, -235, and -238. Iodine-129 analysis was included for locations where iodine-129 was known to exist in the ground water as a result of past Hanford operations. Riverbank springs were also analyzed for various nonradiological contaminants including metals, anions, and volatile organic compounds. All analyses were conducted on unfiltered samples.

Results for Riverbank Springs

Hanford-origin contaminants continued to be detected in riverbank spring water entering the Columbia River along the Hanford Site during 1994. The locations and extent of contaminated discharges were consistent with recent ground-water surveys. Aluminum, chromium, iron, manganese, NO_3, strontium-90, TCE (trichloroethylene), technetium-99, tritium, uranium-234, and -238 were found to be entering the river along the 100 Area shoreline. Aluminum, iodine-129, iron, manganese NO_3, technetium-99, and tritium entered the river along the portion of shoreline extending from the old Hanford Townsite to below the 300 Area. Chromium, uranium-234, and -238 were discharged to the river

along the 300 Area shoreline in addition to the other contaminants. The contaminant concentrations in spring water are typically similar but lower than those found in near-shore ground-water wells. Dilution of ground-water discharge may occur when the ground water mixes with river water that has entered the riverbank previously during high river flow (Dresel et al. 1994).

The results of radiological and chemical analyses conducted on riverbank springs samples in 1994 are documented by Bisping (1995). Radiological results are summarized in Appendix A, Table A.10. In the following discussion, radiological and nonradiological results are addressed separately. Contaminant concentration trends are illustrated for locations for which more than 3 years of data are available.

Radiological Results

All radiological contaminant concentrations measured in riverbank springs in 1994 were less than applicable DOE Derived Concentration Guides (Appendix C, Table C.6.). However, strontium-90 in the 100-D and 100-H Areas, tritium in the 100-N Area and along the old Hanford Townsite, and total alpha in the 300 Area exceeded the Washington State and federal Drinking Water Standards (Appendix C, Table C.2.). Total uranium exceeded the Site-specific proposed EPA Drinking Water Standard in the 300 Area. All other radionuclide concentrations were less than applicable Drinking Water Standards.

Table 5.3.3 provides selected radionuclide concentrations measured in water collected from the shoreline near the 100-N Area from 1989 through 1994. The Near-Facility Environmental Monitoring Program has historically sampled the 100-N Area riverbank seepage from the 199-N-8T monitoring well, which is located close to the river (see Figure 3.2.4). This well was also sampled annually by the Surface Environmental Surveillance Project from 1988 through 1991. In 1992, the Surface Environmental Surveillance Project sample was collected from well 199-N-46 (cassion), which is located slightly inland from well 199-N-8T. The concentrations of some contaminants were significantly different in water collected from well 199-N-46 than from water collected previously from well 199-N-8T. The differences were likely a result of the location of well 199-N-46 relative to well 199-N-8T and differences in sampling protocols. In 1993 and 1994, the Surface Environmental Surveillance Project 100-N Area spring samples were collected from actual ground-water seepage entering the river along the shoreline. Sampling in this manner is consistent with the Surface Environmental Surveillance Project sampling protocol at other riverbank spring locations and avoids duplicating efforts of the Near-Facility Environmental Monitoring Program.

Table 5.3.3 Selected Radionuclide Concentrations in 100-N Riverbank Spring Water During the Years 1989 through 1994. Concentrations are ±2 total propagated analytical uncertainty.

Year	Concentration, pCi/L		
	^{3}H	Total Beta	^{90}Sr
1989[a]	37,100 ± 2,870	10,700 ± 726	6,490 ± 1,240
1990[a]	38,500 ± 2,950	8,520 ± 603	3,990 ± 734
1991[a]	11,300 ± 1,040	7,140 ± 574	5,110 ± 1,000
1992[b]	4,870 ± 501	24,100 ± 1,730	10,900 ± 2,020
1993[c]			
Min	28,500 ± 2,220	2.41 ± 3.17	-0.0104 ± 0.221
Max	28,900 ± 2,260	4.50 ± 3.32	0.0204 ± 0.256
1994[c]	30,900 ± 2,380	8.79 ± 2.26	0.129 ± 0.107

(a) Samples collected from well 199-N-8T (see Figure 3.2.4).
(b) Sample collected from well 199-N-46 (see Figure 3.2.4).
(c) Sample collected from shoreline spring 0.9 km downstream of well 199-N-8T.

During 1993 and 1994, there was no visible groundwater seepage present directly adjacent to well 199-N-8T during sampling. The 100-N Area spring samples were taken from the nearest downstream riverbank spring located approximately 0.9 km (0.5 mi) from the well. As a result of the proximity of the riverbank spring to the contaminant plumes emanating from the 100-N Area, some contaminant concentrations measured in the spring water were significantly different from those previously measured in either of the two wells (see Table 5.3.3). The spring is located closer to the centerline of the tritium plume and farther from the centerline of the strontium-90 plume than were either of the two wells. The lower total beta concentrations in spring water, relative to those in well water, most likely result from lower strontium-90 levels. Technetium-99 and total uranium were the only other measured contaminants whose concentrations exceeded the 2 total propagated analytical uncertainty. The technetium-99 concentration was 0.3% of the Drinking Water Standard. The total uranium concentration was 18% of the Site-specific proposed EPA Drinking Water Standard.

Concentrations of radionuclides of concern in the riverbank spring near the old Hanford Townsite for 1989 through 1994 are provided in Figure 5.3.14. Total beta and technetium-99 concentrations in 1994 were lower than those observed during recent years. Tritium concentrations exhibited a wide fluctuation; the highest concentration was within the range normally observed. The lower contaminant concentrations may result from dilution of groundwater discharge by river water that entered the riverbank during higher flows. The concentrations of all three contaminants were lowest in early September when the river flow was lower than it had been throughout the previous week. With the exception of total uranium, all other measured contaminant concentrations rarely rose above their associated 2 total propagated analytical uncertainty. Total uranium concentrations were less than 30% of the Site-specific proposed EPA Drinking Water Standard. The iodine-129 concentration measured in the old Hanford Townsite riverbank spring (0.0435 ± 0.347 pCi/L) was less than 5% of the Drinking Water Standard.

Figure 5.3.15 depicts the concentrations of constituents of concern in the 300 Area riverbank spring

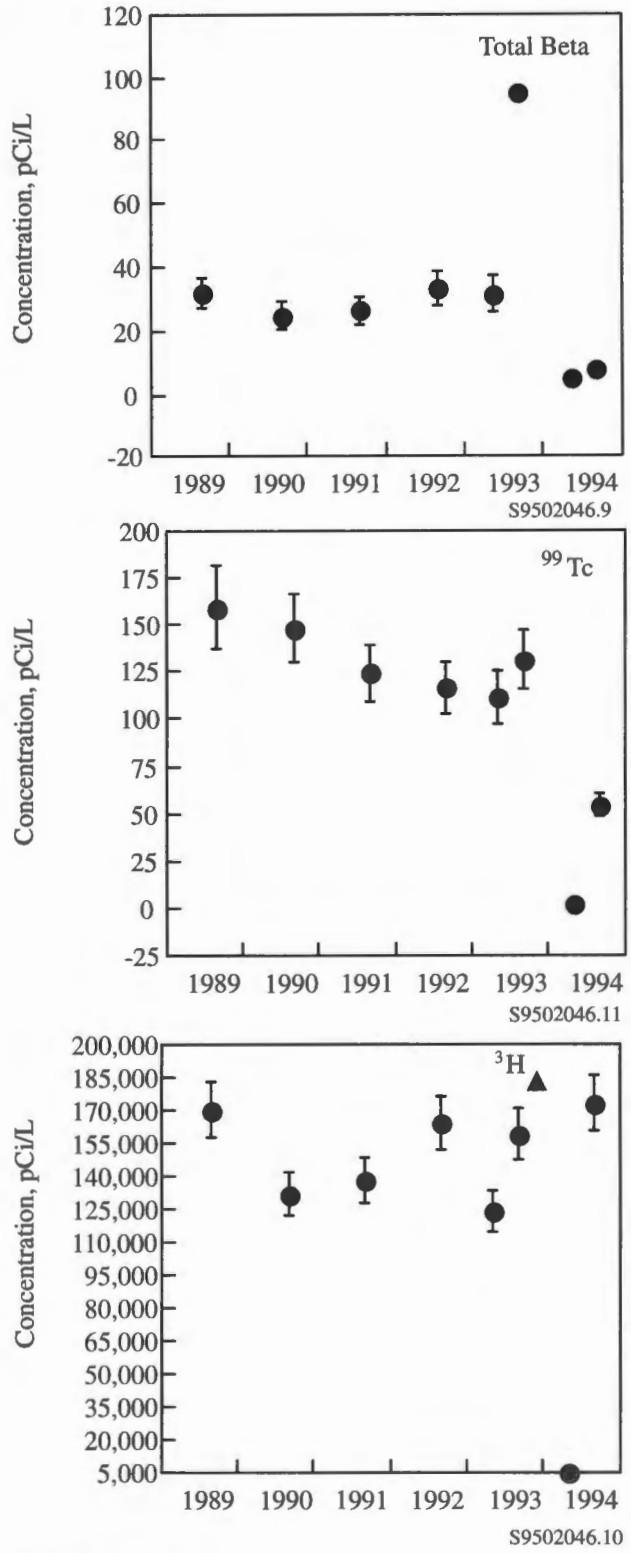


Figure 5.3.14 Constituents of Concern in the Riverbank Spring near the old Hanford Townsite, 1989 Through 1994. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

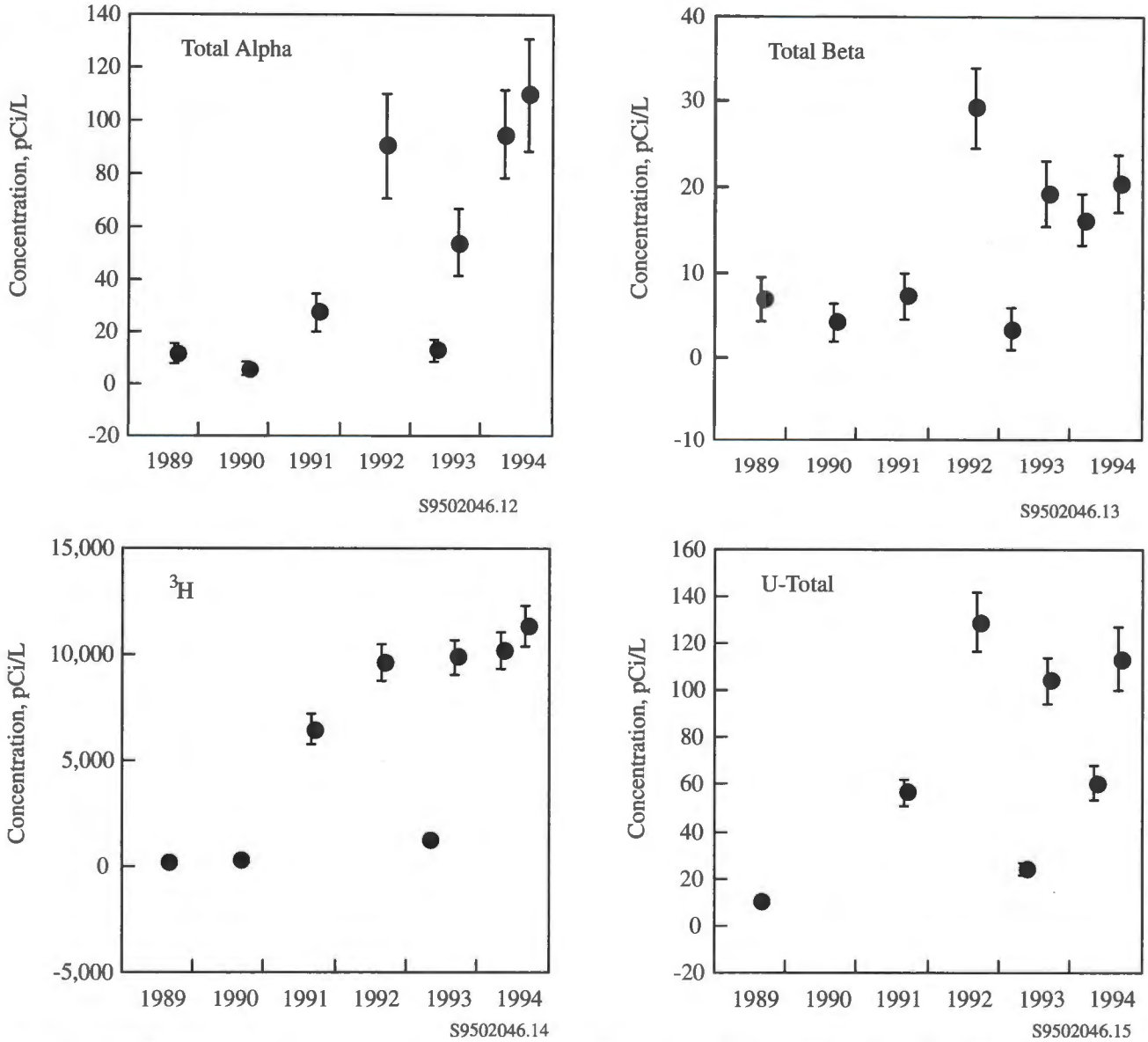


Figure 5.3.15 Constituents of Concern in the 300 Area Riverbank Spring, 1989 Through 1994. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

from 1989 through 1994. Elevated contaminant concentrations during 1992 are believed to result from control of the river water level by special arrangement during the 1992 riverbank spring sampling activities. These activities maximized the contribution of ground water in the springs and minimized the bank storage effect. The rising trend in tritium concentrations measured in the 300 Area riverbank spring during the past 4 years reflects the expansion of the contaminated ground-water plume emanating from the 200 Areas. This plume has expanded into the 300 Area during recent years (Dirkes 1993). Total uranium concentrations discharged to the Columbia River in the 300 Area have also increased in recent years as the plume originating from the Liquid Waste Disposal Facilities moved farther toward the river. Total alpha and total beta concentration trends parallel that of uranium and are likely associated with its presence. With the exception of technetium-99 and iodine-129, whose concentrations were less than 2% and 0.5% of the Drinking Water Standard, respectively, the concentrations of all other measured contaminants in the 300 Area spring were generally

lower than their associated 2 total propagated analytical uncertainty.

The concentrations of measured contaminants in 100-B, 100-D, 100-F, and 100-H Area riverbank springs are listed in Bisping (1995). In each of these 100 Areas springs, technetium-99, tritium, uranium-234, and -238 were the only constituents consistently found in concentrations greater than the 2 total propagated analytical uncertainty. Technetium-99 concentrations were less than 5% of the Drinking Water Standard. Total uranium concentrations were less than 15% of the Site-specific proposed EPA Drinking Water Standard. Tritium concentrations varied widely with location, ranging from less than 6% of the Drinking Water Standard in the 100-F and 100-H Area springs to approximately 75% in the 100-B Area spring. Measurable levels of strontium-90 were found only in the 100-D Area spring.

Nonradiological Results

All nonradiological contaminant concentrations measured in riverbank springs located on the Hanford shoreline in 1994 were below the primary Washington State and EPA Drinking Water Standards (Appendix C, Table C.3.), with the exceptions of chromium and NO_3 in the 100-D Area spring. Chromium and NO_3 concentrations in 100-D Area ground water are commonly found to exceed Drinking Water Standards as a result of past Hanford operations (Dresel et al. 1994). Iron in the 300 Area and aluminum, iron, and manganese in the 100-N Area and along the old Hanford Townsite exceeded the secondary Washington State and EPA Drinking Water Standards in 1994 riverbank springs samples. Secondary Drinking Water Standards are based on factors other than health effects. (Appendix C, Table C.3.)

Onsite Ponds

Three onsite ponds (see Figure 5.3.1) located near operational areas were sampled periodically during 1994. The B Pond, located near the 200-East Area, was excavated in the mid-1950s and expanded in the 1980s for disposal of process cooling water and other liquid wastes that occasionally contained low levels of radionuclides. West Lake, located north of the 200-East Area, is recharged from ground water (Gephart et al. 1976) and has not received direct effluent discharges from Site facilities. The FFTF Pond, located near the 400 Area, was excavated in 1978 for the disposal of cooling and sanitary water from various facilities in the 400 Area.

The Site Operations and Engineering contractor is responsible for monitoring effluents discharged to the ponds and for operational surveillance of the ponds. Although the ponds were inaccessible to the public and did not constitute a direct offsite environmental impact during 1994, they were accessible to migratory waterfowl, creating a potential biological pathway for the dispersion of contaminants (see Section 5.5, "Wildlife Surveillance"). Periodic sampling of the ponds also provided an independent check on effluent control and monitoring systems.

Sample Collection and Analysis

In 1994, grab samples were collected quarterly from B Pond, FFTF Pond and West Lake. Unfiltered aliquots of all samples were analyzed for total alpha and total beta activities, gamma-emitting radionuclides, and tritium. Samples from B Pond were also analyzed for strontium-90 and technetium-99. West Lake samples were also analyzed for strontium-90, technetium-99, uranium-234, -235, and -238. Constituents were chosen for analysis based on their known presence in local ground water and in effluents discharged to the ponds and their potential to contribute to the overall radiation dose delivered to the public.

Results

Analytical results from pond samples collected during 1994 are listed by Bisping (1995). Although the pond water is not used for human consumption, Drinking Water Standards and DOE Derived Concentration Guides provide useful reference concentrations to characterize the pond water quality. With the exception of uranium-234 and -238 in the July sample of West Lake, radionuclide concentrations in onsite pond water were less than applicable Derived Concentration Guides (Appendix C, Table C.6.). The Washington State and EPA Drinking Water Standard (Appendix C, Table C.2.) for total alpha was exceeded in all West Lake samples and in the July sample of B Pond. The Site-specific proposed EPA Drinking Water Standard for uranium was also exceeded in West Lake. The concentration

of all other radionuclides were less than applicable Drinking Water Standards.

Annual concentrations of select radionuclides in B Pond for the years 1989 through 1994 are shown in Figure 5.3.16. Elevated total alpha and total beta results were observed in the July 1994 sample from B Pond. Median concentrations, however, remained within the ranges of previously reported results. Tritium and strontium-90 levels were less than 0.5% and 9% of their respective Drinking Water Standards in 1994 and were within the range observed during the previous 5 years. All other measured contaminant concentrations were less than 20% of applicable Drinking Water Standards and rarely rose above their associated 2 total propagated analytical uncertainty. The B Pond was decommissioned in the summer of 1994. The October 1994 sample was collected from the B Pond Extension. Contaminant concentrations in the B Pond Extension were similar to those found in B Pond itself earlier in the year.

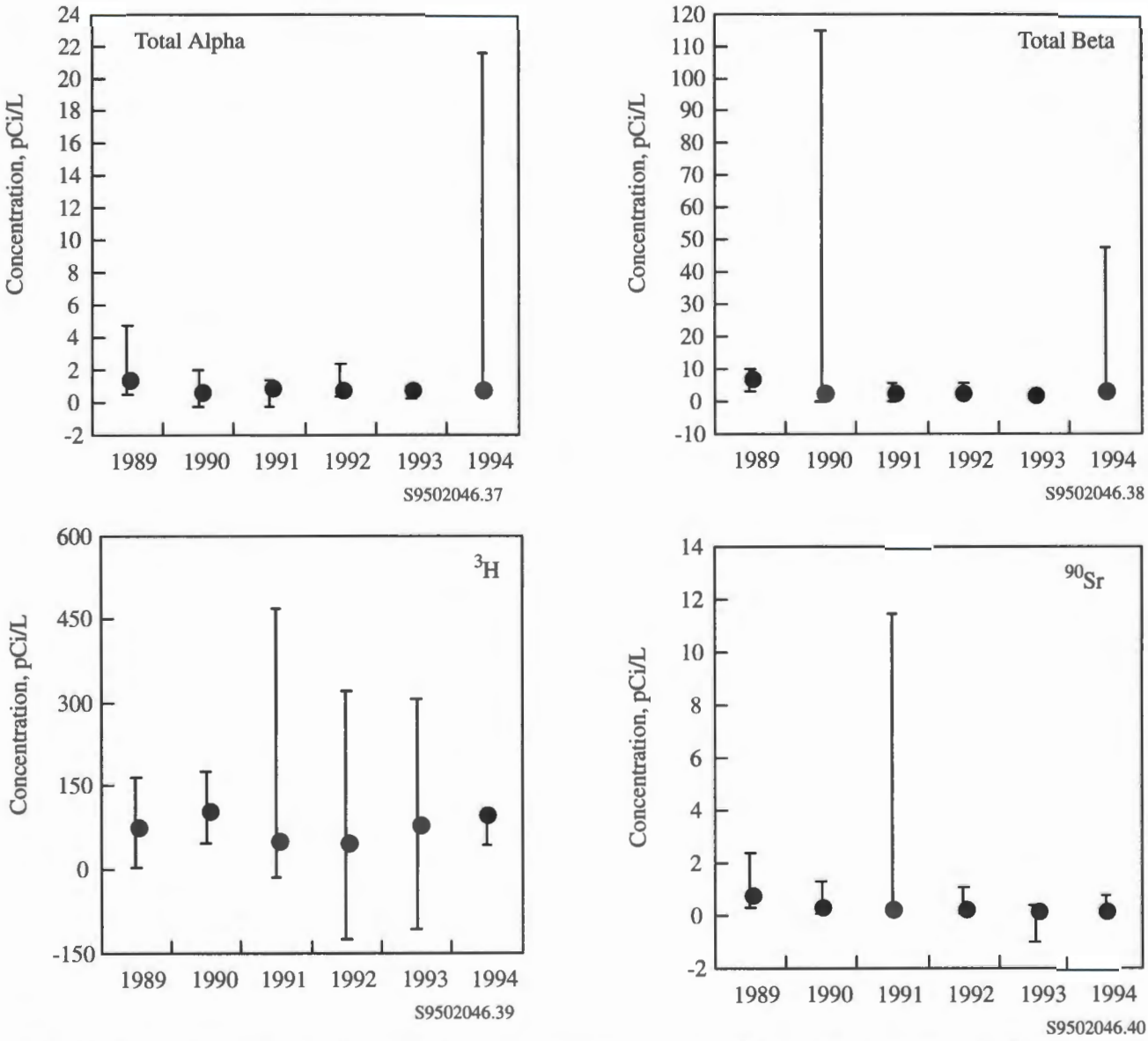


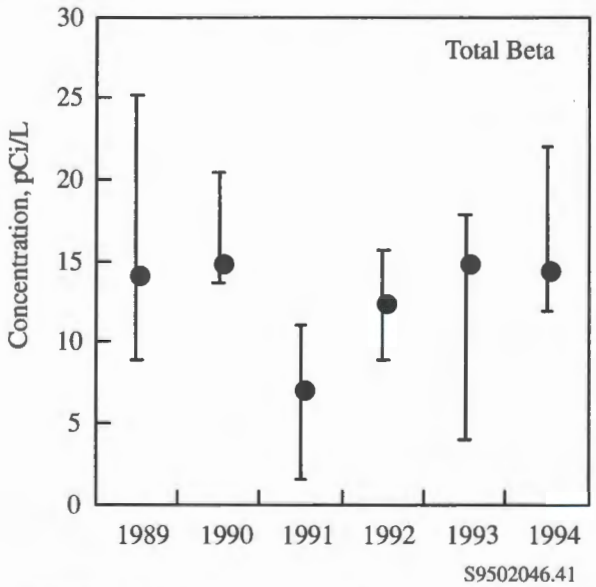
Figure 5.3.16 Minimum, Median, and Maximum Concentrations of Selected Radionuclides in B Pond, 1989 Through 1994. As a result of figure scale, some maximum and minimum values are concealed by point symbol.

Figure 5.3.17 shows the annual total beta and tritium concentrations in FFTF Pond from 1989 through 1994. The concentrations of both constituents have remained stable in recent years. Tritium concentrations observed in FFTF Pond in 1994 were less than 35% of the Drinking Water Standard, lower than those commonly observed in the local unconfined aquifer. The concentrations of all other measured contaminants in FFTF Pond rarely exceeded their respective 2 total propagated analytical uncertainties.

The 1989 through 1994 annual concentrations of select radionuclides in West Lake are shown in Figure 5.3.18. Median total alpha and total beta concentrations during 1994 were similar to those observed in the past. Total alpha and total beta concentrations in West Lake continued to be higher than the alpha and beta levels found in the other onsite ponds. These elevated levels are believed to result from high concentrations of naturally occurring uranium (Poston et al. 1991, Speer et al. 1976). Annual median total uranium concentrations have remained stable over the last 6 years. The range in concentration, however, has shown a dramatic increase. Both the minimum and maximum annual total uranium concentrations have risen in recent years; the highest concentration occurred in summer and fall when the water level in the pond was low. It is believed that relatively large concentrations of suspended sediment in the samples is causing the elevated results. Ground water level declines in the 200 Areas have been recorded since the decommissioning of U Pond in 1984 and the shutdown of production facilities (Dresel et al. 1994). As a result, the water level in West Lake has dropped, and the pond was dry when sampling was attempted in the fall of 1994. Low water levels increase the likelihood of collecting samples that contain newly suspended sediment disturbed during the sampling process. Similar total uranium concentrations were reported by Poston et al. (1991) for West Lake samples that contained high concentrations of suspended sediment. Strontium-90 and tritium concentrations found in West Lake in 1994 were within the range observed during the previous 5 years and reflect local ground-water concentrations. With the exception of technetium-99, whose concentrations were less than 8% of the Drinking Water Standard, the concentrations of all other measured contaminants were generally lower than their associated 2 total propagated analytical uncertainties.

Offsite Water

During 1994, water samples were collected from four water systems directly east of and across the Columbia River from the Hanford Site. Samples were also collected from an irrigation canal downstream from Hanford that obtains water pumped from the Columbia River. As a result of



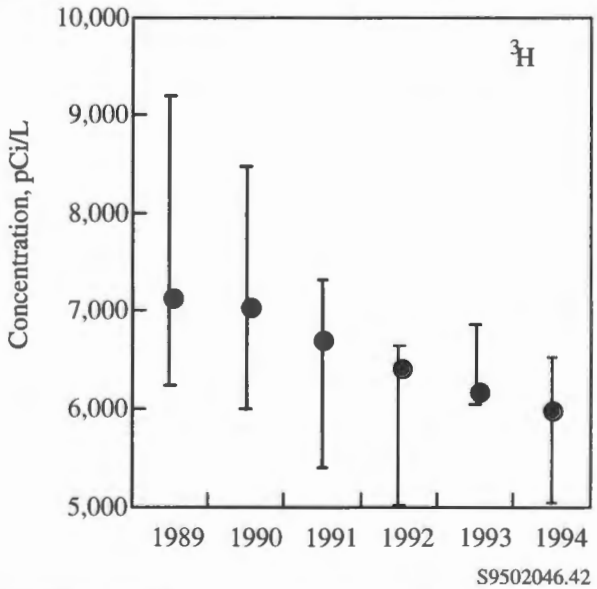


Figure 5.3.17 Minimum, Median, and Maximum Total Beta and Tritium Concentrations in FFTF Pond, 1989 Through 1994

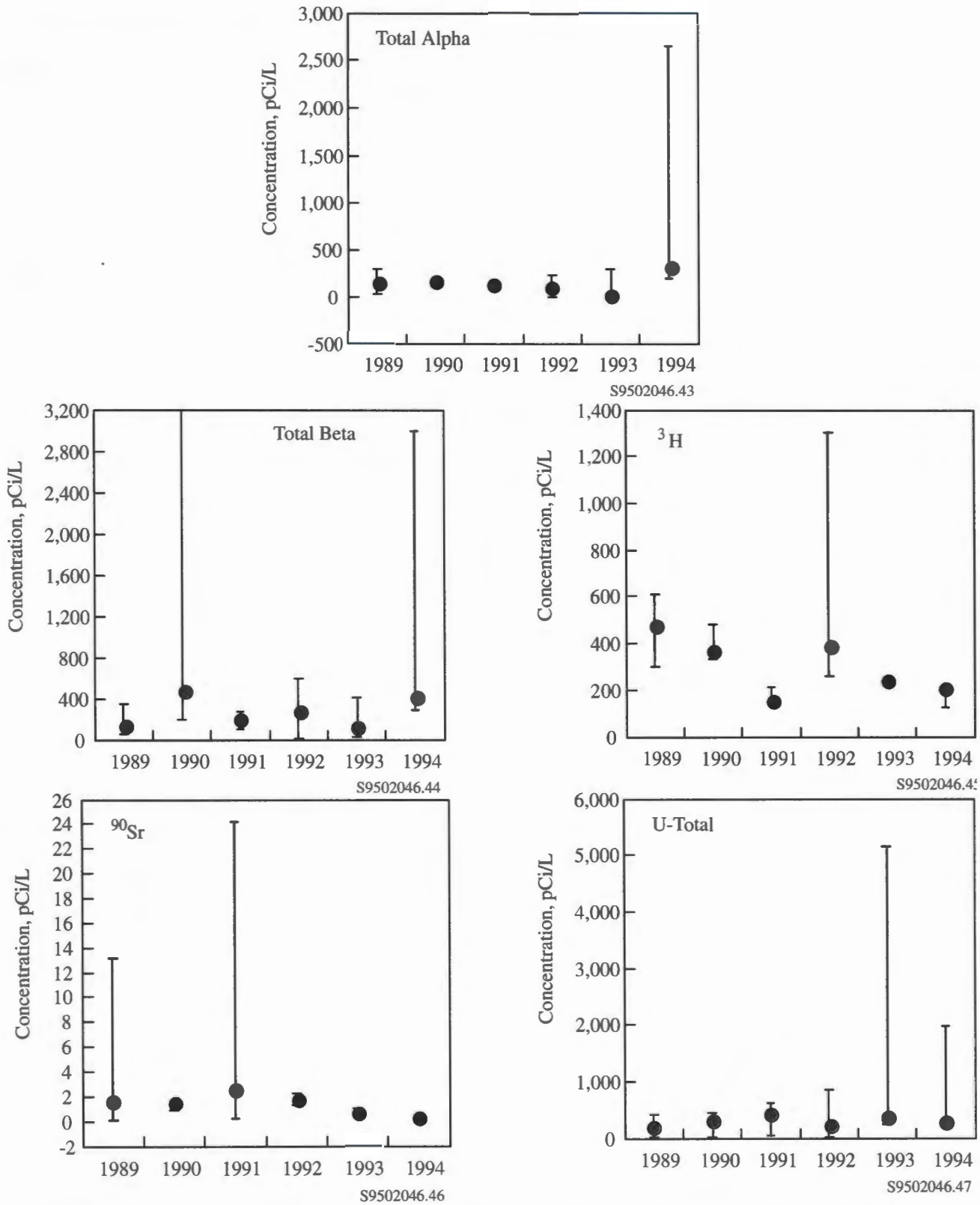


Figure 5.3.18 Minimum, Median, and Maximum Concentrations of Selected Radionuclides in West Lake, 1989 Through 1994. As a result of figure scale, some maximum and minimum values are concealed by point symbol. The maximum total beta concentration in 1990 was 271,000 pCi/L.

public concern about the potential for Hanford-associated contaminants to be present in offsite water, sampling was conducted to document the levels of radionuclides in water used by the public. Consumption of food irrigated with Columbia River water downstream from the Site has been identified as one of the primary pathways contributing to the potential dose to the hypothetical maximally exposed individual (Jaquish and Mitchell 1988).

Sample Collection, Analysis, and Results

Grab samples were collected once from four offsite domestic water supplies during 1994 (see Figure 5.3.1). Analyses of unfiltered aliquots of the samples included gamma scan, total alpha, total beta, tritium, uranium-234, -235, and -238. All radionuclide concentrations measured in offsite water supplies in 1994, and reported by Bisping (1995), were below applicable DOE Derived Concentration Guides (Appendix C, Table C.6) and the Washington State and EPA Drinking Water Standards. The proposed EPA Drinking Water Standard for total uranium, however, was exceeded at Alexander Farm.

Elevated total alpha and beta concentrations measured in offsite water supplies in 1994 were attributable to natural uranium concentrations in the ground water. Uranium was detected at measurable concentrations in all domestic water supplies, with the exception of the deep well of the White Bluffs Water Association. Total uranium concentrations observed in offsite water supplies were comparable to those reported by the state of Washington and were not attributable to Hanford operations. The concentrations of all other measured radionuclides in offsite drinking water during 1994 rarely exceeded their associated 2 total propagated analytical uncertainty.

Water in the Riverview irrigation canal was sampled three times in 1994 during the irrigation season. Unfiltered samples of the canal water were analyzed for gamma emitters, strontium-90, total alpha, total beta, tritium, uranium-234, -235, and -238. Results are presented by Bisping (1995). In 1994, radionuclide concentrations measured in Riverview irrigation water were found to be at the same levels observed in the Columbia River. All radionuclide concentrations were below applicable DOE Derived Concentration Guides and Washington State and EPA Drinking Water Standards. Strontium-90 was the radionuclide of most concern because it has been identified as one of the primary contributors to the calculated hypothetical dose to the public via the water pathway (Jaquish and Bryce 1989). The concentrations of strontium-90 in the irrigation water during 1994 ranged from 0.06 to 0.10 pCi/L and were similar to those reported for the Columbia River at Priest Rapids Dam and the Richland Pumphouse (see Columbia River Water subsection).

5.4 Food and Farm Product Surveillance

T. M. Poston

Alfalfa and a number of foodstuffs including milk, asparagus, wheat, beef, chickens, eggs, vegetables, fruits, and wine were collected at several locations surrounding the Hanford Site (Figure 5.4.1). Samples were collected primarily from locations in the prevailing downwind directions (south and east of the Site) where airborne effluents from Hanford could be expected to be deposited. Samples were also collected in generally upwind directions, on the Site perimeter and at locations somewhat distant from the Site, to provide information on background radioactivity. This section summarizes the radiological analyses performed on samples collected in 1994. Detailed analytical results are listed by Bisping (1995), some of which have been summarized in Appendix A. The potential dose to members of the public from consuming local foods and farm products is addressed in Section 6.0, "Potential Radiation Doses from 1994 Hanford Operations." Results for fruits and vegetables and animal products are reported in pCi/g wet weight. Results for wheat and alfalfa are reported in pCi/g dry weight. Radionuclide concentrations in most samples were less than the limits of detection. Results for tritium (tritium present as water) in milk, wine, and fruits are reported in pCi per liter (pCi/L) of liquid distilled from the food product. Most tritium is found as water, and very little tritium is organically bound to other constituents present in biological material.

The food and farm product sampling design addresses the potential influence of Hanford Site releases in two ways: by comparing results from several downwind locations to those from generally upwind or distant locations, and by comparing results from locations irrigated with Columbia River water withdrawn downstream from Hanford to results from locations irrigated with water from other sources. Specific details of the sampling design including sampling locations and radionuclides analyzed are reported by Bisping (1995) and DOE (1991b) and are summarized in Table 5.4.1. Gamma scans (cesium-137, cobalt-60, and other radionuclides; see Appendix F) and strontium-90 analyses were routinely performed for nearly all products. Selected food products were specifically analyzed for additional radionuclides including iodine-129, plutonium, technetium-99, tritium, and uranium.

One uncontrolled factor influencing concentrations of radionuclides in milk and other dairy products, beef, and poultry is the source of food for the farm animals. Cattle and poultry may be fed with food grown outside of their sampling locations. For radionuclides that are present in fallout from weapons testing, fallout radioactivity in feed may be a significant source of monitored levels in dairy products. Generally, levels of fallout radioactivity in environmental media correlate positively with precipitation.

Milk

Sample Collection and Analysis

Composite samples of raw, whole milk were collected from three East Wahluke and three Sagemoor area dairy farms near the Site perimeter in the prevailingly downwind direction to evaluate possible Hanford impacts (Figure 5.4.1). Milk samples were also collected from a Sunnyside dairy to indicate the general background concentrations of radionuclides at a generally upwind location. Samples were collected monthly throughout the year from the Sagemoor area and quarterly from the other areas.

Milk was analyzed for iodine-129, strontium-90, tritium, and gamma emitters such as cesium-137 because these radionuclides have the potential to move through the air-pasture-cow-milk or water-pasture-cow-milk food chain. Tritium is released into the atmosphere from Site facilities and to the Columbia River via shoreline ground-water springs. Strontium-90 is released into the Columbia River through the N Springs. Iodine-129 has been released to the air from the Hanford Site in the past and is still being released to the Columbia River via the Site ground-water plume. Cesium-137 was present in atmospheric fallout from weapons testing and is found in Site radiological waste. Tritium and gamma analyses were conducted on each monthly

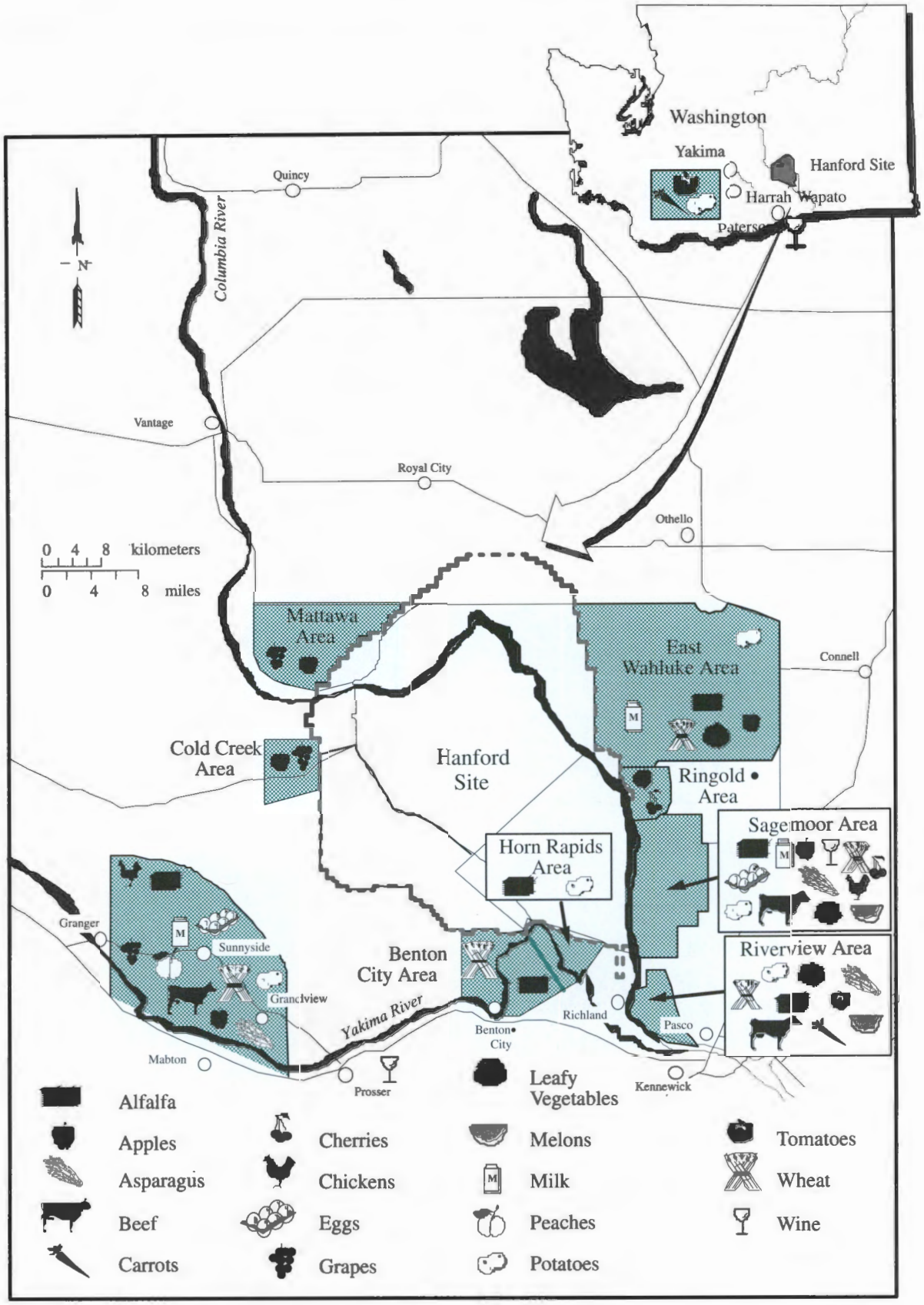


Figure 5.4.1 Food and Farm Product Sampling Locations, 1994

Table 5.4.1 Numbers of Locations, Sampling Frequencies, and Analyses Performed for Routinely Sampled Food and Farm Products, 1994[a]

Media	Number of Locations		Sampling Frequency[b]	Number of Locations Analyzed						
	Upwind	Downwind		^{3}H	Gamma	^{90}Sr	^{99}Tc	^{129}I	U	Pu
Milk	1	2	M, Q, or SA	3	3	3	0	3	0	0
Eggs, meat, and poultry	1	2	SA or A	0	3	3	0	0	0	0
Vegetables	2	4	A	2	6	6	3	1	2	3
Fruit	2	3	A	5	5	5	0	2	0	3
Wheat and alfalfa	1	4	A	0	5	5	0	0	0	2
Wine	2	1	A	3	3	0	0	0	0	0

(a) Media may include multiple varieties for each category. Not all analytes were assayed at all locations or for each variety of media.
(b) M = monthly; Q = quarterly; SA = semiannually; A = annually.

sample, strontium-90 analyses were conducted on each quarterly sample, and iodine-129 analyses were conducted on two semiannual composite samples (one each from Sagemoor and Sunnyside). Tritium analysis was performed on water distilled from milk, and as a consequence, would slightly overestimate the true concentration of tritium in bulk milk.

Results

Tritium was detected in 1 of the 20 (5%) milk samples analyzed; the maximum concentration was 260 ± 200 pCi/L in a sample collected from the Sagemoor area. While there is no tritium standard for milk, the standard for drinking water is 20,000 pCi/L.

Strontium-90 was measured in six of nine (67%) milk samples analyzed in 1994, with no apparent differences between upwind and downwind locations (Table 5.4.2). Concentrations of strontium-90 have remained near the detection limit (4 pCi/L) and relatively constant over the past 6 years (Figure 5.4.2). The maximum observed concentration of strontium-90 in milk in 1994 was 0.97 ± 0.43 pCi/L. While there is no strontium-90 standard for milk, the standard for drinking water is 8 pCi/L.

Iodine-129 was identified by high-resolution mass spectrometry in seven milk samples tested (Table 5.4.2). In recent years, the levels of iodine-129 in milk collected from generally downwind dairies at Sagemoor and East Wahluke have persisted at levels two to four times greater than levels measured upwind in Sunnyside (Figure 5.4.3). Iodine-129 concentrations have been declining with the end of nuclear production activities onsite. Iodine-129 contributes less than 1% of the dose to the maximally exposed individual (MEI) through the consumption of dairy products (see Section 6.0). The maximum observed concentration of iodine-129 in milk in 1994 was 0.0008 ± 0.0002 pCi/L. While there is no iodine-129 standard for milk, the standard for drinking water is 1 pCi/L.

Three of the 21 (14%) milk samples collected and analyzed for cesium-137 in 1994 contained detectable concentrations (>4.0 pCi/L). There was no apparent difference between results upwind and downwind of the Site. The maximum observed concentration of cesium-137 in milk in 1994 was 3.1 ± 2.6 pCi/L. While there is no cesium-137 standard for milk, the standard for drinking water is 200 pCi/L. No other gamma emitters were consistently detectable (Bisping 1995).

Table 5.4.2 Radionuclide Concentrations in Milk (pCi/L), 1994 Compared to Values from the Previous 5 Years

	Location	1994[a] Maximum[b]	Mean[c]	No. Less Than Detection[d]
^{90}Sr				
Downwind	Wahluke Area	0.97 ± 0.43	0.82 ± 0.19	1 of 3
	Sagemoor	0.45 ± 0.38	0.40 ± 0.06	1 of 3
Upwind	Sunnyside	0.84 ± 0.73	0.622 ± 0.39	1 of 3
^{129}I				
Downwind	Wahluke Area	0.0008 ± 0.00017	0.0006 ± 0.00020	0 of 2
	Sagemoor	0.0008 ± 0.00019	0.0007 ± 0.00018	0 of 2
Upwind	Sunnyside	0.0004 ± 0.00004	0.0004 ± 0.00004	0 of 2

	Location	1989-1993[a] Maximum[b]	Mean[c]	No. Less Than Detection[d]
^{90}Sr				
Downwind	Wahluke Area	1.8 ± 0.98	0.71 ± 0.17	4 of 20
	Sagemoor	1.2 ± 0.44	0.63 ± 0.12	3 of 20
Upwind	Sunnyside	3.2 ± 1.20	0.65 ± 0.31	4 of 20
^{129}I				
Downwind	Wahluke Area	0.0041 ± 0.00031	0.0014 ± 0.0007	0 of 9
	Sagemoor	0.0125 ± 0.0016	0.0027 ± 0.0025	0 of 9
Upwind	Sunnyside	0.0032 ± 0.00020	0.0007 ± 0.0006	0 of 9

(a) Results have shown a decreasing trend over the period of 1989 to 1994.
(b) Maximum ±2 total propagated analytical uncertainty.
(c) Mean ±2 standard error of the calculated mean, expressed as a percentage.
(d) Number of samples with values less than the ±2 total propagated analytical uncertainty out of number of samples analyzed. Means are based on all sample results.

Beef, Chickens, and Eggs

Sample Collection and Analysis

Samples of locally produced poultry and eggs were collected twice annually from areas adjacent to the Hanford Site (Sagemoor and Sunnyside, Figure 5.4.1) and analyzed for strontium-90 and gamma emitters such as cesium-137. Beef was collected once in 1994 from the Sagemoor, Riverview, and Sunnyside areas for analysis of strontium-90 and gamma emitters such as cesium-137. Strontium-90 is monitored because it is released into the Columbia River through the N Springs. Cesium-137 is monitored because it is present in Site wastes. Both radionuclides have the potential to move through the food chain to beef, chickens, and eggs.

Results

In 1994, strontium-90 was measured in shells in half the egg samples collected at each location. The maximum concentration was 0.22 ± 0.06 pCi/g in a shell sample from Sagemoor. Strontium-90 was not detected in the edible portion of the eggs

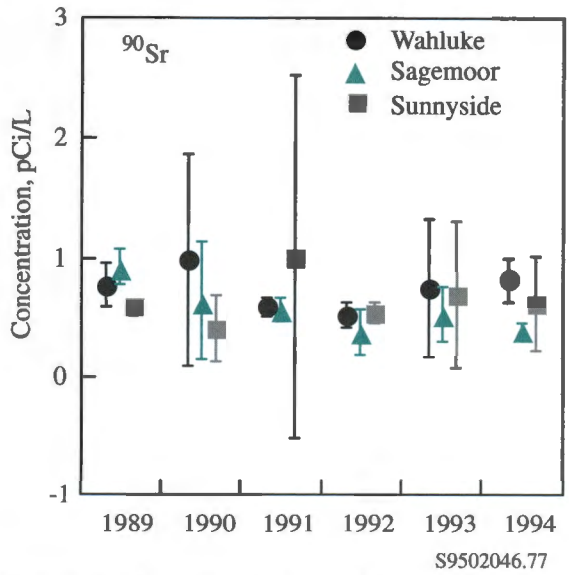


Figure 5.4.2 Mean (± 2 standard error of the mean) Strontium-90 Concentrations in Milk, 1989 Through 1994. As a result of figure scale, some uncertainties are concealed by point symbol.

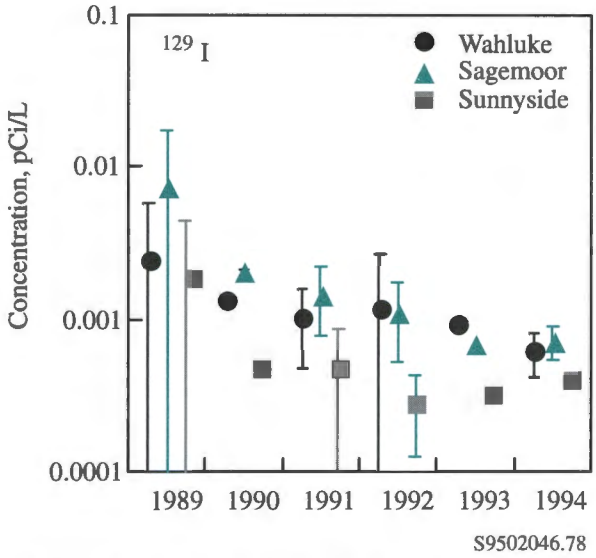


Figure 5.4.3 Mean (± 2 standard error of the mean) Iodine-129 Concentrations in Milk, 1989 Through 1994. As a result of figure scale, some uncertainties are concealed by point symbol.

collected in 1994, nor has it been detected in earlier samplings of the edible portion (Dirkes et al. 1994). Strontium-90 has been previously monitored in Canada goose egg shells as an indicator of environmental contamination (Poston 1994); however, this is the first year that chicken egg shells have been analyzed. No measurable concentrations of any manmade gamma emitter, such as cesium-137, were found in chicken or egg samples.

In 1994, manmade radionuclides were not detected in samples of locally produced beef.

Vegetables

Sample Collection and Analysis

Samples of leafy vegetables (cabbage, broccoli leaves, beet tops, or turnip greens), asparagus, tomatoes, carrots, and potatoes were obtained during the summer from gardens and farms located within the sampling areas (see Figure 5.4.1). In conjunction with DOH, carrots were also sampled from Harrah, a farming community about 13 km (8 mi) south of Yakima and upwind of the Hanford Site. Samples were collected from the Riverview and Horn Rapids areas to assess potential contamination from crop irrigation at those locations. Irrigation water for Horn Rapids and Riverview is withdrawn from the Columbia River downstream from Hanford.

Leafy vegetables are sampled because of the potential deposition of airborne contaminants, and at some locations, deposition from overhead irrigation. Leafy vegetables were provided by the Bailie Memorial Youth Ranch in the East Wahluke sampling area and Country Haven Academy in the Sagemoor Area. All vegetable samples were analyzed for gamma-emitting radionuclides and strontium-90; in addition, tomatoes from selected locations were analyzed for tritium, and potatoes from selected locations were analyzed for plutonium-238, plutonium-239,240, technetium-99, and uranium isotopes. Tritium is monitored because it has been released into the atmosphere from Site facilities and to the Columbia River via shoreline ground-water springs. Strontium-90 is monitored because it is released into the Columbia River at the N Springs and is known to accumulate in some plants. Technetium-99 is monitored because it is known to enter the Columbia River through shoreline seeps and springs, has a long half-life, and can accumulate in farm products that may be irrigated with Columbia River water withdrawn downstream from Hanford. Iodine-129 is monitored because it can move through the air-vegetation-human food chain. Cesium-137 is monitored because it is present in Hanford wastes and atmospheric fallout from

weapons testing. Isotopes of uranium are monitored because they enter the Columbia River in springs near the 300 Area and are known to accumulate in soil and vegetation. Plutonium-238 and plutonium-239,240 are monitored because of past releases and to assure the public that concentrations of plutonium isotopes are not a concern in vegetables.

Results

Many of the analytical results for vegetables were below the detection limits for specific radionuclides. For leafy vegetable samples in 1994, the only radionuclide measured above the detection limit was strontium-90. The Riverview sample (0.030 ± 0.007 pCi/g) and Sagemoor sample (0.025 ± 0.007 pCi/g) exceeded the detection limit of 0.005 pCi/g. For tomato samples in 1994, no manmade radionuclides were detected above the detection limit.

Carrots and potatoes were also sampled at several locations around Hanford. The only radionuclide measured was strontium-90 (0.005 ± 0.004 pCi/g), at the detection limit. Measurements of gamma emitters, plutonium-238, plutonium-239,240, technetium-99, and uranium isotopes were all less than their respective detection limits.

A special sampling of asparagus was conducted in 1994 at Riverview, Sagemoor, and Sunnyside. The only radionuclide found in asparagus was strontium-90 in samples collected from all three locations. Concentrations were at the detection limit of 0.005 pCi/g. The only location with concentrations of uranium above the detection limit was Riverview (0.009 ± 0.004 pCi/g uranium-238). A more extensive study of uranium in asparagus conducted in 1990 (Tiller and Poston 1992) concluded that there was no difference between wild asparagus collected onsite and harvested asparagus collected offsite. The Riverview site was not sampled in that study; however, the Sagemoor site had the highest concentrations of uranium-238 in 1990.

Fruit

Sample Collection and Analysis

Samples of apples, peaches (Sunnyside only), cherries, concord grapes, and melons were collected before or during harvest from the areas shown in Figure 5.4.1 (not all types were collected in each area). The edible portions were analyzed for gamma emitters, strontium-90, tritium, and for selected samples, iodine-129 and plutonium-239,240. Tritium was analyzed in the distillate collected from fruit samples.

Results

With one exception, measurable levels of manmade radioactivity were not detected in apples, peaches, cherries, concord grapes, or melons collected in 1994 from either upwind or downwind locations. The exception was strontium-90 in a melon sample from Riverview (0.008 ± 0.004 pCi/g). These results are consistent with fruit measurements over recent years (Bisping and Woodruff 1990, 1991, 1992, 1993; Bisping 1994b). Minimum levels of detection were 0.02 pCi/g wet weight for cesium-137, 1 pCi/g wet weight for iodine-129, 0.0004 pCi/g wet weight for plutonium-239,240, 0.005 pCi/g wet weight for strontium-90, and 300 pCi/L plant distillate for tritium.

Wine

Sample Collection and Analysis

Locally produced red and white wines (1994 vintage grapes) were analyzed for tritium and gamma-emitting radionuclides . The wines were made from grapes grown at individual vineyards in the Sagemoor Area downwind of the Site, and at two upwind locations, one at Prosser and one at Patterson. Three samples of each wine were obtained from each area. Wine samples collected in 1993 were also subjected to a very sensitive mass spectrometry analysis for tritium that is roughly 15 times more sensitive than the distillation method routinely used for wine analysis (Surano et al. 1992). The DOH performed tritium analysis on wine distilates in

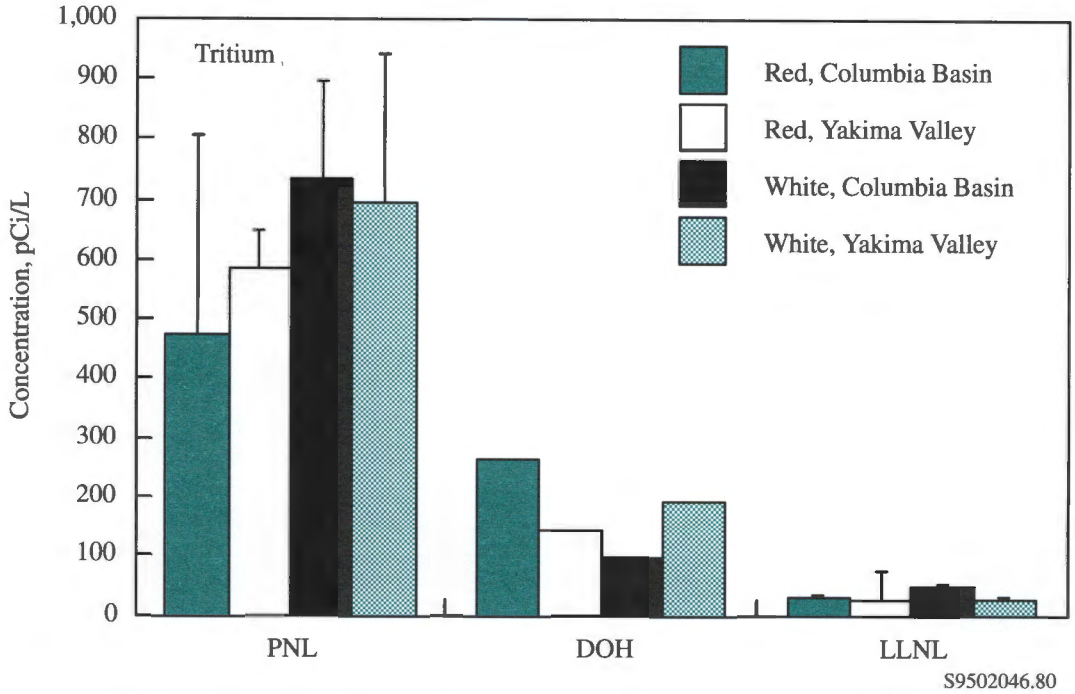


Figure 5.4.4 Comparison of Tritium Concentrations in Replicate Samples of Four Varieties of 1993 Wine Analyzed by PNL, DOH, and LLNL

1993. These 1993 data are summarized in this report.

Results

Gamma spectroscopy of wine samples did not indicate the presence of cesium-137 or cobalt-60 in any of the samples. The minimum detectable concentrations (MDCs) for cesium-137 or cobalt-60 in wine are 9 and 8 pCi/L, respectively.

The results for tritium in 1994 wine samples indicate no difference between upwind and downwind locations (Table 5.4.3). Concentrations reported in 1994 are lower than those observed in 1993; however, the difference between years is small. Over the past 5 years, tritium concentrations in wine have ranged as high as three times the MDC of 300 pCi/L. Split samples analyzed by the DOH are generally lower than levels reported by PNL (Dirkes et al. 1994) . Last year, we split samples with DOH and Lawrence Livermore National Laboratory (LLNL). Samples were analyzed by high-resolution mass spectroscopy of helium (He-MS). Helium is the decay product of tritium, and the amount can be quantified, after an extended incubation period, to determine tritium concentrations. The tritium concentrations determined by He-MS are significantly lower than results obtained by the distillation method used by PNL and DOH. (Figure 5.4.4). Tritium analyses performed on water distilled from wine slightly overestimates the true concentration of tritium in wine, assuming that most wines are about 12% alcohol by volume. Very little tritium is believed to be incorporated into the ethanol fraction of wine (NCRP 1979). The distillation method has been used because of lower cost, shorter turnaround time, and the detection limit of 300 pCi/L, which is considerably higher than the He-MS method but sufficiently low enough to ensure public safety. The concentrations of tritium are well below levels considered hazardous for the consumption of liquids. While there is no tritium standard for wine, the standard for drinking water is 20,000 pCi/L.

Table 5.4.3 Tritium Concentrations in Wine (pCi/L of distilled liquid), 1994 Compared to Values from the Previous 5 Years

Type of Wine	Location	1994 Maximum[a]	1994 Mean[b]	1994 No. Less Than Detection[c]
White wine	Columbia Basin	410 ± 200	330 ± 110	1 of 3
	Yakima Valley	490 ± 210	280 ± 230	1 of 3
Red wine	Columbia Basin	430 ± 200	330 ± 100	0 of 3
	Yakima Valley	560 ± 210	470 ± 150	0 of 3

		1989-1993 Maximum[a]	1989-1993 Mean[b]	1989-1993 No. Less Than Detection[c]
White wine	Columbia Basin	930 ± 300	500 ± 130	4 of 15
	Yakima Valley	940 ± 260	450 ± 110	5 of 15
Red wine	Columbia Basin	790 ± 230	420 ± 100	6 of 15
	Yakima Valley	650 ± 240	390 ± 130	4 of 15

(a) Maximum ±2 total propagated analytical uncertainty.
(b) Mean ±2 standard error of the calculated mean.
(c) Number of samples with values less than the ±2 total propagated analytical uncertainty out of number of samples analyzed.

Wheat and Alfalfa

Sample Collection and Analysis

Samples of ripened wheat and mature alfalfa were collected from the areas shown in Figure 5.4.1. Three replicate samples of alfalfa were collected at each location and analyzed for gamma emitters and strontium-90. Wheat from the Sagemoor area was analyzed for gamma emitters, plutonium-239,240, and strontium-90.

Results

No manmade radionuclides were detected in any of the wheat samples collected in 1994. All results for wheat analyses are listed by Bisping (1995).

Alfalfa irrigated with Columbia River water withdrawn downstream from Hanford (Riverview and Horn Rapids) continued to show slightly higher concentrations of strontium-90 relative to other locations (Figure 5.4.5, Table 5.4.4). Samples from Sagemoor and East Wahluke (locations that use Columbia Basin Irrigation Project water), and

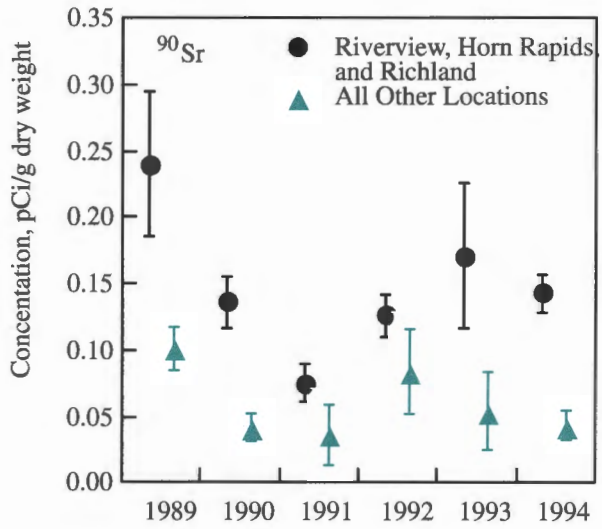


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Figure 5.4.5 Mean (±2 standard error of the mean) Strontium-90 Concentrations in Alfalfa Routinely Collected at Riverview, Horn Rapids, Richland and All Other Sampling Locations, 1989 Through 1994

Table 5.4.4 Strontium-90 in Alfalfa Samples (pCi/g dry weight), 1994

Location	Concentration[a]	No. of Samples	Irrigation Water Source
Horn Rapids	0.149 ± 0.009	3	Columbia River
Riverview	0.138 ± 0.030	3	Columbia River
East Wahluke	0.042 ± 0.007	3	Roosevelt Lake[b]
Sagemoor	0.034 ± 0.009	3	Roosevelt Lake
Sunnyside	0.036 ± 0.005	3	Yakima River
Benton City	0.077 ± 0.004	3	Yakima River

(a) Concentrations are means ±2 standard error of the mean.
(b) Columbia Basin Irrigation Project water.

Sunnyside and Benton City (locations that use water from the Yakima River) had strontium-90 concentrations that were lower than those at Riverview and Horn Rapids in 1994. Analysis of Columbia River water at Priest Rapids Dam and the Richland Pumphouse, however, indicated that strontium-90 concentrations in water from both locations were similar. Differences in strontium-90 concentrations in alfalfa, based on sources of irrigation water, appear significant. However, the actual concentrations at all locations are low and difficult to separate from the influence of fallout (Jaquish 1993).

Cesium-137 was the only manmade gamma emitter detected (in four of the 18 samples; two at Sagemoor, one each at Sunnyside and Horn Rapids) in alfalfa at the detection limit (0.02 ± 0.01 pCi/g).

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5.5 Fish and Wildlife Surveillance

T. M. Poston

Contaminants in fish and wildlife species that inhabit the Columbia River and Hanford Site are monitored for several reasons. Wildlife have access to areas of the Site containing radioactive contamination, and fish can be exposed to contamination in spring water entering the river along the shoreline. Fish and some wildlife species exposed to Hanford effluents might be harvested and may potentially contribute to the dose people receive. In addition, detection of radionuclides in fish and wildlife may indicate that wildlife are entering restricted contaminated areas (for example, burrowing in burial grounds) or that radioactive material is moving out of these restricted areas (for example, through blowing dust). Consequently, samples are collected at various locations annually, generally during the hunting or fishing season, for selected species (Figure 5.5.1).

Many of the operating facilities residing near nuclear facilities are buffered by natural areas, such as the ALE Reserve. These buffer zones isolate nonnomadic species on the Hanford Site (for example, rabbits) from contact with the public. Therefore, these species are not hunted. More detailed rationale for selection of specific species sampled in 1994 can be found in DOE (1991b).

When radionuclides are found in fish or wildlife, it is important to determine what fraction of those radionuclides originated at Hanford. Therefore, samples of fish and wildlife collected from distant locations unaffected by Hanford effluents (background locations) are analyzed, and results are compared to results from Hanford samples to identify any differences. Routine background sampling is conducted roughly every 5 years at locations believed to be unaffected by Hanford releases. Background data may also be collected during special studies or sampling efforts. In 1994, background concentrations were measured in carp from Vantage, pheasants from the Yakima Valley, and deer from offsite.

For each species of fish or wildlife, radionuclides are selected for analysis based on the potential for the contaminant to be found at the sampling site and the potential to accumulate in fish or wildlife (Table 5.5.1). Cesium-137 and strontium-90 have been the most frequently measured radionuclides in fish and wildlife.

Strontium is chemically similar to calcium; consequently, it accumulates in hard tissues high in calcium such as bone, antlers, and egg shells. It has a long biological half-life in hard tissue and may profile the lifetime exposure of an organism to strontium-90. However, strontium-90 in wildlife samples generally does not contribute much to human dose because it does not accumulate in edible portions of fish and wildlife. Spring water in the 100-N Area is the primary source of strontium-90 from Hanford to the Columbia River; however, the current contribution, relative to historical fallout from atmospheric weapons testing, is small (Jaquish 1993).

Cesium is particularly important because it is chemically similar to potassium and accumulates in the muscle tissue of fish and wildlife. It is more likely, therefore, to contribute to the dose received by hunters and fishers from the consumption of game and fish. It has a relatively short biological half-life and is an indicator of more recent exposure to radioactive materials. Cesium-137 is also a major constituent of historical fallout.

Fish and wildlife samples were analyzed by gamma scan to detect a number of gamma emitters (see Appendix F). However, gamma scan results for most radionuclides are not discussed below because concentrations were too low to measure or because measured concentrations were considered artifacts of low background counts. Low background counts occur at random intervals during sample counting and can produce occasional spurious results.

Other specific radiochemical analyses were performed on fish and wildlife samples to measure plutonium-238, plutonium-239,240, technetium-99, uranium-234, uranium-235, and uranium-238. These radionuclides provide an indication of contaminant levels in edible portions of fish and wildlife and are useful when estimating doses to consumers. These radionuclides are important because:

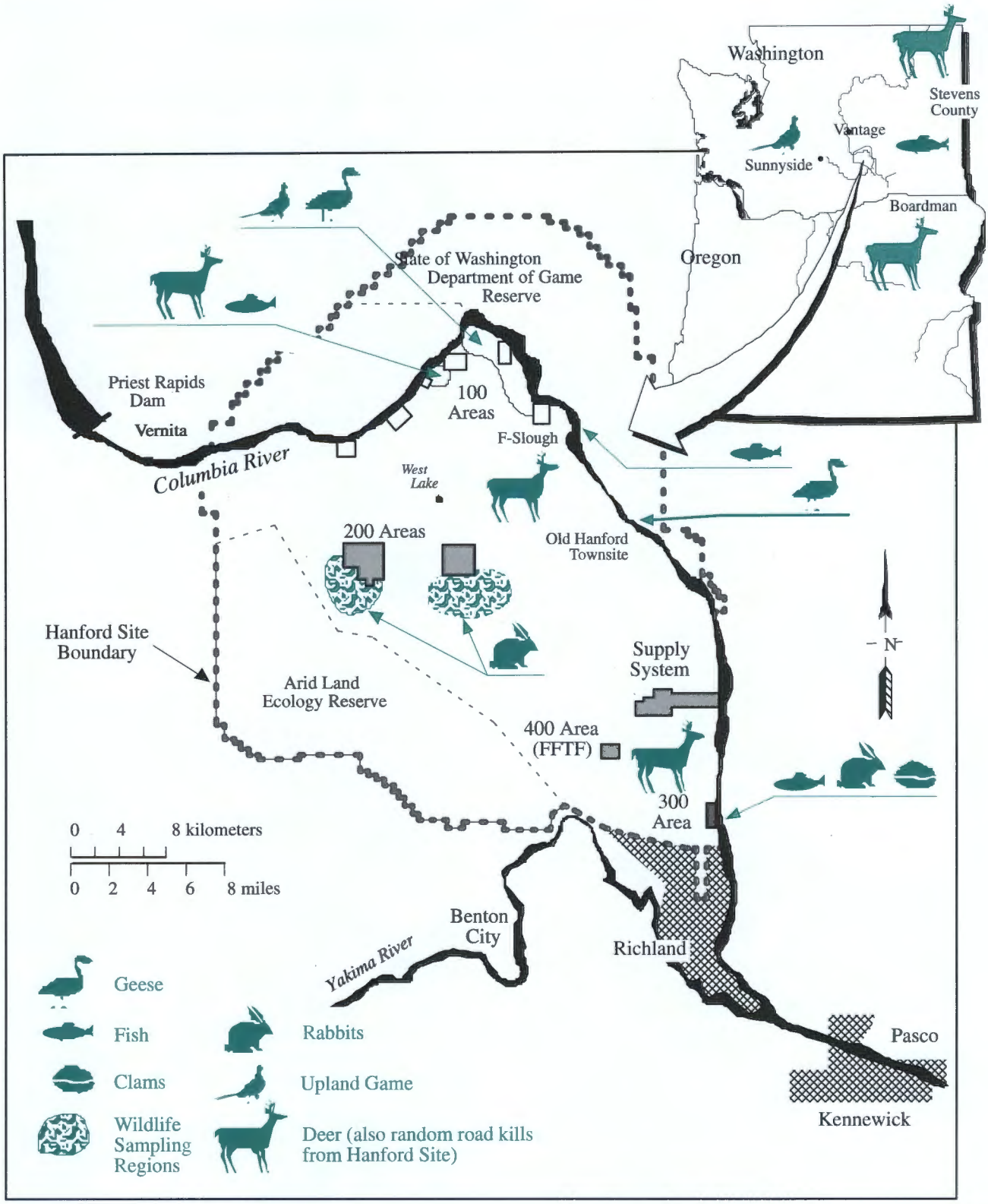

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Figure 5.5.1 Fish and Wildlife Sampling Locations, 1994

Table 5.5.1 Locations, Species, and Radionuclides Sampled for Fish and Wildlife, 1994

Media	Number of Species	Onsite Locations	Radionuclides Sampled/Number of Locations				
			Gamma	^{90}Sr[a]	^{99}Tc	U	Pu[b]
Fish (Bass, Carp, Whitefish)	3	3	3	3	1	1	0
Geese	1	2	2	2	0	0	0
Upland gamebirds	2	3	3	3	0	0	0
Mule deer	1	5	5	2	0	0	3
Rabbits	2	3	3	3	0	0	3
Clams	1	1	1	1	0	1	0

(a) Analyzed in bone and some muscle samples.
(b) Analyzed in liver only.

- Technetium-99 is known to enter the Columbia River in shoreline seeps and springs and has a long half-life. In addition, its potential to accumulate in fish is not well-known.
- Isotopes of uranium enter the Columbia River in springs near the 300 Area and have been reported at slightly elevated concentrations in soil and vegetation near the 300 Area.
- Isotopes of plutonium accumulate in liver and may ultimately be deposited in bone. Liver tissue was analyzed in selected wildlife to monitor potential exposure to terrestrial contamination.

Fish Sampling

Bass, carp, and whitefish were collected from the Hanford Reach in the summer and winter of 1994. Fish are very mobile and the length of time they reside at any given sampling location is unknown. This mobility may explain why analytical results in fish are generally variable. A report on trends of radionuclide concentrations in fish was prepared in 1994 and provides detailed analysis of cesium-137 and strontium-90 in fish samples collected from 1982 through 1992 (Poston 1994). Results from all 1994 samples are listed by Bisping (1995).

Bass

Sample Collection and Analysis

Bass are sampled on alternating even years (Bisping 1994). Five bass were collected from the 100-F Slough in May 1994. The 100-F slough is located downstream of 100-N Springs and represents the largest backwater area suitable for the collection of adequate numbers of bass in the Hanford Reach. Bass were collected in May when they congregate in the sloughs to spawn, which is a behavioral characteristic that facilitates sample collection.

Muscle (fillet) samples and offal (referred to as carcass samples in past reports) samples were collected for analysis of gamma emitters and strontium-90.

Results

Cesium-137 was detected in all five fillet samples collected in 1994. The mean concentration was 0.04 ± 0.01 pCi/g (see Appendix A, Table A.11). When last sampled in 1992, the mean concentration was 0.02 ± 0.01 pCi/g. The 1994 concentrations of cesium-137 represent normal fluctuations close to the MDC of 0.02 pCi/g. Strontium-90 was not detected in any of the five fillet samples analyzed (MDC = 0.005 pCi/g).

The mean concentration of strontium-90 in bass offal was 0.019 ± 0.006 pCi/g (see Appendix A, Table A.11). These results were lower than the mean

concentration observed in bass offal samples collected from 1989-1993 (0.031 ± 0.007 pCi/g). There has been a general reduction in strontium-90 concentrations measured in bass offal since 1986 (Poston 1994); however, the changes in the last 5 years have been small because concentrations are very close to background levels (Figure 5.5.2).

Carp

Sample Collection and Analysis

Five carp were collected from the Columbia River between the 100-N and 100-D Areas because of the proximity of the N Springs and its release of strontium-90 to the river. Five carp were also collected near the 300 Area because of the potential releases of gamma emitting radionuclides, strontium-90, and uranium from ground-water springs along the river shoreline at the 300 Area and upstream. Additionally, carp were collected at Vantage in July 1994 to evaluate background concentrations. Muscle tissues and offal samples were analyzed.

Results

The only manmade radionuclides found in Columbia River carp were strontium-90 in offal and cesium-137 in muscle samples.

Muscle. Strontium-90 was not detected in carp muscle samples from Vantage, the 100 Areas, or the 300 Area (MDC = 0.005 pCi/g). Cesium-137 also was not routinely detected in muscle samples (see Appendix A, Table A.11); however, there were several instances of cesium-137 detected at the MDC of 0.02 pCi/g (Bisping 1995). Concentrations of both radionuclides in carp muscle are hovering at the MDC, and there is no indication of accumulation of cesium-137 above background levels in carp muscle.

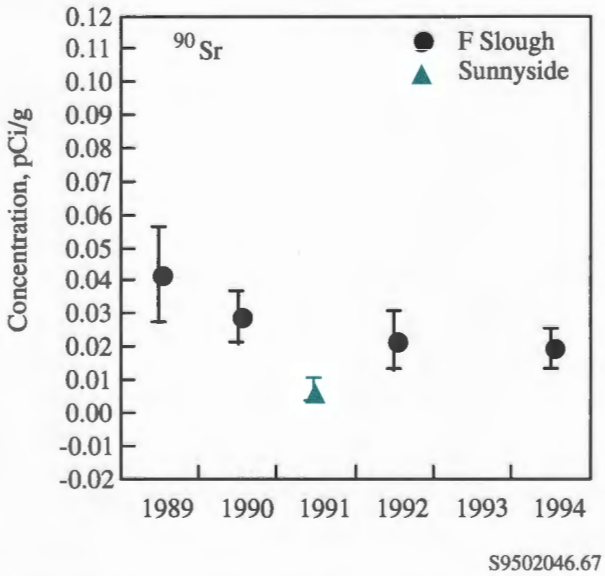

Figure 5.5.2 Strontium-90 (±2 standard error of the mean) in Bass Offal, 1989 Through 1994

Offal. Concentrations of strontium-90 in carp offal were higher in samples collected at Vantage than in samples collected at either the 100-N to 100-D Areas or the 300 Area (see Appendix A, Table A.11). The maximum observed concentration of strontium-90, 0.150 ± 0.035 pCi/g, was found in an offal sample collected from the 300 Area. Concentrations of strontium-90 in offal samples from Vantage generally exceeded concentrations reported in Hanford Reach carp offal samples collected in 1994; however, the range in concentrations at each sampling area is similar.

Whitefish

Sample Collection and Analysis

Whitefish were collected because historically they have been the Columbia River sport fish that accumulated the highest radionuclide concentrations. Whitefish are currently collected from the Columbia River along the 100-N to 100-D Area shoreline and along the 300 Area shoreline. Background samples were collected in 1991 from the Kettle River, which enters the Columbia River upstream from Grande Coulee Dam. Ten whitefish samples were collected between the 100-N and 100-D Areas in August 1994, and seven whitefish samples were collected from the 300 Area in September and December 1994.

Results

Muscle. Strontium-90 was measured in one of the ten muscle samples collected between the 100-N and 100-D Areas in 1994 [0.012 ± 0.005 pCi/g (Bisping 1995)], but was not measured in the nine muscle samples collected and analyzed from the 300 Area (MDC is 0.005 pCi/g).

Cesium-137 was measured in half of the muscle samples collected between the 100-N and 100-D Areas and in none of the samples from the 300 Area (see Appendix A, Table A.11). Concentrations over

the past 6 years have remained near the minimum detectable concentration (0.02 pCi/g).

No other manmade radionuclides were detected in 1994 whitefish muscle samples (Bisping 1995).

Offal. Mean and maximum concentrations of strontium-90 in whitefish offal were higher in 1994 than for the previous 5 years. Strontium-90 was found in all offal samples analyzed (see Appendix A, Table A.11). Mean concentrations of strontium-90 in whitefish offal sampled from the Kettle River in 1991 were approximately three times those reported in 300 Area whitefish offal samples and equivalent to those found in 100 Areas whitefish offal samples in 1994. The higher background concentrations may indicate exposure to elevated levels of fallout radioactivity in that area. The Kettle River drainage generally receives more precipitation, hence potentially more fallout, than does the Hanford Site.

Clam Sampling

Asiatic clams were collected along the Columbia River shoreline downstream of the 300 Area in the summer of 1994. The soft tissues were analyzed for gamma emitters, strontium-90, uranium-234,-235, and -238. The shells were analyzed for strontium-90 only.

Results

Concentrations of radionuclides in Asiatic clams were similar to results reported in the past (Table 5.5.2 and Woodruff et al. 1992). Concentrations of cesium-137 and strontium-90 in soft tissues collect in 1990 from the 300 Area were also very close to the limits of detection (0.005 and 0.02 pCi/g, respectively). The concentration of strontium-90 in clam shell is consistent with levels reported in other hard tissues from Site wildlife (fish offal, wildlife bone, and antler samples).

Wildlife Sampling

Wildlife sampled in 1994 for radioactive constituents included deer, jackrabbits, geese, pheasants, and pigeons. A report on radioactivity in wildlife was prepared in 1994 (Poston and Cooper 1994) and provides additional details on recent concentration trends in wildlife from 1983 through 1992. Results from all 1994 samples are listed by Bisping (1995).

Deer

Sample Collection and Analysis

Samples were taken from Hanford Site mule deer that were selectively hunted (three deer near the 100-N Area) or killed in road accidents. Samples included muscle, bone, antler, and liver, which were analyzed for radionuclides. While deer hunting is not allowed onsite, deer can leave the Site, and a small number of deer potentially from Hanford are harvested annually from Columbia River islands and across the river in Grant and Franklin counties. Road kill sampling was employed to minimize impacts to the Hanford deer population. Radionuclide concentrations in animals collected on the Site were compared to concentrations in deer collected distant from the Site from 1992 through 1994 at Boardman, Oregon and in Stevens County, Washington. The Stevens County deer

Table 5.5.2 Radionuclide Concentrations in Asiatic Clams Collected from the Columbia River Downstream of the 300 Area

Radionuclide	Tissue	Concentration[(a)] 1994	Concentration[(a)] 1991
^{90}Sr	Shell	0.28 ± 0.056	
^{90}Sr	Soft Tissues	0.003 ± 0.004	0.003 ± 0.002
^{137}Cs	Soft Tissues	-0.02 ± 0.03	-0.003 ± 0.008
^{234}U	Soft Tissues	0.052 ± 0.011	0.050 ± 0.006
^{235}U	Soft Tissues	0.002 ± 0.002	0.001 ± 0.001
^{238}U	Soft Tissues	0.042 ± 0.010	0.045 ± 0.006

(a) pCi/g ± 2 total propagated analytical uncertainty.

samples were donated to the program. These comparisons are useful in evaluating Hanford's impact to deer; however, because the distant sampling area at Stevens County gets more rainfall than Hanford, background concentrations of cesium-137 and strontium-90 are usually higher in those deer than in onsite deer (Poston and Cooper 1994). This relationship was not noted in deer at the background location in Boardman, Oregon because the climate is similar to Hanford.

Results

Muscle. Two of seven deer sampled at Hanford had positive measurements of cesium-137 in muscle (see Appendix A, Table A.12). Both were collected near the 100-N Area. The maximum concentration of cesium-137 was 0.007 ± 0.003 pCi/g. This maximum concentration was less than background concentrations of cesium-137 measured in donated deer samples collected in 1992 and 1994 from Stevens County and in 1994 deer samples from Boardman, Oregon.

Bone. Strontium-90 was detected in all deer bone samples analyzed in 1994, and the maximum concentration on the site was 0.93 ± 0.24 pCi/g (see Appendix A, Table A.12). Boardman deer bone samples had a mean concentration of 0.11 ± 0.015 pCi/g strontium-90 which was lower than the Stevens County results. These higher levels in onsite deer bone may indicate some route of low-level exposure onsite (Table A.12). During the last 5 years, concentrations of strontium-90 have been elevated in deer bone collected near the 100-N Area relative to the rest of the Site. The likely source of these elevated concentrations is the 100-N Area where strontium-90 is known to enter the river.

Antler. Strontium-90 concentrations in mule deer antlers collected from the Hanford Site from 1991 through 1994 were compared to strontium-90 concentrations in antlers collected at Silver Lake, Oregon. The Silver Lake area was selected because it is semi-arid and has been used in prior studies on background levels of radionuclides in deer. Initial results for antlers collected at Hanford indicated that deer inhabiting the 100 Areas had a higher range of strontium-90 in antlers (0.31 to 0.68 pCi/g) than deer near the Old Hanford townsite and south to the 300 Area (0.10 to 0.26 pCi/g). In comparison, concentrations of strontium-90 in Silver Lake deer antlers were a factor of 10 higher than Hanford Site deer (1.2 ± 0.24 to 4.5 ± 0.83 pCi/g). The reason for the elevated concentrations is that the Silver Lake deer spend the summer months in the surrounding mountains when their antlers are growing. These mountains have historically received more fallout strontium-90 than the semiarid Silver Lake area and the Hanford Site. Soil measurements of strontium-90 from the Silver Lake area ranged from 0.14 ± 0.030 to 0.23 ± 0.045 pCi/g in the valley and 0.54 ± 0.10 to 0.69 ± 0.13 pCi/g in the mountains. The mean (± 2 standard error of the mean) strontium-90 concentration in soils collected from the Hanford Site deer sampling areas was 0.31 ± 0.11 pCi/g for the period 1983 through 1993. Collectively, these results suggest that concentrations of strontium-90 in antler reflect general environmental exposure as indicated by soil concentrations.

Liver. Isotopes of plutonium were not detected in any deer liver samples collected in 1994. Liver data for 1994 are summarized by Bisping (1995).

Rabbits

Sample Collection and Analysis

Rabbits have small home ranges. They cannot be hunted for human consumption on the Hanford Site, and they cannot cross the Columbia River to areas where they could be hunted. However, rabbits are good indicators of potential exposure to contamination because they occupy burrows and can enter fenced restricted areas. Rabbit populations are cyclic and attempts to collect rabbits onsite in 1994 were only marginally successful (16 planned, 6 collected). Muscle, bone, and liver samples were taken from four jackrabbits collected from the 200-E Area, a jackrabbit collected from the 200-West area, and a cottontail collected at the 300 Area. Background samples of jackrabbits and cottontails were last collected at Boardman, Oregon in 1990.

Results

Muscle. Muscle concentrations of cesium-137 were similar to the range measured in the past 5 years (Table 5.5.3). Most values were less than detection limits or measured right at the limit of detection. The maximum observed concentrations of cesium-137 in muscle indicate that some animals may be entering low-level radiation control areas onsite.

Table 5.5.3 Summary of Cesium-137 in Rabbit Muscle (pCi/g wet weight), 1994 Compared to Values from the Previous 5 Years

Location/ Species	1994			1989-1993		
	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
200-East Area jackrabbit	0.04 ± 0.03	0.01 ± 0.04	3 of 4	0.25 ± 0.05	0.03 ± 0.03	11 of 15
200-West Area jackrabbit	-0.02 ± 0.03	---	1 of 1	0.15 ± 0.03	0.02 ± 0.03	7 of 12
300 Area cottontail	0.00 ± 0.04	---	1 of 1	---	---	---
Boardman[d]	---	---	---	0.03 ± 0.027	0.005 ± 0.005	19 of 20

(a) Maximum is the concentration in pCi/g ±2 total propagated analytical uncertainty.
(b) Mean is pCi/g ±2 standard error of the mean.
(c) Number of samples with values less than the detection limit out of number of samples analyzed.
(d) Collected in 1990, combined jackrabbit and cottontail data (no difference).

Bone. Strontium-90 was found in all four 200-E rabbit bone samples at levels about a factor of ten higher than the 200-W Area sample (Table 5.5.4). The maximum concentration of 14.2 ± 3.2 pCi/g indicates onsite exposure to low levels of strontium-90 around or in the 200-E Area.

Liver. No isotopes of plutonium were found above detection limits in liver samples from any rabbits collected in 1994 (<0.0004 pCi/g plutonium-238 or plutonium-239,240 (Bisping 1995).

Waterfowl

Sample Collection and Analysis

Resident duck sampling was terminated in 1994 because the draining and decommissioning of B-Pond and low water levels in West Lake eliminated

Table 5.5.4 Summary of Strontium-90 in Rabbit Bone (pCi/g wet weight), 1994 Compared to Values from the Previous 5 Years

Location/ Species	1994			1989-1993		
	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
200-East Area jackrabbit	14.2 ± 3.2	7.4 ± 5.4	0 of 4	49 ± 8.9	9.5 ± 7.0	0 of 15
200-West Area jackrabbit	0.43 ± 0.10	---	0 of 1	140 ± 4	14 ± 24	0 of 12
300 Area cottontail	0.12 ± 0.05	---	0 of 1	---	---	---
Boardman[d]						
jackrabbit	---	---	---	0.91 ± 0.09	0.47 ± 0.09	0 of 10
cottontail	---	---	---	0.36 ± 0.08	0.27 ± 0.03	0 of 10

(a) Maximum is the concentration in pCi/g ±2 total propagated analytical uncertainty.
(b) Mean is pCi/g ±2 standard error of the mean.
(c) Number of samples with values less than the detection limit out of number of samples analyzed.
(d) Collected in 1990.

most viable duck habitat on the Site. Duck sampling was replaced with Canada goose sampling, and two geese were collected along the Columbia River in 1994: a western Canada goose from the Old Hanford townsite, and a lesser Canada goose from the area between the 100-N and 100-D Areas. The lessor Canada goose was a migrating bird; the western Canada goose may have been either a resident or a migrant. Muscle tissue was analyzed for gamma emitters and strontium-90, and bone was analyzed for strontium-90. Goose eggshell collections were scheduled in 1994; however, coyotes have gained access to Hanford Reach islands, and there was no successful nesting on the islands in 1994.

Results

The concentration of cesium-137 in the Hanford Townsite goose muscle was 0.03 ± 0.02 pCi/g (Table 5.5.5). Strontium-90 was not detected in muscle from either fowl; however, the concentration in bone from the Old Hanford townsite goose was lower than that found in the migrating goose collected from the area between the 100-N and 100-D Areas.

Pheasants

Sample Collection and Analysis

During the fall of 1994, 12 Chinese ringneck pheasants were collected on the Hanford Site. Additionally, ten pheasants were collected in Yakima County, which is located generally upwind of the Hanford Site. This game bird has the potential to migrate across the Columbia River or move onto river islands where it may be hunted. Conversely, hunting pressure in Franklin County may force pheasants onto the Hanford Site. Samples of muscle were analyzed for gamma emitters, and bone samples were analyzed for strontium-90.

Results

Muscle. Cesium-137 was not measured in Yakima Valley pheasant muscle collected in 1994 (Bisping 1995). The maximum value of 0.16 ± 0.14 pCi/g in the Yakima County sample is believed to be an anomalous result. Two of the 12 birds collected from the 100 Areas had detectable concentrations of cesium-137 greater than the MDC of 0.02 pCi/g (Table 5.5.6).

Bone. Strontium-90 was found in Hanford Site pheasant bones at roughly twice the level in background pheasants collected in Yakima County in 1994; however, the 1994 results are within the concentration range seen in background pheasant collected in 1990 (Figure 5.5.3)

Pigeons

Sample Collection and Analysis

Whole body pigeon samples were collected and scanned with a portable gamma spectrometer. This was a qualitative screening analysis to evaluate the possible concentrations of gamma emitters in pigeons. Pigeons collected at the Old Hanford townsite, 100-K Area, and 300 Area were screened. Accumulations of cesium-137 in birds would be expected in stomach contents, grit in the crop, and muscle. If unexpectedly high concentrations had been obtained, the birds would have been submitted for more precise radiochemical analysis.

Table 5.5.5 Concentrations of Radionuclides (±2 total propagated analytical uncertainty) in Canada Geese Sampled in 1994

Radionuclide	Concentration (pCi/g wet weight)	Variety	Tissue	Site Collected
^{137}Cs	0.003 ± 0.020	Lesser	Muscle	100-N to 100-D
^{137}Cs	0.031 ± 0.020	Western	Muscle	old Hanford Townsite
^{90}Sr	0.192 ± 0.059	Lesser	Bones	100-N to 100-D
^{90}Sr	0.049 ± 0.031	Western	Bones	old Hanford Townsite
^{90}Sr	-0.001 ± 0.002	Lesser	Muscle	100-N to 100-D
^{90}Sr	0.000 ± 0.003	Western	Muscle	old Hanford Townsite

Table 5.5.6 Summary of Cesium-137 in Upland Gamebird Muscle (pCi/g wet weight), 1994 Compared to Values from the Previous 5 Years

	1994			1989-1993		
Location	Maximum[a]	Mean[b]	No. Less Than Detection [c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
Pheasants						
100-D to 100-H Areas	0.17 ± 0.03	0.05 ± 0.08	3 of 4	0.04 ± 0.02 [d]	0.01 ± 0.01[d]	21 of 25[d]
100-H to 100-F Areas	0.02 ± 0.01	0.01 ± 0.01	5 of 6			
100-N	-0.01 ± 0.01	-0.02 ± 0.01	2 of 2	2.00 ± 0.20	---	1 of 1
Yakima County	0.16 ± 0.14	0.02 ± 0.03	10 of 10	0.007 ± 0.013	0.001 ± 0.007	10 of 10[e]

(a) Maximum is the concentration in pCi/g ±2 total propagated analytical uncertainty.
(b) Mean is pCi/g ±2 standard error of the mean of all samples analyzed including less-than-detection values.
(c) Number of samples with values less than the detection limit out of number of samples analyzed.
(d) 100-D to 100-F Areas combined.
(e) Collected in 1990.

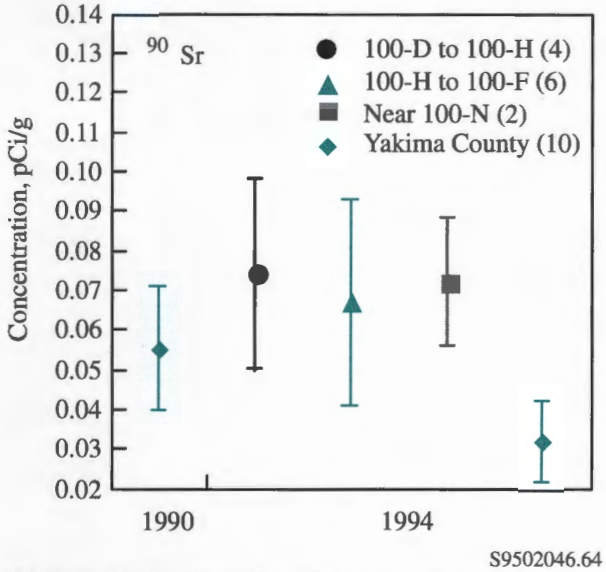

Figure 5.5.3 Strontium-90 (±2 standard error of the mean) in Pheasant Bone Sampled in 1994. The number of samples analyzed is in parentheses.

Results

Screening results are reported as pCi/bird and bird weights are generally about 150 g. The screening analysis found only a slight indication of activity in two of nine birds screened, one from the 100 Areas (5.9 pCi/bird) and one from the old Hanford townsite (2.5 pCi/bird). These concentrations indicate background concentrations and no additional analyses were conducted. Pigeon screening data for 1994 are summarized by Bisping (1995).

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5.6 Soil and Vegetation Surveillance

E. J. Antonio

Soil is a valuable environmental monitoring medium because it can accumulate contaminants from both current air emissions and resuspended materials. Hence, soil sampling and analysis evaluates long-term contamination trends and monitors environmental radionuclide inventories (DOE 1991a). In 1994, 20 surface soil samples were taken to evaluate potential radiological impacts from Hanford operations. Fifteen samples were collected within the Hanford Site boundary, four from locations near the Hanford Site perimeter and one from a distant location.

Vegetation surveillance is conducted offsite to monitor atmospheric deposition of radioactive materials in areas not under cultivation and onsite at locations adjacent to potential sources of environmental radioactivity. Nine samples of perennial vegetation were obtained during 1994, four from onsite locations, one from a distant location, and four from perimeter locations (Figure 5.6.1). Soil and vegetation sampling is conducted to monitor the accumulation of radionuclides released from Hanford facilities, to compare current data with previous years' data to determine long-term trends, and to add to the existing database of radionuclide concentrations in soils and vegetation both on and off the Hanford Site.

Radiological contributions from Hanford operations were assessed by comparing results from samples taken onsite with those collected offsite. Results obtained in 1994 were also compared to results from previous years.

Sample Collection and Analysis

Soil and vegetation samples were collected at locations shown in Figure 5.6.1 and summarized in Table 5.6.1. Onsite soil sampling was concentrated around operational areas. Soil samples designated as perimeter were taken from areas near the Site boundary or well away from operational areas. Downwind perimeter locations (Ringold, Sagemoor area, Byers Landing, and Riverview) are areas where the maximum effects from stack emissions would be expected to be found offsite. Upwind perimeter locations (Berg Ranch, Wahluke Slope, Vernita Bridge, Yakima Barricade, Rattlesnake Springs, Prosser Barricade, and the ALE Reserve) are sampled once every 3 years and were not sampled in 1994. Each soil sample was a composite of five plugs, each 2.54 cm deep by 10.2 cm in diameter (1 in. by 4 in.) and collected within 10 m (33 ft) of one another.

Perennial vegetation samples consisted of new growth from shrub-steppe species, rabbitbrush and sagebrush. Vegetation samples were collected from the same general areas as the soil samples.

Results for Soil

The radionuclides detected most consistently (more than 50% of the time) in soil samples were beryllium-7, cesium-137, plutonium-239,240, potassium-40, strontium-90, and uranium-238. Beryllium-7 is a naturally occurring, cosmogenic radionuclide with a half-life of 53 days and is not of Hanford origin. Potassium-40 is a naturally occurring, primordial radionuclide with a half-life longer than one billion years and is not of Hanford origin. Cesium-137 and strontium-90 are both fission products and have half-lives of 29.1 years and 30 years, respectively; these radionuclides may be of Hanford origin or from atmospheric fallout. Uranium-238 is also a naturally occurring, primordial radionuclide with a half-life of 4.51 billion years and is naturally found in soils on and off the Hanford Site; however, uranium-238 was also a product of the PUREX Plant and former fuel fabrication activities in the 300 Area, and therefore may be of Hanford origin. Plutonium isotopes in soils near the Hanford Site may be from historical Hanford operations or may result from atmospheric fallout.

Radionuclide concentrations in soil are reported in Table 5.6.2 and Appendix A, Tables A.13 through A.16. Concentrations are shown in Figures 5.6.2 and 5.6.3. Nonparametric statistical methods were used to detect differences between locations. The Multi-Response Permutation Procedure (Mielke 1984) calculates the probability that the data sets are similar and represents that likelihood with a p value. A p value

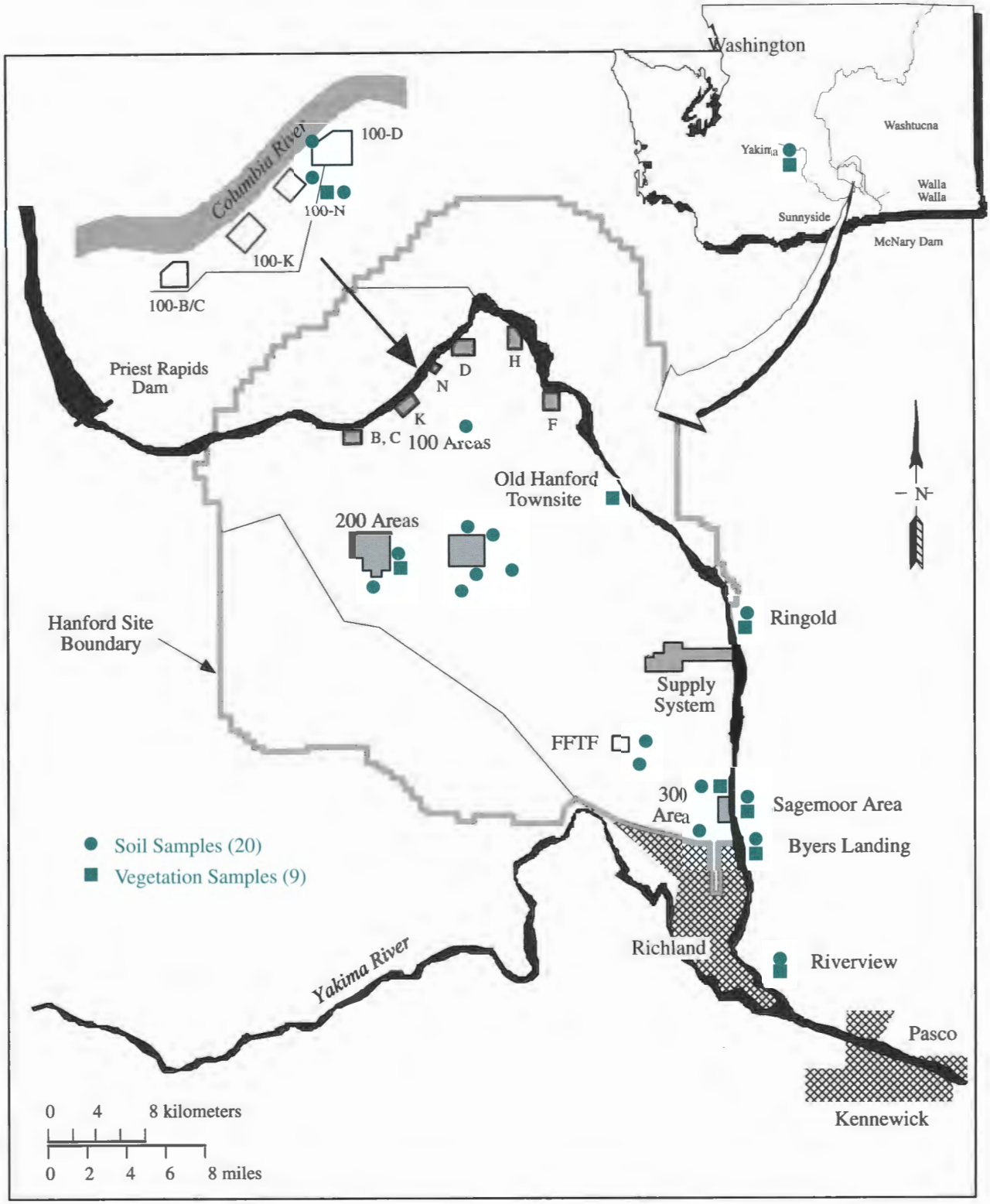

Figure 5.6.1 Soil and Vegetation Sampling Locations, 1994

Table 5.6.1 Soil and Vegetation Samples Collected, 1994

General Location	No. of Samples	Frequency	Analytes
Soil			
Onsite	15	Annual to once every 3 years	Gamma, ^{90}Sr, U_{LEPS}[a], Pu[b], ^{241}Am
Distant	1	Annual	Gamma, ^{90}Sr, U_{LEPS}, Pu, ^{241}Am
Downwind Perimeter	4	Annual to once every 3 years	Gamma, ^{90}Sr, U_{LEPS}, Pu, ^{241}Am
Vegetation			
Onsite	4	Annual to once every 3 years	Gamma, ^{90}Sr, U_{iso}[c], Pu
Distant	1	Annual	Gamma, ^{90}Sr, U_{iso}, Pu
Perimeter	4	Annual	Gamma, ^{90}Sr, U_{iso}, Pu

(a) U_{LEPS} is a method of analyzing for uranium by detecting low-energy photons.
(b) Isotopic plutonium.
(c) U_{iso} is a method of analyzing for uranium by detecting alpha particles.

Table 5.6.2 Radionuclide Concentrations in Soil Samples Collected on and off the Hanford Site (units are pCi/g dry weight), 1994 Compared to Values from the Previous 5 Years

		1994			1989-1993		
Location	Radio-nuclide	No. of Samples	Maximum[a]	Mean[b]	No. of Samples	Maximum[c]	Mean[d]
Onsite	^{90}Sr	15	0.70 ± 0.13	0.15 ± 0.088	54	2.7 ± 0.49	0.27 ± 0.12
	^{137}Cs	15	12 ± 1.3	1.1 ± 1.6	54	18 ± 1.8	1.3 ± 0.76
	$^{238}U_{LEPS}$ [e]	15	1.0 ± 0.52	0.74 ± 0.069	37	1.5 ± 0.29	0.65 ± 0.096
	$^{238}U_{iso}$ (f)				17	1.0 ± 0.13	0.71 ± 0.071
	$^{239,240}Pu$	15	0.39 ± 0.38	0.035 ± 0.051	54	0.66 ± 0.080	0.044 ± 0.033
Perimeter	^{90}Sr	4	0.15 ± 0.029	0.076 ± 0.048	44	0.33 ± 0.063	0.12 ± 0.021
	^{137}Cs	4	0.32 ± 0.092	0.19 ± 0.089	44	1.8 + 0.21	0.54 ± 0.12
	$^{238}U_{LEPS}$	4	1.0 ± 0.41	0.73 ± 0.22	32	1.5 ± 0.30	0.72 ± 0.097
	$^{238}U_{iso}$				15	0.91 ± 0.12	0.74 ± 0.052
	$^{239,240}Pu$	4	0.0061 ± 0015	0.0036 ± 0.0018	44	0.029 ± 0.0044	0.011 ± 0.0022
Distant	^{90}Sr	1	0.094 ± 0.021	0.094	19	0.35 ± 0.085	0.095 ± 0.037
	^{137}Cs	1	0.46 ± 0.059	0.46	19	1.2 ± 0.14	0.43 ± 0.14
	$^{238}U_{LEPS}$	1	0.81 ± 1.1	0.81	10	1.3 ± 0.26	0.74 ± 0.18
	$^{238}U_{iso}$				9	0.84 ± 0.11	0.58 ± 0.076
	$^{239,240}Pu$	1	0.011 ± 0.0022	0.11	19	0.029 ± 0.0051	0.0078 ± 0.0033

(a) Maximum value ± 2 total propagated analytical uncertainty.
(b) Mean value ± 2 standard error of the mean.
(c) Maximum value in previous 5 years ± 2 standard error of the mean.
(d) Five-year mean value ± 2 standard error of the mean.
(e) $^{238}U_{LEPS}$ is a method of analyzing ^{238}U by detecting low-energy photons.
(f) $^{238}U_{iso}$ is a method of analyzing ^{238}U by detecting alpha particles.

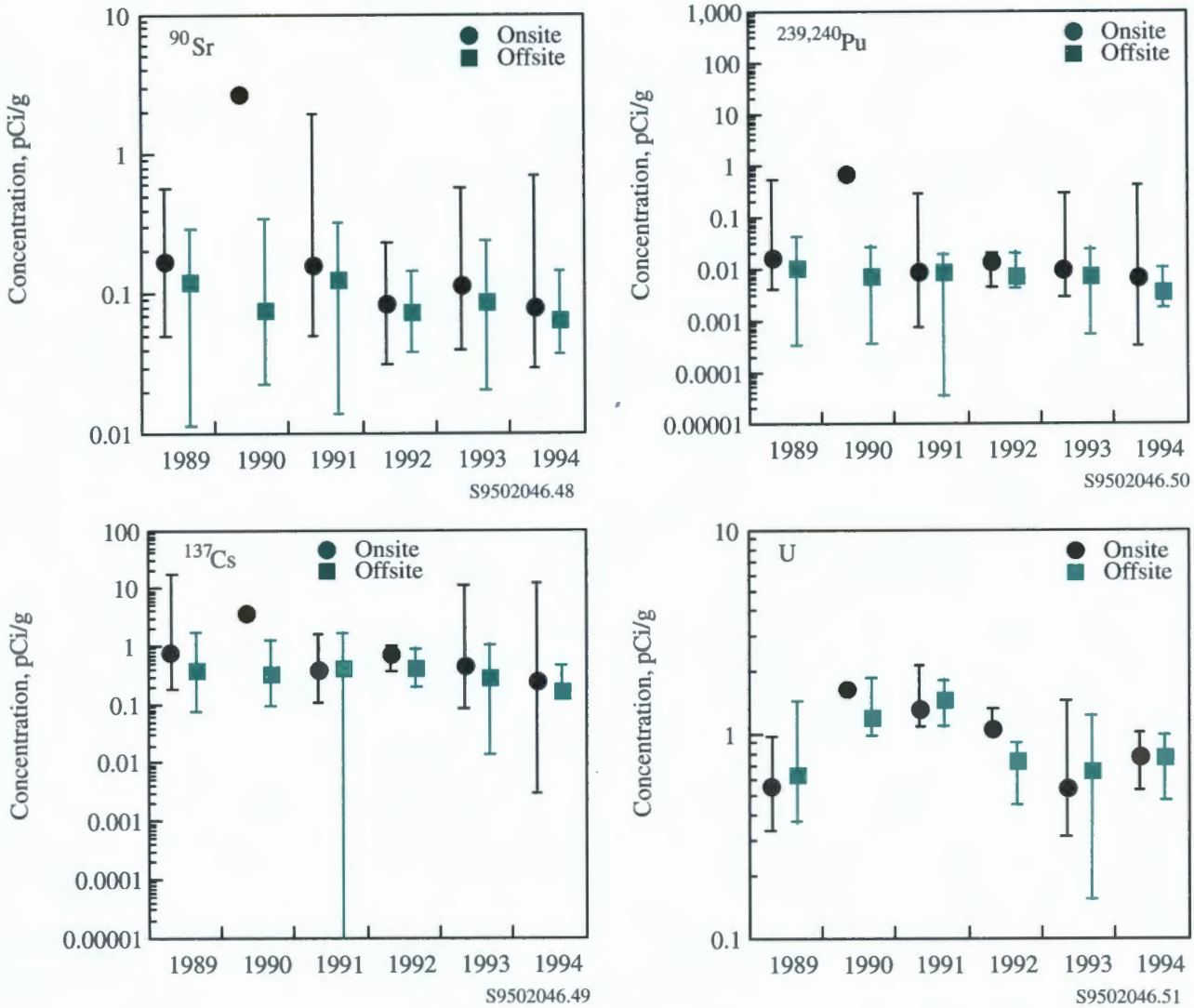

Figure 5.6.2 Selected Radionuclide Maximum, Median and Minimum Concentrations in Soil (units are pCi/g dry weight), 1989 Through 1994. Total uranium results for the 1989 to 1994 sampling period were determined using more than one analytical method (see text).

greater than or equal to 0.1 indicates that the data sets are similar; a p value of less than 0.1 suggests that they are not similar.

Statistical analyses indicated no significant differences between the onsite and offsite concentrations of cesium-137, plutonium-239,240, strontium-90, and uranium-238 (p values were 0.31, 0.47, 0.98, and 0.25, respectively).

Analysis methods for uranium changed between 1989 and 1994 (Appendix A Table A.13). In 1989, and from 1992 through 1994, uranium-238 was measured by detecting low-energy photons (LEPS method). In 1990 and 1991, the alpha spectroscopy method was used, and the activities of uranium-234, -235, and -238 were summed and reported.

Results for Vegetation

The five most consistently detected radionuclides associated with perennial vegetation during 1994 (and percent occurrence) were beryllium-7 (100%), plutonium-239,240 (100%), potassium-40 (100%), strontium-90 (100%), and uranium-238 (50%). Historically, another radionuclide of interest has been cesium-137; it was positively identified in four out of nine vegetation samples analyzed in 1994.

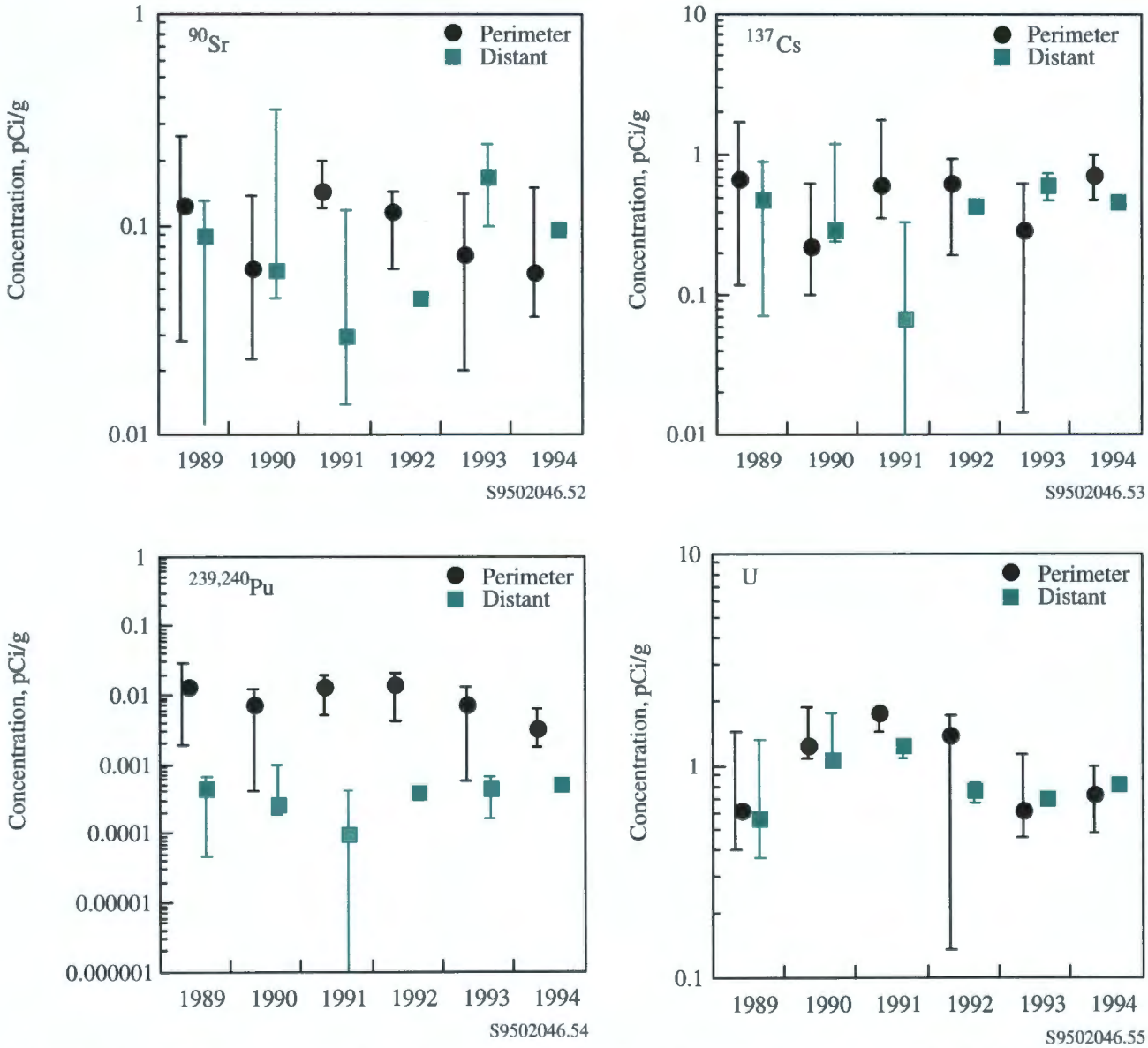

Figure 5.6.3 Selected Radionuclide Maximum, Median, and Minimum Concentrations in Soil (units are pCi/g dry weight) at Perimeter and Distant Locations, 1989 Through 1994. Total uranium results for the 1989 to 1994 sampling period were determined by using more than one analytical method (see text).

Radionuclide concentrations in vegetation are reported in Table 5.6.3 and are shown in Figure 5.6.4. Nonparametric statistical methods were used to detect differences between grouping categories, which were the same as those used in soil data comparisons.

Strontium-90 was identified in or on all perennial vegetation samples. There was no significant difference between the measured strontium-90 concentrations at onsite and offsite locations ($p = 1.0$).

Cesium-137 was identified in only 44% of the vegetation samples collected but is discussed here because of its historical interest. None of the samples obtained offsite had detectable concentrations of cesium-137. Statistical tests confirmed a difference between onsite and perimeter concentrations ($p=0.086$) and between the offsite (pooled perimeter and distant locations) and onsite data, $p = 0.079$.

Table 5.6.3 Radionuclide Concentrations in Vegetation Samples Collected on and off the Hanford Site (units are pCi/g dry weight), 1994 Compared to Values from the Previous 5 Years

		1994			1989-1993		
Location	Radio-nuclide	No. of Samples	Maximum[a]	Mean[b]	No. of Samples	Maximum[c]	Mean[d]
Onsite	^{90}Sr	4	0.17 ± 0.035	0.068 ± 0.067	37	2.2 ± 0.39	0.16 ± 0.12
	^{137}Cs	4	0.027 ± 0.021	0.016 ± 0.010	37	0.30 ± 0.043	0.037 ± 0.018
	U_{NAT}[e]				30	0.036 ± 0.012	0.015 ± 0.0029
	U_{iso}[f]	4	0.0063 ± 0.0074	0.0019 ± 0.0030	7	0.0065 ± 0.0029	0.0022 ± 0.0016
	$^{239,240}Pu$	4	0.0066 ± 0.0011	0.0017 ± 0.0033	37	0.041 ± 0.0050	0.0017 ± 0.0022
Perimeter	^{90}Sr	4	0.069 ± 0.016	0.016 ± 0.011	37	0.36 ± 0.073	0.064 ± 0.024
	^{137}Cs	4	0.011 ± 0.017	0.00022 ± 0.00017	37	0.045 ± 0.027	0.0085 ± 0.0047
	U_{NAT}				32	0.060 ± 0.019	0.019 ± 0.0054
	U_{iso}	4	0.029 ± 0.0080	0.016 ± 0.011	5	0.0061 ± 0.0041	0.0033 ± 0.0021
	$^{239,240}Pu$	4	0.00038 ± 0.0031	0.00022 ± 0.00017	37	0.00075 ± 0.00075	0.00018 ± 0.000052
Distant	^{90}Sr	1	0.016 ± 0.0049	0.016	18	0.74 ± 0.14	0.068 ± 0.080
	^{137}Cs	1	0.0072 ± 0.0084	0.0072	18	0.032 ± 0.025	0.010 ± 0.0048
	U_{NAT}				13	0.47 ± 0.13	0.089 ± 0.077
	U_{iso}	1	0.0051 ± 0.0031	0.0051	5	0.059 ± 0.0095	0.014 ± 0.023
	$^{239,240}Pu$	1	0.00018 ± 0.00014	0.00018	18	0.0013 ± 0.00040	0.00027 ± 0.00017

(a) Maximum value ± 2 total propagated analytical uncertainty.
(b) Mean value ± 2 standard error of the mean.
(c) Maximum value in previous 5 years ± 2 standard error of the mean.
(d) Five-year mean value ± 2 standard error of the mean.
(e) U_{NAT} is a chemical analysis and does not have total propagated analytical uncertainty.
(f) U_{iso} is a method of analyzing for ^{238}U by detecting alpha particles.

Perennial vegetation collected were analyzed for isotopic uranium. Statistical tests showed a difference between onsite and offsite (pooled perimeter and distant locations), $p = 0.05$; the offsite mean uranium-238 concentration (0.014 pCi/g dry weight) was greater than the onsite mean concentration (0.0019 pCi/g dry weight).

The vegetation samples were also analyzed for plutonium-239,240. The nonparametric statistical analysis performed on the analytical data showed no difference between onsite and offsite results, $p = 0.76$.

Special Studies

Milfoil

Milfoil, a nuisance aquatic plant, was collected at five Columbia River locations, one upstream of the Hanford Site (Vernita), three along the Hanford Reach (Benton County shoreline between the 100-N and 100-D Areas, the old Hanford Townsite, and the 300 Area), and one downstream of Hanford at McNary Dam (Lake Wallula). Milfoil was sampled as a potential indicator of contamination entering the Columbia River. Samples were dried and analyzed for gamma emitters, strontium-90, uranium isotopes, and for technetium-99 in selected samples.

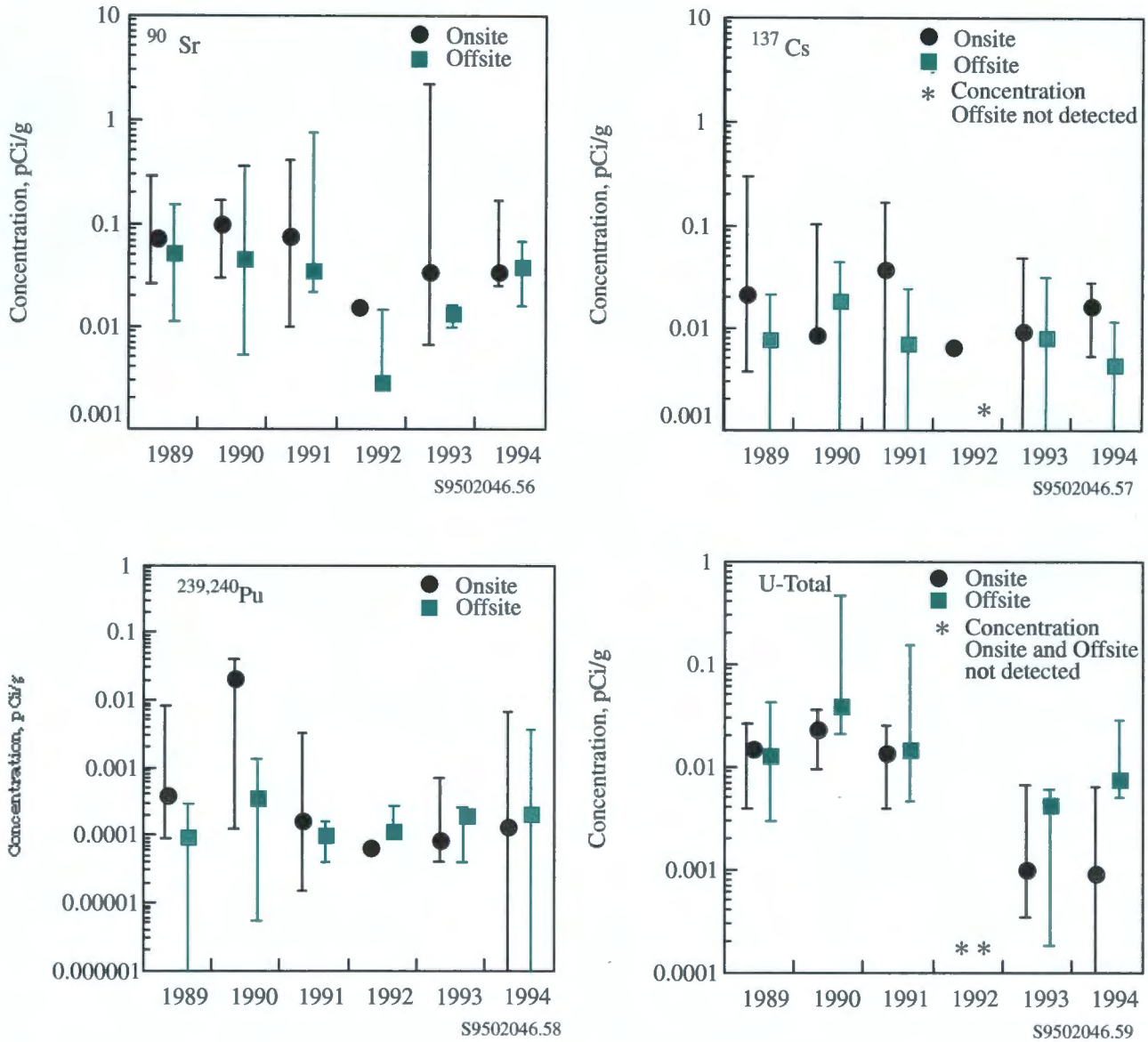

Figure 5.6.4 Selected Radionuclide Maximum, Median, and Minimum Concentrations in Vegetation (units are pCi/g dry weight), 1989 Through 1994

Results

Cesium-137, strontium-90, and uranium-238 were measured in all milfoil samples submitted for analysis. Cesium-137 concentrations were highest in samples collected at the old Hanford Townsite (Figure 5.6.5); however, concentrations were generally low and were similar to results measured upstream of Hanford. Strontium-90 was slightly elevated in samples collected at the 100-N to 100-D Areas and was distinctly elevated in samples collected at the 300 Area (Figure 5.6.6). Concentrations of cesium-137 and strontium-90 represent inputs from historic fallout in the Columbia River drainage basin as well as possible contributions from Hanford springs located along the Hanford Site shoreline.

Uranium-238 was also found at elevated concentrations at the 300 Area location compared to concentrations from other locations (Figure 5.6.7). Elevated concentrations of uranium in milfoil from the 300 Area were also observed in 1992 (Antonio et al. 1993). Concentrations of uranium-238 are low and do not pose a hazard to aquatic life or humans.

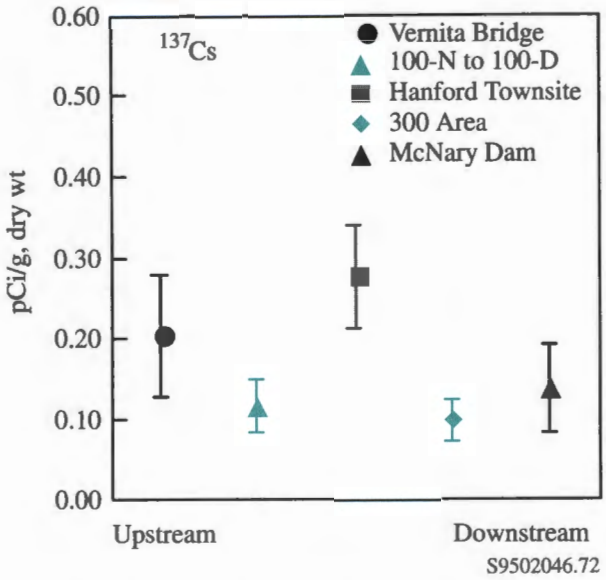

Figure 5.6.5 Concentrations (± 2 standard error of the mean) of Cesium-137 in Milfoil Collected in 1994 from Five Locations on the Columbia River. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

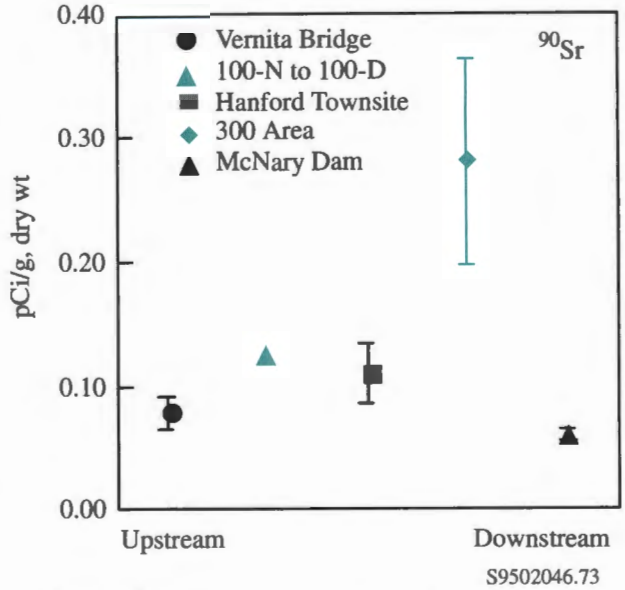

Figure 5.6.6 Concentrations (± 2 standard error of the mean) of Strontium-90 in Milfoil Collected in 1994 from Five Locations on the Columbia River. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

Technetium-99 was not found in milfoil samples collected at the old Hanford Townsite or McNary Reservoir. The MDC for technetium-99 is 2.0 pCi/g dry weight.

5.7 External Radiation Surveillance

E. J. Antonio

External radiation is defined as radiation originating from a source outside the body. External radiation fields consist of a natural component and an artificial or manmade component. The natural component can be divided into 1) cosmic radiation, 2) primordial radionuclides in the earth's crust (primarily potassium-40, thorium-232, and uranium-238), and 3) an airborne component, primarily radon and its progeny. The manmade component consists of radionuclides generated for or from nuclear medicine, nuclear power, nuclear research, nuclear waste management, and consumer products. Environmental radiation fields may be influenced by the presence of radionuclides deposited as fallout from past atmospheric testing of nuclear weapons or those produced and released to the environment during the production or use of nuclear fuel. The interaction of radiation with matter results in energy being deposited in matter. Ionizing radiation energy deposited in a mass of material is called radiation absorbed dose. A special unit of measurement called the rad was introduced for this concept in the early 1950s, and more recently, an International System (SI) unit called the gray (Gy) has been defined.

External radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters (TLDs). External radiation and contamination surveys were also performed with portable radiation survey instruments at locations on and around the Hanford Site. This section describes how external radiation was measured, how surveys were performed, and the results of these measurements and surveys.

External Radiation Measurements

Thermoluminescence, or light output exhibited by TLDs, is proportional to the amount of radiation exposure (X), which is measured in units of roentgen (R). The exposure is multiplied by a factor of 0.98 to convert to a dose (D) in rad to soft tissue (USDHEW 1970). This conversion factor relating R to rad is, however, assumed to be unity (1) throughout this report for consistency with past reports. This dose is further modified by a quality factor, Q = 1 for beta and gamma radiation, and the product of all other modifying factors (N). N is assumed to be 1 to obtain dose equivalence (H), measured in rem. The Seivert, Sv, is the SI equivalent of the rem.

$$D\ (\text{rad}) \approx X\ (R) * 1.0$$
$$H\ (\text{rem}) = D * N * Q$$

To convert to SI units of Gy and Sv, divide rad and rem by 100, respectively.

An environmental TLD comprises three plastic cards that each hold four LiF (TLD 700) chips and one calcium fluoride:dysprosium (TLD 200) chip. TLDs are positioned 1 m (3.3 ft) above the ground at various locations both on and off the Hanford Site. The TLDs are collected and read quarterly; those located along the Columbia River shoreline at the 100-N Area are processed monthly. The 12 TLD 700 chips at each location are used to determine the average total environmental dose at that location. The average dose rate is computed by dividing the average total environmental dose by the length of time the TLD was in the field. The three TLD 200 chips are included to determine doses in the event of a radiological emergency.

The TLDs are positioned at numerous locations onsite (Figure 5.7.1), around the Site perimeter, in nearby and distant communities, (Figure 5.7.2), and along the Hanford Reach of the Columbia River (Figure 5.7.3). All community and most of the onsite and perimeter locations are collocated with air monitoring stations. These locations were selected based on historical determinations of the highest potentials for public exposures (access areas, downwind population centers) from past and current Hanford operations.

Dose rates were also measured using both TLDs and survey instruments at three community-operated stations located at Edwin Markham Elementary School north of Pasco, Basin City Elementary School in Basin City, and Leslie Groves Park in Richland (Figure 5.7.2).

Twenty-eight TLD locations have been established on the Columbia River shoreline, from upstream of

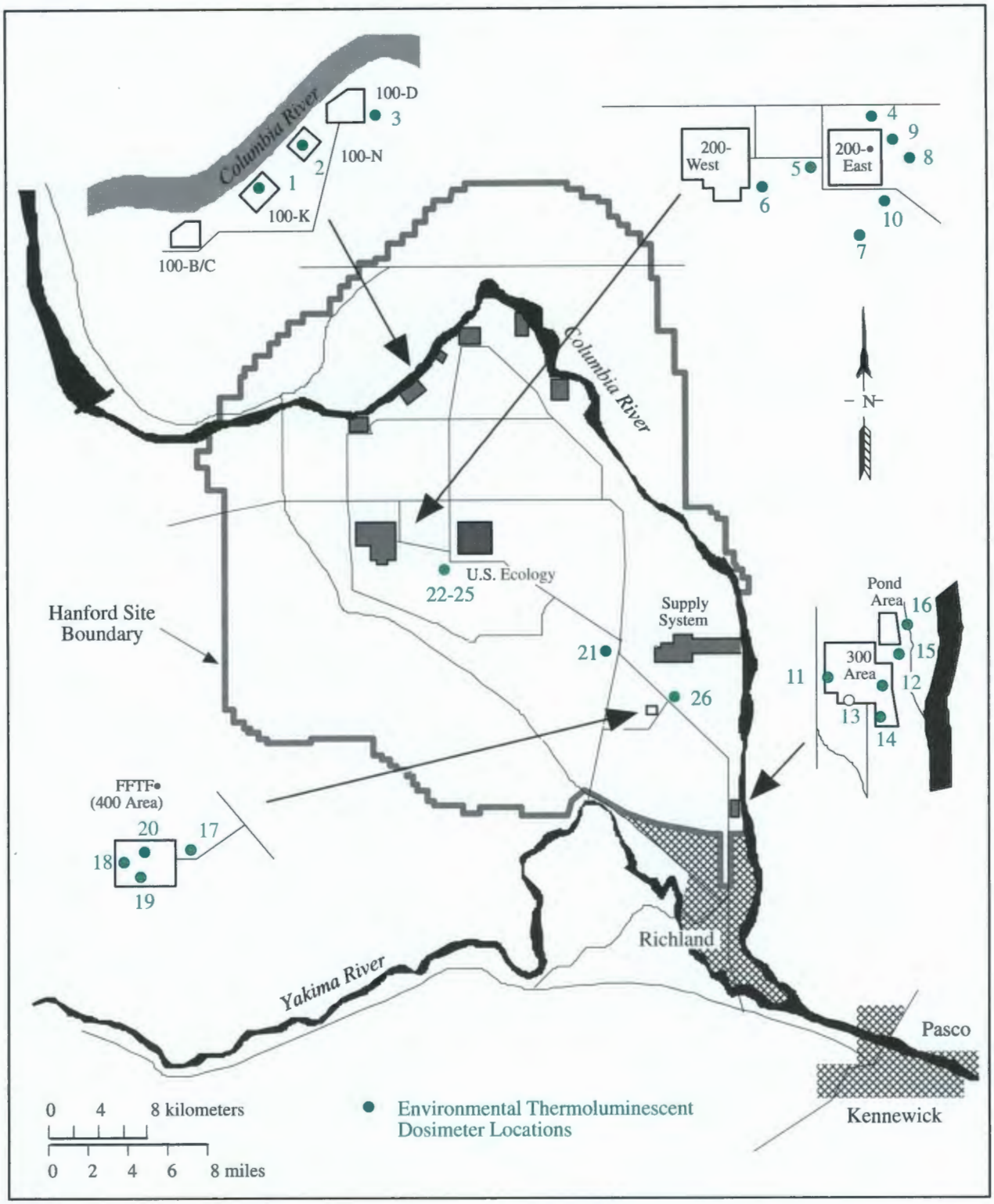

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Figure 5.7.1 Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 1994

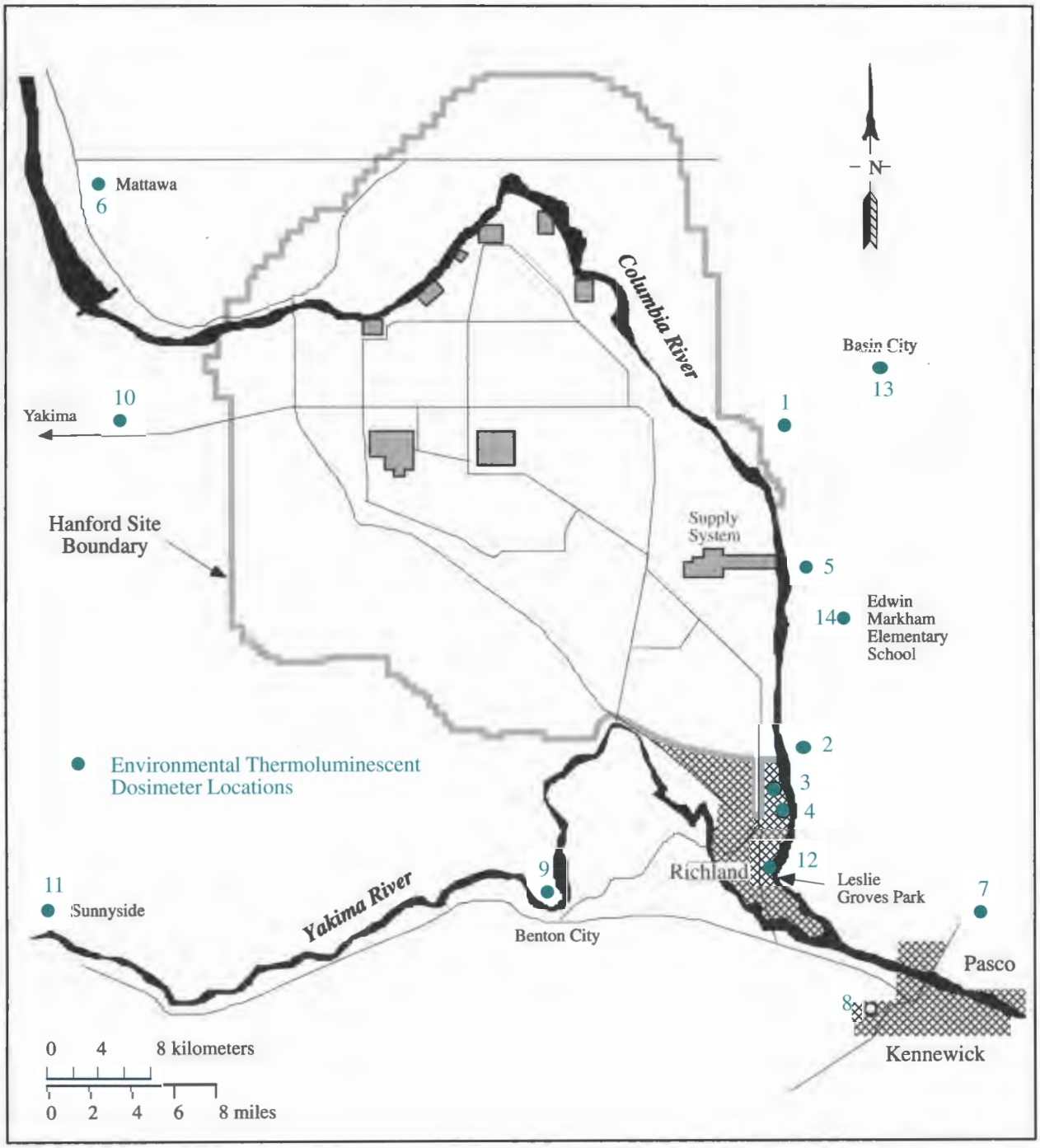

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Figure 5.7.2 Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 1994

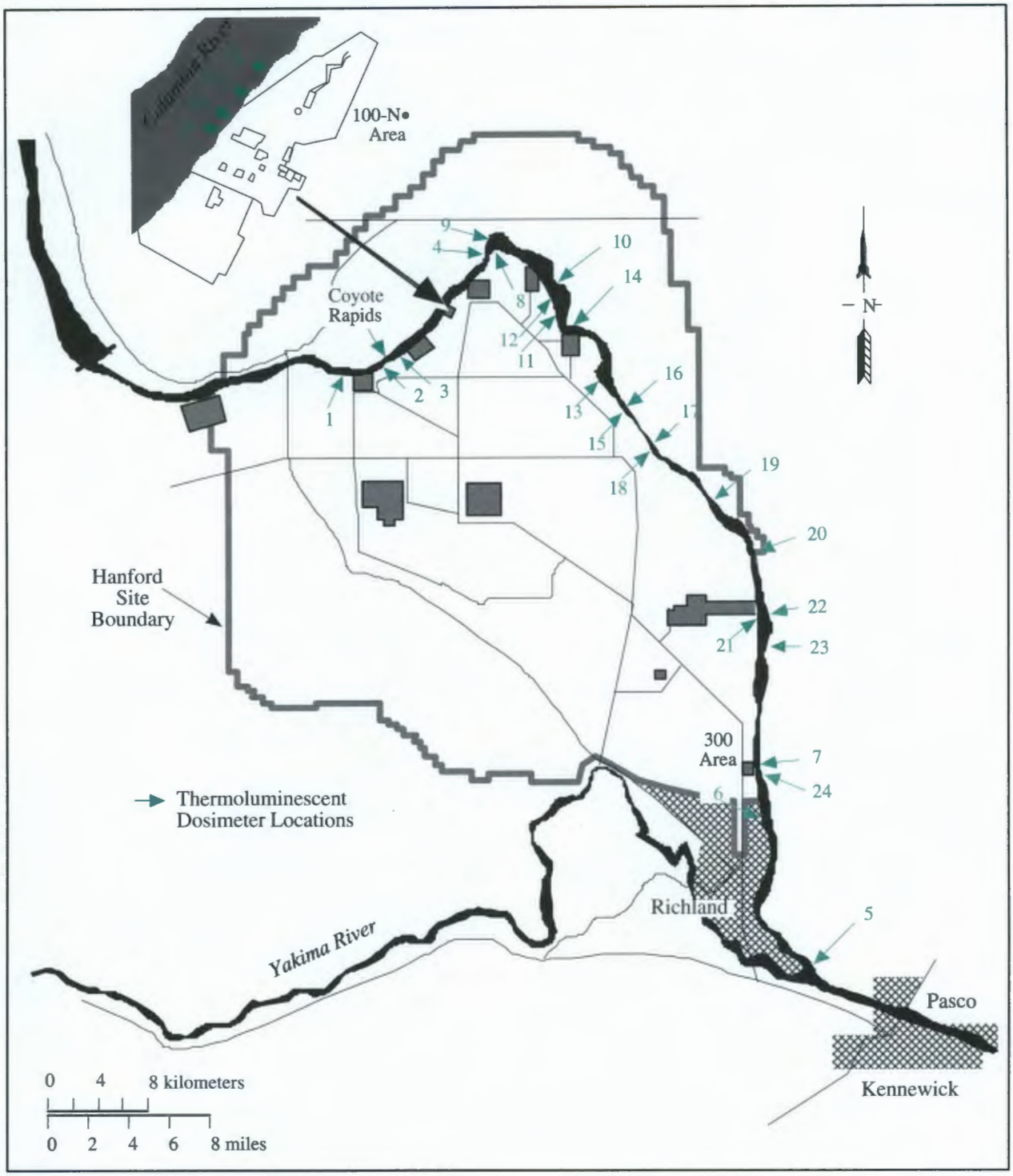

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Figure 5.7.3 Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Reach of the Columbia River, 1994

the 100-B Area to just downstream of Bateman Island at the mouth of the Yakima River. The general public has access to most of this shoreline. Historically, dose rates measured along the shoreline have been higher than typical background rates. Sula (1980) attributed these elevated rates to cobalt-60 and europium-154 deposited in shoreline sediments as a result of liquid releases to the Columbia River during past reactor operations in the 100 Areas.

External Radiation Results

Perimeter and offsite locations, primarily downwind of the Site and near population centers, were monitored with TLDs. TLD exposures have been converted to dose equivalent rates by the process described above. Table 5.7.1 shows maximum and average dose rates for perimeter and offsite locations measured in 1994 and the previous 5 years. Quarterly dose rates (mrem/day) at each location were converted to annual dose equivalent per year by averaging the quarterly dose rates and multiplying by 365 days/yr. Dose rates reported in Tables 5.7.1 through 5.7.3 represent the maximum annual average dose rate ($\pm$ 2 standard error of the mean) for all locations within a given area. Mean dose rates for each area were computed by averaging annual means for each location within the area. The error term is ± 2 standard error of the mean.

Perimeter dose rates for 1994 were similar to those observed in 1993. In 1994, the average perimeter external radiation dose rate was 110 $\pm$ 7 mrem/year while in 1993, the average was 100 $\pm$ 6 mrem/year. Variations in natural background radiation can occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15 to 25%, NCRP 1987). Other factors possibly affecting annual dose rates reported here may include variations in the sensitivity of individual TLDs zero-dose readings, fading, random errors in the readout equipment or procedures (Rathbun 1989), and changes in TLD station locations.

The average background external radiation dose rate (at distant locations) was 96 $\pm$ 8 mrem/year as compared to the perimeter average of 110 $\pm$ 7 mrem/year. This difference in average dose rates may be due to natural geographic variations in terrestrial radiation (the soils at many of the perimeter locations are rich in potassium-40 and thorium isotopes [Rathbun 1989]) and variations resulting from human activity. Human activities affecting the average dose rates may include landscape modifications such as buildings and other

Table 5.7.1 Average and Maximum Dose Rates Measured by Thermoluminescent Dosimeters (TLDs) at Perimeter and Offsite Locations, 1994 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1994		1989-1993		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum	Mean[c]
Perimeter	1 - 5	120 ± 17	110 ± 9.2	53	110 ± 3.0	91 ± 2.6
Nearby communities	6 - 9	110 ± 16	97 ± 6.2	34	96 ± 9.6	83 ± 3.0
Distant communities	10 - 11	100 ± 11	96 ± 8.3	19	96 ± 6.8	82 ± 3.5
COES stations	12 - 14	100 ± 15	100 ± 4.6	9	100 ± 20	87 ± 5.3

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 5.7.2.
(c) Maximum annual average dose rate ($\pm$ 2 standard error of the mean) for all locations within a given area.
(d) Means ± 2 standard error of the mean computed by averaging annual means for each location within the area.

Table 5.7.2 Average and Maximum Dose Rates Measured Along the Hanford Reach of the Columbia River, 1994 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1994			1989-1993	
Location	Map Location [b]	Maximum [c]	Mean[d]	No. of Samples	Maximum	Mean[c]
Typical shoreline area	1 - 24	140 ± 25	110 ± 5.2	87	170 ± 160	100 ± 3.8
100-N shoreline[e]	25 - 28	250 ± 22	200 ± 38	18	360 ± 31	240 ± 31
All shoreline		250 ± 22	130 ± 14	105	360 ± 31	130 ± 12

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 5.7.3.
(c) Maximum annual average dose rate (± 2 standard error of the mean) for all locations within a given area.
(d) Means ±2 standard error of the mean computed by averaging annual means for each location within the area.
(e) Monthly integrated exposure readings in mR/d converted to annual dose equivalent rates in mrem/yr.

Table 5.7.3 Average and Maximum Dose Rates for Thermoluminescent Dosimeter (TLD) Locations on the Hanford Site, 1994 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1994			1989-1993	
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum	Mean
100 Areas[e]	1 , 3	110 ± 11	110 ± 16	14	120 ± 35	92 ± 6.3
200 Areas	4 - 10	120 ± 10	110 ± 4.1	32	110 ± 3.2	94 ± 3.1
300 Area	11 - 16	110 ± 18	100 ± 3.1	24	110 ± 6.9	92 ± 3.1
400 Area	17 - 20	110 ± 18	110 ± 3.6	19	110 ± 15	91 ± 4.6
600 Area	21 - 26	160 ± 16	120 ± 19	35	180 ± 16	100 ± 8.6

(a) Quarterly integrated readings in mrem were converted to annual dose equivalent rates.
(b) Locations are identified in Figure 5.7.1.
(c) Maximum annual average dose rate (± 2 standard error of the mean) for all locations within a given area.
(d) Means ±2 standard error of the mean computed using pooled quarterly data.
(e) Location 2 was discontinued after the first calendar quarter. Reading was 120 mrem/yr.

construction, which may shield a portion of the terrestrial component. Figure 5.7.4 graphically displays a comparison between, and trends of, onsite, perimeter, and distant TLD locations during 1989 through 1994. Year-to-year variability is possible for these reasons, and 10% variability is possible (NCRP 1987).

Figure 5.7.3 shows locations of TLDs positioned along the Columbia River shoreline, and Table 5.7.2 shows the maximum and average measured dose rates for shoreline locations. Dose rates were highest near the 100-N Area shoreline, two times higher than typical shoreline dose rates. The high rates measured in the 100-N Area are attributed to past waste management practices in that area. The public does not have legal access to the 100-N Area shoreline, but does have access to the adjacent Columbia River. The dose implications associated with this access are discussed in Section 6.0 "Potential Doses from 1994 Hanford Operations."

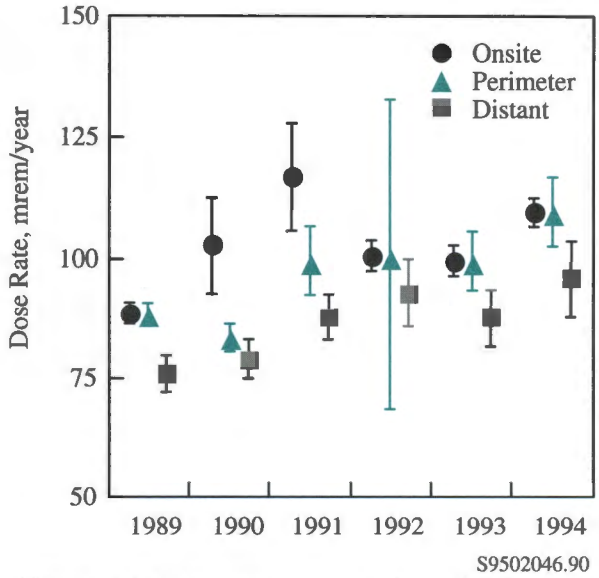

Figure 5.7.4 Annual Average Dose Rates (± 2 standard error of the mean), 1989 Through 1994. As a result of figure scale, some uncertainties are concealed by point symbol.

Figure 5.7.1 displays the 28 onsite locations of TLDs in 1994. Table 5.7.3 summarizes the results of 1994 measurements, which are grouped by operational area. The average dose rates in all operational areas were higher than dose rates measured at background locations. The highest average dose rate onsite was seen in the 600 Area and was due to waste disposal activities at US Ecology Inc., a non-DOE facility.

Radiation Survey Results

In 1994, radiation surveys were conducted at selected Columbia River shoreline locations.

Hand-held survey instruments were used to perform radiation surveys at certain Columbia River shoreline TLD locations. These surveys provided a coarse screening for elevated radiation fields. The surveys showed that radiation levels were comparable to levels observed at the same locations in previous years. The highest levels were seen along the Columbia River shoreline in the 100-N Area and ranged from 4 to 40 mrem/h. Survey results are not included in the 1994 data volume (Bisping 1995), but are maintained in the Surface Environmental Surveillance Project files at PNL.

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5.8 Ground-Water Protection and Monitoring Program

P. E. Dresel

The strategy for protecting ground water at the Hanford Site is presented in the *Hanford Site Ground-Water Protection Management Plan* (DOE 1994h). Two of the key elements of this strategy are to 1) protect the unconfined aquifer from further contamination, and 2) conduct a monitoring program to provide an early warning when contamination of ground water does occur. These elements are reaffirmed by the recommendations of the Hanford Future Site Uses Working Group to "protect the Columbia River from contamination" and to "deal realistically and forcefully with ground-water contamination" (Drummond et al. 1992). The ground-water monitoring program at Hanford monitors and documents ground-water quality to effectively meet the needs of these elements. The monitoring program at Hanford is designed to document the distribution and movement of existing ground-water contamination. This information is used to assess the movement of contamination into previously uncontaminated areas. The monitoring provides the historical baseline for evaluating current and future risk from exposure to the contamination and for deciding on remedial options. The geology and hydrology of the Hanford Site are the major controls on the movement of contaminants in ground water so hydrogeologic studies are integrated into the monitoring program.

Geology

The Hanford Site lies within the Pasco Basin, one of several topographic and structural basins within the Columbia Plateau. Principal geologic units beneath the Hanford Site include, in ascending order, the Columbia River Basalt Group, the Ringold Formation, and the Hanford formation (Figure 5.8.1).

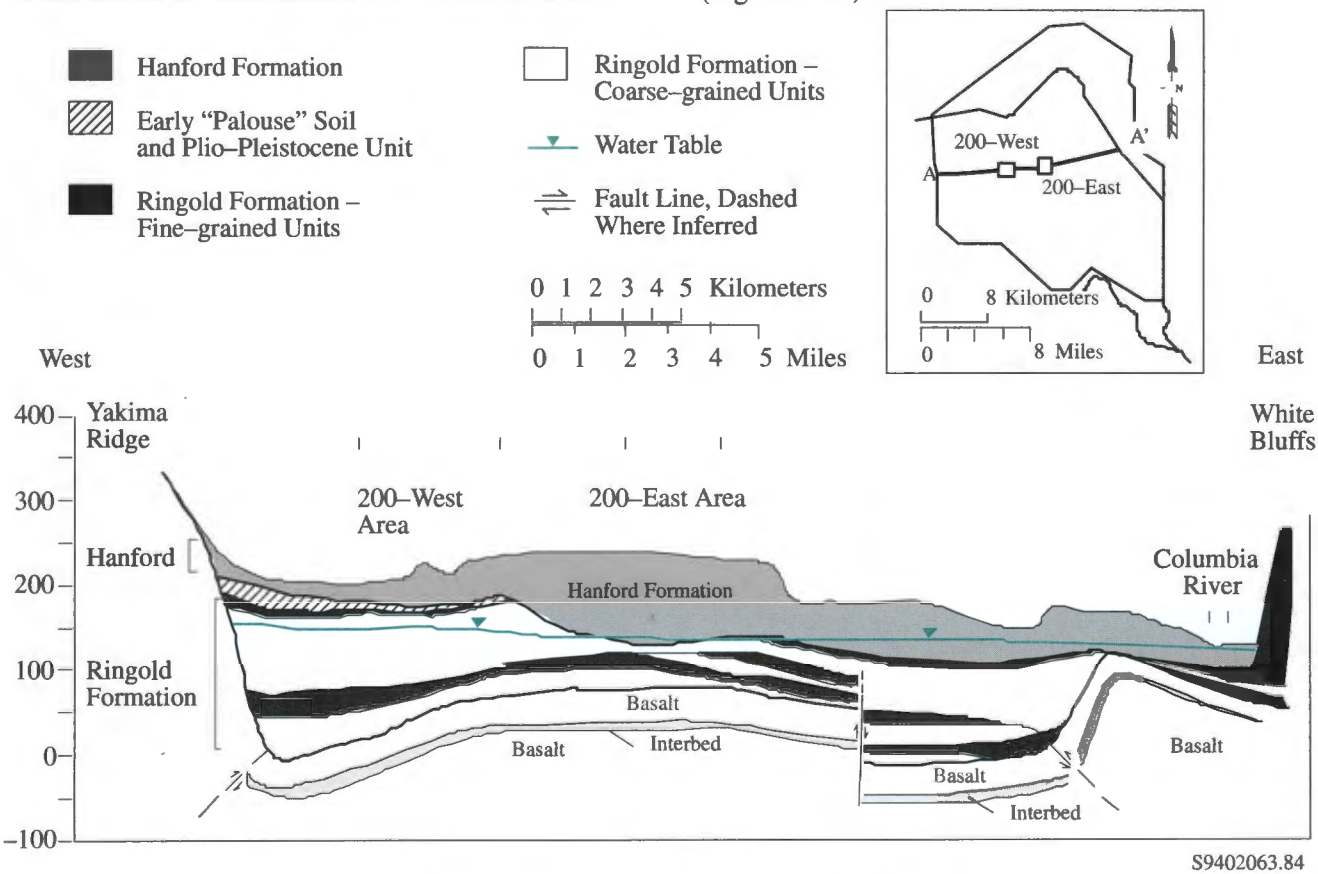

Figure 5.8.1 Geologic Cross Section of the Hanford Site

Columbia River basalts erupted from volcanic fissures, starting 17 million years ago, to ultimately cover 163,000 km^2 (62,900 mi^2) of Washington, Oregon, and Idaho. The basalt flows consist of generally dense, impermeable basalt that have more permeable top and bottom portions. At first, there was little time between eruptions for the development of soils or accumulation of sediments between flows. However, the frequency of eruptions eventually slowed, and the regional river system eroded the basalt, depositing sediments across the basalt surfaces between eruptions. These sediments form the Ellensburg Formation of sedimentary interbeds that are found between the basalt flows. Zones between the basalt flows and the sedimentary interbeds are frequently water-bearing zones that are used as water sources in areas around the Hanford Site. Flow between the basalt aquifers and the surficial aquifer generally occurs along faults that bring a water-bearing interbed in contact with other sediments or where the overlying basalt has been eroded to reveal an interbed (Graham et al. 1984, Newcomb et al. 1972, Reidel et al. 1992).

During the period of basalt deposition, tectonic pressure was very slowly deforming the basalt flows into the generally east-west trending ridges that border the Pasco Basin today. Basins also developed at this time. These basin ridges gradually began to affect the distribution of the river beds, moving them toward the Pasco Basin. Ringold Formation deposition began after the last major eruption 8.5 million years ago with the ancestral Columbia River meandering across the relatively flat basalt surface and depositing sand and gravel in the central portion of the Pasco Basin. This pattern continued for the next 5 million years, with two major interruptions occurring when the Columbia River was blocked downstream, which caused a lake to develop in the Pasco Basin. Relatively thick mud layers accumulated in the lake each time. The mud layers are much less permeable than the sand and gravel layers, and act as partial barriers to vertical ground-water flow within the Ringold Formation.

About 3.4 million years ago, the Columbia River began to erode, rather than deposit, sediments in the Pasco Basin. The uppermost lacustrine mud was eroded from much of the Pasco Basin, and in places an impermeable caliche layer, part of the Plio-Pleistocene unit, developed on the eroded Ringold surface. The Ringold Formation sediments have undergone varying degrees of consolidation and cementation, which has decreased their permeability.

The Hanford formation sediments in the Pasco Basin are represented primarily by sand and gravel deposited by catastrophic ice age floods during the past 700,000 years. These floods were caused by collapse of glacier ice dams blocking an immense lake in Montana. The floodwater eroded some of the sediments in the Pasco Basin and deposited large gravel bars in the main channels and sand in the turbulent areas. The Hanford formation sediments are unconsolidated and generally much more permeable than similar Ringold Formation sediments. In places, these sediments are covered by up to a few meters of recent alluvial or windblown deposits.

More detailed information on the geology of the Pasco Basin can be found in Connelly et al. (1992a and b), DOE (1988), Hartman and Lindsey (1993), Lindberg (1993a and b), Lindsey and Jaeger (1993), and Swanson (1992).

Ground-Water Hydrology

Both confined and unconfined aquifers are present beneath the Hanford Site. An aquifer is a water-saturated geologic unit that has a high permeability, meaning it can transmit significant quantities of water. A confined aquifer is bound above and below by low-permeability materials such as the central parts of basalt flows, clay, or well-cemented sediments. The confined aquifers are found primarily within interflows and interbeds of the Columbia River basalts, as well as below the relatively impervious clays and silts of the Ringold Formation. In some areas of the Site, the lower units of the Ringold Formation are only locally confined by discontinuous silty layers above. Unconfined aquifers, or water-table aquifers, are overlain by unsaturated sediments. In general, the unconfined aquifer is located in the upper parts of the Ringold Formation, the glaciofluvial sediments of the Hanford formation, and in more recent alluvial sediments in some areas adjacent to the Columbia River. The unconfined aquifer forms the uppermost ground-water zone and has been directly impacted by waste-water disposal at Hanford. For this reason, it is the most thoroughly monitored aquifer beneath the Site.

Figure 5.8.2 shows the locations where the water table (the upper surface of the unconfined aquifer) lies within the Hanford and Ringold Formations.

The saturated thickness of the unconfined aquifer is greater than 61 m (200 ft) in some areas of the Hanford Site and thins out along the flanks of the basalt ridges (Figure 5.8.3). Depth from the ground surface to the water table ranges from less than 0.3 m (1 ft) near the Columbia River to more than 106 m (348 ft) in the center of the Site. The unconfined aquifer is bounded below by either the basalt surface or, in places, the relatively impervious clays and silts of the Ringold Formation. The water table defines the upper boundary of the unconfined aquifer. Laterally, the unconfined aquifer is bounded by the basalt ridges that surround the Pasco Basin and by the Yakima and Columbia Rivers. The basalt ridges have a low permeability and act as a barrier to lateral flow of ground water where they rise above the water table (Gephart et al. 1979). The elevation of the water table in meters above mean sea level for the Hanford Site and adjacent portions of Franklin and Grant Counties is shown in Figure 5.8.4.

The water-table elevation contours shown in Figure 5.8.4 indicate the magnitude of hydraulic gradient in the unconfined aquifer. Ground-water flow is generally perpendicular to the water-table contours from areas of higher elevation or head to areas of lower head. Areas where the contours are closer together are high-gradient areas where the "driving force" for ground-water flow is greater. However, sediments with low permeabilities inhibit ground-water flow and produce steeper gradients, therefore high gradient does not necessarily mean high ground-water velocity. The permeability of the Ringold sediments is generally lower than that of the Hanford sediments, so lower transmissivity and steeper gradients are often associated with areas where the water table is below the Hanford formation. Figure 5.8.5 shows the distribution of transmissivity used in current ground-water flow models.

Recharge to the unconfined aquifer originates from several sources (Graham et al. 1981). Natural recharge occurs from infiltration of precipitation along the mountain fronts, runoff from intermittent streams such as Cold Creek and Dry Creek on the western margin of the Site, and limited infiltration of precipitation on areas of the Hanford Site that have loose soil. The unconfined aquifer is recharged by the Yakima River where it flows along the southern boundary of the Hanford Site. The Columbia River recharges the unconfined aquifer for short periods during high stages when river water is transferred to the aquifer along the riverbank. For most of the year, the Columbia River is the primary discharge area for the unconfined aquifer. Recharge from infiltration of precipitation is highly variable on the Hanford Site and depends on soil texture, vegetation, and climate (Gee et al. 1992). The recharge rate from precipitation ranges from near zero, where fine-grained soils and deep-rooted vegetation are present, to more than 10 cm/yr (4 in./yr) in areas where soils are coarse-textured and bare of vegetation.

Large-scale artificial recharge to the unconfined aquifer occurs from liquid-waste disposal in the operating areas and offsite agricultural irrigation. The operational discharge of water has created two major ground-water mounds in the 200 Areas. The first of these mounds was created by past disposal at U Pond in the 200-West Area. The water table beneath U Pond rose 18 m (59 ft) from 1950 to 1980 (Newcomer 1990). This mound is slowly dissipating because the pond was decommissioned in 1984. The second mound was created by discharge to B Pond, east of the 200-East Area. The water-table elevation near B Pond increased by a maximum of about 9 m (29 ft) before 1990 (Newcomer 1990) and has decreased slightly over the last 5 years because of reduced discharge. These mounds have altered the unconfined aquifer's natural flow pattern, which is generally from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east and north. Water levels in the unconfined aquifer have changed continually during Site operations because of variations in the volume and location of waste water discharge. Consequently, the movement of ground water and its associated constituents has also changed with time. Ground-water mounding has also occurred in some of the 100 Areas and the 300 Area. Ground-water mounding in these areas is not as great as in the 200 Areas because of lower discharge volumes, high permeability and proximity to the Columbia River.

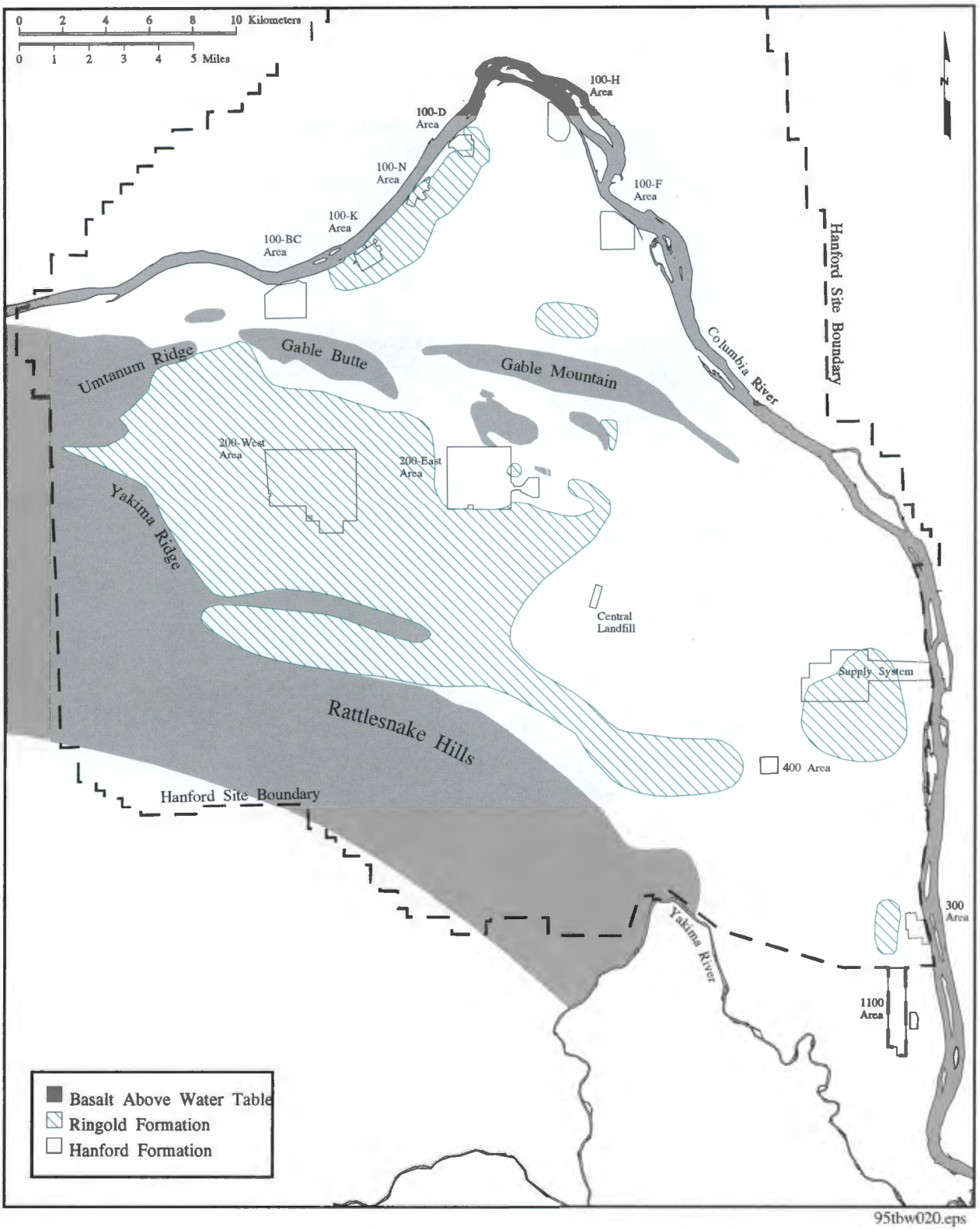

Figure 5.8.2 Geologic Units Present at Water Table, June 1993

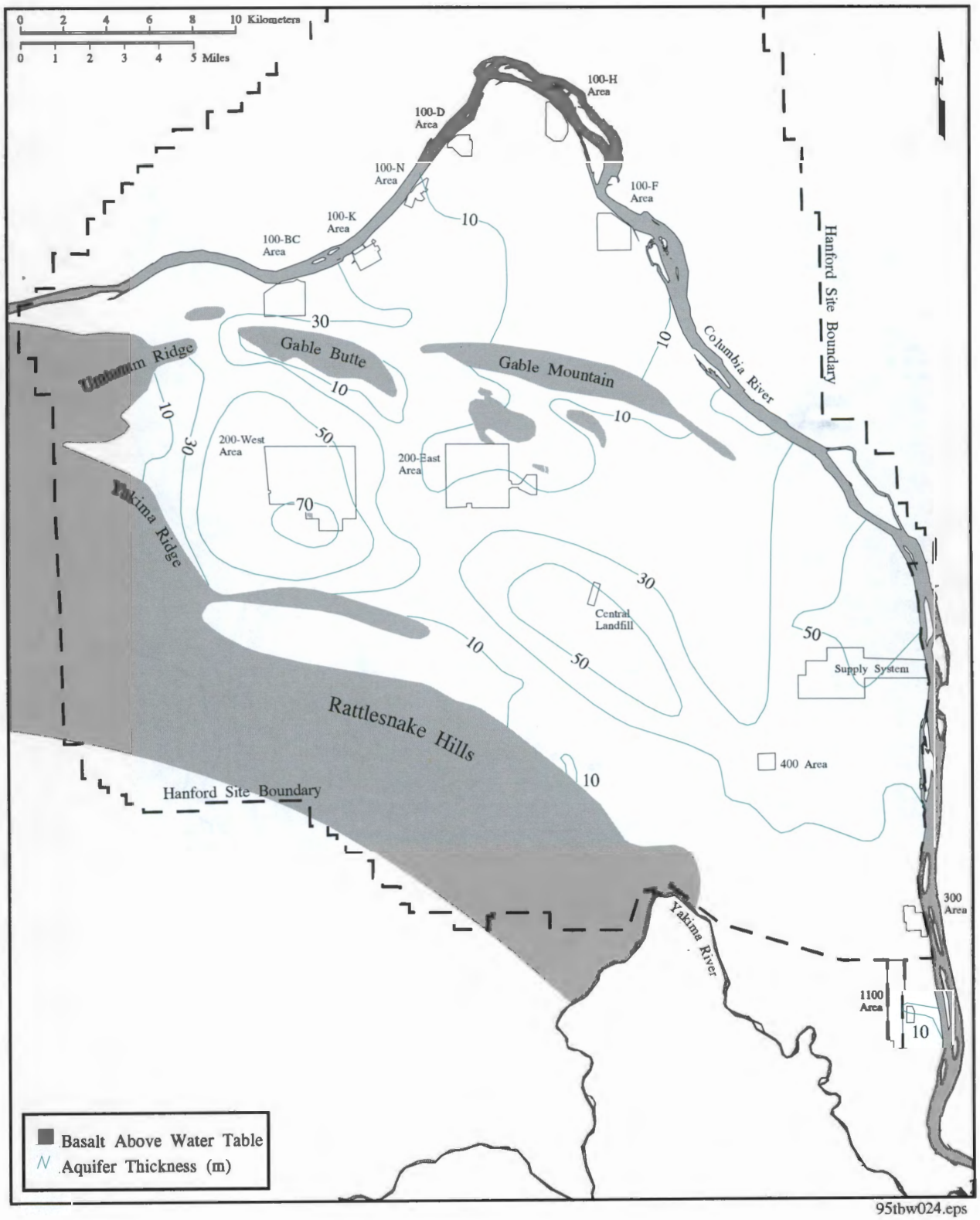

Figure 5.8.3 Saturated Thickness of the Unconfined Aquifer at the Hanford Site

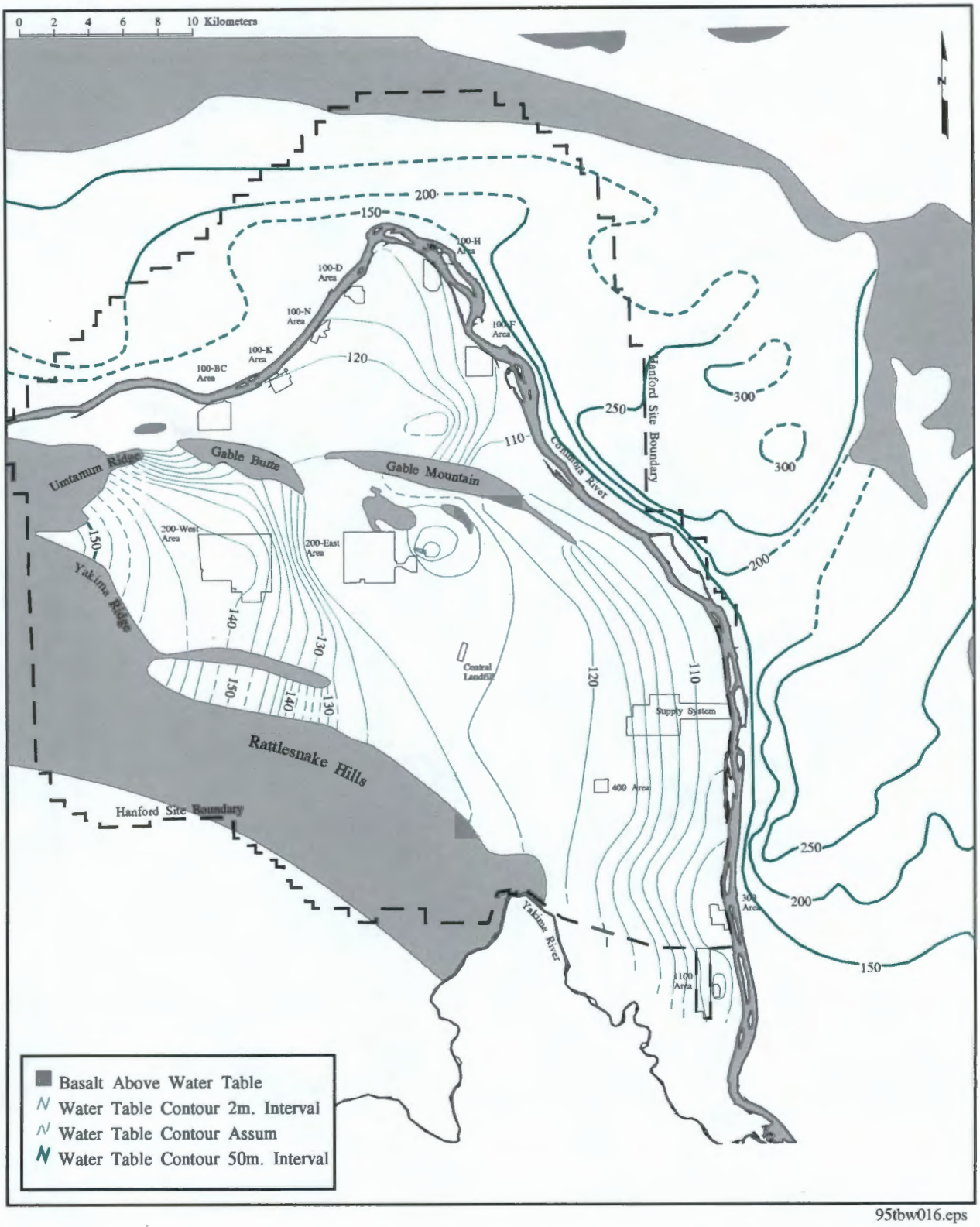

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Figure 5.8.4 Water-Table Elevations for the Unconfined Aquifer at Hanford and Parts of Franklin County, June 1994

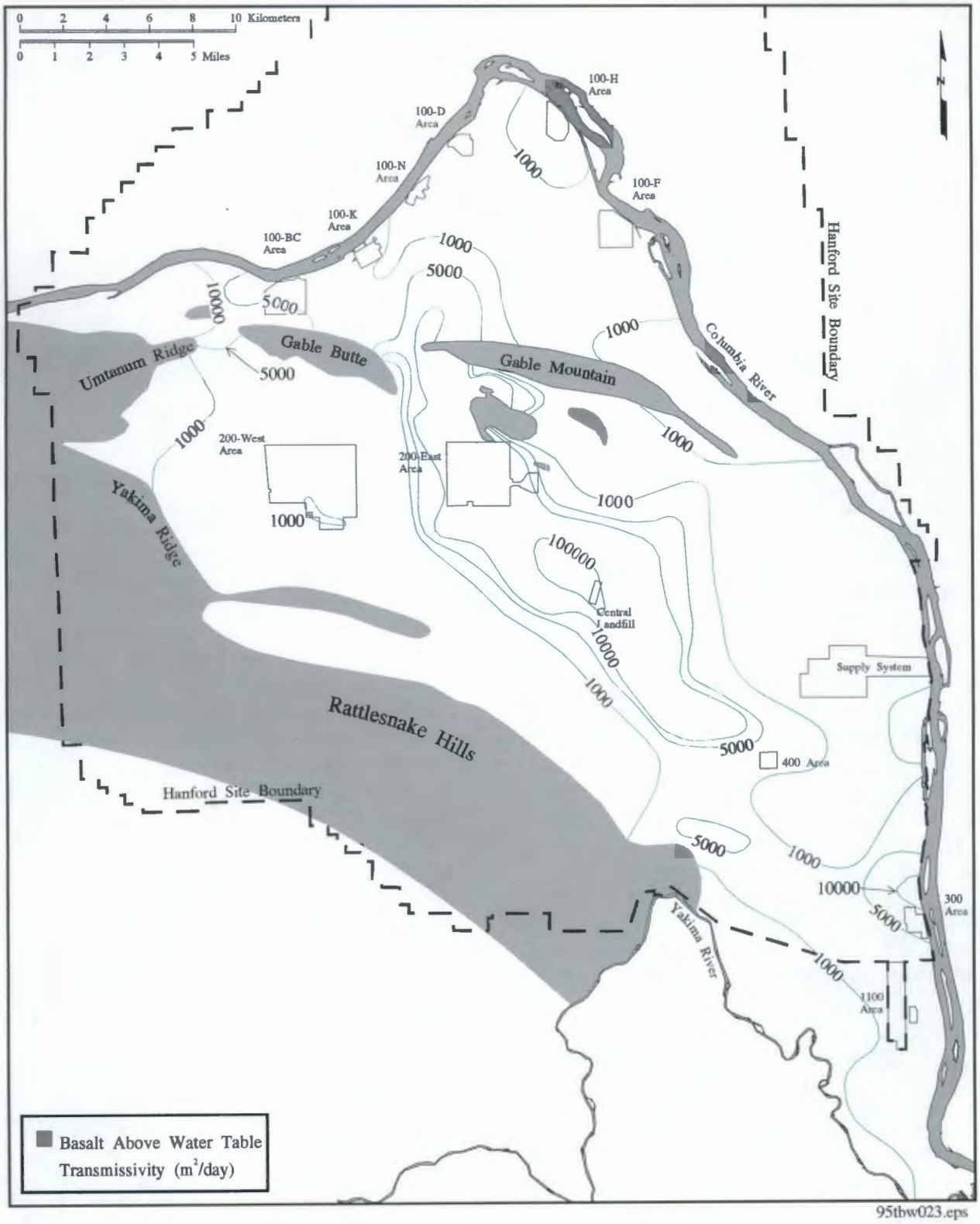

Figure 5.8.5 Distribution of Transmissivity of the Unconfied Aquifer at the Hanford Site

Water-table elevations are currently declining in response to the decrease in liquid-waste discharges from Hanford operations. One result of decreasing water levels is that a number of monitoring wells are becoming difficult to sample or are going dry. A ground-water flow model based on predicted changes to discharge indicated that this trend will continue, and many more wells will become impossible to sample during the next 10 years (Wurstner and Freshley 1994).

In the 100 and 300 Areas, water levels are greatly influenced by river stage. Water levels in the Columbia River fluctuate greatly on annual and even daily cycles. The river level is controlled by the operation of Priest Rapids Dam upstream of the Hanford Site. As the river stage rises, the increased water pressure is transmitted inland, increasing water levels in wells near the river. Very near the river, water will flow from the river into the aquifer as the river stage rises and will flow in the opposite direction as the river stage falls. This produces some dilution of contaminants near the river and makes it difficult to define the exact extent of contamination.

Recharge from irrigation in the Cold Creek Valley enters the Hanford Site as ground-water flow across the western boundary. Recharge to ground water across the Columbia River from the Hanford Site is primarily from irrigation and irrigation canal leakage. As indicated in Figure 5.8.4, the water-table elevation to the east of the Columbia River is from 100 to 150 m (328 to 492 ft) higher than the water-table elevation on the Hanford Site.

Contaminant Transport

The present distribution of contamination in ground water at the Hanford Site is controlled by the disposal history and the physical and chemical principles of contaminant transport. The conceptual model of contaminant transport describes the processes that control the contaminant movement. Major features of a conceptual model for contamination at the Hanford Site are discussed below.

Most ground-water contamination at Hanford results from discharges in the reactor areas (the 100 Areas), the fuel processing and plutonium purification areas (the 200 Areas), and the fuel fabrication and research area (the 300 Area). Table 5.8.1 lists major contaminants found in each area and the type of operation that generated the contaminants.

Most of the ground-water contamination onsite resulted from discharge of water contaminated by Site processes. In the 100 Areas, discharges included reactor cooling water, fuel storage-basin water, filter backwash, and smaller amounts of waste from a variety of other processes. Large quantities of contaminated water from fuel processing were discharged in the 200 Areas. Other contamination sources in the 200 Areas include plutonium purification waste and decontamination waste. In contrast to other major contaminant sources, the plutonium purification process also resulted in contamination from discharge of nonaqueous-phase liquid, including carbon tetrachloride. This liquid slowly releases contamination to the ground water and has a major impact on ground-water remediation strategy. Contamination in the 300 Area was mainly released in process water that was discharged to ponds and trenches. The discharge of large quantities of water during Site operations had a major impact on ground-water flow and thus on the rate and direction of contamination spread.

Table 5.8.1 Major Chemical and Radiological Ground-Water Contaminants and Their Link to Site Operations

Facilities Type	Area	Constituents Generated
Reactor operations	100	Tritium, ^{60}Co, ^{90}Sr, ^{125}Sb, Cr^{+6}, SO_4^{-2}
Irradiated fuel processing	200	Tritium, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, Pu, U, CN^-, Cr, F^-, NO_3^-
Plutonium purification	200	Pu, ^{241}Am, carbon tetrachloride, chloroform, NO_3^-
Fuel fabrication	300	^{99}Tc, U, Cr^{+6}, Cu, trichloroethylene

As significant quantities of liquid effluents were discharged to the ground at Hanford facilities, these effluents percolated downward through the unsaturated zone to the water table. Radionuclide and chemical constituents moved through the soil column at varying rates, and in some cases, entered the ground water. In some locations sufficient water was discharged that the soil became saturated up to the surface.

Not all contaminants travel at the same rate as the water in the subsurface. Chemical processes such as adsorption onto soil particles, chemical precipitation, and ion exchange slow the movement of some constituents such as cesium-137, plutonium-239,240, and strontium-90. Other radionuclides such as iodine-129, technetium-99, tritium, and ions such as nitrate are not as readily retained by the soil and move vertically through the soil column at a rate nearly equal to the infiltrating water. When the liquid effluents reach the water table, their concentrations are reduced by dilution. As these constituents move with the ground water, radionuclide and chemical concentrations are further reduced by adsorption and spreading (dispersion), and radionuclide concentrations are reduced by radioactive decay.

Outside the source areas at the Hanford Site there is typically little or no downward gradient so contamination tends to remain close to the water table. Flow in the unconfined aquifer is toward the Columbia River. Contamination that reaches the river is further diluted by the river water.

Ground-Water Protection

The effort to protect ground-water quality is being implemented through programs to minimize wastes being discharged to the soil column and through site remediation activities being carried out in accordance with an agreement among Ecology, DOE, and EPA. This agreement, called the Hanford Federal Facility Agreement and Consent Order, or the Tri-Party Agreement, provides a framework for remediation of the Hanford Site over a 40-year period. A summary of accomplishments in waste minimization and Site remediation is presented in Section 2.0, "Environmental Compliance Summary."

In 1987, Congress directed DOE to prepare a *Plan and Schedule to Discontinue Disposal of Liquids Into the Soil Column at the Hanford Site* (DOE 1987b). That document presents an implementation plan for providing alternative treatment and disposal of contaminated effluent discharged to the soil on the Hanford Site. The 33 major waste streams that have been identified will be addressed in two phases. Phase I projects are considered higher priority, and cessation or alternative treatment and disposal systems will be implemented during 1995 for most of those waste streams. Phase II streams will be dealt with after completion of Phase I projects. Preparations are being made to treat remaining Phase I streams before diverting them to a treated effluent disposal facility, which will be located east of the 200-East Area. In addition, plans are being made to discharge process condensate from the 242-A Evaporator to the CO-18 facility north of the 200-West Area. This discharge will also be treated to remove contaminants; however, the discharge will contain tritium because there is currently no viable treatment technology for tritium removal. The disposal facilities for the 33 major streams are shown in Figure 5.8.6. Ground water is pumped for drinking water and other uses at a few locations on the Hanford Site. These locations are shown in Figure 5.8.7. Drinking water supplies are monitored at the point of use by the Hanford Environmental Health Foundation (Thurman 1992). Water samples are collected directly from water supply wells by the Ground Water Surveillance Project.

Ground-Water Monitoring

Ground-water monitoring at the Hanford Site is an integral part of the *Hanford Site Ground-Water Protection Management Plan* (DOE 1994h). The plan includes monitoring at active waste disposal facilities to comply with RCRA (DOE 1993b), operational monitoring in and adjacent to reactor and chemical processing facilities, and environmental surveillance. Monitoring is also carried out during cleanup investigations under the CERCLA programs (DOE 1992d). The RCRA and operational monitoring programs are managed by the Site operating contractor. CERCLA characterizations are managed by the Environmental Restoration Contractor and the U.S. Army Corps of Engineers. Additional details on RCRA-compliant monitoring

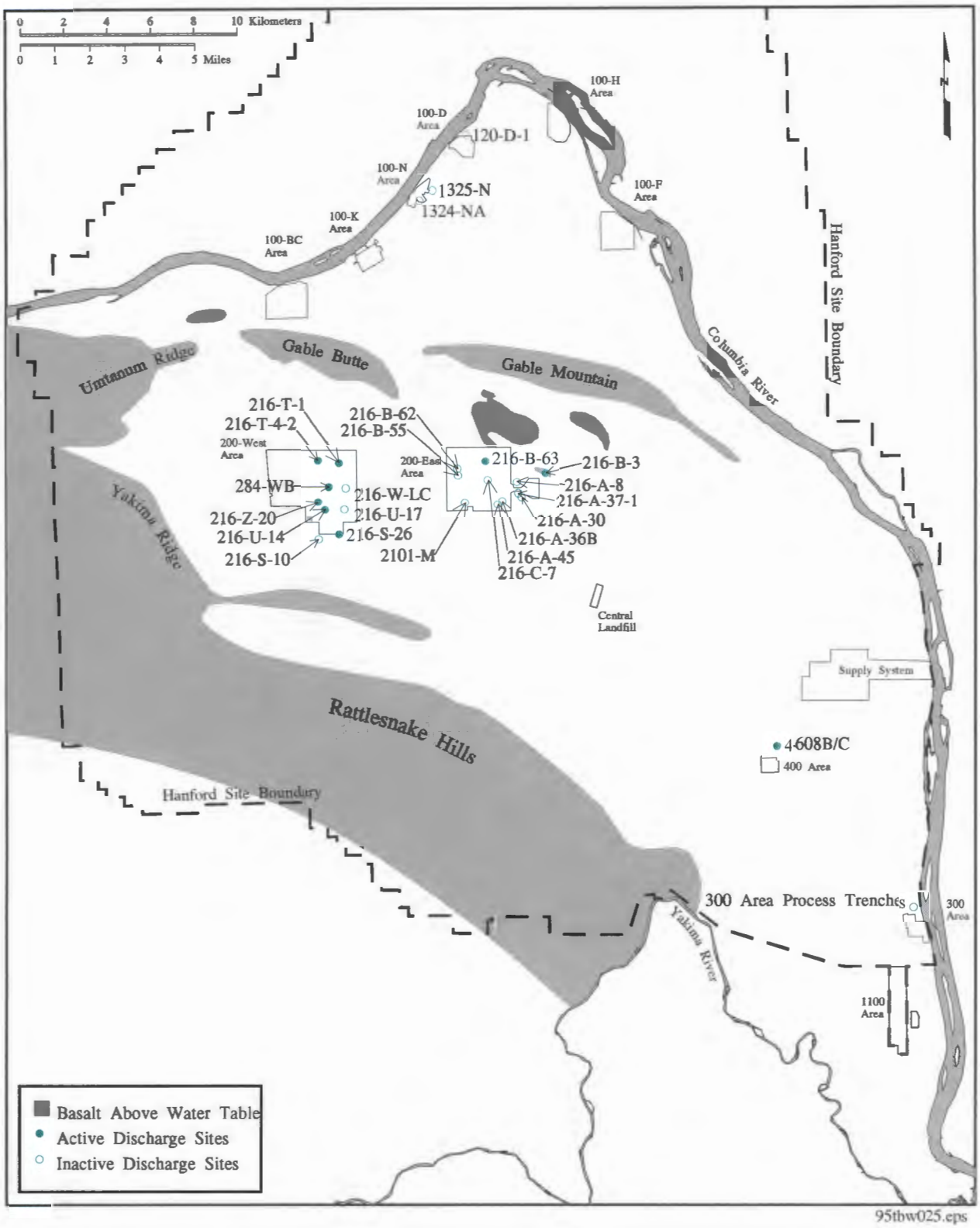

Figure 5.8.6 Disposal Facilities for the Major Liquid Waste Streams at the Hanford Site

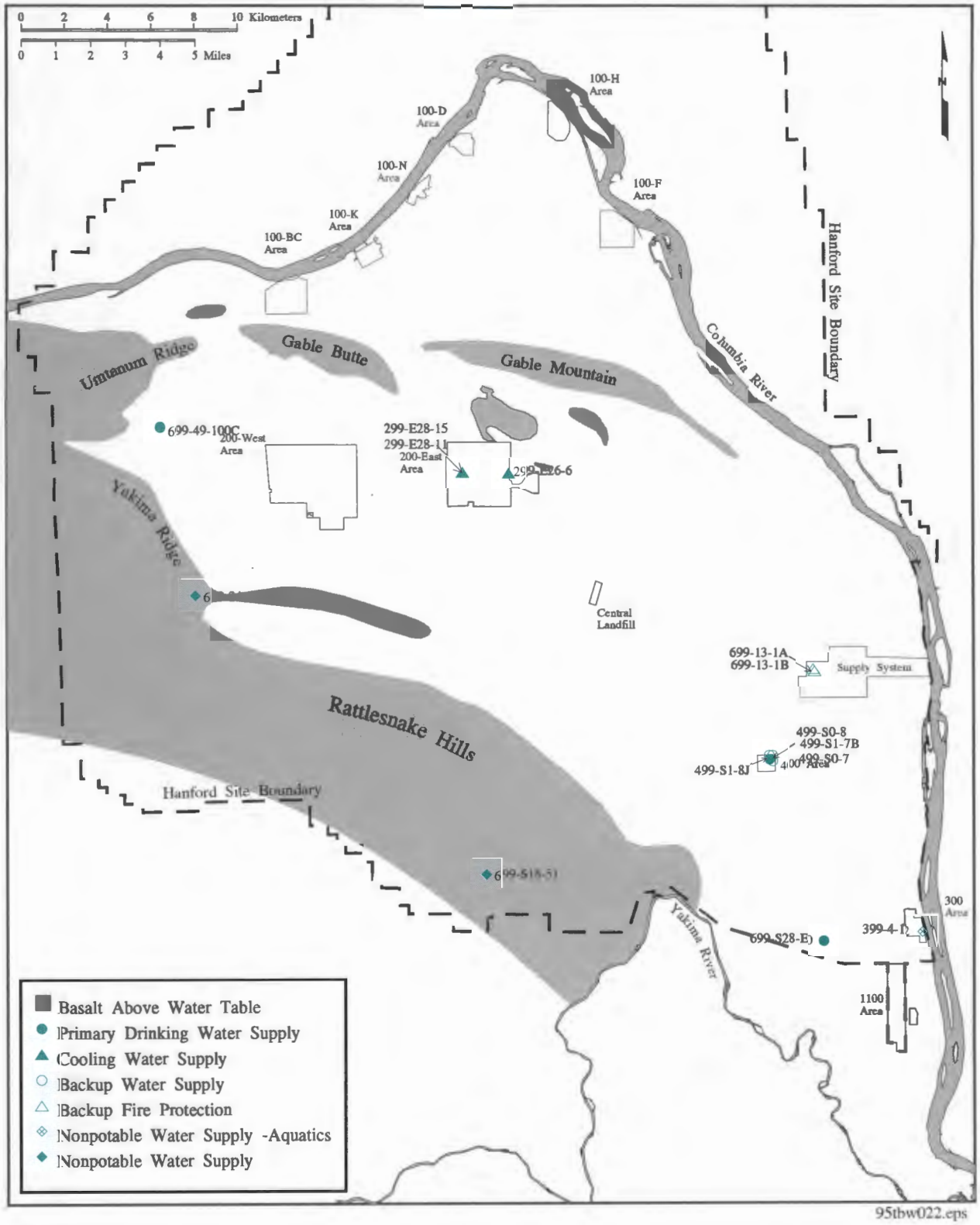

Figure 5.8.7 Water Supply Wells at the Hanford Site

are presented in Section 2.0, "Environmental Compliance Summary."

The environmental surveillance program assesses the impact of Hanford operations on ground water, both onsite and offsite, independently of the operating contractor's programs. The Hanford Ground-Water Surveillance Program has been designed to assess the distribution and movement of existing ground-water contamination, and to identify potential and emerging ground-water contamination problems. The program integrates information on contaminant distribution and transport into a sitewide evaluation of ground-water quality.

Sample Collection and Analysis

Ground-water samples were collected as part of the Hanford Ground-Water Surveillance Program and other monitoring programs. The Hanford Ground-Water Surveillance Program uses data from other programs to provide a more complete interpretation. Data from past years of monitoring supplement the current analyses and allow for the evaluation of trends through time. Wells monitored by the various programs are shown in Figures 5.8.8 and 5.8.9. Ground-water monitoring was conducted at the facilities shown in Figure 5.8.10 to comply with RCRA (Hartman 1994).

Ground-water samples were collected from approximately 800 wells for the monitoring programs during 1994. The monitoring frequency for the wells was selected based on regulatory requirements, proximity to waste sources, and characteristics of the ground-water flow system at the sample location. Of the wells sampled, 241 were sampled once, 280 were sampled twice, 116 were sampled three times, 111 were sampled four times and 58 were sampled more frequently during the year.

Each monitoring program has access to ground-water data collected by other programs through a common database used to store and manage data. This database, called the Hanford Environmental Information System, currently contains approximately 1.3 million ground-water monitoring result records. After the data are verified and/or validated, they are made available to federal and state regulators for retrieval.

Most ground-water monitoring wells on the Site are 10 to 20 cm (4 to 8 in.) in diameter. Monitoring wells for the unconfined aquifer are constructed with well screens or perforated casing generally in the upper 3 to 6 m (10 to 20 ft) of the unconfined aquifer, extending across the water table. This construction allows sample collection at the top of the aquifer, where maximum concentrations of radionuclides tend to be found. Wells monitoring the shallowest of the confined aquifers have screens, perforated casing, or an open hole within the monitored aquifer. Wells drilled before 1985 were generally constructed with carbon steel casing. Wells recently constructed for RCRA monitoring projects and CERCLA characterizations have been constructed with stainless-steel casing. Most monitoring wells onsite are sampled using either submersible or Hydrostar pumps although some wells are sampled with bailers or air-lift systems.

Samples were collected for all programs following documented sampling procedures (PNL 1993, WHC 1991b) based on EPA guidelines (EPA 1986b). Analytical techniques used are listed in Bryce et al. (1991), the *Environmental Monitoring Plan* (DOE 1991b), and CERCLA work plans. The radionuclides and chemicals analyzed are listed in Table 5.8.2. Several of the parameters listed in Table 5.8.2 were seldom analyzed during 1994 because sufficient characterization has been obtained by past analyses.

Most ground-water samples collected onsite in 1994 were analyzed for tritium. Selected samples were analyzed for other radionuclides. Sample results for radionuclides are generally presented in pCi/L. However, the results for total uranium, which is usually measured by laser fluorescence, are given in μg/L. The results for analysis of individual uranium isotopes are reported in pCi/L.

Nitrate analyses were performed on most samples collected during 1994 because of the extensive areas with elevated nitrate concentrations originating from onsite and offsite sources. Selected monitoring wells were used for additional chemical surveillance. Chemical sampling wells were chosen by considering the results of previous chemical analyses and the proximity to known active and inactive chemical disposal sites.

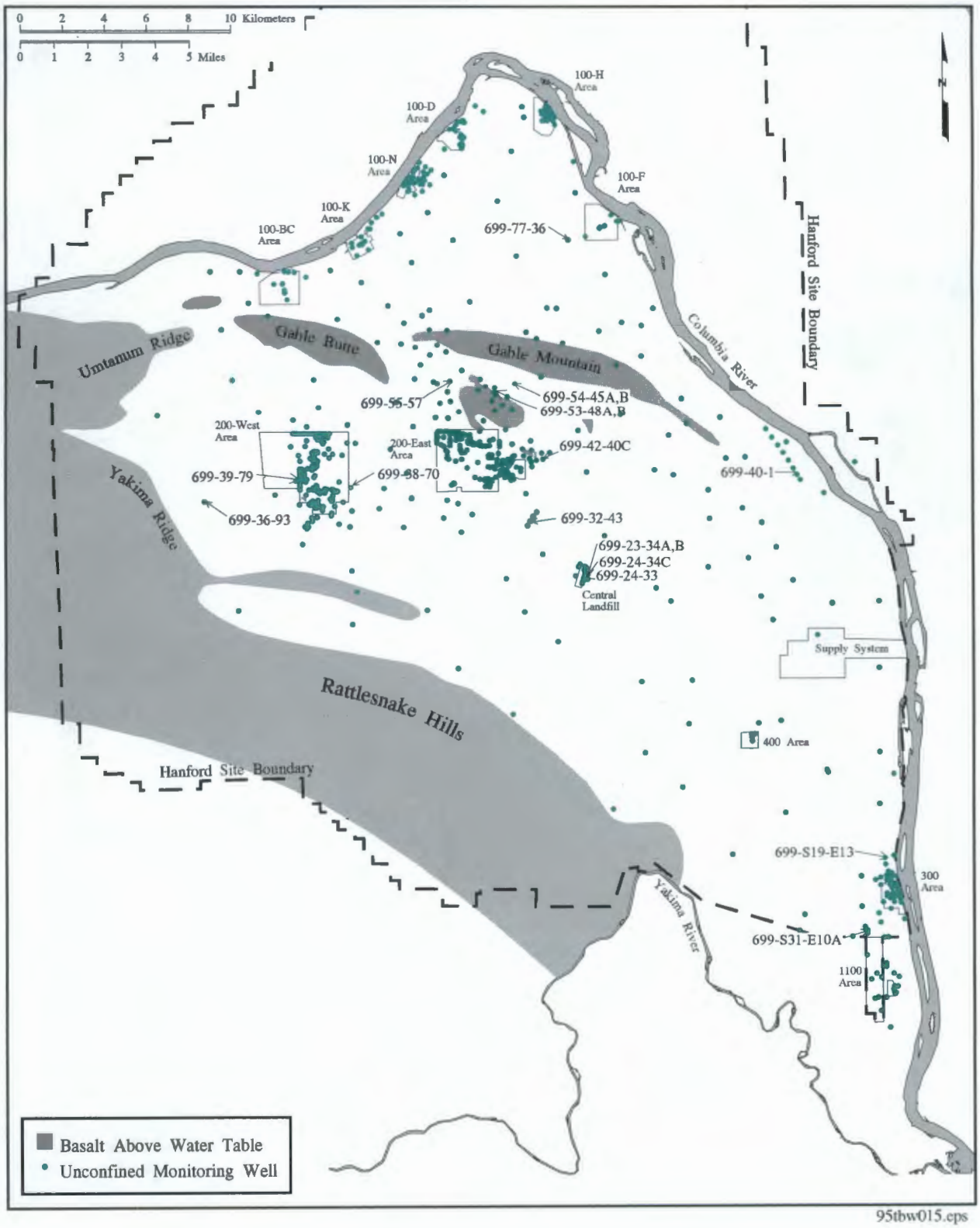

Figure 5.8.8 Hanford Site Unconfined Aquifer Monitoring Well Locations, 1994

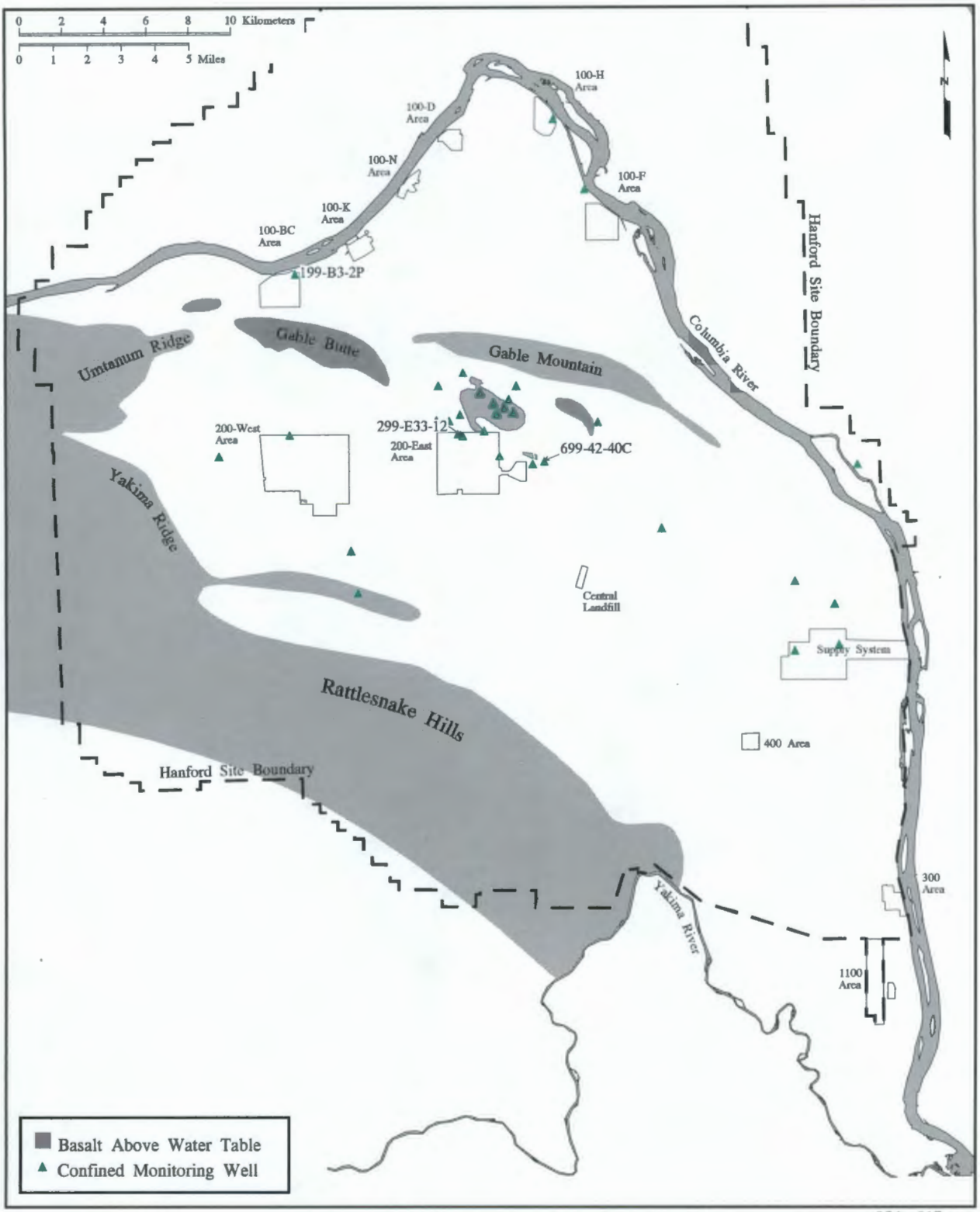

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Figure 5.8.9 Hanford Site Confined Aquifer Monitoring Well Locations, 1994

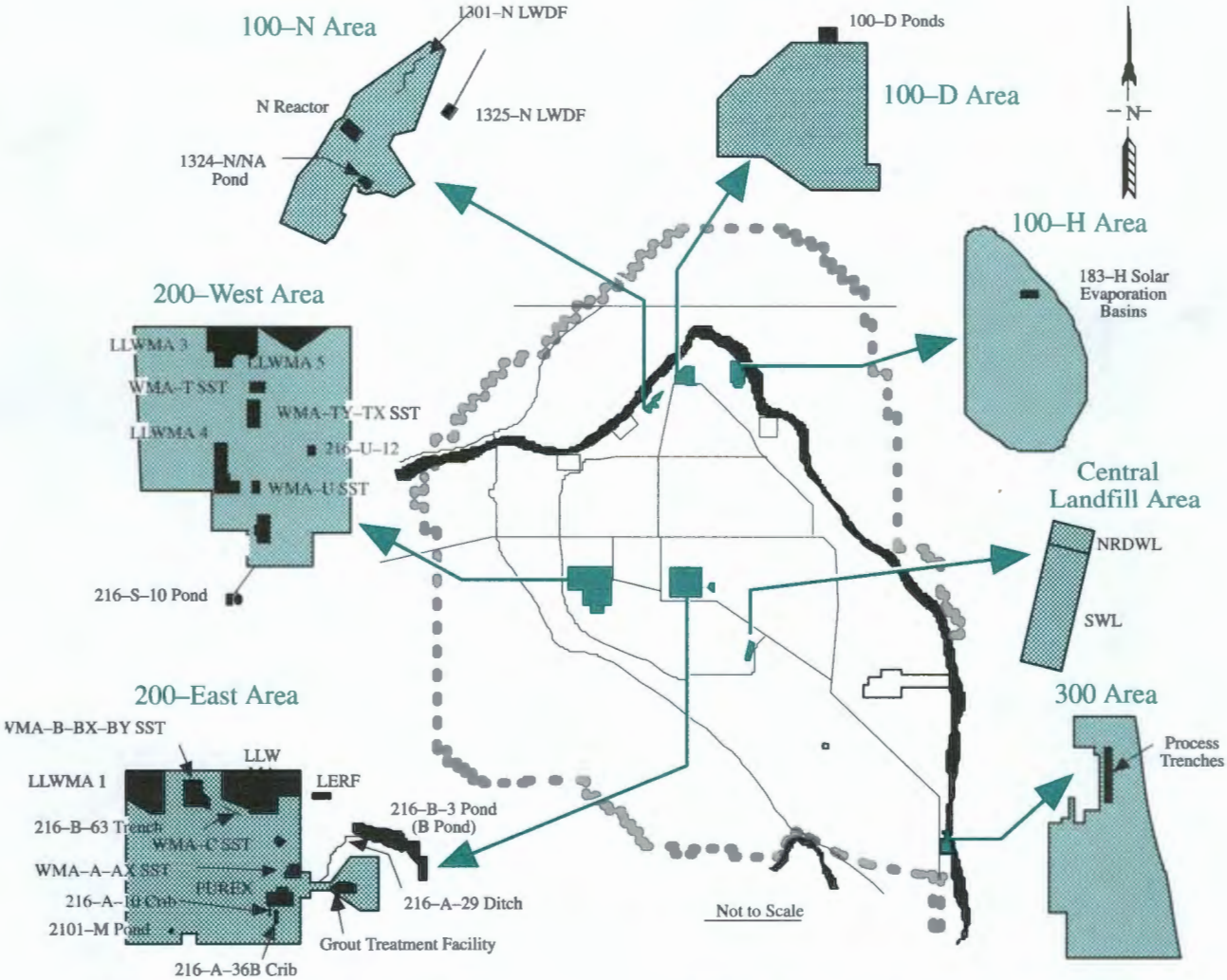

Figure 5.8.10 Locations of RCRA Ground-Water Monitoring Projects and Landmarks on the Hanford Site

Data Interpretation

Each analysis of a ground-water sample provides information on the composition of ground water at one time at one location in the aquifer. Uncertainty in the analyses results from a number of sources. Some of the sources of uncertainty are discussed below. Several techniques used in this discussion to interpret the sample results are also discussed.

Sampling techniques are designed to provide a sample that is reasonably representative of the constituent concentration in the aquifer when the sample is taken. However, there are limitations in collecting representative samples or even defining precisely the volume of the aquifer represented by the sample. Proper well construction and maintenance, well purging, sample preservation, and, in some instances, filtering are used to help ensure consistent and representative samples. Careful sample labeling protocols, chain-of-custody documentation, and bottle preparation avoid many gross errors in sample results. Duplicate samples and field blanks are used to assess the sampling procedure.

Table 5.8.2 Radionuclides and Chemicals Analyzed for in Ground Water

Radiological Parameters	Chemical Parameters
^{3}H	pH (field and laboratory)
^{14}C	Conductance (field)
^{60}Co	Alkalinity
^{90}Sr	Total carbon
^{99}Tc	Total organic carbon
^{103}Ru	Total organic halogens
^{106}Ru	B, Be, Na, Mg, Al, K, Co, Si
^{125}Sb	Ca, V, Cr, Mn, Fe, Ni
^{129}I	Cu, Zn, Sr, Ag, Cd, Sb, Ba
^{131}I	F^-, Cl^-, NO_3^-, PO_4^{-3}, SO_4^{-2}, NO_2^-, Br^-
^{137}Cs	CN^-
^{241}Am	NH_4^+
Total alpha	Volatile organic compounds (VOCs)
Total beta	Semivolatile organic constituents
Plutonium isotopes	PBCs
Uranium isotopes	Dioxins/furans
Uranium (total)	Pesticides/herbicides
	Biological oxygen demand/chemical oxygen demand
	Dissolved oxygen

Uncertainties are inherent in laboratory analysis of samples. Gross errors can be introduced in the laboratory or during sampling. Gross errors include transcription errors, calculation errors, mislabeling results, or other errors that result from not following established procedures. Often, these gross errors can be recognized because unreasonably high or unreasonably low values result. Data review protocols are used to investigate and correct gross errors. Even if the source of a possible gross error cannot be identified, a marker is entered into the database indicating the review has occurred and the datum may be suspect.

Random errors are unavoidably introduced in the analytical procedures. Usually there are insufficient replicate analyses to assess the overall random error at each sample location. Instruments for analysis of radioactive constituents count the number of radioactive decay products at a detector, and background counts are subtracted. The nature of radioactive decay and the instrument design result in a random counting error, which is reported with the analytical result. Generally, sample results less than the counting error indicate the constituent was not detected. The background subtraction may result in the reporting of results that are less than zero. Although below-zero results are physically impossible, the negative values are of use for some statistical analyses.

Systematic errors may result from instrument calibration, standard or sample preparation, chemical interferences in analytical techniques, as well as sampling methodology and sample handling. Sample and laboratory protocols have been designed to minimize systematic errors. The laboratories used by the Ground-Water Surveillance and other programs participate in interlaboratory comparisons in which many laboratories analyze blind samples prepared by the EPA. The laboratories used have compared favorably with other laboratories, indicating that systematic error is within acceptable limits.

In 1994, double-blind samples for specific constituents were analyzed as part of the Ground-Water

Surveillance Program (see Section 7.0, "Quality Assurance," for further discussion of double-blind results). Several wells were also co-sampled with DOH for intercomparison. Co-sampling results for 1994 are presented in the *Environmental Radiation 1994 Annual Report* (DOH 1995).

The chemical composition of ground water may fluctuate from differences in the contaminant source, recharge, or the ground-water flow-field. The range of this concentration fluctuation can be estimated by taking many samples, but there is a limit to the number that can be practicably taken. Comparison of results through time help interpret this variability.

Overall sample uncertainty may be factored into data evaluation by considering the concentration trend in a given well over time. This often helps identify gross errors, and overall long-term trends can be distinguished from short-term variability. The interpretation of concentration trends depends on an understanding of chemical properties as well as site hydrogeology. The trend analysis in turn aids in refining the conceptual model of the chemical transport.

Plume maps presented in this section are diagrams that interpret Site ground-water chemistry. Although analytical data are only available at specific points where wells were sampled, contours are drawn to join the approximate locations of equal chemical concentration or radionuclide activity. The contour maps are simplified representations of plume geometry because of map scale, the lack of detailed information, and the fact that plume depth and thickness cannot be fully represented on a two-dimensional map. Plume maps are a powerful tool because knowledge of concentrations in surrounding wells, ground-water flow, site geology, and other available information may be factored into preparation of the maps. Integration of data from multiple sources minimizes the impact of uncertainty or error in any particular sample.

Results

Ground-water monitoring information obtained for the RCRA monitoring program is reported by DOE (DOE 1995d), and information on drinking water supplies on the Hanford Site is reported by the Hanford Environmental Health Foundation (Thurman 1992). Onsite drinking water supply wells at the FFTF are discussed in Section 6.0, "Potential Radiation Doses from 1994 Hanford Operations." Information gathered in support of the CERCLA program is reported in remedial investigation reports (DOE 1992d). Sitewide ground-water monitoring results for the year are detailed in the Ground-Water Surveillance Programs' annual report (Dresel et al. 1995), which provides further information on the interpretations reported below. This report also includes a summary of ground-water analytical results for the year in electronic format.

One way to assess the impact of radionuclides and chemicals in ground water is to compare the concentrations to EPA's Drinking Water Standards and DOE's Derived Concentration Guides (Appendix C, Tables C.2, C.3, and C.6). Derived Concentration Guides are presented in DOE Order 5400.5. Specific drinking water standards had been proposed for only a few radiological constituents at the time this report was prepared. Drinking water standards resulting in an annual dose of 4 mrem/yr have been calculated for other radionuclides by considering the half-life of the isotope, the energy and nature of the radioactive decay for that isotope, and physiological factors such as the buildup of the isotope in particular organs. Drinking water standards are more restrictive than the Derived Concentration Guides because the Drinking Water Standards are based on an annual dose to the affected organ of 4 mrem/yr, and the Derived Concentration Guides are based on an effective dose equivalent of 100 mrem/yr (see Appendix C, "Applicable Standards and Permits"). The Derived Concentration Guides are available only for radionuclides. Primary and secondary Drinking Water Standards are given for some chemical constituents. Secondary Drinking Water Standards are based on aesthetic rather than health considerations.

Radiological Monitoring Results for the Unconfined Aquifer

Radionuclides analyzed in ground water are listed in Table 5.8.2. Iodine-131, ruthenium-103, and ruthenium-106 have relatively short half-lives and historically have been detected near operating reactors or liquid waste disposal facilities near active fuel reprocessing facilities. These radionuclides

have not been observed in concentrations above the Drinking Water Standards, and in general, have not been detected since soon after the shutdown of N Reactor and the PUREX Plant. The detection limit for ruthenium-106 by gamma scan is higher than the Drinking Water Standard, but with a half-life of only 1 year ruthenium-106 decays rapidly to concentrations less than the Drinking Water Standard. Gross (total) alpha and beta are used as indicators of radionuclide distribution and are not discussed in detail because the specific radionuclides contributing to these measurements are discussed. The distribution of antimony-125, cobalt-60, cesium-137, iodine-129, plutonium, strontium-90, technetium-99, tritium, and uranium will be discussed in the following sections. The types of operations resulting in the release of these radionuclides to ground water are listed in Table 5.8.1. The table also lists the locations where these operations were performed.

Tritium

Tritium was present in many waste streams discharged to the subsurface and is the most mobile radionuclide onsite. As a result, tritium reflects the extent of contamination in the ground water from Site operations and is the radionuclide most frequently monitored at the Hanford Site. Significant quantities of tritium are associated with irradiation of nuclear fuel. The source of the tritium is generally believed to be low-yield ternary fission (rare events, in which the nucleus decays into three atomic fragments) although irradiation of lithium impurities in the fuel could also be responsible. Tritium is released through decladding and dissolution of the fuel. Process condensates associated with the elevated temperature portions of the fuel processing cycle provide a release pathway for that tritium. Tritium was also manufactured as part of the Site mission. Tritium was produced by irradiating lithium-containing targets in the 100-H and 100-B reactors from 1949 to 1952 (Gerber 1993). In the late 1960s, tritium production took place in the 100-N reactor (Gerber 1992). Figure 5.8.11 shows the 1994 distribution of tritium in the unconfined aquifer.

Tritium in the 100 Areas. Tritium concentrations greater than the 20,000-pCi/L Drinking Water Standard were detected in the 100-D, 100-F, 100-K, and 100-N Areas. Tritium concentrations greater than the Drinking Water Standard were detected in five wells in the 100-D Area. The maximum tritium level reported was 69,000 pCi/L in monitoring well 199-D5-17. Many of the wells were installed recently as part of the CERCLA program, and long-term trend data are unavailable.

Only one well in the 100-F Area (199-F8-3) contained tritium at concentrations greater than the Drinking Water Standard (98,300 pCi/L).

The 100-K Area well, 199-K-30, continued to contain the highest tritium concentration within the 100 Areas, with a maximum concentration of 1,040,000 pCi/L reported in November 1994. This well contained tritium in excess of the Derived Concentration Guide (2,000,000 pCi/L) in April and May 1993. The tritium trend for well 199-K-30 is shown in Figure 5.8.12. Concentrations in this well fluctuate; the previous high value was in late 1987. The source of tritium contamination found in well 199-K-30 is subject to some dispute. Although the contamination has been attributed to leakage of the K-East reactor fuel storage basin, another potential source is past disposal to a french drain east of the reactor building (DOE 1993a). A careful evaluation of the contaminant trends and distribution of other constituents such as antimony-125, carbon-14, and strontium-90 suggests that the source of tritium is not leakage of the fuel storage basin. However, basin leakage has possibly contributed to contamination found in well 199-K-27. Tritium concentrations in monitoring well 199-K-27 remained high but below the Derived Concentration Guide (maximum of 628,000 pCi/L) in 1994.

Tritium in the 100-N Area is found in concentrations greater than the Drinking Water Standard in the northern part of the area, extending to the surrounding 600 Area. This plume is associated with two liquid waste disposal trenches, 1301-N Liquid Waste Disposal Facility and 1325-N Liquid Waste Disposal Facility. The maximum tritium level reported in the 100-N Area in 1994 was 74,200 pCi/L. This value is comparable to most results for the past several years.

Tritium in the 200 Areas. The highest tritium concentrations in the 200-East Area continued to be in wells near cribs that received effluent from the PUREX Plant. Concentrations greater than the 2,000,000-pCi/L Derived Concentration Guide were

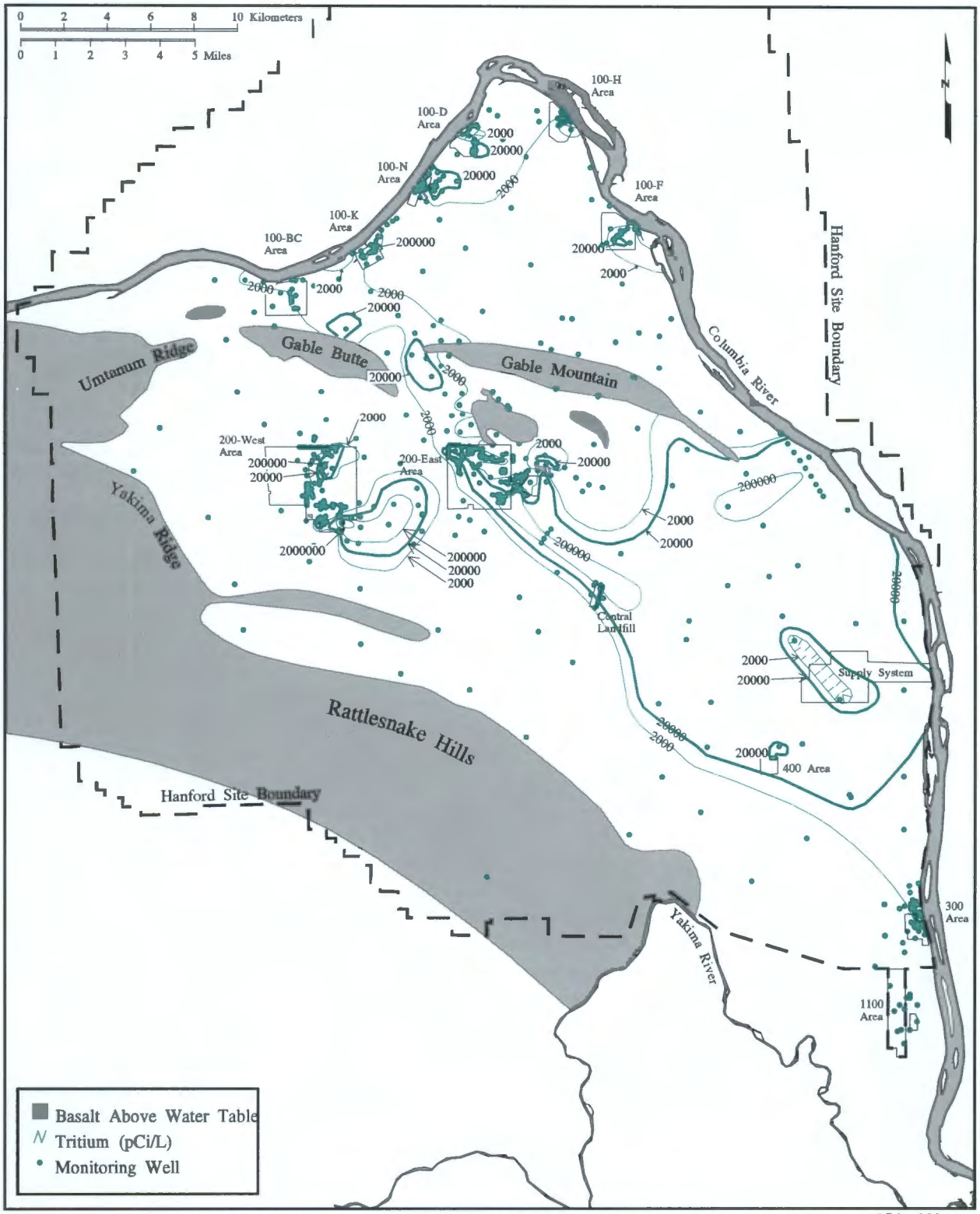

Figure 5.8.11 Tritium Concentrations in the Unconfined Aquifer, 1994

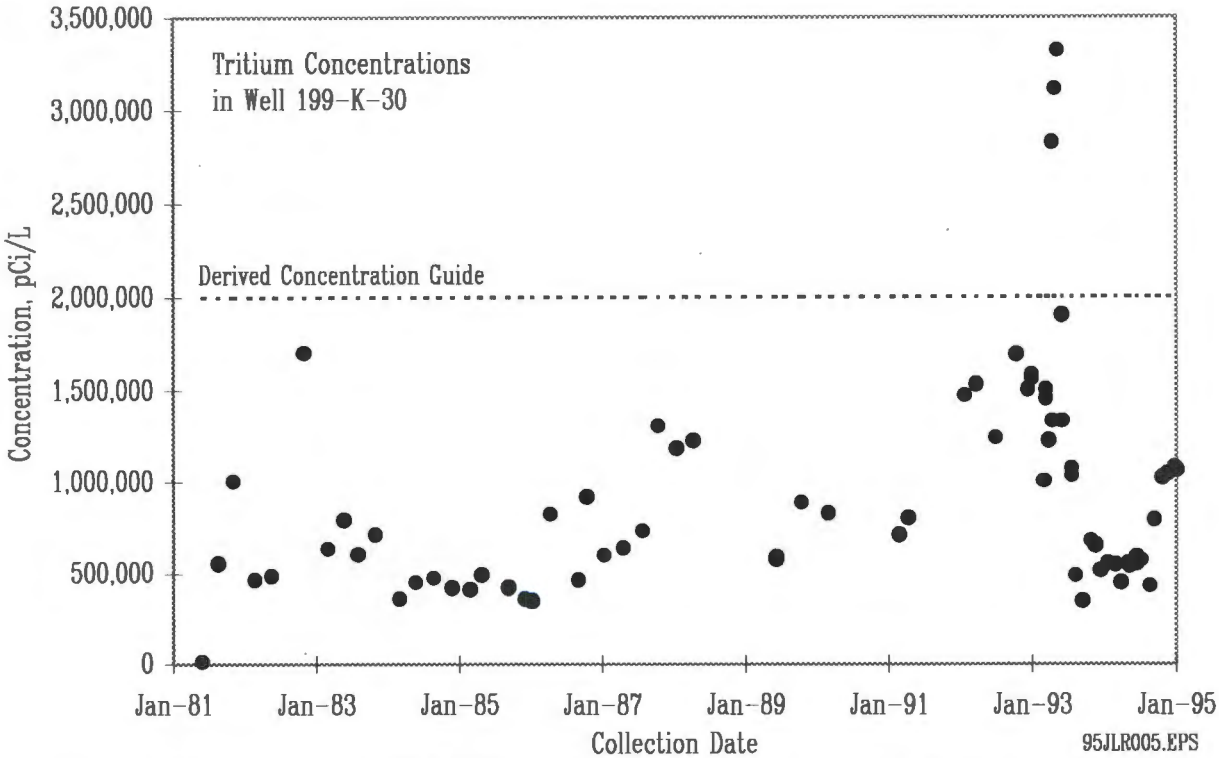

Figure 5.8.12 Tritium Concentrations in Well 199-K-30, 1981 Through 1994

detected in only one well in 1994 in the 200-East Area, 299-E17-9. The tritium level detected in this well monitoring the 216-A-36B Crib was 3,370,000 pCi/L, which was the highest concentration detected in any well onsite. The tritium trend in this well is shown in Figure 5.8.13. Concentrations in monitoring wells downgradient of the 216-A-10 Crib decreased to less than the Derived Concentration Guide in 1993 and remained below the DCG in 1994. Although tritium concentrations are generally decreasing in wells near the PUREX cribs, tritium concentrations exceeding the Drinking Water Standard continued to occur in many wells affected by PUREX Plant discharge.

The movement of the widespread tritium plume (see Figure 5.8.11) extending from the southeastern portion of the 200-East Area to the Columbia River was consistent with patterns noted earlier (Dirkes et al. 1994, Dresel et al. 1994). Separate tritium pulses associated with the two episodes of PUREX operations can be distinguished in the plume. The 200,000-pCi/L lobe of the plume east of the 200-East Area near the Columbia River is a result of discharges to ground water during the operation of the PUREX Plant from 1956 to 1972. Following an 11-year shutdown, plant operation began again in 1983 and ceased in December 1988. Elevated tritium concentrations measured in several wells (e.g., wells 699-32-43 and 699-24-33) downgradient from the 200-East Area represent a second pulse of tritium moving away from PUREX waste disposal facilities. Movement of the leading edge of this plume is clearly observable in well 699-24-33, Figure 5.8.14, which shows arrival of the plume in early 1987 following the passage of the plume from the earlier operation of the PUREX Plant. Tritium concentrations from the first plume were much higher than from the second. By contrast, a trend plot of the tritium concentrations in well 699-40-1 located near the shore of the Columbia River (Figure 5.8.15) shows the arrival in the mid-1970s of the plume from the first campaign and no indication that the second pulse has yet arrived. The area near the Columbia River with tritium concentrations greater than 200,000 pCi/L continues to shrink from approximately 4.2 km^2 (16 mi^2) in 1988 (Evans et al. 1989) to 5 km^2 (2 mi^2) in 1994. However, the overall extent of contamination from the PUREX Plant at levels greater than the 20,000 pCi/L Drinking Water Standard remained nearly the same as in previous years.

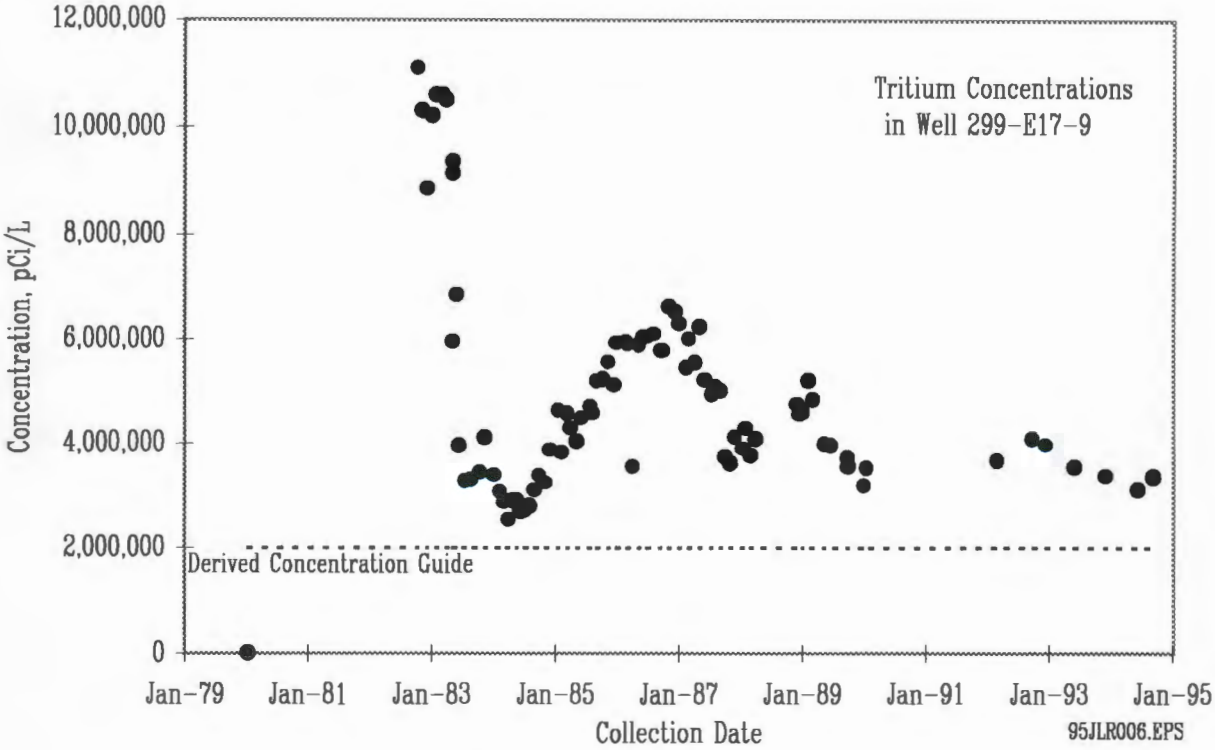

Figure 5.8.13 Tritium Concentrations in Well 299-E17-9, 1980 Through 1994

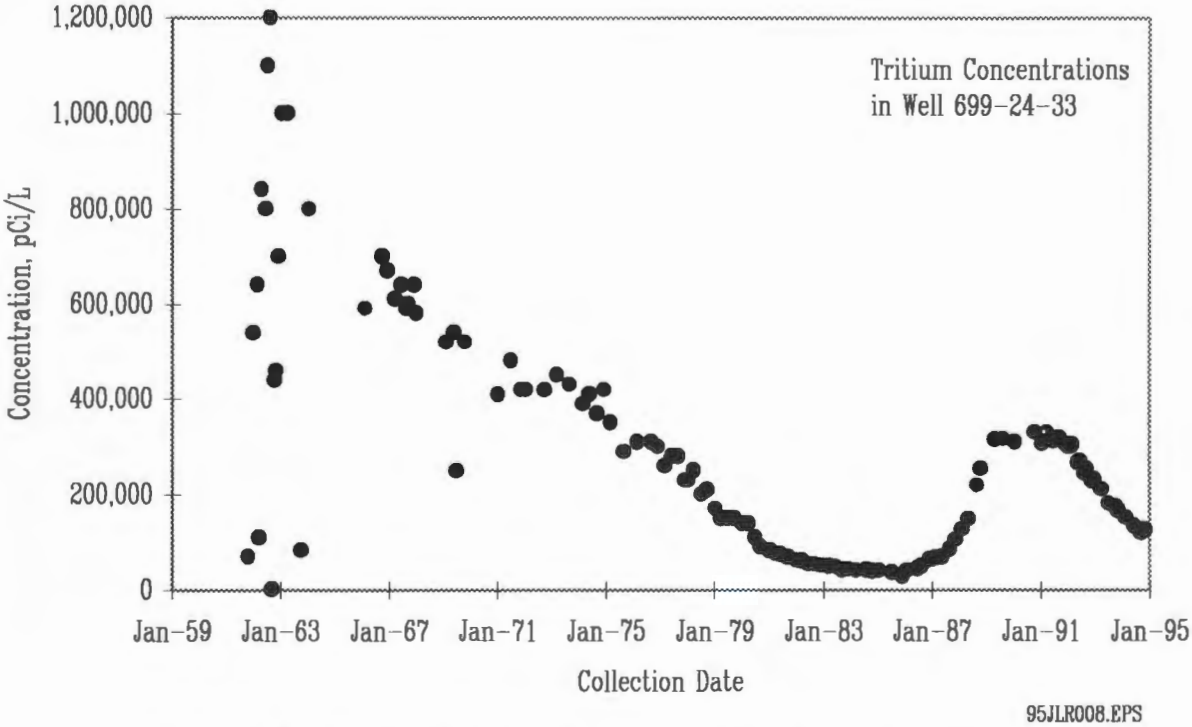

Figure 5.8.14 Tritium Concentrations in Well 699-24-33, 1962 Through 1994

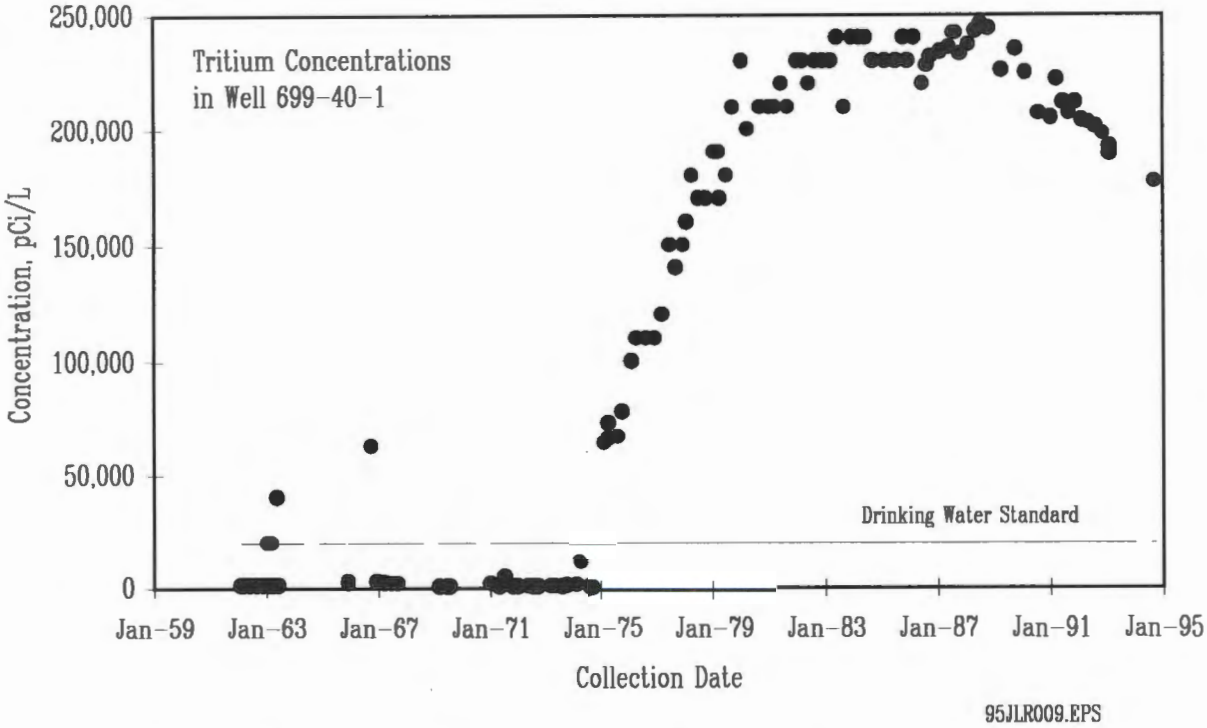

Figure 5.8.15 Tritium Concentrations in Well 699-40-1, 1962 Through 1994

The tritium plume resulting from Site activities has been monitored for much of the time the Site has been in operation, providing information on the change in extent of contamination over time. Figure 5.8.16 shows the extent of tritium from 1964 to 1988. This figure was created from maps in Wilson (1965), Raymond et al. (1976), Prater et al. (1984), and Jaquish and Bryce (1989). The contours in the original references were recalculated and interpreted to provide uniform contour intervals. Figure 5.8.16 shows that tritium at concentrations greater than the Drinking Water Standard reached the Columbia River in approximately the mid-1970s. Variation in the extent of tritium mapped in the 100 Area appears to result from differences in the monitoring network and different interpretation of results between investigators.

The eastern portion of the tritium plume continues to move to the east-southeast and discharge into the Columbia River. Figure 5.8.17 shows the trend of tritium concentrations in well 699-S19-E13, located just north of the 300 Area. In recent years, this well has shown a general increase in tritium, reaching a maximum value of 13,300 pCi/L in November 1994. The tritium plume has reached the 300 Area but is not expected to impact the North Richland well field because of the influence on ground-water flow from the Yakima River and recharge from infiltration ponds at the North Richland Wellfield. The Yakima River is at a higher elevation and recharges the ground water in this area, which discharges to the Columbia River (Newcomer et al. 1991). As a result, as shown in Figure 5.8.18, ground water flows from west to east, decreasing the southward movement of the contaminant plume. Recharge ponds at the North Richland Wellfield are supplied with Columbia River water, which infiltrates to the ground water. The amount of recharge water exceeds the amount pumped at the wellfield by a factor of approximately 2:1, resulting in ground-water flow away from the wellfield. This further ensures that the Site ground water will not reach the wellfield.

The configuration of the western portion of the tritium plume closely matches previous predictions of the direction of contaminant movement from the 200-East Area (Freshley and Graham 1988). Movement is forced to the south by the flow originating at the ground-water mound beneath B Pond. Flow to the southeast also appears to be promoted by a

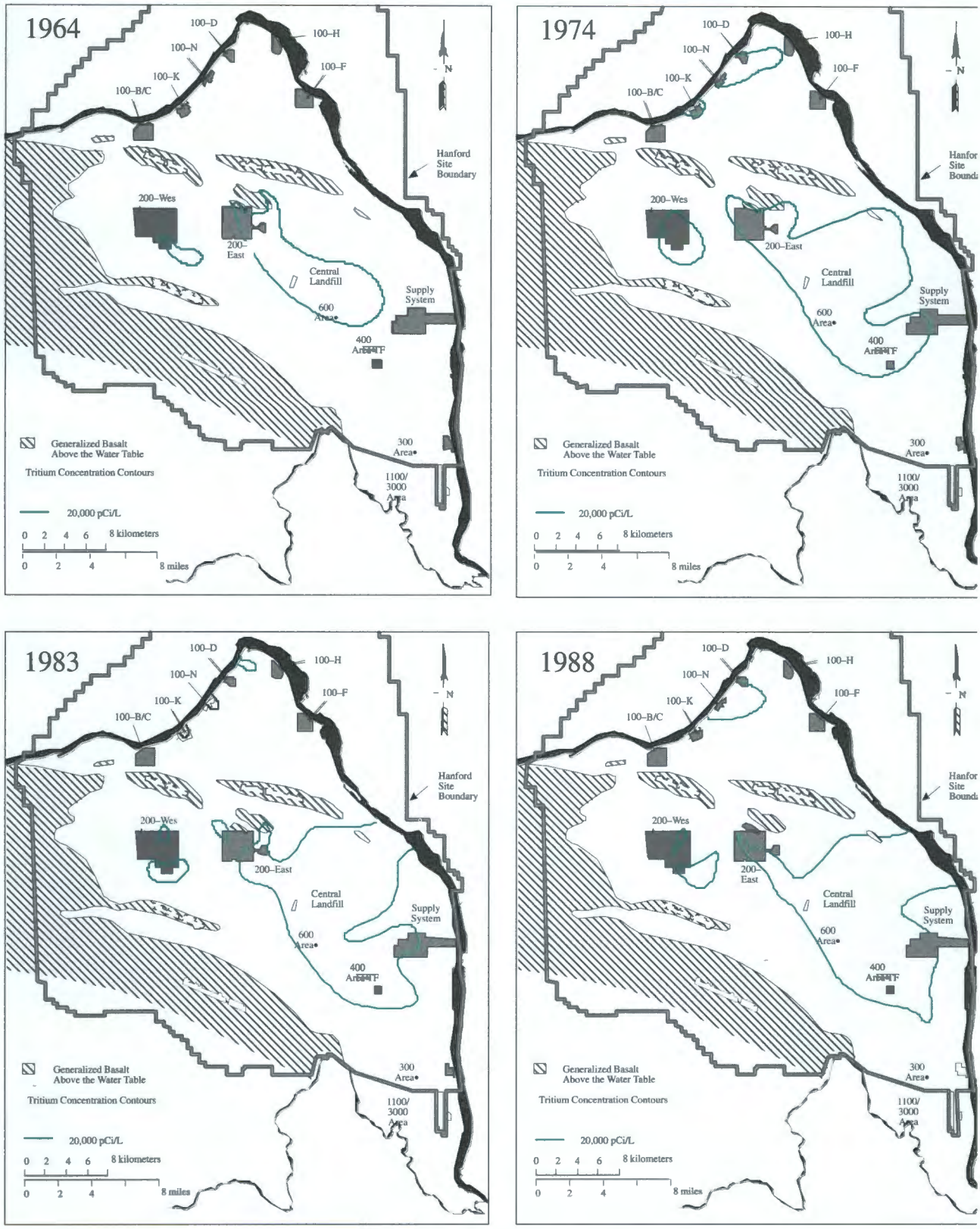

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Figure 5.8.16 Historical Tritium Concentrations on the Hanford Site

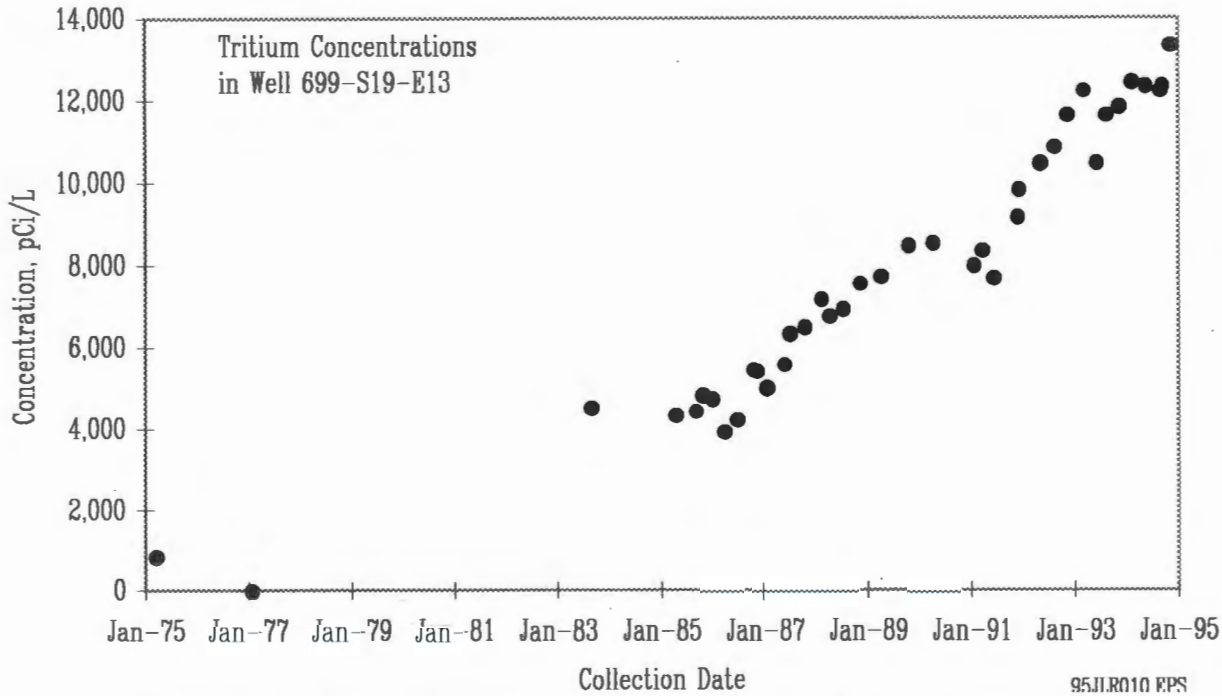

Figure 5.8.17 Tritium Concentrations in Well 699-S19-E13, 1975 Through 1994

zone of high-permeability sediments stretching from the 200-East Area toward the 400 Area (Jacobson and Freshley 1990). Tritium is largely absent from recent disposal to B Pond, which produces a spreading area of essentially uncontaminated water. However, in the immediate vicinity of the pond samples from several wells contain tritium at levels above the Drinking Water Standard. This tritium apparently results from earlier disposal to B Pond. Tritium in the vicinity of B Pond can be seen in the 1974 plume map shown in Figure 5.8.16. The mound under B Pond is expected to start to dissipate in 1995 as flow is diverted to the 200-East treated effluent disposal facility. A new mound will presumably form farther east under the treated effluent disposal facility as long as it is used for disposal of Site effluent.

Tritium is also found at levels above the Drinking Water Standard in the northwestern part of the 200-East Area. This plume appears to extend to the north through the gap between Gable Mountain and Gable Butte, indicating a divide in ground-water flow direction across the 200-East Area.

The extent of tritium plumes in and around the 200-West Area is also consistent with previous observations. Tritium from sources near the Reduction-Oxidation (REDOX) Plant forms the most extensive and highest concentration plume in the 200-West Area. The REDOX Plant is located in the southeastern part of the 200-West Area and operated from 1951 through 1967. Only one well in the 200-West Area continued to show tritium levels in excess of the Derived Concentration Guide during 1994. This well, 299-W22-9, contained 2,400,000 pCi/L of tritium, continuing its decline in concentration (Figure 5.8.19). The movement of ground water in the 200-West Area is slow because the Ringold sediments have low permeability. Dissipation of the plumes in the 200-West Area is also slow as a result of declining gradients since the closure of U Pond in 1984.

A smaller area of tritium contamination is found in the north-central part of the 200-West Area in the vicinity of the WMA-TY-TX single-shell high-level waste tanks (Figure 5.8.10) and disposal facilities, which received liquid waste from T-Plant operations. This plume extends northeast past the boundary of the 200-West Area.

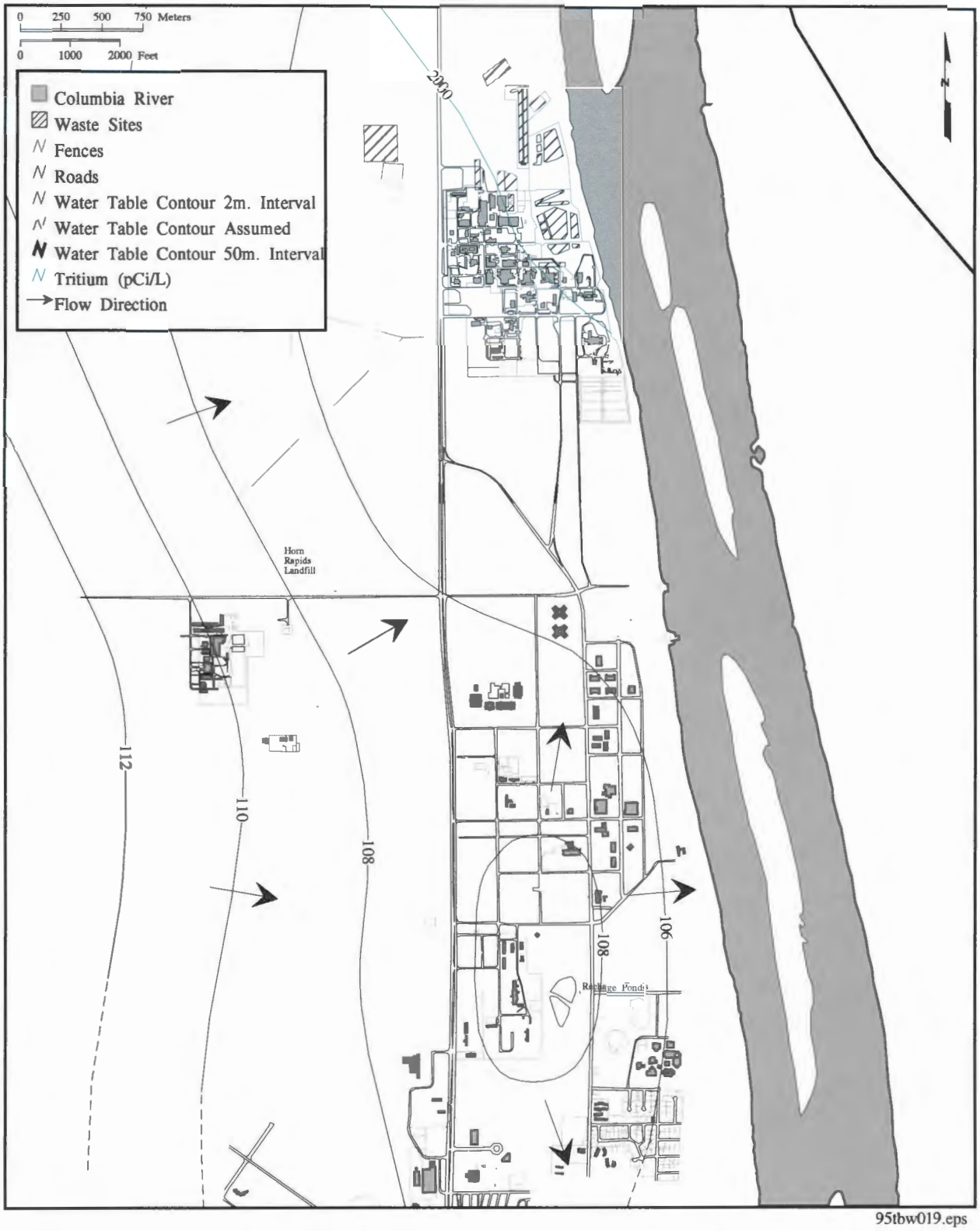

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Figure 5.8.18 Tritium Concentrations and Ground-Water Flow Near the 300 Area, 1994

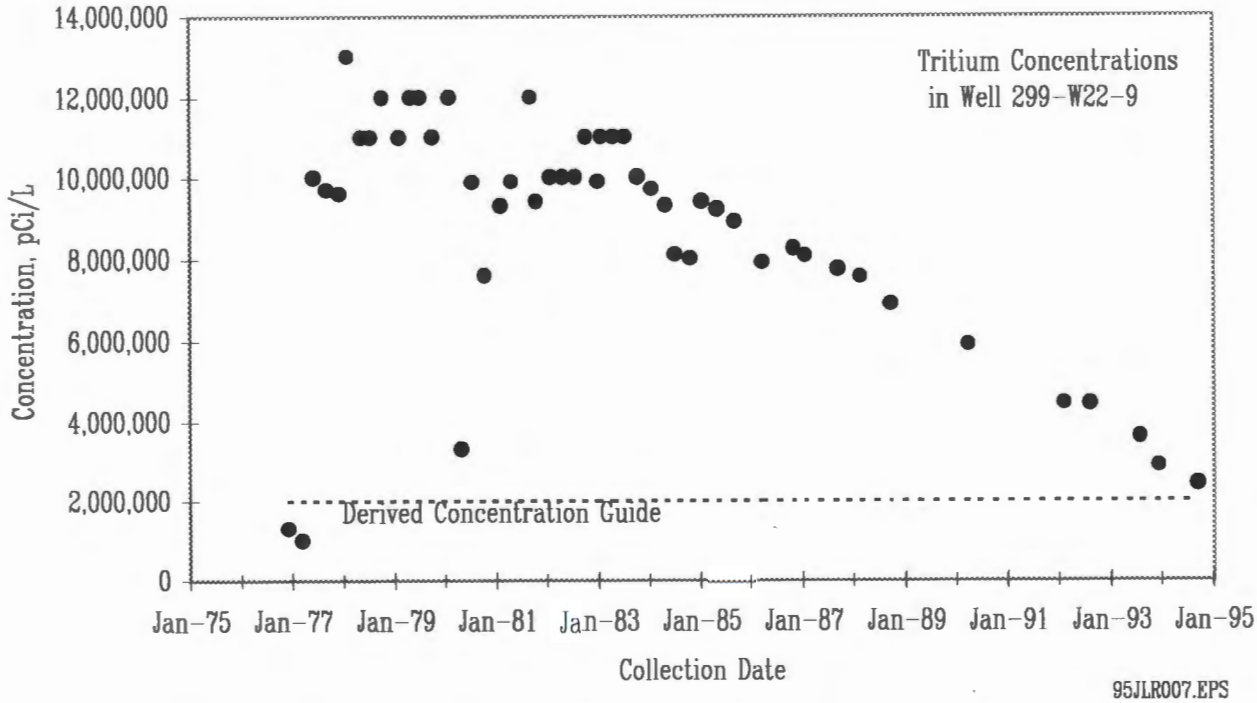

Figure 5.8.19 Tritium Concentrations in Well 299-W22-9, 1976 Through 1994

Iodine-129

The presence of iodine-129 in ground water is significant because of its relatively low Drinking Water Standard (1 pCi/L), its potential for accumulation in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and its long half-life (16,000,000 years). The relatively low fission yield for production of iodine-129 combined with its long half-life limits its specific activity in Hanford wastes. Iodine-129 may be released as a vapor during fuel dissolution and other elevated-temperature processes and thus may be associated with process condensate wastes. At Hanford, the main contributor of iodine-129 to ground water has been liquid discharges to cribs in the 200 Areas. The highest concentrations observed onsite are downgradient from the PUREX and REDOX Plants in the 200-East and 200-West Areas, respectively. No iodine-129 samples were above the Derived Concentration Guide of 500 pCi/L. Iodine-129 extends into the 600 Area as shown in Figure 5.8.20.

The highest iodine-129 concentrations in the 200-East Area are in the northwest near the 216-BY Cribs and in the southeast near the PUREX Plant. The maximum concentration of iodine-129 detected in 1994 in the 200-East Area was 11.8 pCi/L in well 299-E17-9. This well is located south of the PUREX Plant near the 216-A36B Crib. The iodine-129 plume from the PUREX area extends southeast into the 600 Area and appears coincident with the nitrate and tritium plumes. The more limited extent of the iodine-129 detection at levels above the Drinking Water Standard shown in Figure 5.8.20 results from the lower initial concentrations of iodine-129 than the initial concentrations of nitrate and tritium. However, current data indicate that iodine-129 levels above the Drinking Water Standard are approaching the Columbia River (Figure 5.8.20). The iodine-129 plume likely had the same sources as the nitrate and tritium plumes. Iodine-129 has essentially the same high mobility in ground water as nitrate and tritium. Iodine-129 is also present in ground water at levels above the Drinking Water Standard in the northwestern 200-East Area near the BY Cribs and the WMA-B-BX-BY high-level waste, single-shell tanks. This plume extends northwest into the 600 Area into the gap between Gable Mountain and Gable Butte.

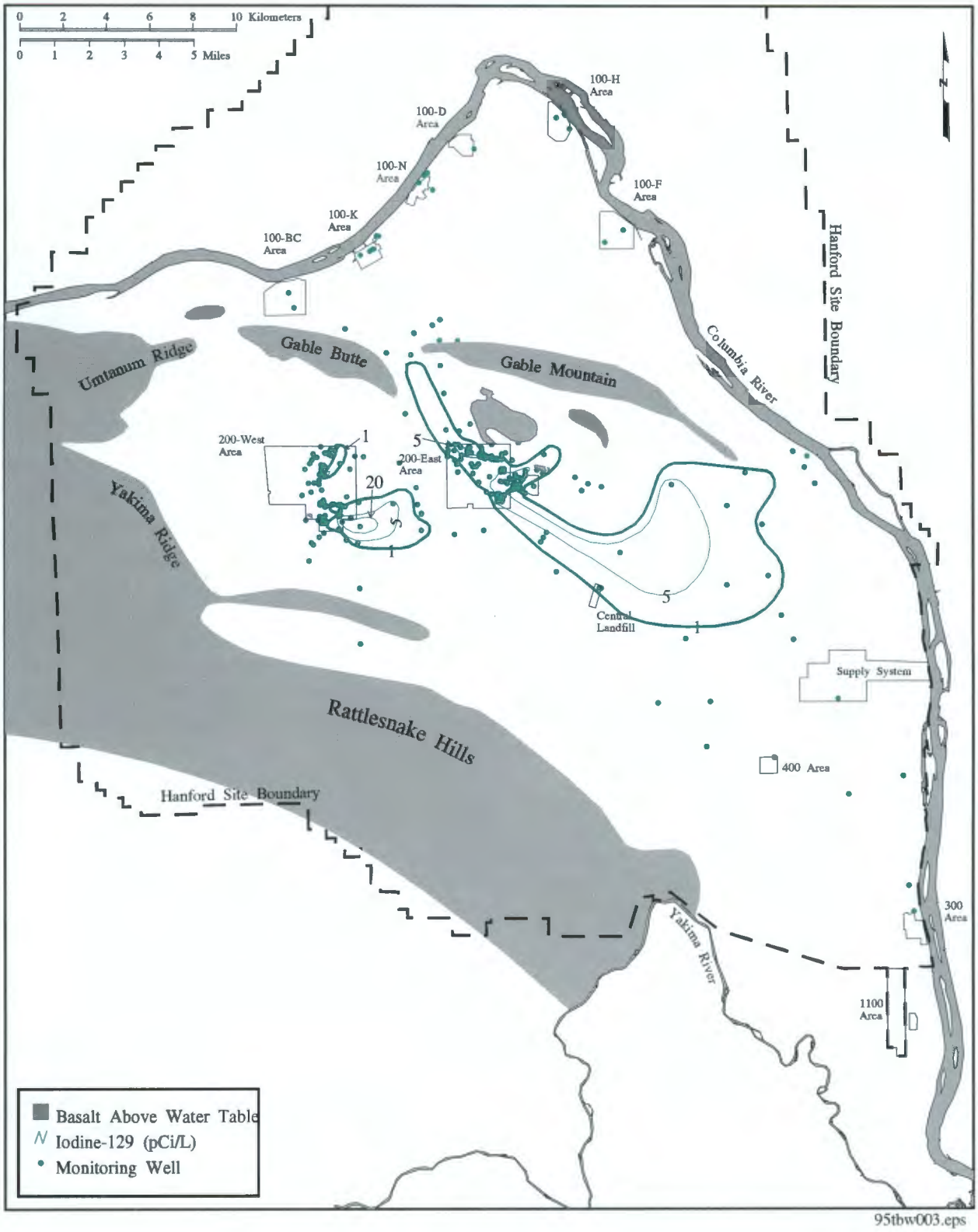

Figure 5.8.20 Distribution of Iodine-129 in the Unconfined Aquifer, 1994

The highest iodine-129 concentration observed in 1994 in Hanford ground water was 86.1 pCi/L in well 299-W22-9, in the southern part of the 200-West Area near the REDOX Plant. This plume is essentially coincident with the nitrate and tritium plumes although there appears to be a contribution from cribs to the north, near the U Plant. A second iodine-129 plume originates near the WMA-T-SST tank farm and nearby disposal facilities and extends northeast toward T Plant, coincident with the technetium-99 and tritium plume in this area.

Strontium-90

Strontium-90 is produced as a high-yield fission product and is present in waste streams associated with fuel processing. Reactor operations may also result in the release of some strontium-90 associated with fuel element breaches. Strontium-90 mobility in Hanford ground water is reduced by adsorption onto sediment particles. Because this adsorption is much weaker than for cesium-137, cobalt-60, and plutonium isotopes, the strontium-90 is still moderately mobile. The sorption does mean that a significant portion of the strontium-90 in the subsurface is not in solution. If ground-water concentrations decrease due to natural processes or remediation activities, the sorbed strontium-90 will desorb and remobilize. This limits the options for ground-water remediation.

Concentrations of strontium-90 were greater than the 8-pCi/L Drinking Water Standard in wells in the 100-B, 100-D, 100-F, 100-H, 100-K, 100-N, 200-East, 200-West, and 600 Areas. Concentrations of strontium-90 were greater than the 1,000-pCi/L Derived Concentration Guide in the 100-N and 200-East Areas.

Strontium-90 in the 100 Areas. Strontium-90 is found at levels greater than the Drinking Water Standard in the 100-B Area and extends into the 600-Area to the east. The maximum concentration detected in 1994 was 56.7 pCi/L in a sample from monitoring well 199-B3-46. The extent of strontium-90 greater than the Drinking Water Standard in the 100-B Area is shown in Figure 5.8.21. The sources for the strontium-90 appear to be liquid waste disposal sites near the B Reactor and liquid overflow trenches near the Columbia River (DOE 1993b). The extent of strontium-90 to the east of the 100-B Area is not completely defined by the current monitoring network.

Strontium-90 continues to be detected at levels greater than the Drinking Water Standard in the 100-D Area in well 199-D5-12. The maximum concentration in 1994 was 44.0 pCi/L, similar to that in 1993. This is the only well in the 100-D Area with strontium-90 concentrations greater than the Drinking Water Standard.

Ground water within a small part of the 100-F Area has strontium-90 concentrations greater than the Drinking Water Standard. The maximum concentration detected in 1994 was 20.5 pCi/L in monitoring well 199-F5-1. Concentrations greater than 200 pCi/L have been detected in well 199-F5-3 in previous years, so the 1994 value of only 18.4 pCi/L is suspect. The 100-F Area strontium-90 plume is shown in Figure 5.8.22.

The extent of strontium-90 at levels greater than the Drinking Water Standard in the 100-H Area is shown in Figure 5.8.23. The maximum concentration detected in the 100-H Area in 1994 was 28 pCi/L in monitoring well 199-H4-13. This is similar to the level detected in 1993.

The extent of strontium-90 at levels greater than the Drinking Water Standard in the 100-K Area is shown in Figure 5.8.24. The maximum concentration detected in 1994 was in new well 199-K-109A, where the concentration reached 803 pCi/L. This level is considerably higher than levels noted in wells sampled in past years and indicates a previously unidentified strontium-90 plume. Strontium-90 is also found near the K-West reactor building, and an extensive plume continues to be found near the liquid waste trench.

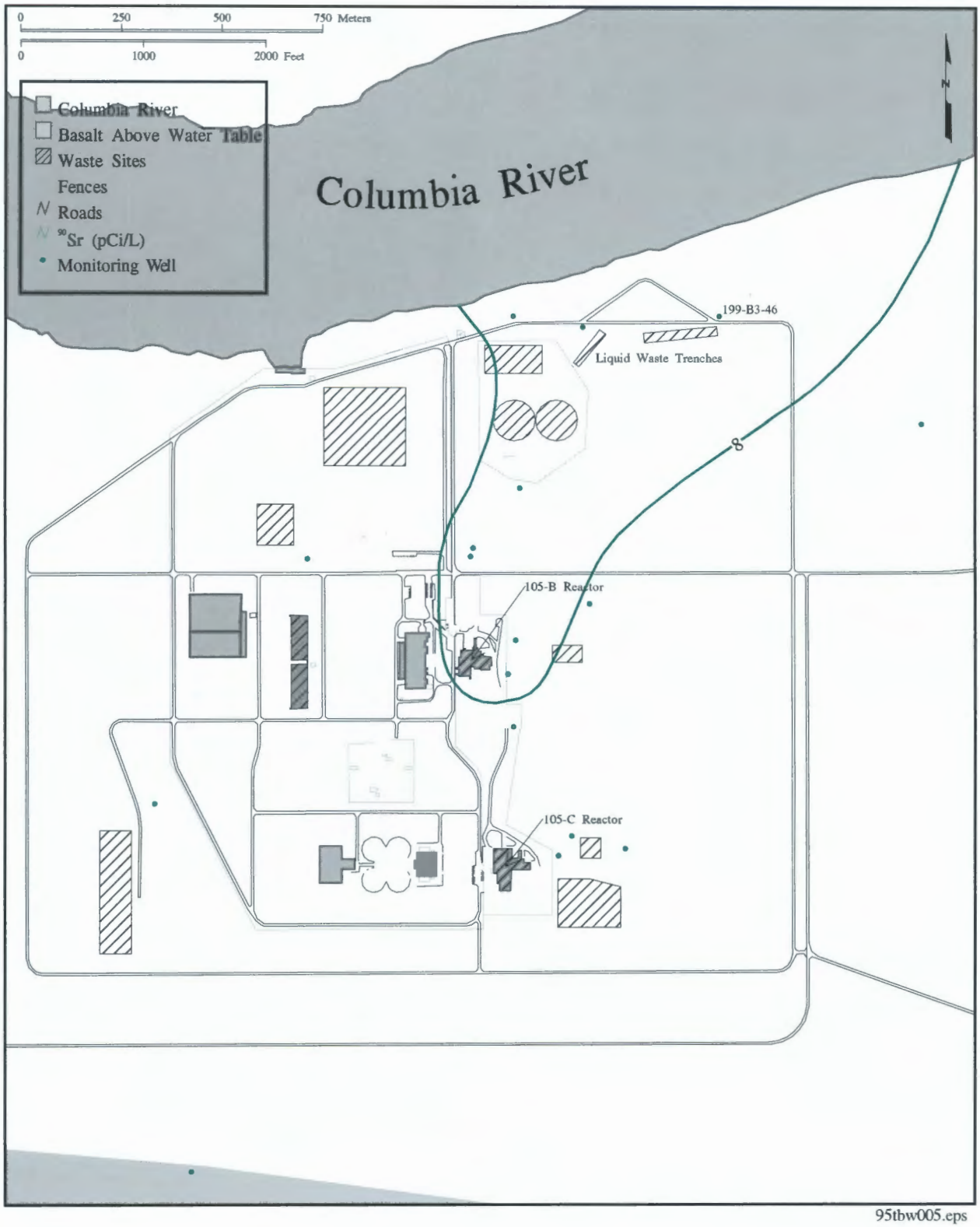

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Figure 5.8.21 Concentrations of Strontium-90 in the Unconfined Aquifer in the 100-B Area, 1994

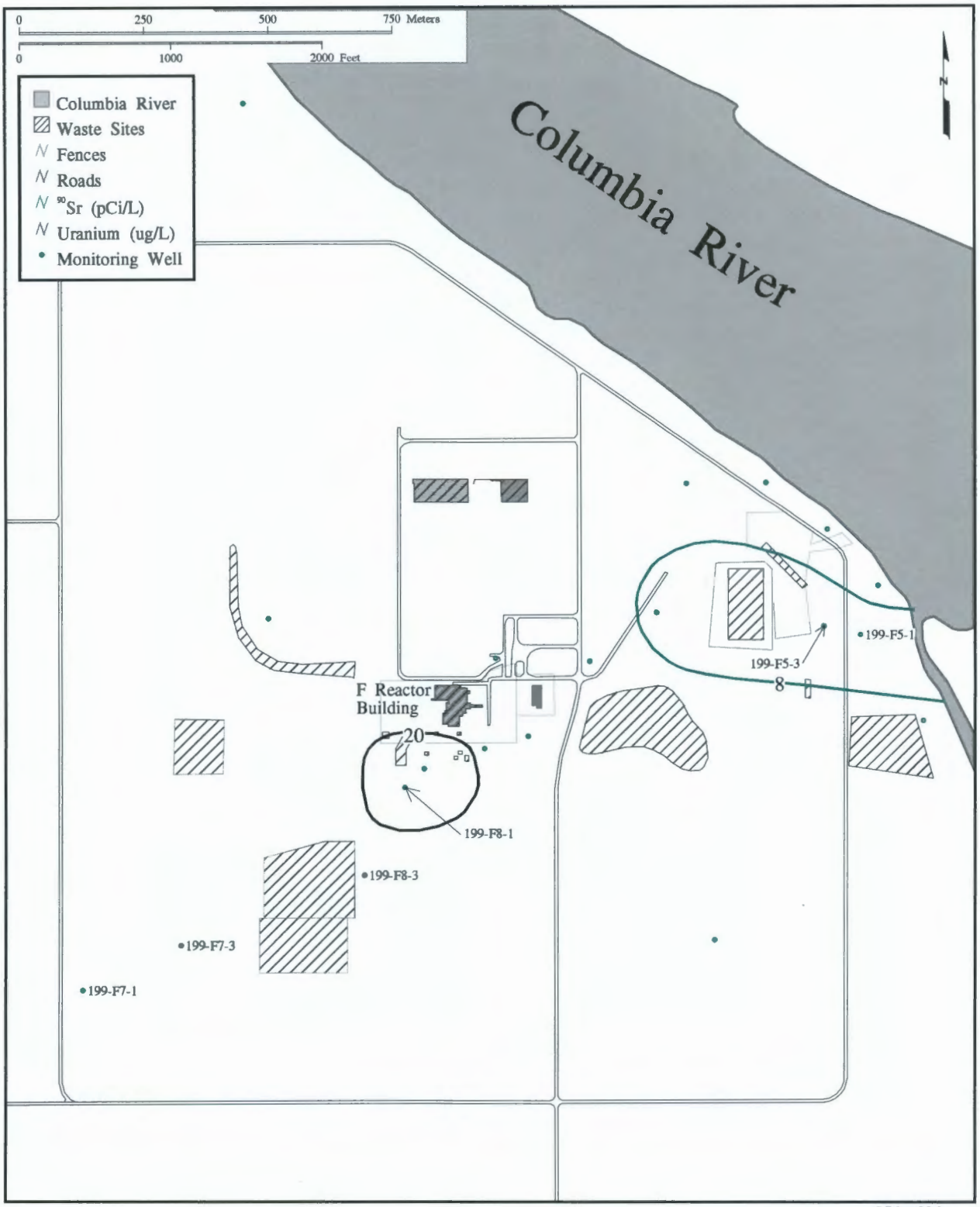

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Figure 5.8.22 Concentrations of Strontium-90 and Uranium in the Unconfined Aquifer in the 100-F Area, 1994

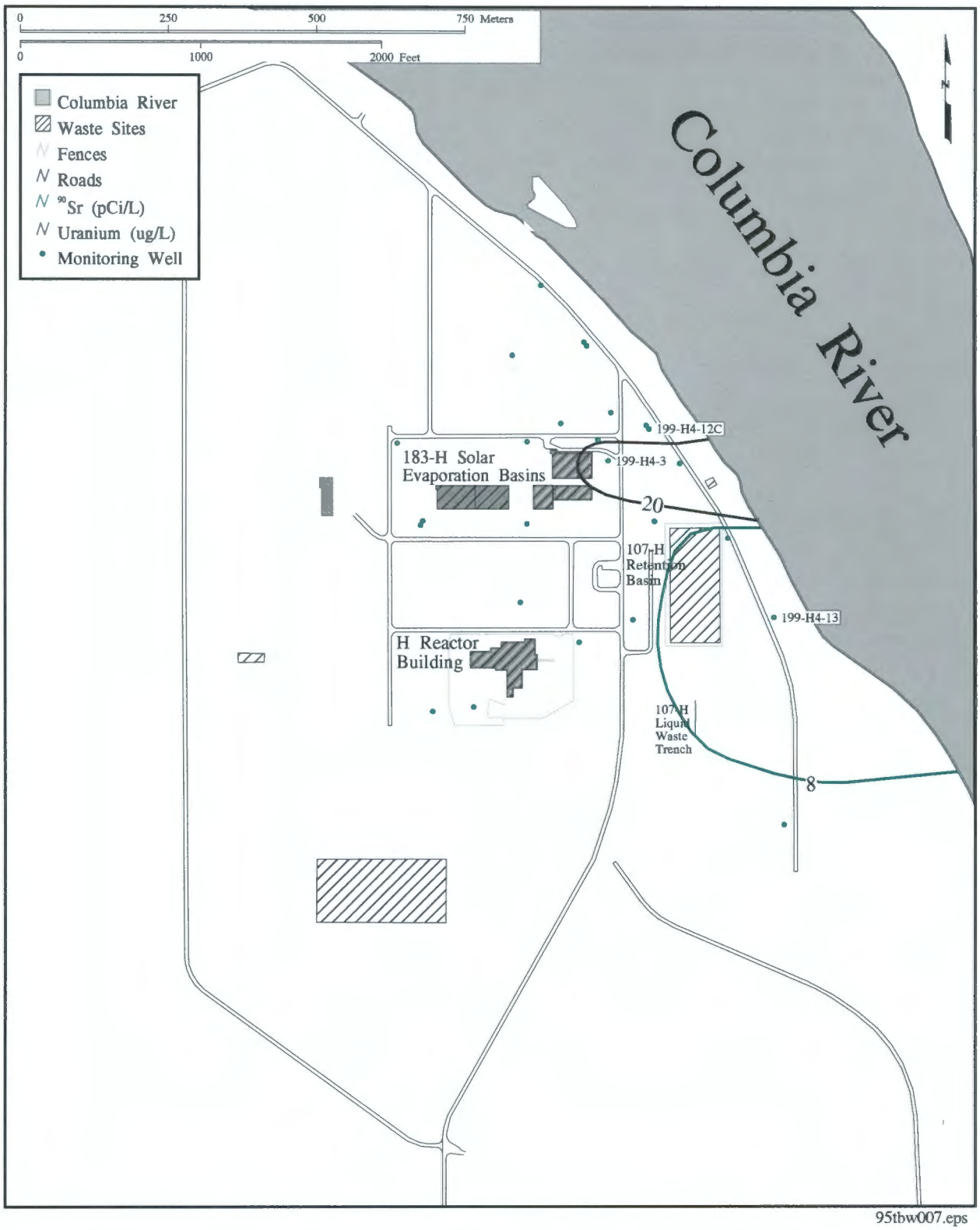

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Figure 5.8.23 Concentrations of Strontium-90 and Uranium in the Unconfined Aquifer in the 100-H Area, 1994

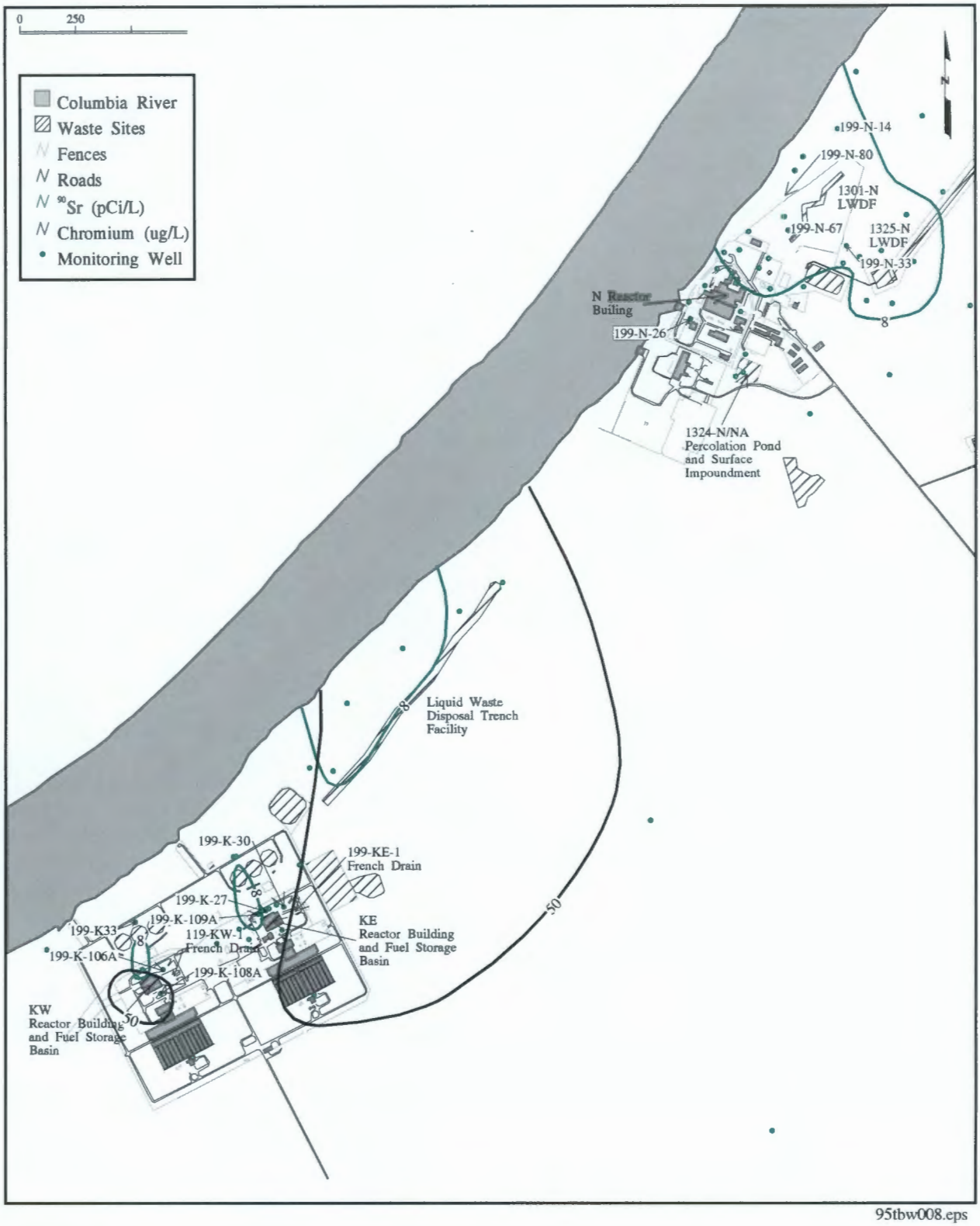

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Figure 5.8.24 Concentrations of Strontium-90 and Chromium in the Unconfined Aquifer in the 100-K and 100-N Areas, 1994

Strontium-90 was detected in concentrations greater than the 1,000 pCi/L Derived Concentration Guide in the 100-N Area in 1994. The maximum level detected was 4,030 pCi/L in well 199-N-67. This well is located between the 1301-N Liquid Waste Disposal Facility and the Columbia River. The distribution of strontium-90 in the 100-N Area is shown in Figure 5.8.24. Concentrations in well 199-N-67 have dropped to less than one-fourth of the maximum of 23,400 pCi/L measured in 1989 but the concentrations have leveled off in recent years as shown in Figure 5.8.25. Strontium-90 discharges to the Columbia River in the 100-N Area through springs along the shoreline, which are sampled as part of the surface water surveillance and near-facility environmental monitoring programs. The strontium-90 plume spread northward in the 1980s is illustrated by the trend data from well 199-N-14 (Figure 5.8.26). The strontium-90 concentrations in this well have remained approximately level since 1989. Wells farther northeast do not show detectable strontium-90. The steady levels indicate the plume is not spreading at any discernible rate at this time.

Strontium-90 in the 200 Areas. Concentrations of strontium-90 in the 200-East Area ranged up to 9,740 pCi/L in well 299-E28-23 near the 216-B-5 Reverse Injection Well. Strontium-90 was also found at 69.3 pCi/L in well 299-E28-2, which is approximately 150 m (490 ft) from the 216-B-5 injection well. Strontium-90 distribution in the 200-East Area is shown in Figure 5.8.27. Strontium-90 has been detected in past years at levels above the Drinking Water Standard in wells near the PUREX Plant cribs.

Strontium-90 is detected occasionally in the 200-West Area. In 1994, samples from two wells exceeded the Drinking Water Standard, with the maximum concentration detected at 14.5 pCi/L in well 299-W19-24.

Strontium-90 in the 600 Area. Concentrations of strontium-90 greater than the Drinking Water Standard but less than the Derived Concentration Guide of 1,000 pCi/L are detected in several wells in the former Gable Mountain Pond area (Figure 5.8.27). Strontium-90 contamination in this area resulted from the discharge of radioactive waste to the

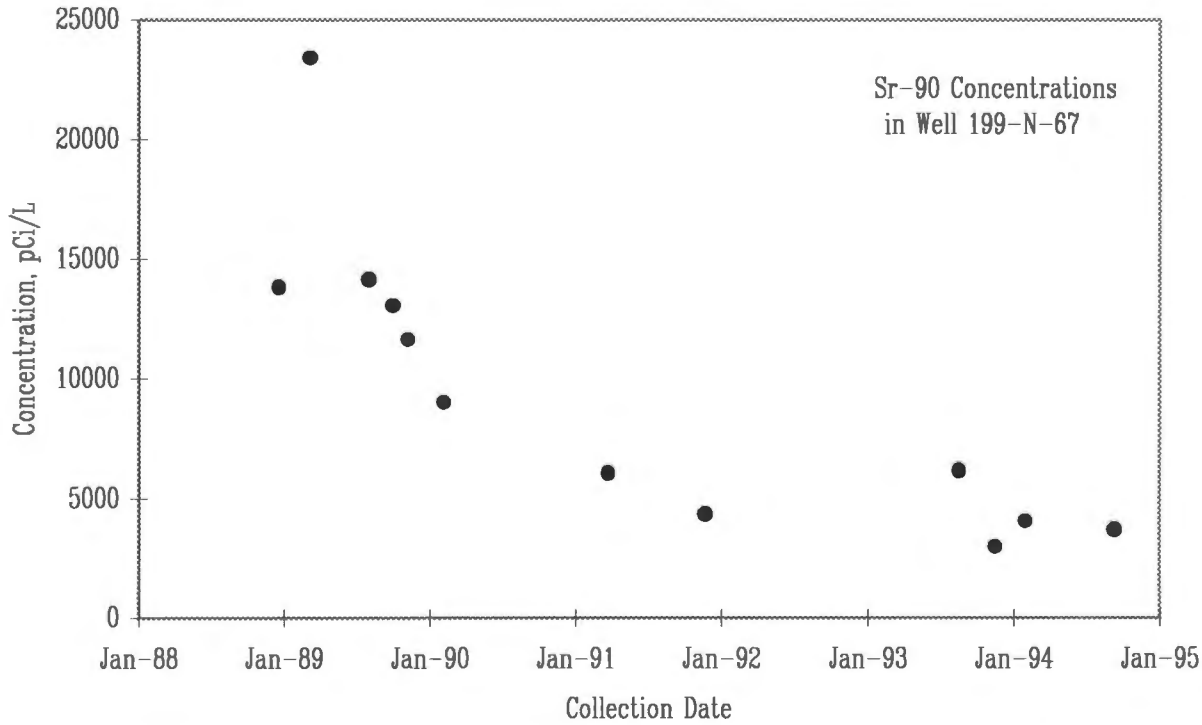

Figure 5.8.25 Strontium-90 Concentrations in Well 199-N-67, 1988 Through 1994

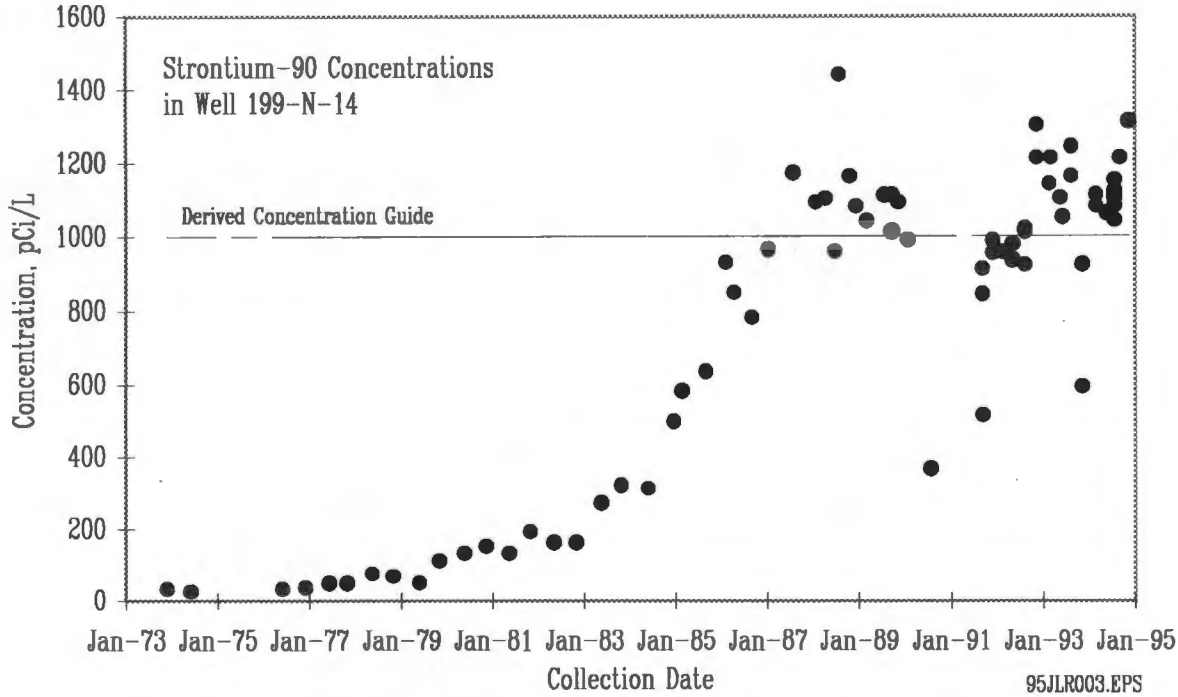

Figure 5.8.26 Strontium-90 Concentrations in Well 199-N-14, 1973 Through 1994

former Gable Mountain Pond during its early use. Strontium-90 has since migrated through the sedimentary column to the ground water, which is relatively close to the surface at that location. Initial breakthrough occurred in 1980 in some areas. The depth to bedrock is also small in the former Gable Mountain Pond area, and strontium-90 has been detected in wells completed in the basalt just below the unconsolidated sediments. The maximum concentration of strontium-90 detected in the former Gable Mountain Pond area was 994 pCi/L in well 699-53-48B.

Technetium-99

Technetium-99 is produced as a fission product and is present in waste streams associated with fuel processing. Reactor operations may also result in the release of some technetium-99 associated with fuel element breaches. Technetium-99 is normally present in an anionic form and thus tends to migrate in Hanford ground water essentially unretarded.

Technetium-99 was found at concentrations greater than the 900-pCi/L Drinking Water Standard in two areas of the Hanford Site. The first area is the northwestern part of the 200-East Area and a part of the 600 Area extending north toward the gap between Gable Mountain and Gable Butte (Figure 5.8.27). The source of this technetium was apparently the BY Cribs (DOE 1993c, Dresel et al. 1994). The technetium-99 plume is associated with cobalt-60, cyanide contamination, and tritium. The maximum technetium-99 concentration detected in this plume in 1994 was 4,310 pCi/L in well 699-52-54, which represents an increasing concentration from monitoring in past years (Figure 5.8.28).

Technetium-99 is also detected at levels greater than the Drinking Water Standard in the 200-West Area and the adjacent 600 Area (Figure 5.8.29). The largest technetium-99 plume in the 200-West Area originates in the cribs that received effluent from U Plant. The maximum technetium-99 concentration detected in the 200-West Area in 1994 was in well 299-W19-24. This well had a technetium-99 concentration of 23,700 pCi/L. This plume extends well into the 600 Area towards the 200 Area. As shown in Figure 5.8.29, several smaller areas with technetium-99 greater than the Drinking Water Standard were also found in the 200-West Area. The northernmost technetium-99 plume in the 200-West Area is essentially coincident with the northern tritium plume and appears to originate near

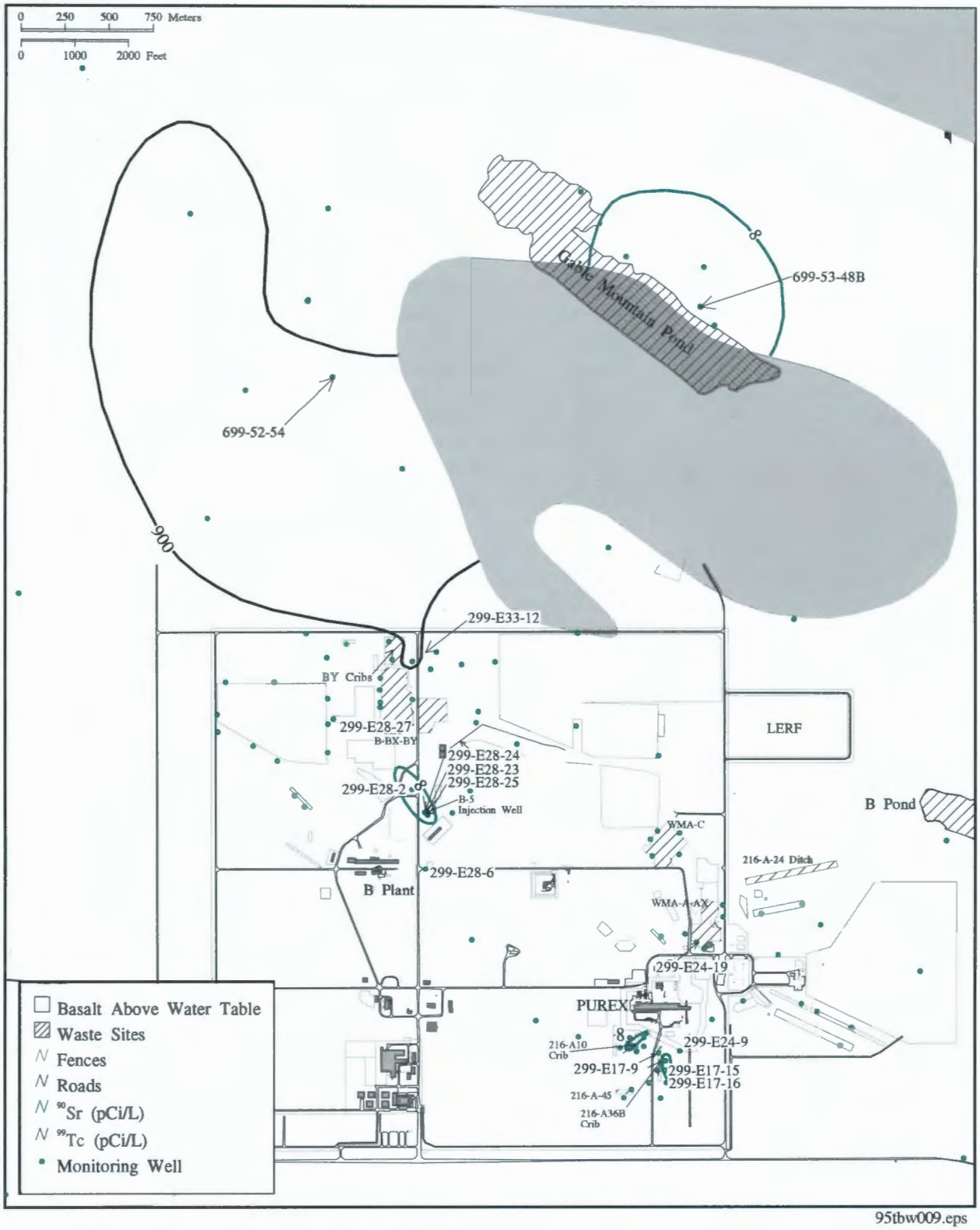

Figure 5.8.27 Concentrations of Strontium-90 and Technetium-99 in the Unconfined Aquifer Near the 200-East Area, 1994

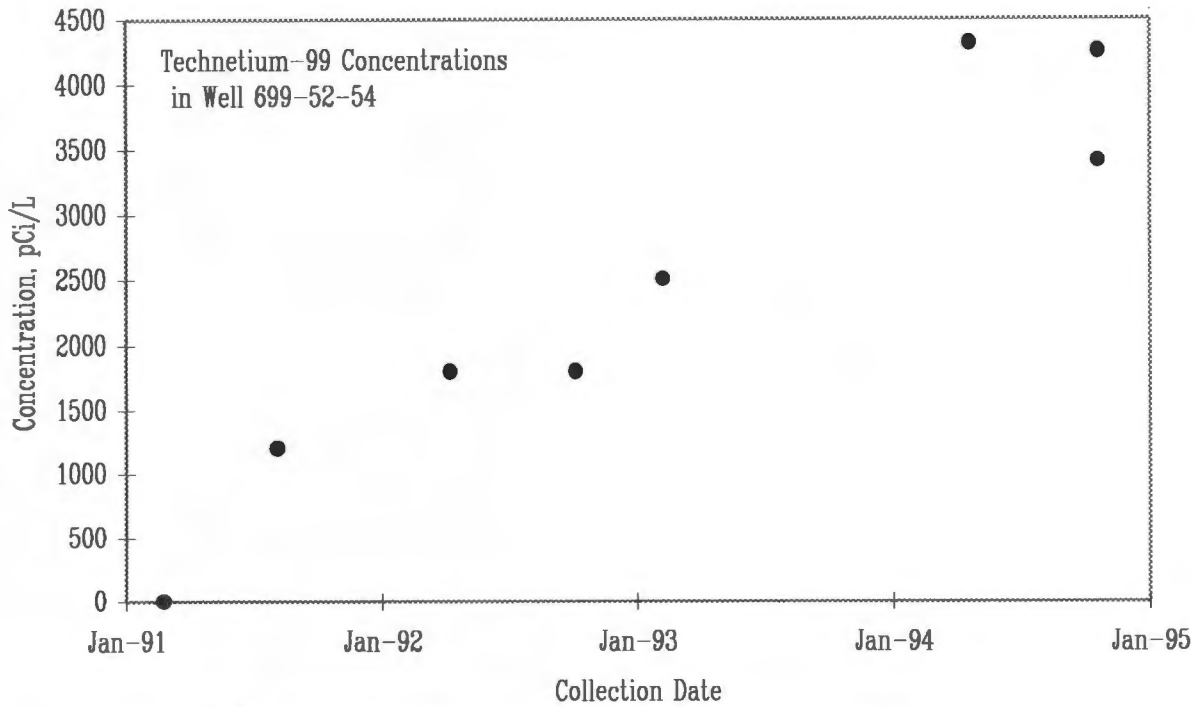

Figure 5.8.28 Technetium-99 Concentrations in Well 699-52-54, 1991 Through 1994

the disposal facilities in the vicinity of the WMA-TY-TX single-shell, high-level waste tanks. The southernmost plume in the 200-West Area originates near the disposal facilities of the WMA-S-SX high-level waste, single-shell tank farm.

Uranium

There are numerous possible sources of uranium released to the ground water at Hanford including fuel fabrication, fuel processing, and uranium recovery operations. Uranium may exist in several states including elemental uranium or uranium oxide as well as tetravalent and hexavalent cations. Only the hexavalent form has significant mobility in ground water, largely by forming dissolved carbonate species. Uranium mobility is thus dependent on both oxidation state and pH. Uranium is observed to migrate in Hanford ground water but is retarded relative to more mobile species such as technetium and tritium.

The EPA has proposed a Drinking Water Standard of 20 μg/L for uranium. This is in contrast to other radionuclides for which the standards are given in pCi/L. The reason for the difference is evidence that uranium ingestion may cause kidney damage, which is assessed as a chemical hazard rather than a radiological hazard. However, uranium may be analyzed by an alpha-counting method and has an associated risk through its radioactivity, so it is important to be able to convert between ground-water concentrations expressed in μg/L and those expressed in pCi/L. The conversion factor depends on the proportions of uranium-234, -235, and -238 in the ground water. The EPA considers the Drinking Water Standard of 20 μg/L to be equivalent to a standard of 30 pCi/L, based on a series of ground-water analyses throughout the United States (EPA 1986c). However, site-specific data for Hanford indicate that the proportion of the different uranium isotopes in ground water is similar to the average proportion in natural rock. In this case, the uranium activity in μg/L should be multiplied by 0.67 to convert to the concentration in pCi/L. This gives a proposed Drinking Water Standard equivalent of 13.4 pCi/L. The site-specific conversion factor provides a more stringent standard for activity data and will be used in the discussion below.

Uranium has been detected at concentrations greater than the proposed Drinking Water Standard in the 100-F, 100-H, 200-East, 200-West, and 300 Areas. The highest concentrations detected onsite in 1994

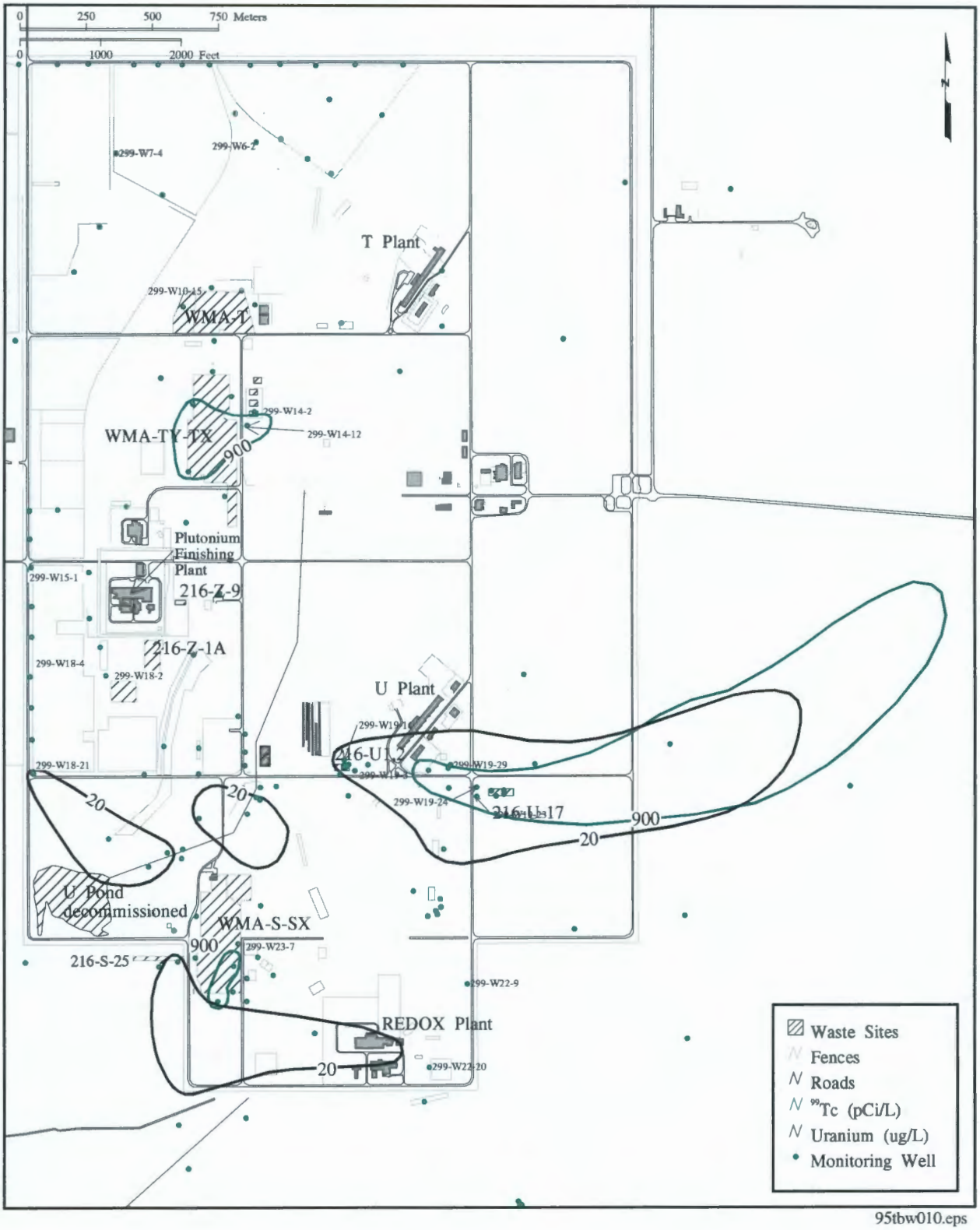

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Figure 5.8.29 Concentrations of Technetium-99 and Uranium in the Unconfined Aquifer in the 200-West Area, 1994

were in the 200-West Area near the 216-U-1 and 216-U-2 cribs.

Uranium in the 100 Areas. In 1994, uranium was detected at concentrations greater than the proposed Drinking Water Standard near the reactor building in the 100-F Area (Figure 5.8.22). The maximum concentration detected was 133 µg/L in well 199-F8-1.

Uranium was detected at concentrations greater than the proposed Drinking Water Standard in two wells in the 100-H Area (Figure 5.8.23). The maximum concentration detected in 1994 was 93.9 µg/L in well 199-H4-3. Uranium concentrations in this well fluctuate widely; the lowest concentration detected in this well in 1994 was 1.37 µg/L.

Uranium in the 200 Areas. A few wells in the 200-East Area contained uranium at concentrations greater than the proposed Drinking Water Standard for at least one sampling event. The highest concentration detected in the 200-East Area was 64.3 µg/L in well 299-E28-6 located to the east of B Plant in the central part of the area.

The highest uranium levels in Hanford ground water occurred near U Plant in the 200-West Area in wells adjacent to the inactive 216-U-1, 216-U-2, and 216-U-17 cribs (Figure 5.8.29). Uranium concentrations in these wells have been decreasing over the last 5 years following remediation activities associated with those cribs. A trend plot of uranium concentrations in samples from well 299-W19-3, immediately downgradient from the 216-U-1 and 216-U-2 cribs, is shown in Figure 5.8.30. The uranium levels in this well continue to decrease slowly but remain greater than the proposed Drinking Water Standard. The maximum concentration detected in this area was 2,720 µg/L in a sample from well 299-W19-29. Results from that well have been erratic since 1991. However, the concentration detected in well 299-W19-29 represents isotopic values greater than the Derived Concentration Guide of 500 pCi/L for uranium-234 and 600 pCi/L for uranium-238. Other areas within the 200-West Area with uranium contamination are also shown in Figure 5.8.29, including fairly widespread areas west and northwest of the REDOX Plant.

Uranium in the 300 Areas. A plume of uranium exists in the unconfined aquifer beneath the 300 Area in the vicinity of uranium fuel fabrication facilities and inactive waste sites known to have received uranium waste. The plume extends downgradient from active and inactive Liquid Waste

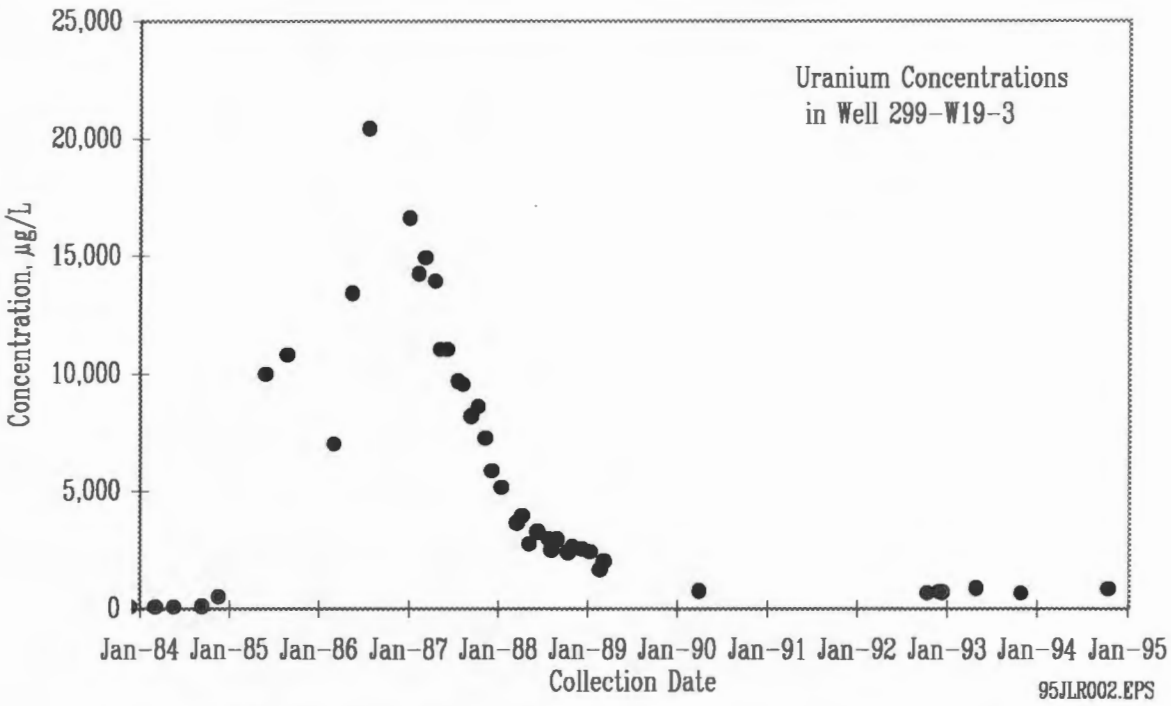

Figure 5.8.30 Uranium Concentrations in Well 299-W-19-3, 1984 Though 1994

Disposal Facilities (Figure 5.8.31). The maximum concentration of uranium detected in the 300 Area in 1994 was 150 µg/L in well 399-2-2. An Expedited Response Action performed on the 300 Area Process Trenches in mid-1991 was aimed at reducing the uranium source in that area. Use of the trenches for disposal of cooling water and small quantities of nonhazardous maintenance and process waste (Borghese 1994) was resumed following completion of the remedial action, although recent discharge to the trenches was much lower than prior to the expedited response. Uranium levels in well 399-1-17A, located near the trenches, appear to have been reduced following that remedial action; levels apparently stabilized about a factor of 10 below the maximum values seen in 1990. However, levels from a number of samples collected since the remediation remained greater than the proposed Drinking Water Standard. A trend plot showing the uranium concentrations in well 399-1-17A is shown in Figure 5.8.32.

Cobalt-60

Cobalt-60 is a neutron activation product typically associated with wastes generated by processing of reactor effluent water. Cobalt-60 is normally present as a divalent transition metal cation and as such tends to be highly immobile in ground water but may be mobilized by complexing agents.

Cobalt-60 results reported in 1994 were generally at or below the detection limit of approximately 20 pCi/L. The only value greater than the Drinking Water Standard of 100 pCi/L was reported in 100-N Area well 199-N-33 (732 pCi/L). The water level in this well has declined to near the bottom of the well screen because of reduction in discharge in the 100-N Area, and the high values appear related to increased suspended solids in the samples. Cobalt-60 adsorbs strongly to aquifer sediments, and the samples were not filtered. Thus, although the samples are probably not representative of mobile ground-water concentrations, they indicate that radionuclides continue to be present, adsorbed to solid particles.

Cobalt-60 was detected near the PUREX Plant in a June 1994 sample from the 200-East Area well 299-E17-16 (40.1 pCi/L). This well consistently shows detectable but low levels of cobalt-60. Several 200-East Area wells near the BY Cribs had low levels of cobalt-60, with the highest reported value of 36 pCi/L from well 299-E33-12, completed in the upper basalt confined aquifer system. Cobalt-60 levels above detection form a plume that extends into the 600 Area to the northwest; however, the concentrations remained less than the Drinking Water Standard in all 1994 samples. The cobalt in the plume from the BY Cribs is apparently mobilized by reaction with cyanide or ferrocyanide, forming a dissolved cobalt species. Only one 200-West Area well, 299-W14-12, contained detectable cobalt-60 in 1994 samples. The highest value reported in this well was 13.2 pCi/L.

Cesium-137

Cesium-137 is produced as a high-yield fission product and is present in waste streams associated with fuel processing. Reactor operations may also result in the release of some cesium-137 associated with fuel element breaches. Cesium-137 is normally observed to be strongly sorbed on soil and thus is very immobile in Hanford ground water.

Cesium-137 is consistently detected in two wells, 299-E28-23 and 299-E28-25, located in the 200-East Area near the 216-B-5 Injection Well. The injection well received cesium-137-bearing wastes from 1945 to 1947. The maximum 1994 concentration of cesium-137 in well 299-E28-23 was 2,310 pCi/L, and the maximum concentration in well 299-E-28-25 was 191 pCi/L. The Drinking Water Standard for cesium-137 is 200 pCi/L, and the Derived Concentration Guide is 3,000 pCi/L. Cesium-137 appears to be restricted to the immediate vicinity of the injection well by its extremely low mobility in ground water. One sample from 200-West Area, well 299-W23-7, contained 21.8 pCi/L of cesium-137.

Plutonium

Plutonium has been released to the soil column in several locations in both the 200-West and 200-East Areas. Plutonium is generally considered to bind strongly to sediments and thus has limited mobility in the aquifer.

Ground water sampled at 200-East Area wells located near the 216-B-5 Injection Well ranged up to 2,670 pCi/L of plutonium-239,240 in well 299-E28-24 in 1994. Plutonium-238 was also detected but at considerably lower levels, up to 7.79 pCi/L, in the same sample from well 299-E28-24.

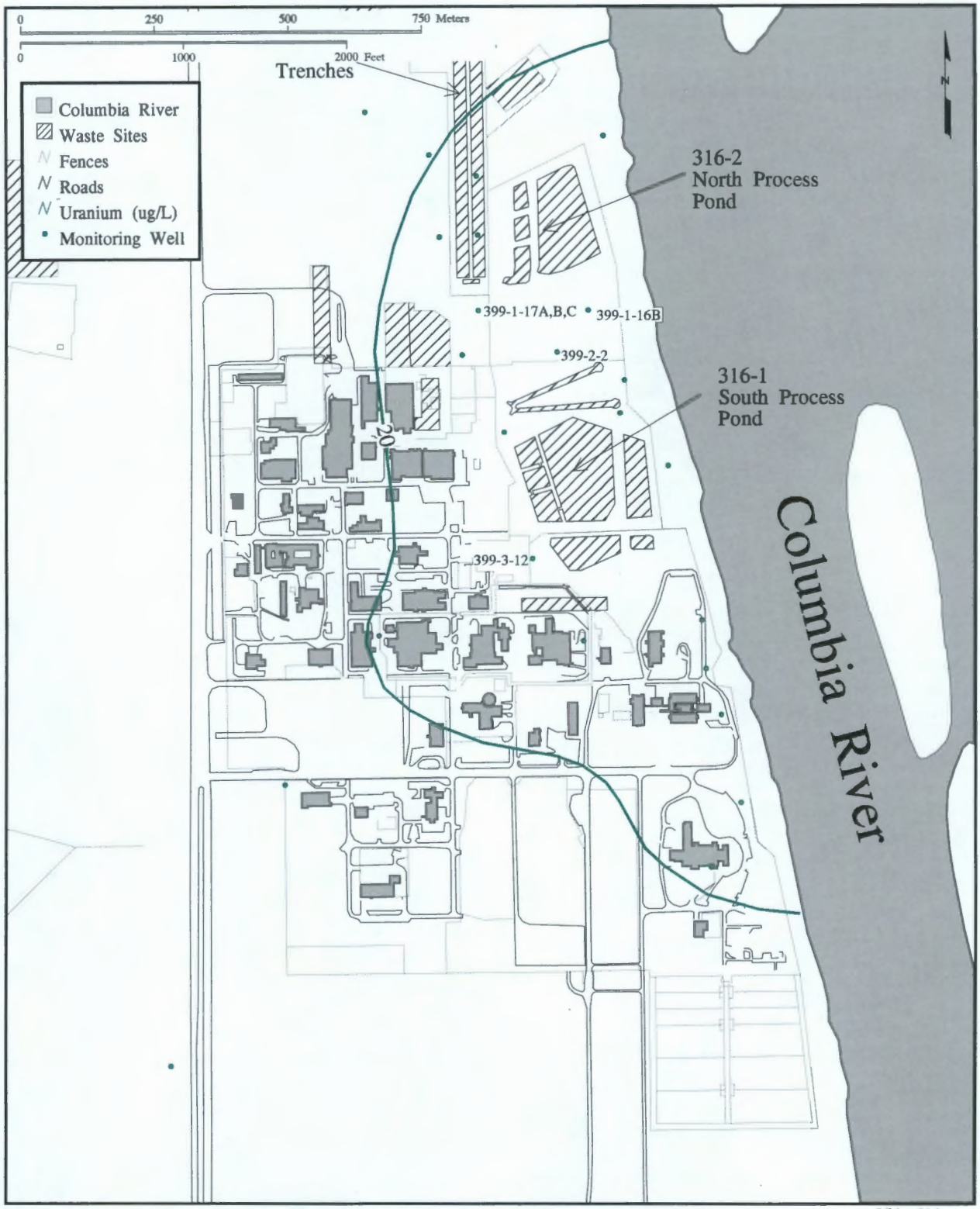

Figure 5.8.31 Uranium Concentrations in the Unconfined Aquifer in the 300 Area, 1994

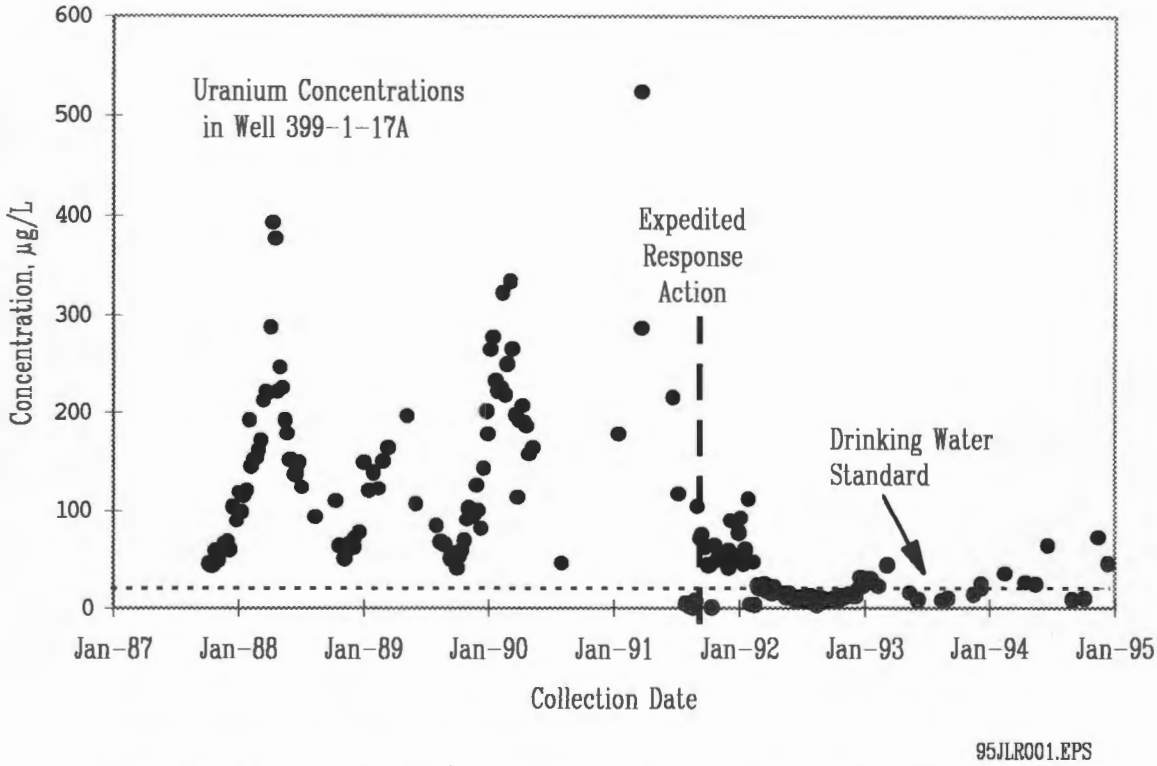

Figure 5.8.32 Uranium Concentrations in Well 399-1-17A, 1987 Through 1994

These levels are significantly higher than detected in previous years but the presence of plutonium has been detected continuously in this area. Because plutonium is strongly adsorbed to sediments and may have been injected into the aquifer as suspended particles, it is likely that the values measured result in part from solid rather than dissolved material. However, plutonium-239,240 was also detected in a sample from well 299-E28-2, which is approximately 150 m (490 ft) from the injection well. The 216-B-5 Injection Well received an estimated 244 Ci of plutonium-239,240 during its operation from 1945 to 1947 (Stenner et al. 1988). The Derived Concentration Guide for either plutonium-239 or plutonium-240 is 30 pCi/L. There is no explicit Drinking Water Standard for plutonium-239; however, the gross alpha Drinking Water Standard of 15 pCi/L would be applicable at a minimum. Alternately, if the Derived Concentration Guide (which is based on a 100-mrem dose standard) is converted to the 4-mrem dose equivalent used for the Drinking Water Standard, 1.2 pCi/L would be the relevant guideline.

Antimony-125

Antimony-125 is produced as a fission product and is present in waste streams associated with fuel processing. Reactor operations may also result in the release of some antimony-125 associated with fuel element breaches. Antimony-125 tends to migrate in Hanford ground water with low retardation but generally has not been observed in recent years because of its relatively short half-life (2.7 years).

Antimony-125 has been measured in the past in a few wells in the 100-N and 100-K Areas. Levels detected in 1994 were all well below the Drinking Water Standard of 300 pCi/L.

Chemical Monitoring Results for the Unconfined Aquifer

Chemical analyses performed in past years on ground-water samples by various monitoring programs at Hanford have identified eight hazardous chemicals that have been found in recent years at concentrations greater than existing or proposed federal drinking water standards. These are nitrate,

cyanide, fluoride, chromium, carbon tetrachloride, chloroform, trichloroethylene, and tetrachloroethylene.

A number of the parameters measured such as conductance, total carbon, total organic carbon, and total organic halogens are used as indicators of contamination. These will not be discussed in detail in this report because the specific contaminant contributing to these parameters will be discussed. Other chemicals and parameters listed in Table 5.8.2 are indicators of the natural chemical composition of ground water and in general are not contaminants from operations at Hanford. These include alkalinity, pH, sodium, magnesium, potassium, aluminum, silica, calcium, manganese, and iron. Chloride and sulfate are both naturally occurring and site-related constituents. There is no primary Drinking Water Standard for chloride or sulfate (the secondary standard for each is 250 mg/L and is based on aesthetic rather than health considerations) so they will not be discussed in detail. The analytical technique used to determine the concentration of metals in ground water provides results for a number of constituents such as antimony, barium, beryllium, boron, cadmium, copper, nickel, silver, strontium, vanadium, and zinc that are rarely observed at greater than background concentrations.

The following subsections present additional information on the eight chemical constituents occurring in ground water at concentrations greater than existing or proposed Drinking Water Standards.

Nitrate

Most ground-water samples collected in 1994 were analyzed for nitrate. Nitrate was measured at concentrations greater than the Drinking Water Standard (45 mg/L as nitrate ion) in wells in all operational areas except the 100-B and 400 Areas. Nitrate is associated primarily with process condensate liquid wastes but other liquids discharged to the ground also contained nitrate. Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical reprocessing operations. However, additional sources of nitrate are located offsite to the west and southwest. The distribution of nitrate on the Hanford Site is shown in Figure 5.8.33; this distribution is similar to previous evaluations. Although nitrate contamination can be detected over large areas of the Site, the areas impacted by levels greater than the Drinking Water Standard are much more restricted.

Nitrate in the 100 Areas. Nitrate is found at levels greater than the Drinking Water Standard in parts of the 100-D Area. The highest nitrate value found in the 100-D Area in 1994 was 205 mg/L as nitrate in well 199-D8-3.

The 100-F Area also contains nitrate in ground water at levels greater than the Drinking Water Standard. This plume appears to extend to the south into the 600 Area but the extent of nitrate at low levels in the 600 Area west and south of the 100-F Area suggests there is also an unknown source upgradient. The maximum nitrate detected in the 100-F Area in 1994 was 110 mg/L in well 199-F7-3.

Nitrate in the 100-H Area is restricted to a small area downgradient of the 183-H Solar Evaporation Basins. The maximum concentration of nitrate detected in this area in 1994 was 730 mg/L in well 199-H4-3.

Nitrate at levels greater than the Drinking Water Standard in the 100-K Area is found downgradient of both the K-East and K-West reactor buildings. The maximum concentration detected in 1994 was 110 mg/L in samples from wells 199-K-106A and 199-K-30.

Minor nitrate contamination is found in parts of the 100-N Area. The maximum detected in a 1994 sample was 65 mg/L in well 199-N-26, located in the southwestern part of the area.

Nitrate in the 200-East Area. The highest nitrate concentrations in the 200-East Area continued to be found near Liquid Waste Disposal Facilities that received effluent from PUREX operations. Nitrate concentrations in wells near the 216-A-10 and 216-A-36B cribs generally have tended to decrease in the past few years but remained greater than the Drinking Water Standard even though these facilities were removed from service in 1987. The maximum nitrate concentration detected in this vicinity was 120 mg/L in well 299-E17-15 adjacent to the 216-A-36B Crib. High nitrate concentrations in the 600 Area north of the 200-East Area are apparently related to past disposal practices at the BY Cribs. Nitrate was detected in well 699-55-57 at 100 mg/L in 1994. Nitrate is also found in a few wells near

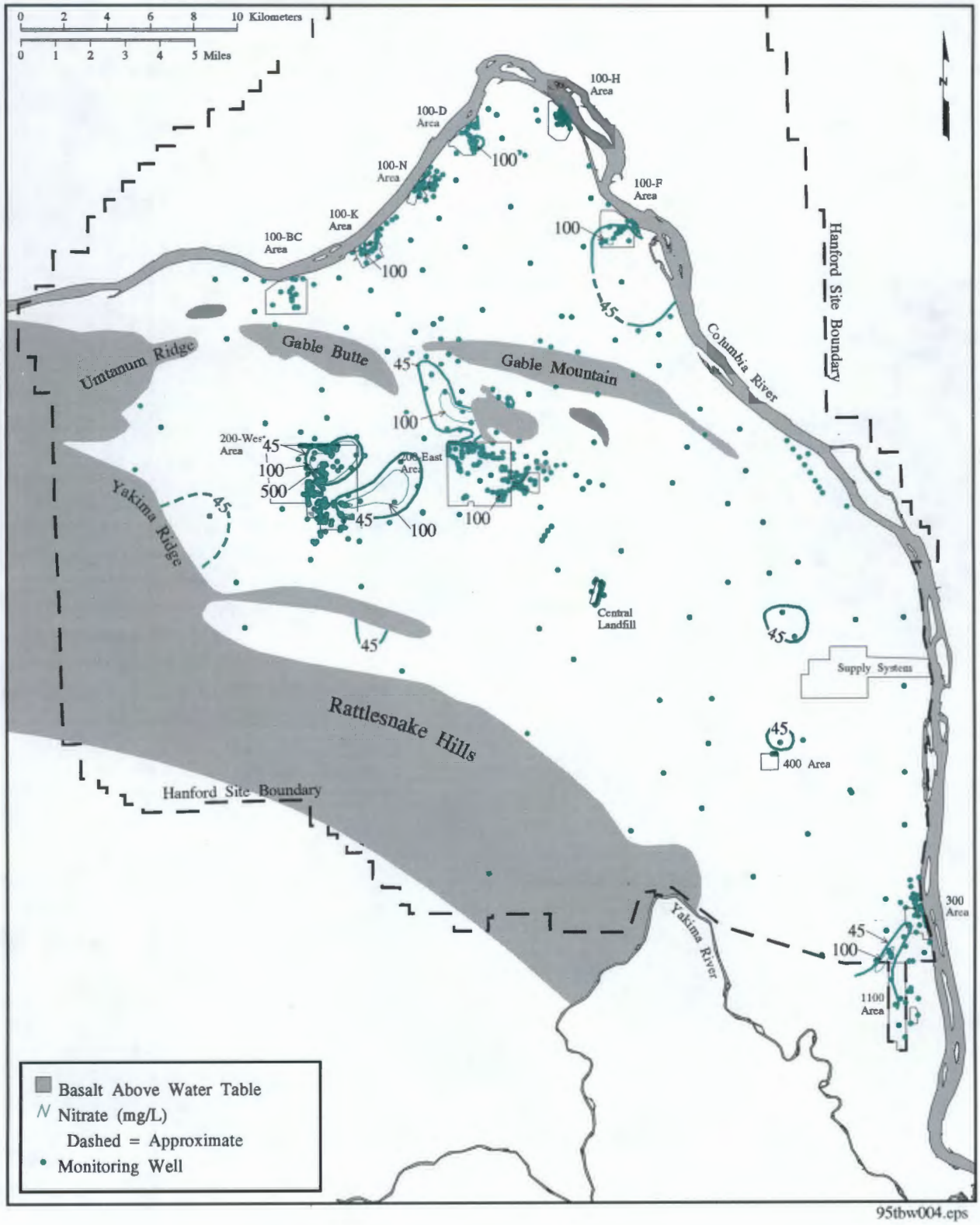

Figure 5.8.33 Distribution of Nitrate in the Unconfined Aquifer, 1994

the former Gable Mountain Pond, north of the 200-East Area. The nitrate plume related to PUREX operations is coincident with the tritium plume shown in Figure 5.8.11. However, as shown in Figure 5.8.33, nitrate is only found at levels above the Drinking Water Standard in a few restricted areas.

Nitrate in the 200-West Area. Nitrate concentrations greater than the Drinking Water Standard were widespread in ground water beneath the 200-West Area and adjacent parts of the 600 Area. The major nitrate plumes were found in wells east of U Plant and wells in the north-central part of the 200-West Area. The highest nitrate concentrations across the Site continued to be found in wells east of U Plant near the 216-U-17 Crib, where the maximum concentration detected in 1994 was 1,700 mg/L in well 299-W19-23. The presence of nitrate in wells near this crib was observed before February 1988 when the crib went into operation. The source of nitrate is believed to be wastes disposed of in the 216-U-1 and 216-U-2 Cribs. These cribs received over 1,000,000 kg of nitrate during their operation from 1951 to 1967 (Stenner et al. 1988). Nitrate concentrations in wells located near the 216-U-1 and 216-U-2 Cribs west of U Plant continued to decrease, with concentrations in several of the wells dropping to less than the Drinking Water Standard. For example, the nitrate concentration in well 299-W19-3 located near U Plant has decreased to less than the Drinking Water Standard, as shown in Figure 5.8.34.

Several wells in the northwestern part of the 200-West Area continued to contain nitrate at concentrations greater than the Drinking Water Standard. These wells are located near several inactive Liquid Waste Disposal Facilities that received waste from early T Plant operations. Maximum concentrations in these wells in 1994 ranged up to 1,100 mg/L in well 299-W10-1. The area with ground-water nitrate at levels greater than the Drinking Water Standard extends from the vicinity of the Plutonium Finishing Plant to approximately the northeast corner of the 200-West Area.

Nitrate in Other Areas. Although most nitrate observed onsite is the result of Hanford operations, elevated nitrate concentrations in wells in the western part of the Site appear to be the result of increasing agricultural activity in Cold Creek Valley, west of Hanford. There is no known source of nitrate in that area associated with Site operations

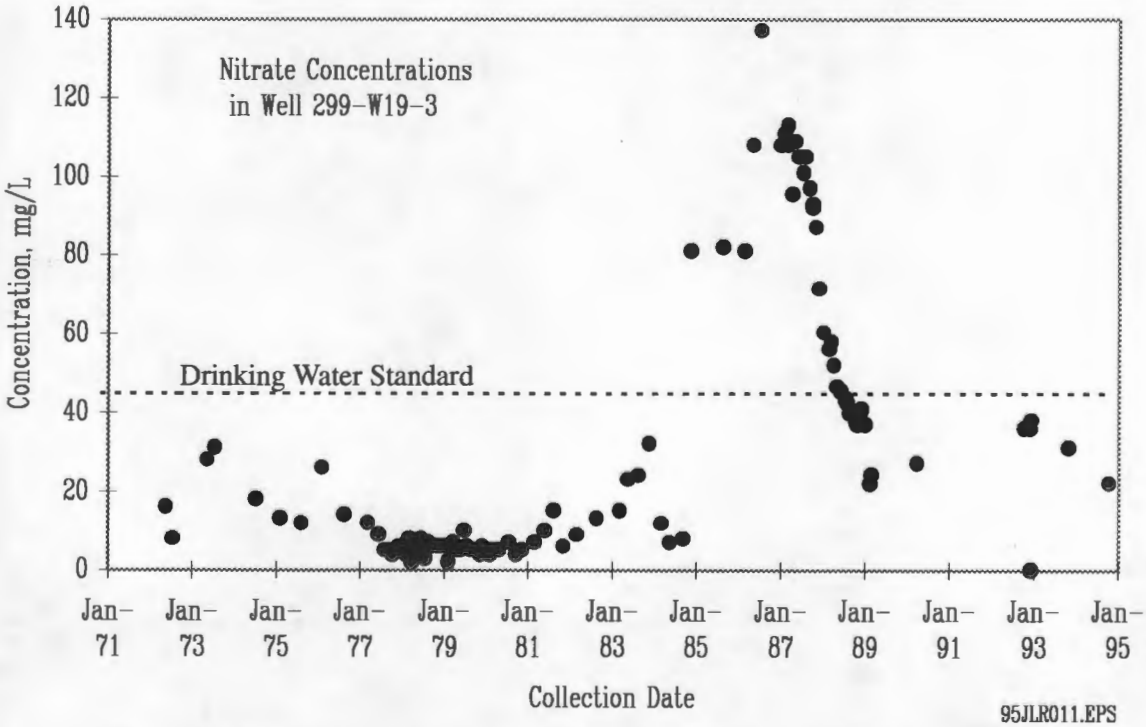

Figure 5.8.34 Nitrate Concentrations in Well 299-W19-3, 1972 Through 1994

and the ground-water flow is from the west toward the Hanford facilities to the east. Nitrate levels have fluctuated considerably in wells upgradient of the 200 Areas over the past 30 years. Nitrate levels have been near or greater than the Drinking Water Standard in well 699-36-93 since 1985.

Nitrate concentrations near the City of Richland and in the 1100 Area, 3000 Area, and adjacent parts of the 600 Area are also apparently affected by offsite nitrate sources. These sources may include agriculture, food processing, urban horticulture, and nuclear fuel processing at offsite commercial facilities. The part of this plume that is greater than the Drinking Water Standard extends from offsite to the 300 Area.

Cyanide

Waste fractionation activities performed in the late 1950s used large quantities of sodium and nickel ferrocyanide to recover cesium-137. Large volumes of aqueous supernatant waste containing excess ferrocyanide were disposed to the ground in both the north and south portions of the 200-East Area. Smaller quantities were also disposed to cribs in the 200-West Area. Analytical tests performed according to EPA procedures do not distinguish between ferrocyanide and free cyanide. Cyanide results reported here are thus normally assumed to be residual ferrocyanide associated with the discharges from the waste fractionation activities performed more than 30 years ago.

No samples collected onsite in 1994 exceeded the Drinking Water Standard of µg/L cyanide. Cyanide was detected in samples collected from wells in the northwestern part of the 200-East Area and in samples from north of the 200-East Area. Samples taken from the 200-East Area in 1994 had a maximum cyanide concentration of 39.5 µg/L in well 299-E33-12, which is east of the BY Cribs. The highest concentration detected in the plume to the north of the 200-East Area was 110 µg/L in well 699-52-55. Wells containing cyanide often contain concentrations of several radionuclides, including cobalt-60. Although cobalt-60 is normally immobile in the subsurface, it appears to be chemically complexed and mobilized by cyanide or ferrocyanide. A chemical speciation study performed in 1988 indicated that approximately one-third of the cyanide is present as free cyanide, and the rest may be present as ferrocyanide (Evans et al. 1989a and b).

Low-level cyanide contamination is found in limited locations in the 200-West Area. Cyanide is found near the 216-T-26 Crib, which received a total estimated inventory of 6,000 kg of ferrocyanide from 1955 to 1956 (Stenner et al. 1988). The maximum cyanide detected in this vicinity was 20 µg/L in 299-W14-2. Low levels of cyanide are also detected near the U Plant and into the 600 Area between the 200-West and 200-East Areas.

Fluoride

Fluoride currently has a primary Drinking Water Standard of 4.0 mg/L and a secondary standard of 2.0 mg/L. Secondary standards are based primarily on aesthetic considerations and are not federally enforceable rules, although the state of Washington claims the right to require corrective action from drinking water suppliers if secondary standards are exceeded. Both standards will be used in the discussion below; however, it should be remembered that only the primary standard is based on health considerations. Fluoride was detected at levels greater than the primary Drinking Water Standard in the 200-West Area. Fluoride concentrations greater than the 2.0-mg/L secondary standard were detected in past years in the 200-East Area in well 299-E28-24 near the 216-B-5 Reverse Injection Well. Well 299-E28-24 was not sampled for fluoride in 1994.

A few wells in the 200-West Area near T Plant had fluoride concentrations greater than the secondary standard in 1994, although only one well was greater than the primary Drinking Water Standard. Well 299-W10-15 showed a maximum fluoride concentration of 5.1 mg/L in 1994. Aluminum fluoride nitrate used in the 200-West Area processes is the probable source of the fluoride plume.

Chromium

Chromium use on the Hanford Site has been extensive. In the 100 Areas, sodium dichromate was added to cooling water as a corrosion inhibitor, and some residual chromium remains from that use. Hexavalent chromium was also used for decontamination in the 100, 200, and 300 Areas. Hexavalent chromium was also used for oxidation state control in the REDOX process. In the hexavalent form,

chromium is present in an anionic state. Hexavalent chromium is thus freely mobile in the ground water.

Both filtered and unfiltered samples were collected for chromium and other metals from many of the wells onsite. Unfiltered samples may contain metals present as particulate matter, while filtered samples are representative of the more mobile dissolved metals. Filtered samples may also contain some colloidal particles fine enough to pass through the filter. Drinking water standards are based on unfiltered concentrations; however, differences in well construction and pumping between monitoring wells and water-supply wells make it difficult to predict potential drinking water concentrations from monitoring well data when the metals are present as particulate matter. Comparison of filtered to unfiltered samples provides a greater understanding of the transport of chromium onsite.

Chromium in the 100 Areas. Chromium has been detected in ground water from wells in each of the 100 Areas. However, concentrations in the 100-B/C Area were less than the federal Drinking Water Standard of 100 μg/L and the Washington State maximum contaminant level of 50 μg/L.

High chromium concentrations were detected at similar levels in both filtered and unfiltered samples from the 100-D Area. This indicates that the chromium concentrations are representative of the mobile concentrations in the ground water. The maximum chromium concentration from samples in the 100-D Area in 1994 was 1,360 μg/L in well 199-D5-15. The chromium distribution in the 100-D Area is shown in Figure 5.8.35.

Relatively few chromium analyses were available from the 100-F Area in past years. Recent well installation activities in the 100-F Area have improved the coverage. The highest chromium level observed in 1994 in the 100-F Area was 82.4 μg/L in well 199-F8-3.

Many samples from the 100-H Area contained chromium at levels greater than the Drinking Water Standard (Figure 5.8.35). Chromium was often present at similar levels in both filtered and unfiltered samples. The maximum chromium concentration from 100-H Area samples in 1994 was 300 μg/L in well 199-H4-3. Chromium is also found at levels above the Drinking Water Standard in deeper parts of the unconfined aquifer in the 100-H Area. For example, samples from well 199-H4-12C contained up to 290 μg/L chromium in filtered samples. Potential chromium sources in the 100-H Area include disposal of sodium dichromate near the reactor building and to the 107-H Liquid Waste Disposal Trench, and chromium in acid wastes stored in the 183-H Solar Evaporation Basins (Peterson and Connelly 1992). Chromium was also detected in parts of the 600 Area upgradient from the 100-H Area indicating an upgradient source.

Chromium is found in both filtered and unfiltered samples from the 100-K Area at levels greater than the Drinking Water Standard (Figure 5.8.24), with a maximum concentration in 1994 of 210 μg/L in well 199-K-108A, near the K-West reactor building. Chromium is also found near the 100-K Area Liquid Waste Disposal Trench.

At the 100-N Area, only one well sampled in 1994, 199-N-80, contained filtered chromium at concentrations greater than the Drinking Water Standard. This well is completed in a sandy layer in the lower part of the unconfined aquifer or a confined zone within the Ringold Formation. The maximum concentration detected in samples from this well was 200 μg/L. The occasional and erratic high chromium concentrations in unfiltered samples collected in the 100-N Area may result from greater amounts of particulate matter in the samples and do not appear to represent actual dissolved ground-water concentrations.

Chromium in the 200 Areas. Chromium at concentrations greater than the Drinking Water Standard in the 200-East Area is generally found only in unfiltered samples with the exception of samples from well 299-E24-19, where the concentration detected in a filtered sample was 60 μg/L, and well 299-E25-43, where the maximum concentration detected was 73 μg/L. In past years, filtered samples from well 299-E24-9 have contained hundreds to over 1,000 μg/L of chromium. Other 1994 samples from well 299-E25-43 contained chromium at levels well below the Drinking Water Standard. The widespread presence of chromium associated with particulate matter in the 200-East Area may be related to the stainless-steel well construction. Chromium is a component of stainless steel, and it is not clear that the sample concentrations are

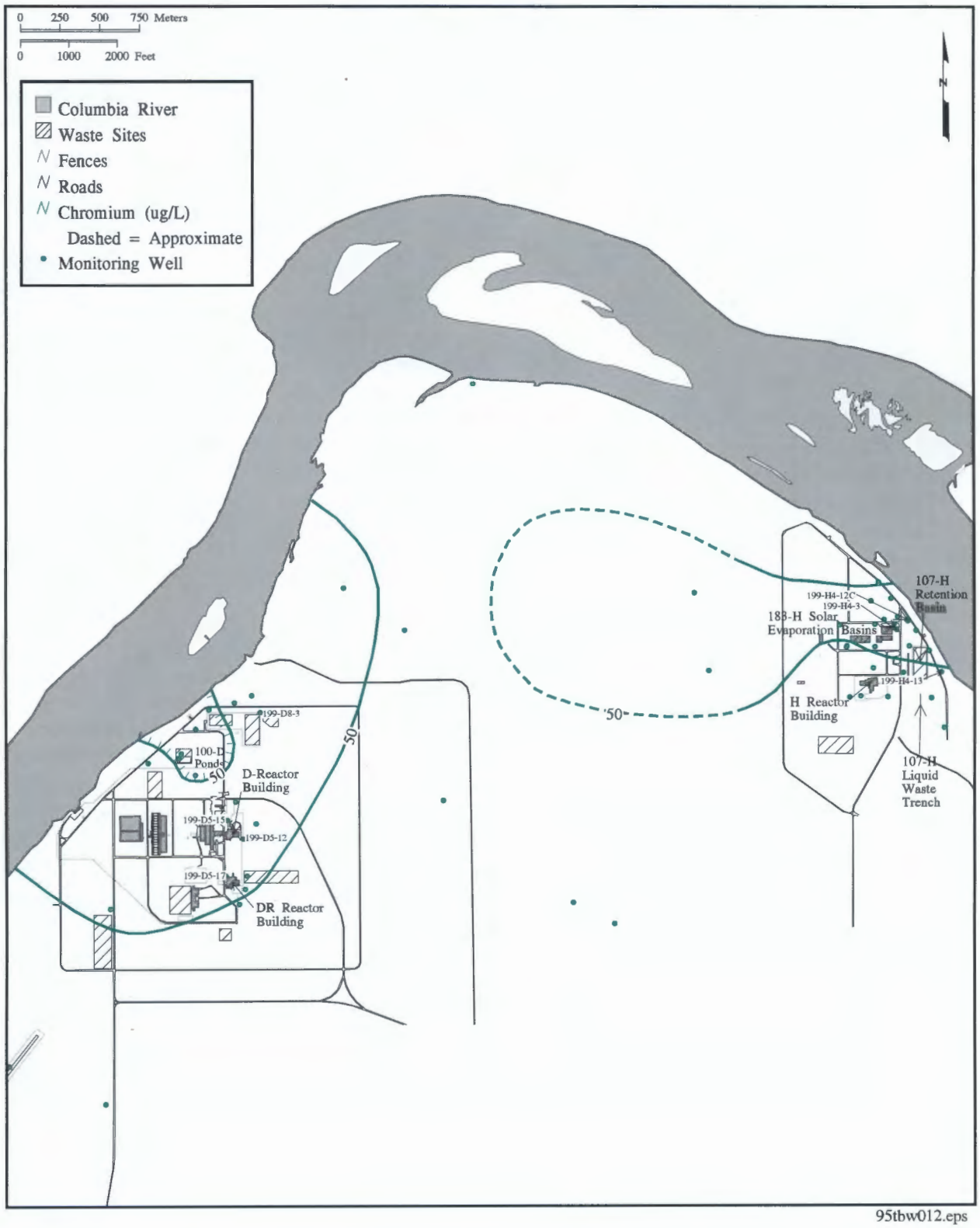

Figure 5.8.35 Distribution of Chromium in the 100-D and 100-H Areas, 1994

representative of the ground water. Chromium concentrations in well 299-E24-9 are possibly related to well corrosion because nickel (another stainless-steel component) concentrations are also high. Some of the chromium and nickel may be associated with ultra-fine or colloidal particles that pass through the 0.45–μm filters used in ground-water sampling.

Chromium contamination has been found at several locations in the 200-West Area. Chromium in the 200-West Area is found in both filtered and unfiltered samples, although the filtered concentrations tend to be somewhat lower in many instances. The highest filtered chromium concentration observed in that area in 1994 was 500 μg/L in one sample from well 299-W10-15.

Chromium in the 300 Area. Chromium is sporadically detected at concentrations greater than the Drinking Water Standard in unfiltered samples from the 300 Area. The concentrations in filtered samples were in all cases less than the Drinking Water Standard. This difference suggests that the high chromium concentrations found in these monitoring wells represent particulate matter that may be related to well construction and are affected by the well purging procedures, the time between samples, or other effects that do not reflect the general ground-water quality.

Chromium in Other Areas. Chromium concentrations greater than the Drinking Water Standard have also been detected locally in filtered samples from 600 Area monitoring wells. As discussed above, chromium contamination in the vicinity of the 100-D and 100-H Areas extends into the 600 Area. Chromium is also measured at levels above the Drinking Water Standard in unfiltered samples near B Pond. In the B Pond area, high chromium levels were found in wells monitoring the top of the unconfined aquifer or monitoring what is referred to as the semi-confined aquifer. It appears that the stainless-steel well casings or well screens may be contributing particulate chromium to the unfiltered samples.

Carbon Tetrachloride and Chloroform

Carbon tetrachloride contamination was found in the unconfined aquifer beneath much of the 200-West Area. The contamination is believed to be from waste disposal operations associated with the Plutonium Finishing Plant. Carbon tetrachloride was used as the carrier solvent for tributyl phosphate in the final purification of weapons-grade plutonium. Carbon tetrachloride was also used in the same facility as a nonflammable thinning agent in association with lard oil for machining of plutonium. Carbon tetrachloride is immiscible in water but exhibits a relatively high solubility (805,000 μg/L at 20° C). Carbon tetrachloride has been found to have a relatively high degree of mobility in ground water. Mobilization above the water table can also occur through vapor transport. A concentration of 8,100 μg/L was found in a well near the Plutonium finishing Plant first monitored in October 1988 (well 299-W15-16). Carbon tetrachloride concentrations in well 299-W15-16 remained fairly constant in 1994, reaching a maximum of 5,200 μg/L. Other wells in the vicinity of the Plutonium Finishing Plant had carbon tetrachloride levels ranging from 1,000 to 5,000 μg/L. The distribution of carbon tetrachloride in the 200-West Area greater than the Drinking Water Standard is shown in Figure 5.8.36.

The carbon tetrachloride distribution in the 200-West Area ground water has remained relatively stable since the presence of the contaminant plume was first noted in 1987. Figure 5.8.36 shows the trends in carbon tetrachloride concentrations with time for wells located at the east, west, north, and south parts of the plume. Well 699-39-79 shows a major increase during 1987 and 1988, indicating arrival of the bulk of the plume at that time. Since 1988, the concentration in well 699-39-79 has remained relatively constant or decreased slightly. Wells 299-W7-4 and 299-W6-2 in the north show an increase in concentrations in recent years, although the most recent measurement in 299-W6-2 is low. Concentrations in well 299-W18-21 exhibit increased concentrations of carbon tetrachloride since approximately 1992, and values continue to climb. Concentrations in wells 299-W19-16 to the southeast of the Plutonium Finishing Plant have risen in recent years, while well 699-38-70 exhibits fairly steady concentrations.

The extent of carbon tetrachloride contamination is poorly defined in several directions. The greatest uncertainty lies in the extent of contamination to the west and the northeast. In addition, there is

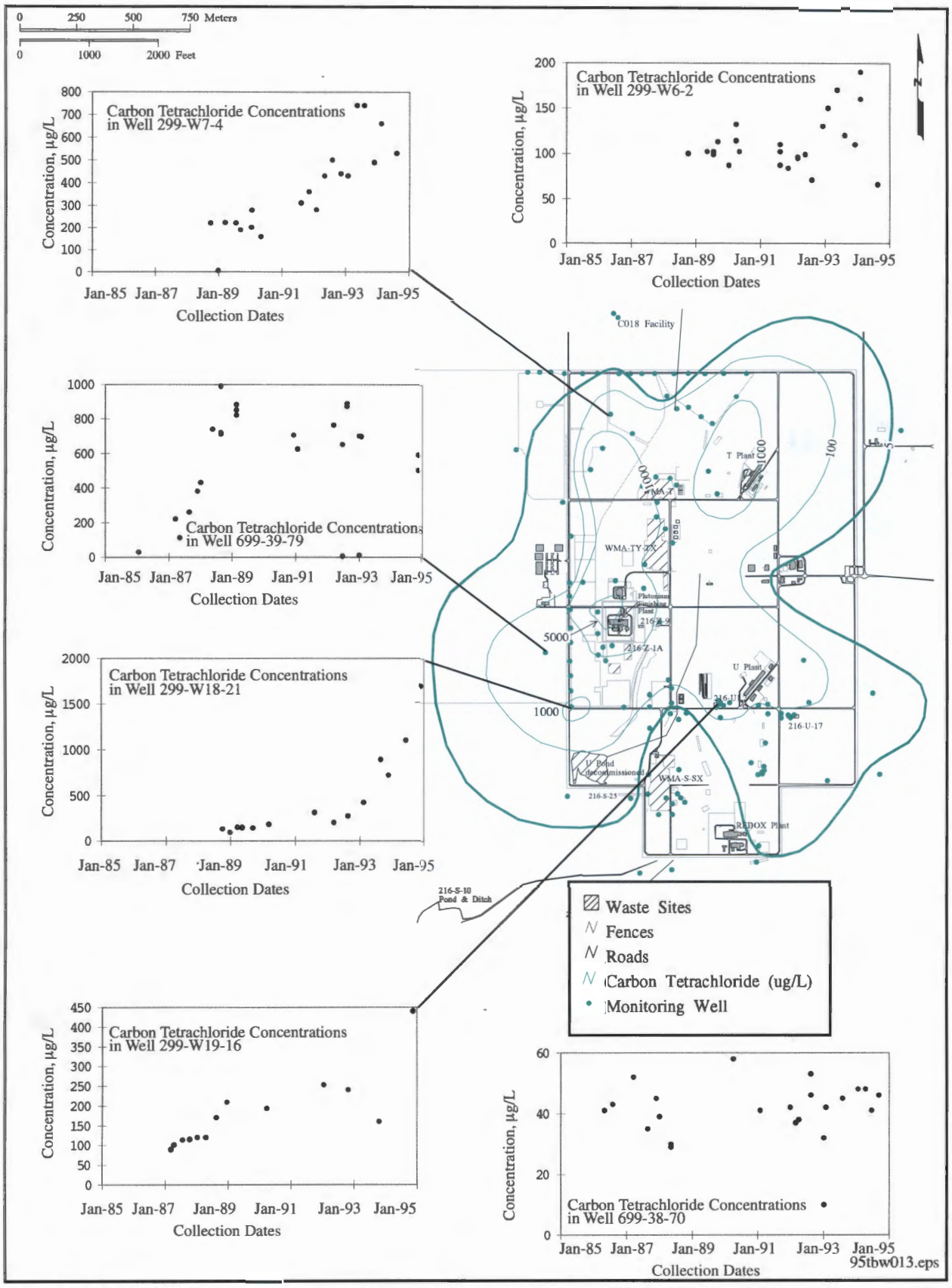

Figure 5.8.36 Distribution of Carbon Tetrachloride in the Unconfined Aquifer in the 200-West Area, 1994

considerable uncertainty regarding the extent of contamination in deeper parts of the aquifer.

Changes in ground-water flow since decommissioning U Pond may influence the exact plume configuration and the concentrations at particular locations. Another potential influence is the continued spreading of carbon tetrachloride above the water table, in either the liquid or vapor phase. Free-phase liquid carbon tetrachloride above and possibly below the water table provides a continuing source of contamination. Thus, expansion of the carbon tetrachloride plume is expected to continue slowly.

The Drinking Water Standard for carbon tetrachloride is 5 μg/L. In addition to carbon tetrachloride, significant amounts of other chlorinated hydrocarbon solvents were found in 200-West Area ground water, including chloroform. The highest level recorded in 1994 was 107 μg/L in one sample from well 299-W18-4. Well 299-W18-2, which contained the highest concentrations of chloroform in 1993 samples, was not sampled by the CERCLA Program in 1994. The chloroform plume appears to be associated with, but not exactly coincident with, the carbon tetrachloride plume. The Drinking Water Standard for chloroform is 100 μg/L (total trihalomethanes), 20 times higher than that for carbon tetrachloride. The location of the chloroform plume is shown on Figure 5.8.37. Chloroform may result from the degradation of carbon tetrachloride, either in the process or in the subsurface, as the result of biodegradation. The extent of chloroform contamination appears to be decreasing

Trichloroethylene

Trichloroethylene has a Drinking Water Standard of 5 μg/L. In 1994, trichloroethylene was detected at levels greater than the Drinking Water Standard in wells in the 100-F, 100-K, 200-West, 300, and parts of the 600 Area.

Trichloroethylene in the 100 Areas. Trichloroethylene was detected in 1994 at levels less than the Drinking Water Standard in 100-B/C Area wells. It was detected at levels greater than the Drinking Water Standard in 100-F Area wells. The maximum concentration detected in the 100-F Area in 1994 was 27 μg/L in a sample for well 199-F7-1. In addition, trichloroethylene was found at 25 μg/L in well 699-77-36, west of the 100-F Area, indicating a potential source upgradient.

Only one well sampled in 1994 in the 100-K Area contained trichloroethylene at levels above the Drinking Water Standard. However, other wells sampled in previous years had reported concentrations above the Drinking Water Standard for at least one sample event. The maximum concentration detected in 1994 was 20 μg/L in monitoring well 199-K-33.

Trichloroethylene in the 200 Areas. Trichloroethylene was detected in 1994 at levels greater than the Drinking Water Standard in the 200-West Area in several areas (Figure 5.8.38). The first location is to the west of T Plant, and concentrations up to 44 μg/L were detected in 1994. The second location is near the U Plant. Although only a few wells in this area contained trichloroethylene at levels above the Drinking Water Standard, the plume extends into the 600 Area to the east, and the downgradient spread has not been well-defined. Trichloroethylene contamination is found near the Plutonium Finishing Plant, near the source area for the carbon tetrachloride plume. Trichloroethylene was also measured at 33 μg/L in a sample from well 299-W22-20 near the REDOX Plant.

Trichloroethylene in the 300 Area. Trichloroethylene was detected in several wells throughout the 300 Area although levels were generally below the Drinking Water Standard. The highest level detected in the northern half of the 300 Area was 5.4 μg/L in well 399-1-16B. This well monitors the lower portion of the unconfined aquifer system. Samples from this well also contained up to 130 μg/L of cis-1,2-dichloroethylene, which is commonly found as a biodegradation product of trichloroethylene. The Drinking Water Standards for trichloroethylene and cis-1,2-dichloroethylene are 5 μg/L. Trichloroethylene was also detected at levels above the Drinking Water Standard in a few wells in the southern half of the 300 Area. The maximum concentration reported in 1994 was 6.1 μg/L in well 399-3-12.

Trichloroethylene in the 600 Area. Several wells at the Solid Waste Landfill (part of the central landfill) contained trichloroethylene levels less than the Drinking Water Standard (maximum of 2.7 μg/L in well 699-23-34A). Solid Waste Landfill wells had shown trichloroethylene concentrations greater than

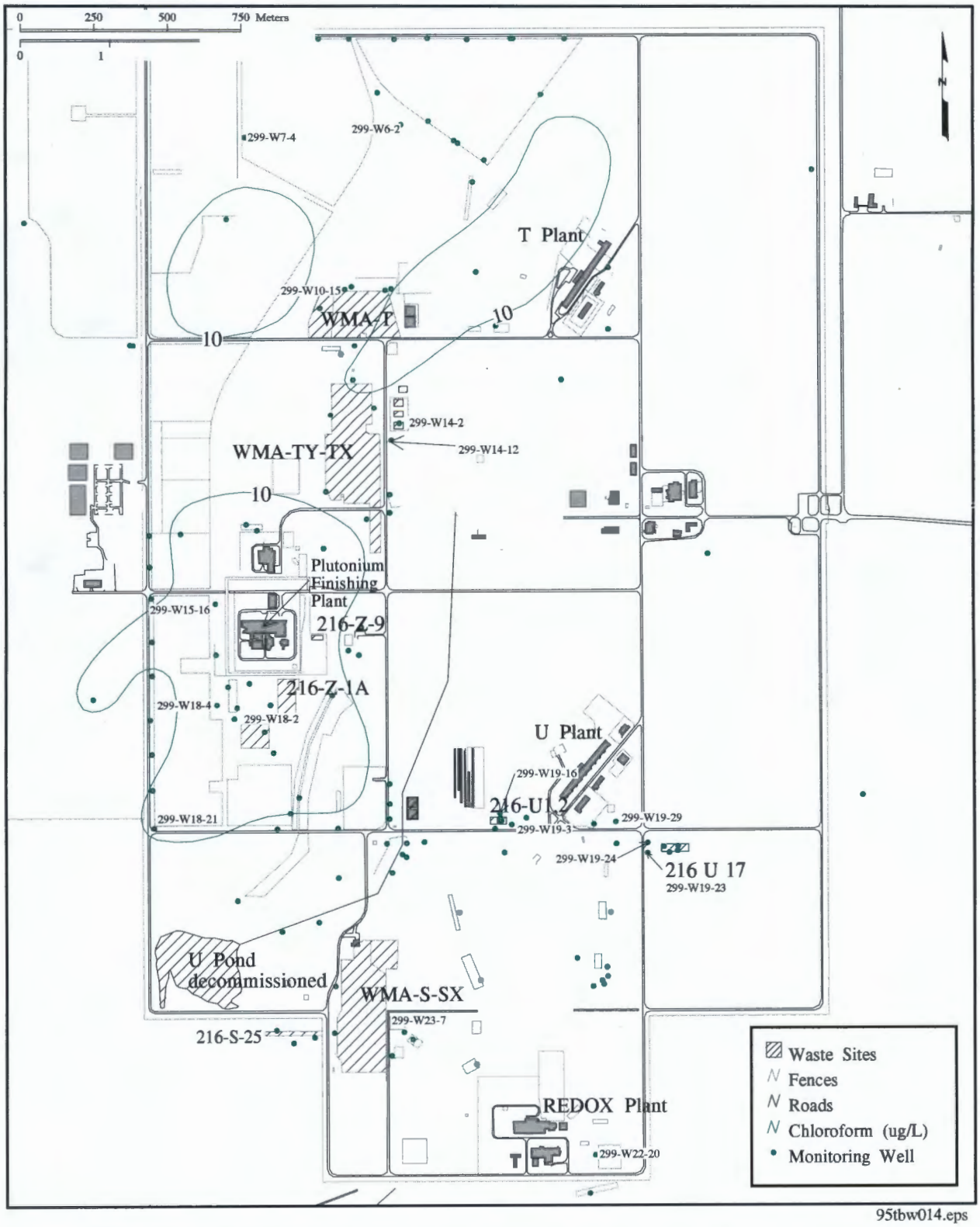

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Figure 5.8.37 Distribution of Chloroform in the Unconfined Aquifer in the 200-West Area, 1994

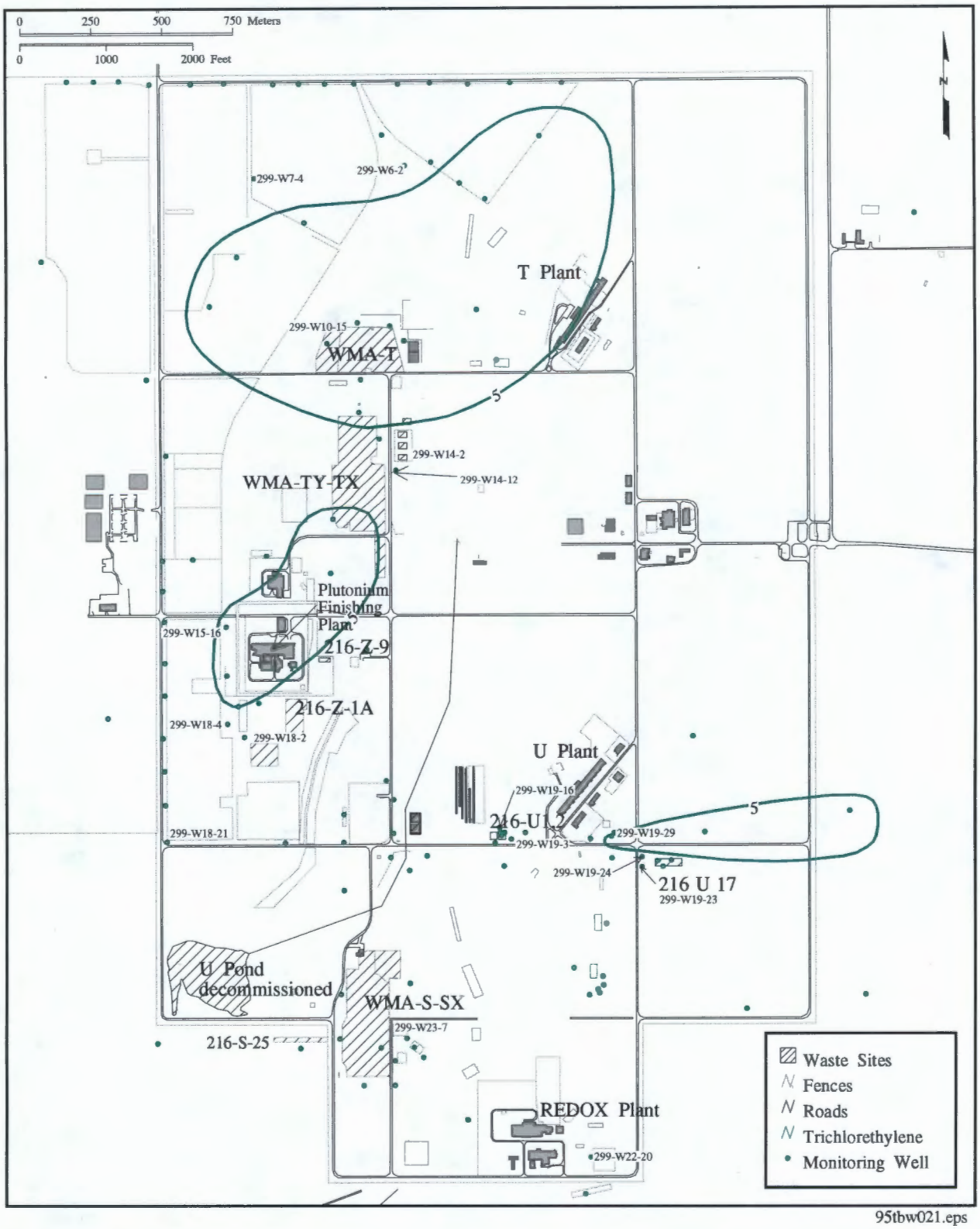

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Figure 5.8.38 Distribution of Trichloroethylene in the Unconfined Aquifer in the 200-West Area, 1994

the Drinking Water Standard in previous years. The source of the trichloroethylene in this area is apparently disposal of waste from vehicle maintenance operations in the mid-1980s through 1987. A sample from one well south of Gable Mountain, 699-54-45A, contained 12 μg/L of trichloroethylene in 1994. Trichloroethylene is found at levels above the Drinking Water Standard in a number of wells in the vicinity of Horn Rapids Landfill in the southern part of the Site. This contamination forms a plume leading towards the 300 Area but appears to have an origin off the Hanford Site. The maximum trichloroethyene contamination detected in this plume in 1994 was 46 μg/L in well 699-S31-E10A. DOE monitors this plume under the 1100-EM-1 Record of Decision and through the Environmental Surveillance Program. The Environmental Surveillance Program also monitors the plume through analyzing for concentrations of trichloroethylene in soil gas above the plume. This provides a cost-effective way to obtain further detail on contaminant distribution.

Tetrachloroethylene

Tetrachloroethylene, also referred to as perchloroethylene, was detected at low levels in a number of areas of the Site including the 200-West Area, the 300 Area, and parts of the 600 Area. A number of samples from wells in the 1100 and North Richland Areas contained low concentrations of tetrachloroethylene. In 1994, tetrachloroethylene was not detected at concentrations greater than the Drinking Water Standard of 5 μg/L in the Solid Waste Landfill, where the concentrations reached a maximum of 4.9 μg/L in well 699-24-34C. In past years, tetrachloroethylene has exceeded the Drinking Water Standard near the Solid Waste Landfill. Tetrachloroethylene is commonly used as a degreasing solvent.

Radiological and Chemical Monitoring Results for the Confined Aquifer

The uppermost (Rattlesnake Ridge) confined aquifer was monitored to determine the extent of ground-water contamination resulting from interaction between the confined and unconfined aquifers. Intercommunication between aquifers has been previously identified by Gephart et al. (1979) and Graham et al. (1984). Ground-water samples from selected confined aquifer wells have been analyzed for a variety of radionuclides and hazardous chemicals. In most cases, no indication of contamination was observed. Detection of radionuclides in well 299-E33-12 is attributed to contamination by high-salt waste that migrated by density flow into the borehole when it was open to both the unconfined and the confined aquifer during drilling (Graham et al. 1984). The 1994 samples from well 299-E33-12 contained up to 770 pCi/L of tritium, similar to levels detected since 1991. The 1994 samples from this well also contain cobalt-60 at levels up to 36.4 pCi/L, nitrate at levels up to 46 mg/L, technetium-99 at levels up to 1530 pCi/L, and cyanide at levels up to 39.5 μg/L. Although all of these are indicators of contamination, only nitrate and technetium-99 were detected at levels greater than the Drinking Water Standard.

Elevated levels of tritium have been measured in ground water from the Rattlesnake Ridge interbed in well 699-42-40C located adjacent to B Pond. This well contained a maximum of 7,050 pCi/L of tritium in 1994 samples, which were slightly lower levels than in 1993, and well below the Drinking Water Standard.

Samples collected in 1994 from well 199-B3-2P in the 100-B Area, contained up to 20.9 pCi/L of strontium-90 and 504 pCi/L of tritium. This well is currently completed in the confined aquifer but was open to both the unconfined and confined aquifer between 1953 and 1970 so it is possible that the well provided a conduit downward for contamination in the unconfined aquifer. The current extent of contamination in the confined aquifer is unknown.

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Potential Radiation Doses from 1994 Hanford Operations

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6.0 Potential Radiation Doses from 1994 Hanford Operations

J. K. Soldat and E. J. Antonio

Present and past operations at Hanford have resulted in the release of radionuclides into the surrounding environment. Members of the public are potentially exposed to low levels of radiation from these effluents through a variety of pathways. The potential radiation doses[(a)] to the public in 1994 from Hanford operations were calculated for the hypothetical MEI and for the general public residing within 80 km (50 mi) of the Hanford Site. These doses were calculated from effluent releases reported by the operating contractors, and radionuclide measurements in environmental media, using Version 1.485 of the GENII code (Napier et al. 1988a, 1988b, 1988c) and Hanford Site-specific parameters listed in Appendix D and by Bisping (1995).

The potential dose to the MEI in 1994 from Hanford operations was 0.05 mrem (5×10^{-4} mSv) compared to 0.03 mrem (3×10^{-4} mSv) reported for 1993. The potential dose to the local population of 380,000 persons (Beck et al. 1991) from 1994 operations was 0.6 person-rem (0.006 person-Sv), compared to 0.4 person-rem (0.004 person-Sv) reported for 1993. The 1994 average dose to the population was 0.002 mrem (2×10^{-5} mSv) per person. The current DOE radiation dose limit for an individual member of the public is 100 mrem/yr (1 mSv/yr), and the national average dose from natural sources is 300 mrem/yr (3 mSv/yr). During 1994, the MEI potentially received 0.05% of the DOE dose limit and 0.02% of the natural background average dose. The average individual potentially received 0.002% of the standard and 5×10^{-4}% of the 300 mrem/yr received from typical natural sources.

The small additional dose to the MEI in 1994 was a result of increased concentrations of uranium isotopes measured in Columbia River water collected downstream of the Hanford site and of continued experimental work in the 300 Area. This work entailed the release of radon isotopes (160 Ci of radon-220 and 1.2 Ci of radon-222) to the atmosphere from the 327 Building ventilation system (see Table 3.1.1). The new MEI location chosen for the 1993 dose calculations [1.5 km across the river (east) from the 300 Area] was retained for 1994.

During 1994, radionuclides reached the environment in gaseous and liquid effluents from present and past Hanford operations. Gaseous effluents were released from operating stacks and ventilation exhausts. Liquid effluents were released from operating waste-water treatment facilities and in seepage of contaminated ground water into the Columbia River. These radioactive materials were then transported throughout the environment by wind and the Columbia River. Eventually, animals and people can be exposed to these radionuclides through external exposure and inhalation and ingestion of contaminated air, water, and foodstuffs. Because of the many variables involved in the transport of the radionuclides in the environment and differing living habits of people, the assumptions used to describe the exposure scenarios are conservative (i.e., the doses are likely to be overestimated).

Potential radiation doses to the public from these releases were evaluated in detail to determine compliance with pertinent regulations and limits. The potential radiological impacts of 1994 Hanford operations were assessed in terms of the following:

- dose to a hypothetical MEI at an offsite location
- maximum dose rate from external radiation at a publicly accessible location on or within the Site boundary
- dose to an avid sportsman who consumes wildlife exposed to radionuclides onsite
- dose to the population residing within 80 km (50 mi) of the operating areas

(a) Unless stated otherwise, the term "dose" in this chapter is the "effective dose equivalent" (see Glossary).

- absorbed dose rate (rad/d) potentially received by animals associated with contaminant releases to the Columbia River.

To the extent possible, radiation dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations in the surrounding environment. The amounts of most radioactive materials released during 1994 were generally too small to be measured directly once they were dispersed in the offsite environment. For many of the measurable radionuclides, it was difficult to identify the contributions from Hanford sources in the presence of contributions from worldwide fallout and from naturally occurring uranium and its decay products. Therefore, in nearly all instances, potential offsite doses were estimated using environmental pathway models that calculate concentrations of radioactive materials in the environment from effluent releases reported by the operating contractors.

As in the past, the differences in measured concentrations of certain radionuclides in samples of Columbia River water collected upstream and downstream of the Hanford Reach were used to estimate the doses to the public from these radionuclides entering the river with riverbank seepage of ground water. During 1994, iodine-129, tritium, and isotopes of uranium were found in the Columbia River downstream of Hanford at greater concentrations than predicted from direct discharge from the 100 and 300 Areas.

Although the uncertainty associated with the radiation dose calculations has not been quantified, whenever Hanford-specific data were not available for parameter values (for example, vegetation uptake and consumption factors), conservative values were selected from the literature for use in environmental transport models. Thus, radiation doses calculated using environmental models should be viewed as maximum estimates of potential doses resulting from Hanford operations.

Maximally Exposed Individual Dose

The MEI is a hypothetical person who lives at a location and has a postulated lifestyle such that it is unlikely that other members of the public would receive higher radiation doses. This individual's characteristics were chosen to maximize the combined doses from all realistic environmental pathways of exposure to radionuclides in Hanford effluents. In reality, such a combination of maximized parameters is unlikely to apply to any single individual.

The location selected for the MEI can vary from year to year depending on the relative importance of the several sources of radioactive effluents released to the air and to the Columbia River from Hanford facilities. Historically, two separate locations in the Hanford environs have been identified as potential sites for the MEI: the Ringold area, 26 km (16 mi) east of the 200 Areas separation facilities, and the Riverview irrigation district across the river from Richland (Figure 6.0.1). The principal differences between the two MEI locations are that Ringold is closer than Riverview to the Hanford facilities, which had been the major contributors of airborne effluents in the past, but the MEI at Ringold does not drink water derived from the Columbia River. The MEI at Riverview, although farther from the Hanford sources of airborne radionuclides, can be exposed to the one additional pathway of irrigation water derived from the Columbia River.

During 1994, the hypothetical MEI (assumed to be located 1.5 km [1 mi] directly across the Columbia River from the 300 Area) was calculated to have received a slightly higher dose in 1994 than an MEI located at either Ringold or Riverview. The farms located across from the 300 Area use water obtained from the Columbia Irrigation System far upstream of the Hanford Site for irrigation and well water for sanitary purposes. Foods grown there would only contain radionuclides released with airborne effluents of Hanford origin. Therefore, the conservative assumption was made that the diet of the MEI residing across from the 300 Area consisted totally of foods purchased from the Riverview area, which could contain radionuclides present in both liquid and gaseous effluents from Hanford. The added contribution of the radionuclides in the Riverview irrigation water maximizes the calculated dose from all air and water pathways combined.

The following exposure pathways were included in the calculation of doses potentially received by the hypothetical MEI for 1994: inhalation of and submersion in air downwind of the Site, consumption of foods contaminated by radionuclides deposited from the air and by irrigation with water from the

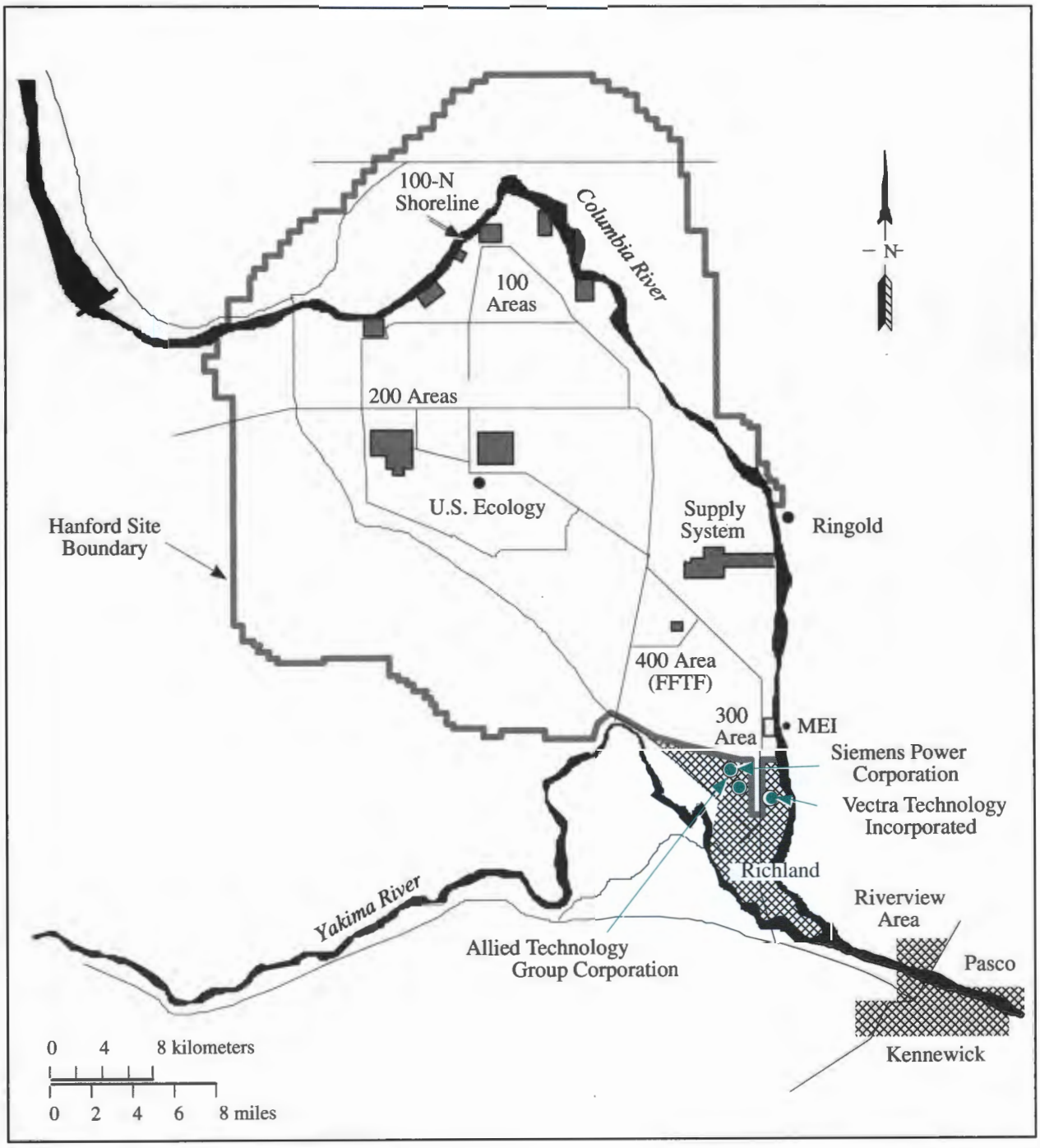

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Figure 6.0.1 Locations Important to Dose Calculations

Columbia River, direct exposure to radionuclides deposited on the ground, consumption of fish taken from the Columbia River, and external radiation during recreation activities on the Columbia River and its shoreline. The MEI for 1994 was postulated to be an individual who:

- was a resident of the closest farm 1.5 km (1 mi) across the Columbia River from the 300 Area

- consumed foodstuffs irrigated with Columbia River water grown in the Riverview Irrigation District
- used the Columbia River extensively for boating, swimming, and fishing and consumed the fish caught
- drank well water that did not contain radionuclides of Hanford origin
- was exposed via inhalation and external exposure to the airborne radionuclides released from Hanford facilities.

Radiation doses to the MEI were calculated using the effluent data in Sections 3.1, Tables 3.1.1, 3.2.1, and 3.2.2, and measured quantities of radionuclides assumed to be present in the Columbia River from riverbank springs as input to the GENII code. The calculated doses for the MEI are summarized in Table 6.0.1. These values include the potential doses received from exposure to liquid and airborne effluents during 1994, as well as the future dose from radionuclides that were deposited in the body during 1994 via inhalation and ingestion. As releases from facilities and the doses from these sources decrease, the contribution of diffuse sources, such as wind-blown contaminated soil, becomes relatively more significant. An upper estimate of the dose from diffuse sources is discussed in a following subsection ("Comparison with Clean Air Act Standards"). This contribution is not included in the MEI dose. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix D.

The total potential radiation dose to the hypothetical MEI in 1994 was calculated to be 0.05 mrem (5×10^{-4} mSv) compared to 0.03 mrem (3×10^{-4} mSv) calculated for in 1993. The primary pathways contributing to this dose as determined by the computer calculations were

- consumption of fish containing radionuclides, principally isotopes of uranium, from the Columbia River (33%)
- consumption of food irrigated with Columbia River water containing radionuclides, principally tritium and uranium (27%)
- inhalation of airborne radionuclides, principally the iodine-129 released from the 200 Area (20%).

The DOE radiation dose limit for any member of the public from all routine DOE operations is 100 mrem/yr (1 mSv/yr). The dose calculated for the MEI for 1994 was 0.05% of the DOE limit.

The doses from Hanford operations for the MEI for 1990 through 1994 are illustrated in Figure 6.0.2.

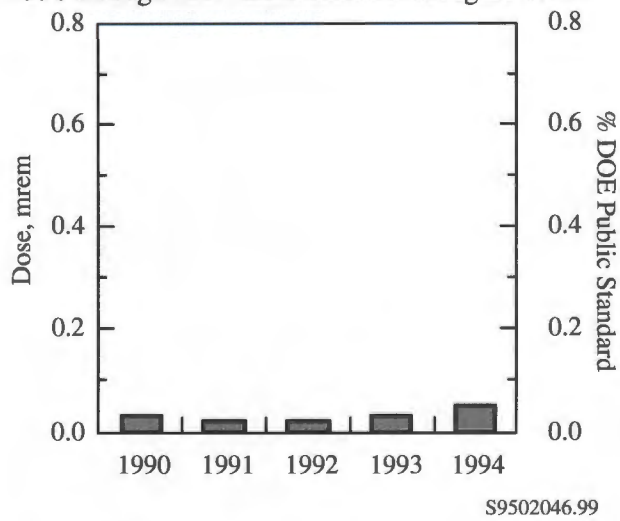

Figure 6.0.2 Calculated Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual, 1990 Through 1994

During each year the doses were estimated using methods and computer codes that were state-of-the-art at the time. During the period of 1990 through 1992, the MEI was located at either Ringold or Riverview, whichever location represented the maximum hypothetical dose. For 1993 and 1994, the hypothetical MEI was located across the Columbia River from the 300 Area.

Table 6.0.1 Dose (mrem) to the Hypothetically Maximally Exposed Individual Residing across from the 300 Area from 1994 Hanford Operations

		Operating Area Contribution Dose, mrem[a,b]				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External[c]	7.9×10^{-8}	2.8×10^{-6}	1.3×10^{-4}	2.5×10^{-8}	1.3×10^{-4}
	Inhalation	2.3×10^{-5}	6.4×10^{-4}	9.8×10^{-3}	1.9×10^{-5}	1.0×10^{-2}
	Foods[d]	6.5×10^{-7}	1.5×10^{-3}	3.3×10^{-5}	6.3×10^{-8}	1.5×10^{-3}
	Total Air	2.4×10^{-5}	2.1×10^{-3}	1.0×10^{-2}	1.9×10^{-5}	1.2×10^{-2}
Water	Recreation[e]	9.7×10^{-7}	2.0×10^{-4}	2.1×10^{-8}	0.0[f]	2.0×10^{-4}
	Foods[g]	3.9×10^{-4}	1.4×10^{-2}	6.2×10^{-6}	0.0	1.4×10^{-2}
	Fish[h]	3.2×10^{-4}	1.7×10^{-2}	5.4×10^{-6}	0.0	1.7×10^{-2}
	Drinking Water	2.4×10^{-5}	6.7×10^{-3}	5.1×10^{-7}	0.0	6.7×10^{-3}
	Total Water	7.3×10^{-4}	3.8×10^{-2}	1.2×10^{-5}	0.0	3.9×10^{-2}
	Combined Total	7.6×10^{-4}	4.0×10^{-2}	1.0×10^{-2}	1.9×10^{-5}	5.1×10^{-2}

(a) To convert these dose values to mSv, divide them by 100.
(b) Values rounded after adding.
(c) Includes air submersion and exposure to ground-deposited radionuclides.
(d) Includes consumption of all foodstuffs contaminated via deposition from the air.
(e) External exposure during river recreation plus inadvertent ingestion of water while swimming.
(f) There are no releases to the river from the 400 Area.
(g) Includes consumption of all foodstuffs contaminated via irrigation water.
(h) Consumption of fish taken from the Columbia River.

Special Case Exposure Scenarios

While characteristics that define the standard and historical MEI are selected to define a high-exposure scenario that is unlikely to occur, they do not necessarily represent the scenario with the highest conceivable radiation dose. Low-probability exposure scenarios exist that could conceivably result in somewhat higher doses. Two potential scenarios include an individual who could spend time at the Site boundary location with the maximum external radiation dose rate, and a sportsman who might obtain contaminated wildlife that migrated from the Site. These special cases are discussed below, as is the potential dose from consumption of drinking water at the FFTF Visitors Center.

Maximum "Boundary" Dose Rate

The "boundary" radiation dose rate is the external radiation dose rate measured at publicly accessible locations on or near the Site. The "boundary" dose rate was determined from radiation exposure measurements using TLDs at locations of expected elevated dose rates onsite and at representative locations offsite. These boundary dose rates should not be used to calculate annual doses to the general public because no one can actually reside at any of these boundary locations. However, these rates can be used to determine the dose to a specific individual who might spend some time at that location.

External radiation dose rates measured in the vicinity of the 100-N, 200, 300, and 400 (FFTF) Areas are described in Section 5.7, "External Radiation Surveillance." The 200 Areas results were not used because these locations are not accessible to the general public. Radiation measurements made at the 100-N Area shoreline (Figure 6.0.1) were consistently above the background level and represent the highest measured boundary dose rates. The Columbia River provides public access to an area

within a few hundred meters of the N Reactor and supporting facilities.

The annual average dose rate at the location with the highest exposure rate along the 100-N shoreline during 1994 was 0.03 mrem/h (3×10^{-4} mSv/h), or about 0.02 mrem/h (2×10^{-4} mSv/h) above the average background dose rate of 0.01 mrem/h (1×10^{-4} mSv/h) normally observed at offsite shoreline locations. Therefore, for every hour someone spent at the 100-N Area shoreline during 1994, the external radiation dose received from Hanford operations would be about 0.02 mrem (2×10^{-4} mSv). This dose would be in addition to the annual dose calculated for the hypothetical MEI. The public can approach the shoreline by boat, but they are legally restricted from stepping onto the shoreline.

The FFTF Visitors Center, located southeast of the FFTF Reactor building (Figure 6.0.1), was opened to the public during the first 9 months of 1994. Dose rates measured at this location continued to be essentially equal to normal background radiation levels in the vicinity of Hanford (0.01 mrem/h [1×10^{-4} mSv/h]).

Sportsman Dose

Wildlife have access to areas of the Site that contain contamination and could thereby become contaminated. The potential also exists for contaminated wildlife to move offsite. For this reason, sampling is conducted onsite to estimate maximum contamination that might possibly exist in animals hunted offsite. This is a unique and relatively low probability scenario that is not included in the MEI calculation.

Listed below are examples of the estimated radiation doses that could have resulted if wildlife containing the maximum concentrations measured in onsite wildlife in 1994 migrated offsite, were hunted, and were consumed. These are very low doses and qualitative observations suggest that the significance of this pathway is further reduced because of the relatively low migration offsite and the inaccessibility of onsite wildlife to hunters. Not all of the maximum values were observed in the same animal of each species sampled. However, the maximum values were compounded to arrive at an upper limit to the potential concentrations. These doses would be in addition to the MEI dose.

- The dose from eating 1 kg (2.2 lbs) of meat containing the maximum concentration of cesium-137 measured in a deer collected onsite is estimated to be 4×10^{-4} mrem (4×10^{-6} mSv).
- The dose from eating 1 kg (2.2 lbs) of meat containing the maximum concentration of cesium-137 and cobalt-60 measured in any game bird collected onsite is estimated to be 8×10^{-3} mrem (8×10^{-5} mSv).
- The dose from eating 1 kg (2.2 lbs) of meat containing the maximum concentration of cesium-137 measured in a rabbit collected onsite is estimated to be 2×10^{-3} mrem (2×10^{-5} mSv).
- The dose from eating 1 kg (2.2 lbs) of meat containing the maximum concentrations of cesium-137 and cobalt-60 measured in bass, whitefish, or carp collected from the Hanford Reach of the Columbia River is estimated to be 7×10^{-3} mrem (7×10^{-5} mSv).
- The dose from eating 1 kg (2.2 lbs) of meat containing the concentrations of uranium isotopes measured in a composite sample of small asiatic clams collected from the Columbia River downstream of the 300 Area is estimated to be 2×10^{-2} mrem (2×10^{-4} mSv).

The methodology for calculating doses from consumption of wildlife are addressed in more detail in Soldat et al. (1990).

FFTF Visitors Center Drinking Water

During 1994, ground water was used as a drinking water source at the FFTF Visitors Center (Figure 6.0.1). This water is sampled and analyzed throughout the year in accordance with applicable drinking water regulations. Radionuclide concentrations during 1994 were well below applicable drinking water standards but concentrations of iodine-129 and tritium were detected at levels greater than typical background values. Based on these measurements, the potential dose received by a member of the public from drinking 1 L (~1 qt) of drinking water during a visit to the FFTF Visitors Center was calculated to be 4×10^{-4} mrem

(4×10^{-6} mSv). The maximum organ dose (thyroid) was calculated to be 5×10^{-4} mrem (5×10^{-6} mSv). These doses are very small percentages of the DOE limit of 4 mrem effective dose equivalent (0.04 mSv) from drinking water.

Comparison with Clean Air Act Standards

Limits for radiation dose to the public from airborne emissions at DOE facilities are provided in 40 CFR 61, Subpart H, of the Clean Air Act Amendments. The regulation specifies that no member of the public shall receive a dose of more than 10 mrem/yr (0.1 mSv/yr) (EPA 1989) from exposure to airborne radionuclide effluents (other than radon) released at DOE facilities. It also requires that each DOE facility submit an annual report that supplies information about atmospheric emissions for the preceding year and their potential offsite impacts. The following summarizes information that is provided in more detail in the 1994 air emissions report (Diediker et al. 1995).

The 1994 air emissions from monitored Hanford facilities including radon releases from the 300 Area resulted in a potential dose to an MEI across from the 300 Area of 0.01 mrem (1×10^{-4} mSv), which is 0.1% of the limit. Of this total, radon emissions from the 300 Area contributed 0.007 mrem and nonradon emissions from all stack sources contributed 0.005 mrem. Therefore, the estimated annual dose from monitored stack releases at the Hanford Site during 1994 was well below the Clean Air Act standard. The Clean Air Act requires the use of CAP-88-PC or other EPA models to demonstrate compliance with the standard, and the assumptions embodied in these codes differ slightly from standard assumptions used at the Hanford Site for reporting to DOE via this document. Nevertheless, the result of calculations performed with CAP-88-PC for air emissions from Hanford facilities agrees reasonably well with that calculated using the GENII code (0.01 mrem or 1×10^{-4} mSv).

The 1990 amendments to the Clean Air Act (40 CFR 61, Subpart H) also require DOE facilities to estimate the dose to a member of the public for radionuclides released from diffuse and unmonitored sources as well as from monitored point sources. The EPA has not specified or approved methods for estimating emissions from diffuse sources, and standardization is difficult because of the wide variety of such sources at DOE sites. Estimates of potential diffuse source emissions at the Hanford Site have been developed using environmental surveillance measurements of airborne radionuclides at the Site perimeter.

During 1994, the dose to the MEI across the river from the 300 Area was 0.05 mrem (5×10^{-4} mSv), which was greater than the estimated dose at that location from stack emissions (0.01 mrem or 1×10^{-4} mSv). Doses at other locations around the Hanford Site perimeter ranged from 0.02 to 0.08 mrem (2×10^{-4} to 8×10^{-4} mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1994 was much less than the EPA standard.

Population Dose

Pathways of exposure to the population from releases of radionuclides to the atmosphere include inhalation, air submersion, and consumption of contaminated food. Pathways of exposure associated with Hanford-generated radionuclides present in the Columbia River include consumption of drinking water, fish, and irrigated foods, and external exposure during aquatic recreation. The regional population dose from 1994 Hanford operations was estimated by calculating the radiation dose to the population residing within an 80-km (50-mi) radius of the onsite operating areas. Results of the dose calculations are shown in Table 6.0.2. Food pathway, dietary, residency, and recreational activity assumptions for these calculations are given in Appendix D.

Table 6.0.2 Dose (person-rem) to the Population from 1994 Hanford Operations

Effluent	Pathway	Operating Area Contribution Dose, person-rem[a,b] 100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External[c]	1.3×10^{-5}	2.4×10^{-4}	1.4×10^{-3}	8.2×10^{-7}	1.7×10^{-3}
	Inhalation	5.3×10^{-3}	8.1×10^{-2}	5.9×10^{-2}	8.8×10^{-4}	1.5×10^{-1}
	Foods[d]	1.8×10^{-4}	1.8×10^{-1}	1.6×10^{-3}	7.1×10^{-6}	1.8×10^{-1}
	Total Air	5.5×10^{-3}	2.6×10^{-1}	6.2×10^{-2}	8.9×10^{-4}	3.3×10^{-1}
Water	Recreation[e]	6.9×10^{-6}	1.0×10^{-3}	1.3×10^{-7}	0.0[f]	1.0×10^{-3}
	Foods[g]	4.1×10^{-4}	1.6×10^{-2}	6.4×10^{-6}	0.0	1.6×10^{-2}
	Fish[h]	1.2×10^{-4}	6.4×10^{-3}	2.0×10^{-6}	0.0	6.5×10^{-3}
	Drinking Water	1.0×10^{-3}	2.8×10^{-1}	2.2×10^{-5}	0.0	2.8×10^{-1}
	Total Water	1.5×10^{-3}	3.0×10^{-1}	3.1×10^{-5}	0.0	3.0×10^{-1}
	Combined Total	7.0×10^{-3}	5.6×10^{-1}	6.2×10^{-2}	8.9×10^{-4}	6.3×10^{-1}

(a) To convert these dose values to person-Sv, divide them by 100.
(b) Values rounded after adding.
(c) Includes air submersion and exposure to ground-deposited radionuclides.
(d) Includes consumption of all foodstuffs contaminated via deposition from the air.
(e) External exposure during river recreation plus inadvertent ingestion of water while swimming.
(f) There are no releases to the river from the 400 Area.
(g) Includes consumption of all foodstuffs contaminated via irrigation water and external exposure to ground contaminated via irrigation.
(h) Consumption of fish taken from the Columbia River.

The potential dose calculated for the population was 0.6 person-rem (0.006 person-Sv) in 1994, compared to 0.4 person-rem (0.004 person-Sv) in 1993. The 80-km (50-mi) population doses attributed to Hanford operations from 1990 through 1994 are compared in Figure 6.0.3.

Primary pathways contributing to the 1994 dose to the population were

- consumption of drinking water contaminated with radionuclides (principally tritium and uranium) released to the Columbia River at Hanford (44%)
- consumption of foodstuffs contaminated with radionuclides (principally iodine-129 released with gaseous effluents primarily from the PUREX Plant stack [29% of the total dose])
- inhalation of radionuclides (principally iodine-129) that were released to the air from the PUREX Plant stack (24%).

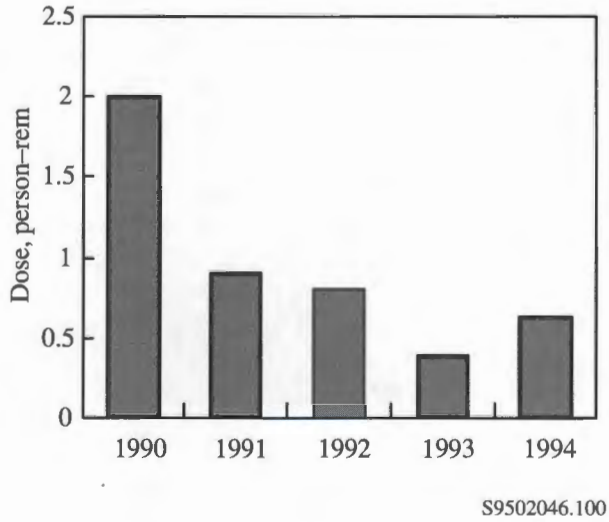

Figure 6.0.3 Calculated Effective Dose Equivalent to the Population Within 80 km (50 mi) of the Hanford Site, 1990 Through 1994

Table 6.0.3 Summary of Doses to the Public in the Vicinity of Hanford from Various Sources, 1994

Source	Maximum Individual, mrem[a]	80-km Population, person-rem[a]
All Hanford effluents[b]	0.05	0.6
DOE limit	100	--
Percent of DOE limit	0.05%	--
Background radiation	300	110,000
Hanford doses percent of background	0.02%	6×10^{-4}%
Doses from gaseous effluents[c]	0.01	--
EPA air standard	10	--
Percent of EPA standard	0.1%	--

(a) To convert the dose values to mSv or person-Sv, divide them by 100.
(b) Calculated with the GENII code (Napier et al. 1988a, 1988b, 1988c).
(c) Calculated with the EPA CAP-88-PC code.

The average per capita dose from 1994 Hanford operations, based on a population of 380,000 within 80 km (50 mi), was 0.002 mrem (2×10^{-5} mSv). This dose estimate may be compared with doses 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. The national average radiation doses from these other sources are illustrated in Figure 6.0.4. The estimated per capita dose to individual members of the public from Hanford sources is a small fraction (approximately 6×10^{-4}%) of the annual per capita dose (300 mrem) from natural background sources.

The doses to the MEI and to the 80-km (50-mi) population from Hanford effluents are compared to appropriate standards and natural background radiation in Table 6.0.3. This table shows that the calculated radiation doses from Hanford operations in 1994 are a small percentage of the standards and of natural background.

Doses from Other Than DOE Sources

DOE maintains an awareness of other manmade sources of radiation (other than DOE sources), which if combined with the DOE sources might have the potential to exceed a dose contribution to any member of the public of 10 mrem (0.1 mSv). Various non-DOE industrial sources of public radiation exposure exist at or near Hanford. These include the low-activity commercial radioactive waste burial ground at Hanford operated by US Ecology, the nuclear generating station at Hanford operated by Washington Public Power Supply System, the nuclear fuel production plant operated by Siemens Power Corporation, the commercial low-activity radioactive waste compacting facility operated by Allied Technology Group Corporation, and a commercial decontamination facility operated by Vectra Technology, Inc. (Figure 6.0.1). With information gathered from these companies, it was conservatively determined that the total 1994 individual dose from their combined activities is on the order of 0.05 mrem (5×10^{-4} mSv). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 1994 was well below any regulatory dose limit.

Hanford Public Radiation Dose in Perspective

Several scientific studies (NRC 1980, 1990; UNSCEAR 1988) have been performed to estimate the potential risk of developing detrimental health effects from exposure to low levels of radiation. These studies have provided vital information to government and scientific organizations that recommend radiation 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, most

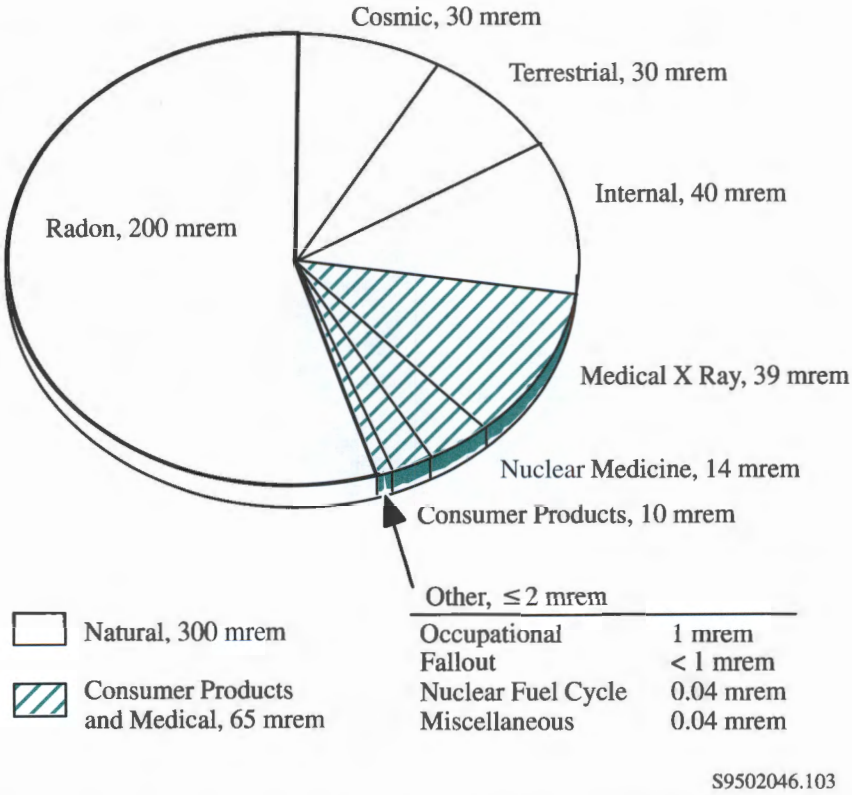

Figure 6.0.4 National Annual Average Radiation Doses from Various Sources (mrem) (NCRP 1987)

scientists accept the conservative hypothesis that low-level doses might increase the probability that certain types of effects, such as cancer, could occur. Regulatory agencies conservatively (cautiously) assume that the probability of these types of health effects at low doses (down to zero) is proportional to the probability of these same health effects observed historically at much higher doses (in atomic bomb victims, radium dial painters, etc.). Therefore, using conservative assumptions, one can postulate that even the natural background radiation (which is many hundreds of times greater than radiation from Hanford releases) increases each person's probability or chance of developing a detrimental health effect.

Scientists do not agree about how to translate the available data on health effects into the numerical probability (risk) of detrimental effects from low-level radiation doses. Some scientific studies have even indicated that low radiation doses may be beneficial (HPS 1987). Because cancer and hereditary diseases in the general population may be caused by a multitude of sources (e.g., genetic defects, sunlight, chemicals, and background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be determined accurately. The EPA has used a probability value of approximately 4 per 10 million (4×10^{-7}) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) in developing Clean Air Act regulations (EPA 1989). Recent data (NRC 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 activities (for example, DOE facilities, nuclear power plants, chemical plants, and hazardous waste sites). All of these industrial activities are considered beneficial to people in some way, such as providing electricity, national defense, waste disposal, and consumer products. These government agencies have a complex task in establishing environmental regulations that control levels of risk to the public without unnecessarily reducing the needed benefits from the industry.

The public is subjected to some incremental risks from exposure to industrial pollutants (radiological and non-radiological). These risks can be kept in perspective by comparing them to the increased risks involved in other typical activities. For instance, two added risks that an individual receives from flying on an airline are the risks of added radiation dose (stronger cosmic radiation field at higher altitude) and the possibility of being in an aircraft accident. Table 6.0.4 compares the estimated risks from various radiation doses to the risks of some activities encountered in everyday life.

Another way of looking at the risk of detrimental health effects from Hanford radioactive releases is illustrated in Table 6.0.5. Listed are some activities considered approximately equal in risk to the hypothetical risk from the potential radiation dose received by the MEI from Hanford releases in 1994.

Dose Rates to Animals

Conservative (upper) estimates have been made of the potential radiation dose to "native aquatic animal organisms," in accordance with a DOE Order 5400.5 interim requirement for management and control of liquid discharges. Potential radiation dose rates during 1994 were calculated for several possible exposure modes, including exposure to radionuclides in water entering the Columbia River from springs near the 100-N Area, and internally deposited radionuclides measured in samples of animals collected from the Columbia River and onsite.Because the volumetric flow of the springs at the 100-N Area is so low, no aquatic animal can live directly in this spring water. Exposure to the radionuclides from the springs cannot occur until the spring water has been noticeably diluted in the Columbia River. The unlikely assumption was made that a few aquatic animals might be exposed to the maximum concentration of radionuclides measured in the spring water (see Table 3.2.5) after dilution at only 10 to 1 by the river. Radiation doses were calculated for several different types of aquatic animals, using highly conservative assumptions and the computer code CRITR2 (Baker and Soldat 1992). The animal receiving the highest potential dose was calculated to be a duck consuming aquatic plants. However, even if such a duck spent 100% of its time in the one-tenth spring water consuming only plants growing there, it would only receive a radiation dose rate of 0.02 rad/d. This dose rate is 2% of the limit of 1 rad/d given for native aquatic animal organisms in DOE Order 5400.5.

Doses were also estimated for clams, fish, and waterfowl exposed to Columbia River water containing a mixture of all the radionuclides reaching the Columbia River from Hanford sources during 1994. The highest potential dose was 4×10^{-3} rad/d for a plant-eating duck.

Dose estimates based on the maximum concentrations of cesium-137 and cobalt-60 measured in muscle of animals collected onsite and from the Columbia River ranged from 2×10^{-7} rad/d to a mule deer to 3×10^{-6} rad/d for a pheasant.

Table 6.0.4 Estimated Risk from Various Activities and Exposures[a]

Activity or Exposure Per Year	Risk of Fatality
Riding or driving in a passenger vehicle (300 miles)	2×10^{-6}[b]
Home accidents	100×10^{-6}[b]
Drinking 1 can of beer or 4 ounces of wine per day (liver cancer/cirrhosis)	10×10^{-6}
Pleasure boating (accidents)	6×10^{-6}[b]
Firearms, sporting (accidents)	10×10^{-6}[b]
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	3600×10^{-6}
Eating 4 tablespoons of peanut butter per day (liver cancer)	8×10^{-6}
Eating 90 pounds of charcoal-broiled steaks (gastrointestinal-tract cancer)	1×10^{-6}
Drinking chlorinated tap water (trace chloroform—cancer)	3×10^{-6}
Taking contraceptive pills (side effects)	20×10^{-6}
Flying as an airline passenger (cross country roundtrip—accidents)	8×10^{-6}[b]
Flying as an airline passenger (cross country roundtrip—radiation)	0 to 5×10^{-6}
Natural background radiation dose (300 mrem, 3 mSv)	0 to 120×10^{-6}
Dose of 1 mrem (0.01 mSv)	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford in 1994 (0.05 mrem, 5×10^{-4} mSv)	0 to 0.02×10^{-6}

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

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

Table 6.0.5 Activities Comparable in Risk to That from the 0.05-mrem Dose Calculated for the 1994 Maximally Exposed Individual

Driving or riding in a car 5 km (3 mi)
Smoking 1/20 of a cigarette
Flying 13 km (8 mi) on a commercial airline
Eating 4 tablespoons of peanut butter
Eating one 0.8-kg (1.8-lb) charcoal-broiled steak
Drinking about 4.8 L (5 quarts) of chlorinated tap water
Being exposed to natural background radiation for about 1.5 hours in a typical terrestrial location
Drinking about 3/4 of a can of beer or 3/4 of a glass of wine

Quality Assurance

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7.0 Quality Assurance

B. M. Gillespie and B. P. Gleckler

Quality assurance (QA) and quality control (QC) practices encompass all aspects of Hanford Site environmental monitoring and surveillance programs. Samples are analyzed according to documented standard analytical procedures. Analytical data quality is verified by a continuing program of internal laboratory QC, participation in interlaboratory cross-checks, replicate sampling and analysis, submittal of blind standard samples and blanks, and splitting samples with other laboratories.

QA/QC for ground-water environmental surveillance also includes procedures and protocols for 1) documenting instrument calibrations, 2) conducting activities in the field and laboratory, 3) maintaining wells to ensure representative samples are collected, and 4) using dedicated sampling pumps to avoid cross-contamination.

This section discusses specific measures taken to ensure quality in project management, sample collection, and analytical results.

Environmental Surveillance

Comprehensive QA programs, including various QC practices, are maintained to ensure the quality of data collected through the surveillance programs. QA plans are maintained for all surveillance activities, defining the appropriate controls and documentation required to meet the guidance of the American Society of Mechanical Engineers (ASME) NQA-1 QA program document (U.S. nuclear industry's standard, ASME 1989) and DOE Orders.

Project Management Quality Assurance

Site surveillance and related programs, such as processing of TLDs and performing dose calculations, are subject to an overall QA program. This program implements the requirements of Richland Operations Office Order DOE 5700.6C, "Quality Assurance," and is based on ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME 1989). The program is defined in a QA manual (PNL 1992c), which provides guidance for implementation by addressing the following 18 QA elements. These 18 elements are:

1. Organization
2. Quality Assurance Program
3. Design Control
4. Procurement Document Control
5. Instructions, Procedures, and Drawings
6. Document Control
7. Control of Purchased Items and Services
8. Identification and Control of Items
9. Control of Processes
10. Inspection
11. Test Control
12. Control of Measuring and Test Equipment
13. Handling, Storage, and Shipping
14. Inspection, Test, and Operating Status
15. Control of Nonconforming Items
16. Corrective Action
17. Quality Assurance Records
18. Audits.

The environmental surveillance projects have current QA plans that describe the specific QA elements that apply to each project. These plans are approved by a QA organization that conducts surveillances and audits to verify compliance with the plans. Work performed through contracts, such as sample analysis, must meet the same QA requirements. Potential equipment and services suppliers are audited before contracts are awarded for services or the purchase of materials are approved, which could have a significant impact on quality within the project.

Sample Collection Quality Assurance/Quality Control

Environmental surveillance samples were collected by staff trained to conduct sampling according to

approved and documented procedures (PNL 1992a). Continuity of all sampling location identities is maintained through careful documentation. Field duplicates are collected for specific media, and results are addressed in the individual media sections of 5.0, "Environmental Surveillance Information."

Samples for ground-water monitoring are collected by trained staff according to approved and documented procedures (PNL 1993). Chain-of-custody procedures are followed (EPA 1986a) that provide for the use of evidence tape in sealing sample bottles to maintain the integrity of the samples during shipping. Full trip blanks and field duplicates were obtained during field operations. Summaries of the 1994 results are provided in Tables 7.0.1 and 7.0.2.

Analytical Results Quality Assurance/Quality Control

Routine hazardous and nonhazardous chemical analyses for environmental and ground-water surveillance water samples are performed by DataChem Laboratories, Inc., Salt Lake City, Utah. The laboratory participates in the EPA Water Pollution and Water Supply Performance Evaluation Studies. DataChem Laboratories maintains an internal QC program that meets the requirements of EPA SW-846 (EPA 1986a), which is audited and reviewed. PNL submits additional QC double-blind spiked samples for analysis.

Routine radiochemical analyses for environmental and ground-water surveillance samples are performed by International Technology Corporation's (IT) Richland Laboratory. The laboratory participates in the DOE's Quality Assessment Program and the EPA's Laboratory Intercomparison Studies. An additional QC blind spiked sample program for each project is conducted. IT's Richland Laboratory also maintains an internal QC program, which is audited and reviewed. Additional information on these QC efforts is provided in the following subsections.

Table 7.0.1 Summary of Ground-Water Surveillance Full Trip Blank Samples, 1994

Constituents	Number of Results Reported	Number Within Control Limits[a]
Radionuclides		
Gross alpha	1	1
^{3}H	7	7
^{60}Co	2	2
^{99}Tc	7	7
^{129}I	4	4
^{106}Ru	2	2
^{125}Sb	2	2
^{137}Cs	2	2
Alkalinity	1	1
Cyanide	2	2
ICP metals	5	
Mn, Ni, K, Ag, Sn, Sb, Ba, Be, Cd, Cr, Co, Cu, V		5
Al, Mg, Ca		4
Zn, Fe		2
Na		0
Anions	8	
Bromide, Nitrite, Phosphate, Sulfate		8
Fluoride		7
Chloride		6
Nitrate		2
Volatile Organics	56	55

(a) Control limit is less than detection level (method detection level for hazardous constituents and below total propagated analytical uncertainty for radioactive constituents).

Table 7.0.2 Summary of Ground-Water Surveillance Field Duplicate Samples, 1994

Constituents	Number of Results Reported	Number Above Detection Level	Number Within Control Limits[a]
Radionuclides			
Gamma isotopes (^{60}Co, ^{137}Cs, ^{106}Ru, and ^{125}Sb)	3	0	NA[b]
^{129}I	3	1	1
^{3}H	6	4	4
Total uranium	3	3	3
ICP metals (18 elements each report)	19	9	9
Ions			
Bromide, chloride, fluoride, nitrate, nitrite, phosphate, sulfate	16	12	12
Cyanide	1	1	1
Volatile organic constituents	28	3	3

(a) Control limits are as follows: If the result is less than 5 times detection level, then duplicate results must be ± detection level. If the result is greater than 5 times detection level, then results must be ± 20 Relative Percent Difference. If either value is less than detection level then Relative Percent Difference was not calculated.

(b) NA = Not applicable because sample results were below detection level.

U.S. Department of Energy and U.S. Environmental Protection Agency Comparison Studies

DataChem Laboratories participated in the EPA Water Pollution and Water Supply Performance Evaluation Studies. Standard water samples were distributed blind to participating laboratories. These samples contained specific organic and inorganic analytes with concentrations unknown to the analyzing laboratories. After analysis, the results were submitted to EPA for comparison to known values and other participating laboratory concentrations. Summaries of the results during the year are provided in Table 7.0.3. Approximately 97% of the results during the year were within the typically used "3-sigma control limits" (± 3 standard errors of the mean).

The DOE Quality Assessment program and EPA's Intercomparison Studies Program provide standard samples of various environmental media (water, air filters, soil, and vegetation) containing specific amounts of one or more radionuclides that are unknown by the participating laboratory. After sample analysis, the results were forwarded to DOE or EPA for comparison with known values and results from other laboratories. Both EPA and DOE have established criteria for evaluating the accuracy of results (Jarvis and Siu 1981, Sanderson 1985). Summaries of the 1994 results for the programs are provided in Tables 7.0.4 and 7.0.5. Approximately 83% of the results during the year were within the typically used "3-sigma control limits" (± 3 standard errors of the mean).

Table 7.0.3 Summary Results of DataChem Laboratories EPA Water Pollution and Water Supply Performance Evaluation Studies, 1994

Analytes	Number of Results Reported	Number Within Control Limits[a]
Metals		
Ag, Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, Sr, Ti, Tl, V, Zn	55	55
Other inorganic tests		
pH, conductivity, total dissolved solids, total hardness, calcium, potassium, sodium, alkalinity, chloride, fluoride, sulfate, ammonia, nitrate, nitrite, chemical oxygen demand, etc.	79	78
Organic tests		
total organic carbon, PCBs, pesticides, herbicides, volatile organic constituents, other	113	108

(a) Control limits from EPA (1982).

Table 7.0.4 Summary of International Technology Corporation Performance on DOE Quality Assessment Program Samples, 1994

Media	Radionuclides	Number of Results Reported for Each	Number Within Control Limits[a]
Air filters	^{54}Mn, ^{57}Co, ^{60}Co, ^{125}Sb, ^{137}Cs, ^{144}Ce, ^{238}Pu, ^{239}Pu, U total	2	2
	^{90}Sr, ^{241}Am	2	1
	^{106}Ru, ^{134}Cs, ^{234}U, ^{238}U	1	1
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{241}Am	2	2
	total uranium	2	1
	^{234}U	1	1
	^{238}Pu, ^{238}U, ^{239}Pu	1	0
Vegetation	^{40}K, ^{60}Co, ^{90}Sr, ^{134}Cs	2	2
	^{241}Am	2	1
	^{238}Pu, ^{239}Pu	1	1
Water	^{3}H, ^{54}Mn, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{241}Am, total uranium	2	2
	^{90}Sr	2	1
	^{234}U, ^{238}Pu, ^{238}U, ^{239}Pu, ^{244}Cm	1	1

(a) Control limits are from Sanderson (1985) and Sanderson et al. (1995).

Pacific Northwest Laboratory Evaluations

In addition to DOE and EPA interlaboratory QC programs, a QC program is maintained by PNL to evaluate analytical contractor precision and accuracy and to conduct special intercomparisons. This program includes the use of blind spiked samples and replicate samples. Blind spiked QC samples and blanks were prepared and submitted to check the accuracy and precision of analyses at DataChem Laboratories and IT's Richland Laboratory. In 1994, blind spiked samples were submitted for air filters, vegetation, soil, water, and ground water. Overall, 81% of the DataChem Laboratories blind spiked determinations were within control limits and 93% of IT's Richland Laboratory blind spiked determinations were within control limits (Table 7.0.6 and 7.0.7). This indicates, overall, acceptable results.

Table 7.0.5 Summary of International Technology Corporation Performance on EPA Intercomparison Program Samples, 1994

Media	Radionuclides	Number of Results Reported for Each	Number Within Control Limits[a]
Air filters	Total alpha, total beta, ^{90}Sr, ^{137}Cs	1	1
Milk	^{89}Sr, ^{90}Sr, ^{131}I, ^{137}Cs	1	1
Water	^{239}Pu	1	1
	^{106}Ru	1	0
	^{133}Ba, ^{3}H, ^{65}Zn	2	2
	^{60}Co, ^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs	4	4
	Total alpha, ^{226}Ra, ^{228}Ra	5	5
	Total beta, total uranium	5	4

(a) Control limits are from Jarvis and Siu (1981).

Table 7.0.6 Summary of Ground-Water Surveillance Project Quarterly Blind Spiked Determinations, 1994

Constituents	Number of Results Report[a]	Number Within ± 30 RPD[b]
^{3}H	9	9
^{60}Co	9	9
^{90}Sr	9	9
^{99}Tc	9	9
^{129}I	9	9
^{137}Cs	9	9
^{239}Pu	9	7
Total uranium	9	8
Chloroform	3	3
Carbon tetrachloride	3	3
Trichloroethylene	3	3
Chromium	9	8
Cyanide	9	7
Fluoride	9	4
Nitrate	9	9

(a) Blind samples were submitted in triplicate each quarter and compared to actual spike value. Fourth quarter blind sample results unavailable at time of publication.
(b) RPD = Relative Percent Difference.

PNL also participates in a Quality Assurance Task Force, a program conducted by the DOH. Two Hanford Site ground-water samples were analyzed in triplicate, and a National Institute of Standards and Technology (NIST) reference soil sample was analyzed in duplicate or triplicate by up to six other participating laboratories in the Pacific Northwest (Table 7.0.8). Well 199-N-56 was analyzed for cobalt-60 and tritium concentrations. PNL data compared favorably with those of other participating laboratories. Well 399-1-16A was analyzed for tritium, uranium isotopics, and total uranium concentrations. PNL concentrations compared favorably within the statistical standard deviations of the mean of the other participating laboratories. The NIST reference soil sample was analyzed for cesium-137 and strontium-90 concentrations. PNL's results fell within the ± 2 SEM of the mean of the

concentrations of the other participating laboratories and were acceptable.

Laboratory Internal Quality Assurance Programs

The DataChem Laboratories and IT's Richland Laboratory are required to maintain an internal QC program. Periodically, the laboratories are internally audited for compliance to the QC programs. At the DataChem Laboratories, the QC program meets the QC criteria of EPA SW-846 (EPA 1986a). This program also requires the laboratory to maintain a system for reviewing and analyzing the results of the QC samples to detect problems that may arise from contamination, inadequate calibrations, calculation errors, or improper procedure performance. Method Detection Level determinations are performed semiannually.

IT's Richland Laboratory internal QC program involves routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation check sources and background counts, replicate and spiked sample analyses, matrix and reagent blanks, and maintenance of control charts to indicate analytical deficiencies. Available calibration standards traceable to the NIST were used for radiochemical calibrations. Minimum detectable concentration verification is conducted (when requested) for radionuclide-media combination analyses. Equation 37 from Chapter 6 in EPA 520/1-80-012 (EPA 1980a) is used in the minimum detectable concentration calculations, which involves the use of factors such as the average counting efficiencies and background for detection instruments, length of time for background and sample counts, sample volumes, radiochemical yields, and a predesignated uncertainty multiplier.

In 1994, one inspection of the DataChem Laboratories and one inspection of IT's Richland Laboratory were conducted. These inspections documented conformance with contractual requirements of the analytical facility and provided the framework for identifying and resolving potential performance problems. Responses to audit and inspection findings were documented by written communication, and corrective actions were verified by follow-up audits and inspections.

Table 7.0.7 Summary of Surface Environmental Surveillance Project Blind Spiked Determinations, 1994

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Air filters	^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{239}Pu	8	7
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}U, ^{239}Pu	6	4
Water	^{3}H, ^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{234}U, ^{238}U, ^{239}Pu	11	10
Vegetation	^{40}K, ^{90}Sr, ^{137}Cs, ^{239}Pu	4	4

(a) Control Limits of ± 30% of spike recovery.

Table 7.0.8 Comparison[a] of Quality Assurance Task Force 1994 Intercomparison Samples. PNL analyses are compared against grand mean (±2 standard error of the mean) of participating laboratories

Radionuclide99	No. of Samples	Ground-water well 399-1-16A, pCi/L	No. of Samples	Ground-water well 199-N-56, pCi/L	No. of Samples	NIST Reference Soil Sample, pCi/g
^{3}H						
PNL (IT)	3	10,300 ± 958	3	11,000 ± 346		
Grand Mean	19	10,364 ± 1034	19	10,903 ± 2544		
^{60}Co						
PNL (IT)			3	ND[b]		
Grand Mean			17	3.3 ± 3.6		
^{90}Sr						
PNL (IT)			3	272 ± 50	3	237 ± 10
Grand Mean			16	232 ± 31	14	245 ± 17
^{137}Cs						
PNL (IT)					3	80.2 ± 6.3
Grand Mean					15	86.2 ± 14.8
^{234}U						
PNL (IT)	3	73.4 ± 9.1				
Grand Mean	13	65.9 ± 11.5				
^{235}U						
PNL (IT)	3	2.48 ± 3.0				
Grand Mean	13	3.0 ± 1.5				
^{238}U						
PNL (IT)	3	57.8 ± 1.9				
Grand Mean	13	53.9 ± 7.5				
Total U						
PNL (IT)	3	94.4 ± 5.9				
Grand Mean	16	125.9 ± 55.4				

(a) PNL analyses by IT are compared against grand mean (±2 standard error of the mean) of participating laboratories.
(b) Below minimum detectable concentration.

Internal laboratory QC program data are summarized by the laboratories in quarterly reports. The results of the QC sample summary reports and the observations noted by each laboratory indicated an acceptably functioning internal QC program.

Media Audits and Comparisons

Additional audits and comparisons are conducted on several specific types of samples. The DOH routinely cosampled various environmental media and measured external radiation levels at multiple locations during 1994. Media that were cosampled with the DOH included: 25 ground-water wells; two Columbia River sites; one riverbank spring; one on-site pond; two off-site water systems; three Columbia River sediment sites; five air monitoring stations; 15 TLD sites; offsite onions, potatoes, clams, and milfoil. Also cosampled were upwind and downwind samples of eggs, alfalfa, asparagus, carrots, peaches, apples, pheasant, chicken, and wine. These data will be available in the DOH report, *Environmental Radiation 1994 Annual Report, 33rd Edition*, when published. The National Food and Drug Administration also co-sampled vegetables, fruit and wheat. The data are presented in Table 7.0.9.

Quality Control for environmental TLDs includes the audit exposure of three environmental TLDs per quarter to known values of radiation (between 17 and 28 mR). A summary of 1994 results is shown in Table 7.0.10. On average, the TLD measurements are biased only 0.04% higher than the known values.

Effluent Monitoring

The Site effluent monitoring programs are subject to the QA programs defined in *Quality Assurance Manual* (WHC 1989), and *Quality Assurance Manual* (PNL 1992c). These QA programs comply with DOE Order 5700.6C, "Quality Assurance" (1989 edition, without addenda), using ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME 1989), as their basis. The programs also adhere to the EPA guidelines in *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA 1980b) and *Data Quality Objectives for Remedial Response Activities* (EPA 1987).

The facility effluent and near-facility environmental monitoring programs each have a QA project plan describing applicable QA elements. These plans are approved by contractor QA groups, who conduct surveillances and audits to verify compliance with the plans. Work performed through contracts, such as sample analysis, must meet the requirements of these plans. Suppliers are audited before the contract selection is made for equipment and services that may significantly impact the quality of a project.

Sample Collection Quality Assurance/Quality Control

Effluent and near-facility environmental monitoring samples are collected by staff trained for the task in accordance with approved procedures. Established near-facility sample locations are accurately identified and documented to ensure continuity of data for those sites. Sample locations are described in *Operational Environmental Monitoring* (WHC 1991b) for Westinghouse Hanford Company sampling and in controlled manuals that are not publicly distributed. Field QC samples are also collected. Field QC consists of bottle blanks, equipment blanks, field transfer blanks, duplicates, and daily and full trip blanks.

Analytical Results Quality Assurance/Quality Control

Effluent and near-field monitoring samples are analyzed by four different analytical laboratories. The utilization of these laboratories is dependent on the Hanford contractor collecting the samples and contract(s) established between them and the analytical laboratory(s) used. Table 7.0.11 provides a summary of Hanford's analytical laboratory utilization for effluent and near-field monitoring samples, which are grouped by contractor and sample media.

Table 7.0.9 Comparison of Food and Drug Administration (FDA) Co-sampling, 1994

Location/Media	Radionuclides	PNL Value (pCi/g) ± 2 sigma[a]	FDA Value (pCi/g) ± 2 sigma[a]
East Wahluke			
Apples	^{3}H	<205[b]	ND[c]
	^{90}Sr	<0.00252[d]	0.0021 ± 0.009
	^{106}Ru	<0.0854	ND
	^{131}I	NA[e]	ND
	^{137}Cs	0.0141 ± 0.00813	ND
Riverview Area			
Potatoes	^{3}H	NA	ND
	^{90}Sr	<0.00279	0.00213 ± 0.008
	^{106}Ru	<0.0692	ND
	^{131}I	NA	ND
	^{137}Cs	<0.0062	ND
Leafy vegetables	^{3}H	NA	ND
	^{90}Sr	0.0304 ± 0.00749	0.0126 ± 0.0016
	^{106}Ru	<0.135	ND
	^{131}I	NA	ND
	^{137}Cs	<0.0115	ND
Sagemoor Area			
Apples	^{3}H	<179[b]	ND
	^{90}Sr	<0.00258	0.0016 ± 0.009
	^{106}Ru	<0.0707	ND
	^{131}I	NA	ND
	^{137}Cs	<0.00816	ND
Potatoes	^{3}H	NA	ND
	^{90}Sr	<0.00265	0.0014 ± 0.008
	^{106}Ru	<0.0662	ND
	^{131}I	NA	ND
	^{137}Cs	<0.00718	ND
Wheat	^{3}H	NA	ND
	^{90}Sr	0.00883 ± 0.00433	0.0060 ± 0.0012
	^{106}Ru	<0.0624	ND
	^{131}I	NA	ND
	^{137}Cs	<0.0065	ND

(a) 2 sigma Total Propagated Analytical Uncertainty.
(b) Reported in pCi/L of water extract.
(c) ND = Not Detected.
(d) < values are 2 sigma total propagated analytical uncertainties.
(e) NA = Not Analyzed (PNL did not request analysis).

Table 7.0.10 Comparison of Thermoluminescent Dosimeter Results with Known Exposure, 1994

Quarter	Known Exposure, mR	Determined, mR (±2 standard deviation)	% of Exposure
First	18 ± 0.67	18.39 ± 3.00	102.16
	20 ± 0.74	19.74 ± 3.59	98.72
	27 ± 1.00	27.09 ± 3.17	100.33
Second	23 ± 0.85	23.63 ± 4.70	102.72
	20 ± 0.74	19.77 ± 1.85	98.86
	17 ± 0.63	17.26 ± 5.02	101.52
Third	19 ± 0.70	19.90 ± 2.13	104.72
	26 ± 0.96	26.74 ± 2.21	102.84
	28 ± 1.04	30.03 ± 2.15	107.26
Fourth	18 ± 0.67	16.55 ± 0.84	91.94
	24 ± 0.89	22.80 ± 1.52	95.00
	25 ± 0.93	23.61 ± 1.54	94.44

The quality of the analytical data are assured by several means. Counting room instruments, for instance, are kept within calibration limits through daily checks, the results of which are stored in a computer database to efficiently control tracking. Radiochemical standards used in analyses are regularly measured and the results reported and tracked. Formal, written laboratory procedures are used in analyzing samples. Analytical procedural control is ensured through administrative procedures. Chemical technologists at the laboratory qualify to perform analyses through formal classroom and on-the-job training.

The analytical laboratories participation in EPA and DOE laboratory intercomparison programs also assist in assuring the quality of the data produced. Laboratory intercomparison program results can be found in Tables 7.0.12 and 7.0.13 for the 222-S Analytical Laboratory and Tables 7.0.14 and 7.0.15 for the PNL Analytical Chemistry Laboratory. Laboratory intercomparison results for the International Technology Corporation are provided in Tables 7.0.4 and 7.0.5. Intercomparison results for DataChem Laboratories, Inc. are provided in Table 7.0.3.

Table 7.0.11 Laboratories Utilized in 1994, by Contractor and Sample Type

	Laboratories Used for Effluent Monitoring Samples						Laboratory Used for Near-Field Monitoring Samples		
Contractor	WHC		PNL		BHI		WHC		
Laboratory	Air Sample	Water Samples	Air Samples	Water Samples	Air Samples	Water Samples	Air Samples	Water Samples	Other
222-S Analytical Laboratory	X	X					X	X	X
International Technology Corporation (Richland)	X		X		X	X	X		
PNL Analytical Chemistry Laboratory	X	X	X	X					
DataChem Laboratories, Inc. (Salt Lake City, Utah)				X					

Table 7.0.12 222-S Analytical Laboratory Performance on DOE Quality Assessment Program Samples, 1994

Sample Media	Analysis	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Air Filters	^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{238}Pu, ^{239}Pu, ^{241}Am, total uranium	22	21	1[a]
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, total uranium	10	7	3[b]
Vegetation	^{40}K, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{239}Pu	9	7	1[c]
Water	^{3}H, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu, total uranium	9	8	1[a]

(a) Total uranium analysis was not within control limits.
(b) Total uranium, ^{90}Sr, and ^{239}Pu analyses were not within control limits.
(c) Total plutonium-239 analysis was not within control limits.

Table 7.0.13 222-S Analytical Laboratory Performance on EPA Intercomparison Program Samples, 1994

Sample Media	Analysis	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Air Filters	total alpha, total beta, ^{90}Sr, ^{137}Cs	4	3	1[a]
Alpha, beta, and gamma emitters in water	total alpha, total beta, ^{60}Co, ^{65}Zn, ^{106}Ru, ^{134}Cs, ^{137}Cs, ^{133}Ba	17	16	1[b]
Water	total uranium, ^{239}Pu	4	3	1[c]
Tritium in water	^{3}H	2	2	0
Blind A[d]	total alpha, total uranium	2	1	1[c]
Blind B[e]	total beta, ^{60}Co, ^{134}Cs, ^{137}Cs	4	4	0

(a) Total alpha analysis was not within control limits.
(b) Total beta analysis was not within control limits.
(c) Total uranium analysis was not within control limits.
(d) Blind A samples are liquid samples with unknown quantities of alpha emitters, which are analyzed for total alpha and each radionuclide component.
(e) Blind B samples are liquid samples with unknown quantities of beta emitters, which are analyzed for total beta and each radionuclide component.

Table 7.0.14 PNL Analytical Chemistry Laboratory Performance on DOE Quality Assessment Program Samples, 1994

Sample Media	Analysis	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Air Filters	^{54}Mn, ^{57}Co, ^{60}Co, ^{125}Sb, ^{137}Cs, ^{144}Ce, total uranium	6	6	0
Water	^{3}H, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, total uranium	20	20	0

Table 7.0.15 PNL Analytical Chemistry Laboratory Performance on EPA Intercomparison Program Samples, 1994

Sample Media	Analysis	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Air Filters	total alpha, total beta, ^{137}Cs	3	3	0
Alpha, beta, and gamma emitters in water	total alpha, total beta, ^{60}Co, ^{65}Zn, ^{106}Ru, ^{134}Cs, ^{137}Cs, ^{133}Ba	10	8	2[a]
Water	total uranium	3	3	0
Tritium in water	^{3}H	2	2	0
Blind A[b]	total alpha, total uranium	2	2	0
Blind B[c]	total beta, ^{60}Co, ^{134}Cs, ^{137}Cs	4	4	0

(a) Total beta and ^{106}Ru analysis was not within control limits. EPA has indicated that it is having some problems with the ^{106}Ru analyte being used for the comparison studies, but has not indicated its impact to this evaluation.

(b) Blind A samples are liquid samples with unknown quantities of alpha emitters, which are analyzed for total alpha and each radionuclide component.

(c) Blind B samples are liquid samples with unknown quantities of beta emitters, which are analyzed for total beta and each radionuclide component.

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Emergency Planning and Community Right-to-Know Act of 1986. Public Law 99-499, October 17, 1986, 100 Stat. 1728 (Title 3), (Codified as amended at Title 42 USC 11001 et seq.).

Endangered Species Act. 1973. Public Laws 93-205 through 100-707.

Federal Insecticide, Fungicide, and Rodenticide Act. 1975. Public Laws 94-51 through 94-140.

National Environmental Policy Act (NEPA). 1969. Public Laws 91-190, as amended (42 USC 4321 et seq.).

National Historic Preservation Act. Public Law 89-665, October 15, 1966, 80 Stat. 915-919 (Title 16).

Native American Graves Protection and Repatriation Act. Public Law 101-601, November 16, 1990 (25 USC 3001 et seq.).

Pollution Prevention Act. Public Law 101-508, 1990, 104 Stat. 1388-321 (41 USC 13101 et seq.).

Resource Conservation and Recovery Act. Public Law 94-580, October 21, 1976, 90 Stat. 2795 (Title 42).

Safe Drinking Water Act. Public Law 93-523, December 16, 1974, 88 Stat. 1660 (Title 21).

Superfund Amendments and Reauthorization Act. Public Law 99-499, October 17, 1986, 100 Stat. 1613 (Title 10).

Toxic Substances Control Act. Public Law 94-469, as amended (15 USC 2601 et seq.).

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Appendix A

Additional Monitoring Results for 1994

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Appendix A

Additional Monitoring Results for 1994

This Appendix contains additional information on 1994 monitoring results, supplementing the data summarized in the main body of the report. More detailed information is available in the companion 1994 report by L. E. Bisping, *Hanford Site Environmental Data for Calendar Year 1994-Surface and Columbia River* (PNL-10575, Pacific Northwest Laboratory, Richland, Washington).

Table A.1 Radionuclide Concentrations Measured in Columbia River Water at Priest Rapids Dam, 1994 Compared to Values from the Previous 5 Years.

Radionuclide [b]		1994 No. of Samples	1994 Concentration, pCi/L (10^{-6}µCi/L) [a] Maximum	1994 Concentration, pCi/L (10^{-6}µCi/L) [a] Average	1989-1993 No. of Samples	1989-1993 Concentration,[a] pCi/L Maximum	1989-1993 Concentration,[a] pCi/L Average	Drinking Water Standard[c]
Composite System								
Alpha		12	1.19 ± 0.899	0.524 ± 0.252	59	1.67 ± 1.30	0.567 ± 0.110	15
Beta		12	3.49 ± 2.36	1.61 ± 0.49	59	5.17 ± 2.50	1.26 ± 0.43	50
^{3}H		12	51.1 ± 9.45	37.6 ± 2.8	59	114 ± 15.5	49.8 ± 3.4	20,000
^{90}Sr		12	0.136 ± 0.0493	0.0935 ± 0.0138	58	0.178 ± 0.0845	0.0828 ± 0.0072	8
^{99}Tc		12	0.649 ± 0.554	0.0177 ± 0.152	58	4.06 ± 6.18	-0.174 ± 0.383	900
^{234}U		12	0.444 ± 0.129	0.224 ± 0.059	58	0.335 ± 0.0857	0.240 ± 0.009	
^{235}U		12	0.0316 ± 0.0393	0.009 ± 0.005	58	0.0385 ± 0.0178	0.009 ± 0.002	--[d]
^{238}U		12	0.350 ± 0.111	0.190 ± 0.045	58	0.242 ± 0.0527	0.187 ± 0.008	--
U-Total		12	0.826 ± 0.279	0.423 ± 0.107	58	0.553 ± 0.115	0.436 ± 0.015	--
Continuous System								
^{129}I	D	4	0.0001289 ± 0.0000128	0.0000431 ± 0.0000590	16	0.0000497 ± 0.0000051	0.00000971 ± 0.00000614	--
$^{239,240}Pu$	P	4	0.0000136 ± 0.000113	0.00000445 ± 0.0000109	19	0.0000969 ± 0.0000395	0.0000254 ± 0.0000094	--
	D	4	0.0000609 ± 0.0000532	0.000000025 ± 0.000111	19	0.000627 ± 0.000207	0.0000685 ± 0.0000656	--

(a) Maximum values are ±2 (total propagated analytical uncertainty). Averages are ±2 (standard error of the calculated mean).
(b) Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on unfiltered samples collected by the composite system (see text).
(c) The drinking water standards are in pCi/L from the state of Washington Department of Health and the U.S. Environmental Protection Agency (see Appendix C, Table C.2).
(d) Dashes indicate no concentration guides provided in drinking water standard.

Table A.2 Radionuclide Concentrations Measured in Columbia River Water at the 300 Area Water Intake, 1994 Compared to Values from the Previous 5 Years

Radionuclide[b]	1994 No. of Samples	1994 Concentration, pCi/L (10^{-6}µCi/L) [a] Maximum	1994 Concentration, pCi/L (10^{-6}µCi/L) [a] Average	1989-1993 No. of Samples	1989-1993 Concentration,[a] pCi/L Maximum	1989-1993 Concentration,[a] pCi/L Average	Drinking Water Standard[c]
Composite System							
Alpha	4	1.44 ± 1.02	0.962 ± 0.655	20	1.4 ± 0.953	0.666 ± 0.159	15
Beta	4	10.3 ± 13.7	4.29 ± 4.01	20	2.42 ± 1.03	1.11 ± 0.329	50
^{3}H	4	214 ± 22.5	146 ± 51	20	206 ± 4.86	147 ± 16	20,000
^{90}Sr	4	1.37 ± 0.281	0.405 ± 0.644	20	0.406 ± 0.335	0.101 ± 0.036	8
^{99}Tc	4	0.287 ± 0.551	0.156 ± 0.142	20	52.4 ± 0.919	2.87 ± 5.24	900
^{234}U	4	0.544 ± 0.0933	0.304 ± 0.228	20	0.559 ± 0.0767	0.338 ± 0.041	--[d]
^{235}U	4	0.0209 ± 0.0154	0.011 ± 0.010	20	0.0400 ± 0.020	0.013 ± 0.006	--
238U	4	0.431 ± 0.0790	0.257 ± 0.183	20	0.478 ± 0.0704	0.275 ± 0.034	--
U-Total	4	0.996 ± 0.188	0.572 ± 0.418	20	1.05 ± 0.162	0.627 ± 0.075	--
Continuous System							
^{129}I D	4	0.0001000 ± 0.00000903	0.0000765 ± 0.0000266	16	0.000168 ± 0.0000195	0.000119 ± 0.000018	--
$^{239,240}Pu$ P	4	0.0000323 ± 0.0000167	0.00000445 ± 0.0000109	19	0.0000698 ± 0.0000285	0.0000177 ± 0.0000073	--
D	4	0.000109 ± 0.0000643	0.0000162 ± 0.0000392	19	0.00215 ± 0.000376	0.000180 ± 0.000228	--

(a) Maximum values are ±2 (total propagated analytical uncertainty). Averages are ±2 (standard error of the calculated mean).
(b) Radionuclides are based on unfiltered samples collected by the composite system (see text).
(c) The drinking water standards are in pCi/L from the state of Washington Department of Health and the U.S. Environmental Protection Agency (see Appendix C, Table C.2).
(d) Dashes indicate no concentration guides provided in drinking water standard.

Table A.3 Radionuclide Concentrations Measured in Columbia River Water at the Richland Pumphouse, 1994 Compared to Values from the Previous 5 Years

Radionuclide [b]		1994 No. of Samples	1994 Concentration,[a] pCi/L (10^{-6}µCi/L) Maximum	1994 Concentration,[a] pCi/L (10^{-6}µCi/L) Average	1989-1993 No. of Samples	1989-1993 Concentration,[a] pCi/L Maximum	1989-1993 Concentration,[a] pCi/L Average	Drinking Water Standard[c]
Composite System								
Alpha		12	1.42 ± 0.861	0.763 ± 0.255	79	3.38 ± 1.53	0.580 ± 0.139	15
Beta		12	2.47 ± 2.20	1.07 ± 0.39	79	9.18 ± 2.99	1.15 ± 0.35	50
^{3}H		12	123 ± 15.4	87.4 ± 14.8	59	211 ± 23.2	109 ± 9	20,000
^{90}Sr		12	0.156 ± 0.0619	0.0948 ± 0.0137	77	0.175 ± 0.0732	0.0799 ± 0.0064	8
^{99}Tc		12	0.180 ± 0.542	-0.0496 ± 0.104	58	6.47 ± 2.70	0.271 ± 0.376	900
^{234}U		12	1.94 ± 0.555	0.266 ± 0.069	78	0.454 ± 0.0770	0.251 ± 0.012	--[d]
^{235}U		12	0.0248 ± 0.0317	0.011 ± 0.006	78	0.0382 ± 0.0190	0.009 ± 0.002	--
^{238}U		12	1.79 ± 0.518	0.216 ± 0.074	78	0.350 ± 0.0639	0.202 ± 0.010	--
U-Total		12	3.74 ± 1.16	0.494 ± 0.146	78	0.784 ± 0.154	0.463 ± 0.022	--
Continuous System								
^{129}I	D	4	0.000100 ± 0.00000903	0.0000765 ± 0.0000266	16	0.000168 ± 0.0000195	0.000119 ± 0.000018	--
$^{239,240}Pu$	P	4	0.0000323 ± 0.0000167	0.0000162 ± 0.0000132	19	0.0000698 ± 0.0000285	0.0000177 ± 0.0000073	--
	D	4	0.000109 ± 0.0000643	0.0000586 ± 0.0000392	19	0.00215 ± 0.000376	0.000180 ± 0.000228	--

(a) Maximum values are ±2 (total propagated analytical uncertainty). Averages are ±2 (standard error of the calculated mean).

(b) Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on unfiltered samples collected by the composite system (see text).

(c) The drinking water standards are in pCi/L from the state of Washington Department of Health and the U.S. Environmental Protection Agency (see Appendix C, Table C.2).

(d) Dashes indicate no concentration guides provided in drinking water standard.

Table A.4 Radionuclide Concentrations Measured in Columbia River Water Along Cross Sections of the Hanford Reach, 1994

Transect/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Minimum	Mean
Vernita Bridge				
^{3}H	14	42.5 ± 10.4	32.3 ± 8.3	37.2 ± 1.8
^{90}Sr	14	0.110 ± 0.045	0.0727 ± 0.0386	0.0904 ± 0.0056
^{234}U	14	0.296 ± 0.060	0.163 ± 0.068	0.226 ± 0.021
^{235}U	14	0.050 ± 0.023	0.003 ± 0.008	0.013 ± 0.006
^{238}U	14	0.223 ± 0.077	0.109 ± 0.056	0.173 ± 0.015
U-Total	14	0.505 ± 0.123	0.294 ± 0.124	0.412 ± 0.030
100-N Area				
^{3}H	10	50.2 ± 9.6	31.4 ± 7.8	37.0 ± 3.5
^{90}Sr	10	1.25 ± 0.32	-0.0172 ± 0.122	0.154 ± 0.245
^{234}U	10	0.267 ± 0.055	0.180 ± 0.045	0.217 ± 0.017
^{235}U	10	0.013 ± 0.012	-0.000 ± 0.005	0.008 ± 0.0003
^{238}U	10	0.193 ± 0.045	0.119 ± 0.034	0.166 ± 0.014
U-Total	10	0.465 ± 0.109	0.356 ± 0.096	0.391 ± 0.020
100-F Area				
^{3}H	10	40.3 ± 8.8	32.9 ± 8.2	36.4 ± 1.5
^{90}Sr	10	0.130 ± 0.051	0.0833 ± 0.0397	0.105 ± 0.010
^{234}U	10	0.246 ± 0.055	0.201 ± 0.053	0.224 ± 0.009
^{235}U	10	0.015 ± 0.014	-0.006 ± 0.006	0.006 ± 0.004
^{238}U	10	0.203 ± 0.046	0.124 ± 0.060	0.157 ± 0.014
U-Total	10	0.430 ± 0.103	0.330 ± 0.134	0.388 ± 0.018
old Hanford Townsite				
^{3}H	10	3280 ± 277	29.8 ± 8.2	493 ± 670
^{90}Sr	10	0.141 ± 0.076	0.0744 ± 0.0660	0.103 ± 0.015
^{234}U	9	0.263 ± 0.068	0.130 ± 0.038	0.195 ± 0.026
^{235}U	9	0.025 ± 0.034	0.000 ± 0.012	0.010 ± 0.005

Table A.4 Radionuclide Concentrations Measured in Columbia River Water Along Cross Sections of the Hanford Reach, 1994 (contd)

Transect/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Minimum	Mean
^{238}U	9	0.191 ± 0.057	0.107 ± 0.034	0.146 ± 0.019
U-Total	9	0.434 ± 0.136	0.243 ± 0.081	0.351 ± 0.044
300 Area				
^{3}H	10	66.6 ± 11.1	31.3 ± 8.53	39.5 ± 7.3
^{90}Sr	10	0.106 ± 0.048	0.0616 ± 0.0409	0.0779 ± 0.0082
^{234}U	10	0.356 ± 0.123	0.112 ± 0.081	0.219 ± 0.053
^{235}U	10	0.117 ± 0.132	-0.008 ± 0.013	0.023 ± 0.025
^{238}U	10	0.287 ± 0.197	0.116 ± 0.068	0.184 ± 0.036
U-Total	10	0.669 ± 0.538	0.267 ± 0.203	0.426 ± 0.079
Richland Pumphouse				
^{3}H	40	166 ± 18.5	29.1 ± 8.4	49.9 ± 8.8
^{90}Sr	40	0.873 ± 0.187	0.0529 ± 0.0398	0.107 ± 0.040
^{234}U	30	0.480 ± 0.152	0.167 ± 0.099	0.272 ± 0.019
^{235}U	30	0.100 ± 0.029	-0.023 ± 0.019	0.015 ± 0.008
^{238}U	30	0.392 ± 0.092	0.121 ± 0.101	0.204 ± 0.020
U-Total	30	0.830 ± 0.302	0.350 ± 0.145	0.491 ± 0.037

(a) Maximum and minimum values are ±2 total propagated analytical uncertainty. Mean values are ±2 standard error of the mean.

Table A.5 Columbia River Water Quality Data, 1994

Analysis[a]	Units	Vernita Bridge (upstream)				Richland Pumphouse (downstream)				State Standard[b]
		No. of Samples	Maximum	Minimum	Annual Average	No. of Samples	Maximum	Minimum	Annual Average	
Temperature	°C	5	20.0	5.0	12.5	4	20.0	6.0	11.5	20 (maximum)
Dissolved oxygen	mg/L	5	13.8	9.7	12.0	4	14.2	10.9	12.5	8 (minimum)
Turbidity	NTU[c]	5	0.80	0.30	0.48	4	1.0	0.60	0.72	5 + background
pH	pH units	5	8.4	8.1	8.3	4	8.4	8.0	8.2	6.5 - 8.5
Fecal coliform	#/100 mL	5	15	1	3[d]	4	16	3	8	100
Suspended solids, 105°C	mg/L	4	3	2	2.5	3	5	3	4	---[e]
Dissolved solids, 180°C	mg/L	5	85	70	78	4	90	75	80	---
Specific conductance	µS/cm[f]	5	144	128	136	4	165	132	144	---
Hardness, as $CaCO_3$	mg/L	5	77	56	64	4	74	62	66	---
Phosphorus, total	mg/L	5	0.07	<0.01	<0.01	4	0.01	<0.01	<0.01	---
Chromium, dissolved	µg/L	5	NR[g]	NR	NR	4	<1	<1	<1	---
Total organic carbon	mg/L	5	2.4	1.1	1.6	4	2.8	1.2	2.0	---
Iron, dissolved	µg/L	3	6	<3	4.6	4	5	<3	3	---
Ammonia, dissolved, as N	mg/L	5	0.02	<0.01	<0.01	4	0.02	<0.01	<0.01	---
Nitrogen, total Kjeldahl, as N	mg/L	5	0.20	<0.20	<0.20	4	0.20	<0.20	<0.20	---

Table A.5 Columbia River Water Quality Data, 1994 (contd)

		Vernita Bridge (upstream)				Richland Pumphouse (downstream)				
Analysis[a]	Units	No. of Samples	Maximum	Minimum	Annual Average	No. of Samples	Maximum	Minimum	Annual Average	State Standard[b]
Nitrite + Nitrate, dissolved, as N	mg/L	5	0.110	<0.050	0.057	4	0.097	<0.050	0.070	10.0

(a) Provisional data from USGS sampling program, subject to revision.
(b) See Appendix C.
(c) NTU = nephelometric turbidity units.
(d) Annual geometric mean.
(e) Dashes indicate no standard available.
(f) μ Siemens/cm.
(g) NR = not reported.

Table A.6 Radionuclide Concentrations (pCi/g) in Columbia River Sediment, 1994 Compared to Values from the Previous 5 Years

		1994			1989-1993		
Location		Number of Samples	Maximum[a]	Average[b]	Number of Samples	Maximum[a]	Average[b]
Priest Rapids Dam	^{60}Co	4	0.038 ± 0.049	0.023 ± 0.021	20	0.02 ± 0.021	0.00035 ± 0.0058
	^{137}Cs	4	1 ± 0.15	0.5 ± 0.35	20	0.8 ± 0.11	0.48 ± 0.074
	$^{239/240}Pu$	4	0.018 ± 0.0032	0.009 ± 0.0059	20	0.014 ± 0.0018	0.0078 ± 0.0017
	^{90}Sr	4	0.017 ± 0.0059	0.0098 ± 0.006	20	0.022 ± 0.0078	0.013 ± 0.0021
	^{238}U	4	1.7 ± 0.65	1 ± 0.5	20	1.3 ± 0.29	0.84 ± 0.068
White Bluffs Slough	^{60}Co	1	0.089 ± 0.029	0.089	5	0.098 ± 0.026	0.065 ± 0.022
	^{137}Cs	1	0.93 ± 0.1	0.93	5	0.91 ± 0.096	0.52 ± 0.29
	$^{239/240}Pu$	1	0.0073 ± 0.0017	0.0073	5	0.0041 ± 0.0011	0.0026 ± 0.0014
	^{90}Sr	1	0.0058 ± 0.0064	0.0058	5	0.013 ± 0.0045	0.0068 ± 0.0046
	^{238}U	1	0.26 ± 0.063	0.26	6	2.3 ± 0.27	1.1 ± 0.55
100-F Slough	^{60}Co	1	0.024 ± 0.011	0.024	5	0.055 ± 0.021	0.027 ± 0.02
	^{137}Cs	1	0.2 ± 0.029	0.2	5	0.76 ± 0.082	0.26 ± 0.26
	$^{239/240}Pu$	1	0.0012 ± 0.00064	0.0012	5	0.0015 ± 0.00069	0.00097 ± 0.00039
	^{90}Sr	1	0.0037 ± 0.0043	0.0037	5	0.0052 ± 0.0032	0.0033 ± 0.0018
	^{238}U	1	0.11 ± 0.026	0.11	6	1.4 ± 0.17	0.94 ± 0.29
Hanford Slough	^{60}Co	1	0.085 ± 0.022	0.085	5	0.081 ± 0.022	0.03 ± 0.029
	^{137}Cs	1	0.22 ± 0.032	0.22	5	0.52 ± 0.06	0.19 ± 0.18
	$^{239/240}Pu$	1	0.0024 ± 0.00064	0.0024	5	0.0035 ± 0.00067	0.002 ± 0.0012
	^{90}Sr	1	0.0063 ± 0.0035	0.0063	5	0.021 ± 0.007	0.0086 ± 0.0062
	^{238}U	1	0.19 ± 0.034	0.19	6	2.1 ± 0.23	1.1 ± 0.43
Richland	^{60}Co	1	0.074 ± 0.019	0.074	4	0.075 ± 0.024	0.047 ± 0.021
	^{137}Cs	1	0.3 ± 0.04	0.3	4	0.41 ± 0.053	0.33 ± 0.075
	$^{239/240}Pu$	1	0.0016 ± 0.0007	0.0016	4	0.003 ± 0.00071	0.0021 ± 0.00078
	^{90}Sr	1	0.00031 ± 0.0032	0.00031	4	0.003 ± 0.003	0.0013 ± 0.0018
	^{238}U	1	0.12 ± 0.019	0.12	4	2.3 ± 0.27	1.5 ± 0.58
McNary	^{60}Co	4	0.1 ± 0.069	0.04 ± 0.045	20	0.44 ± 0.063	0.19 ± 0.052

Table A.6 Radionuclide Concentrations (pCi/g) in Columbia River Sediment, 1994 Compared to Values from the Previous 5 Years (contd)

Location		1994			1989-1993		
		Number of Samples	Maximum[a]	Average[b]	Number of Samples	Maximum[a]	Average[b]
	^{137}Cs	4	0.49 ± 0.12	0.32 ± 0.18	20	1.2 ± 0.14	0.6 ± 0.1
	$^{239/240}Pu$	4	0.0098 ± 0.0024	0.0053 ± 0.004	20	0.022 ± 0.0031	0.0096 ± 0.002
	^{90}Sr	4	0.029 ± 0.0081	0.016 ± 0.012	20	0.064 ± 0.014	0.03 ± 0.0066
	^{238}U	4	2 ± 0.81	1.4 ± 0.59	20	1.4 ± 0.32	0.98 ± 0.13

(a) Values are ±2 (total propagated analytical uncertainty).
(b) ±2 standard error of the mean.

Table A.7 Mean Concentrations (mg/kg dry weight) of Metals in Columbia River Sediment, 1994 Surface Environmental Surveillance Project

	Priest Rapids[a]	Hanford Reach[a]	McNary[a]
Aluminum	22,000 ± 12,000	18,000 ± 7,100	24,000 ± 9,200
Barium	150 ± 73	150 ± 68	180 ± 84
Beryllium	0.52 ± 0.23	0.39 ± 0.14	0.65 ± 0.17
Cadmium	6.3 ± 2.4	2.8 ± 0.73	1.8 ± 1.3
Calcium	11,000 ± 7,800	11,000 ± 5,100	12,000 ± 11,000
Chromium	37 ± 19	52 ± 34	34 ± 15
Cobalt	17 ± 10	15 ± 8	21 ± 17
Copper	36 ± 10	47 ± 24	29 ± 9.2
Iron	44,000 ± 31,000	44,000 ± 22,000	57,000 ± 55,000
Magnesium	10,000 ± 5,900	9,600 ± 4,300	11,000 ± 8,500
Manganese	590 ± 410	690 ± 520	900 ± 620
Nickel	31 ± 13	34 ± 17	24 ± 10
Potassium	2,700 ± 1,200	2,400 ± 860	3,200 ± 1,100
Sodium	1,100 ± 830	780 ± 400	1,200 ± 1,200
Vanadium	120 ± 92	110 ± 59	170 ± 200
Zinc	590 ± 150	520 ± 170	270 ± 88

(a) ± 2 standard error of the mean.

Table A.8 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Selected Radionuclides Concentrations (pCi/g) in Sediments[a]. Values are ± 2 total propagated analytical uncertainty unless otherwise noted.

River Area [b]	Sample # [c]	^{60}Co	^{137}Cs	$^{239,240}Pu$	^{90}Sr
Hood River	CR170[d]	0.017 ± 0.012	0.82 ± 0.66	0.0013 ± 0.0014	-
	CR187	0.0062 ± 0.013	0.047 ± 0.019	0.00049 ± 0.00032	-
	CR198	0.0099 ± 0.011	0.062 ± 0.016	0.00062 ± 0.00038	-
Biggs	CR208	0.077 ± 0.022	0.25 ± 0.034	0.004 ± 0.0016	-
	CR250	0.015 ± 0.011	0.18 ± 0.029	0.0044 ± 0.0012	-
	CR270	0.013 ± 0.013	0.12 ± 0.026	0.0017 ± 0.00081	0.0087 ± 0.0051
McNary Dam	CR298[d]	0.058 ± 0.058	0.34 ± 0.024	0.0060 ± 0.0043	0.0016 ± 0.0012
	CR295	0.0034 ± 0.01	0.089 ± 0.019	0.001 ± 0.00039	0.0044 ± 0.006
Lake Wallula	CR300	0.092 ± 0.024	0.5 ± 0.06	0.0082 ± 0.0014	0.0071 ± 0.0035
	CR305	0.014 ± 0.012	0.15 ± 0.03	0.0026 ± 0.00082	0.0077 ± 0.0038
	CR310	0.032 ± 0.015	0.17 ± 0.024	0.0029 ± 0.00077	0.0041 ± 0.0026
	CR315[d]	0.052 ± 0.0069	0.019 ± 0.028	0.0034 ± 0.0020	0.014 ± 0.0010
Walla Walla River	WWR0	-0.005 ± 0.012	0.087 ± 0.02	0.0017 ± 0.00058	0.015 ± 0.006
	CR320[d]	0.062 ± 0.011	0.22 ± 0.080	0.0040 ± 0.0028	0.011 ± 0.0082
Snake River	SR1	0.00087 ± 0.012	0.078 ± 0.023	0.0015 ± 0.0004	0.0072 ± 0.0037
	SR3	0.0031 ± 0.0087	0.016 ± 0.0094	0.00036 ± 0.00025	0.0036 ± 0.0028
	CR325[d]	0.028 ± 0.040	0.17 ± 0.00	0.0014 ± 0.00050	0.0048 ± 0.0041
	CR329	0.041 ± 0.018	0.17 ± 0.027	0.0015 ± 0.0006	0.01 ± 0.0051
	CR335	0.0062 ± 0.01	0.054 ± 0.016	0.0017 ± 0.00047	0.0053 ± 0.0034
	CR335	0.0013 ± 0.013	0.099 ± 0.02	0.0021 ± 0.00053	0.0059 ± 0.0033
	CR335	-0.014 ± 0.011	0.058 ± 0.019	0.0016 ± 0.00055	0.0024 ± 0.0029
Yakima River	YR2[d]	0.00045 ± 0.015	0.060 ± 0.018	0.0012 ± 0.00047	0.0043 ± 0.0018
	CR338	0.014 ± 0.013	0.13 ± 0.024	0.0016 ± 0.00072	0.0036 ± 0.003
	CR339	0.074 ± 0.019	0.3 ± 0.04	0.0016 ± 0.0007	0.00031 ± 0.0032
	CR339	0.0076 ± 0.012	0.12 ± 0.023	0.0012 ± 0.00053	0.0042 ± 0.0039
	CR344	0.024 ± 0.014	0.088 ± 0.018	0.0014 ± 0.00062	0.0062 ± 0.0042

Table A.8 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Selected Radionuclides Concentrations (pCi/g) in Sediments[a]. Values are ± 2 total propagated analytical uncertainty unless otherwise noted. (contd)

River Area [b]	Sample # [c]	^{60}Co	^{137}Cs	$^{239,240}Pu$	^{90}Sr
Wooded Island	CR350	0.061 ± 0.021	0.3 ± 0.038	0.0019 ± 0.00055	0.0025 ± 0.003
	CR354	0.0036 ± 0.011	0.06 ± 0.015	0.00018 ± 0.00019	0.0022 ± 0.0031
	CR360	0.09 ± 0.021	0.25 ± 0.036	0.0027 ± 0.00074	0.0068 ± 0.0047
	CR364	0.085 ± 0.022	0.22 ± 0.032	0.0024 ± 0.00064	0.0063 ± 0.0035
100-F Area	CR368	0.024 ± 0.011	0.2 ± 0.029	0.0012 ± 0.00064	0.0037 ± 0.0043
	CR370	0.089 ± 0.029	0.93 ± 0.1	0.0073 ± 0.0017	0.0058 ± 0.0064
	CR389	-	-	0.00059 ± 0.00047	0.0089 ± 0.006
Priest Rapids Dam	CR400[d]	-0.0059 ± 0.0091	0.40 ± 0.12	0.0072 ± 0.0028	0.012 ± 0.0063

(a) Results are preliminary (draft), final results and data interpretation will be provided in a report by CRCIA.
(b) River Area denotes the approximate location on the river where samples were taken; samples are ordered in downstream to upstream direction.
(c) Letters indicate river name (CR=Columbia River, SR=Snake River, YR=Yakima River, WW=Walla Walla River). Numbers indicate river miles.
(d) Values reported are means ± 2 standard error of the mean.

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d]

	Sample Locations[d,e]										
	Hood River			Biggs		McNary Dam		Lake Wallula			
	CR170[f]	CR187	CR198	CR208	CR245	CR270	CR298[f]	CR295	CR300	CR305	CR310
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
2,3,7,8-Tetrachlorodibenzo-p	ND	-	ND	-	ND	-	ND	-	-	-	-
4,4'-DDD	0.00017	-	ND	-	ND	-	6.9E-05	-	-	-	ND
4,4'-DDE	0.00039	-	ND	-	0.0003	-	0.0002	-	-	-	0.0014
4,4'-DDT	ND	-	ND	-	ND	-	ND	-	-	-	0.0005
Aldrin	0.0006	-	0.0006	-	0.0006	-	ND	-	-	-	0.0015
Alpha-BHC	ND	-	ND	-	ND	-	ND	-	-	-	ND
Aluminum	19,000	23,000	25,000	22,000	37,000	-	19,000	24,000	21,000	21,000	25,000
Antimony	ND	ND	ND	ND	ND	-	7.7	19	ND	ND	ND
Aroclor-1016	ND	-	ND	-	ND	-	ND	-	-	-	ND
Aroclor-1221	ND	-	ND	-	ND	-	ND	-	-	-	ND
Aroclor-1232	ND	-	ND	-	ND	-	ND	-	-	-	ND
Aroclor-1242	ND	-	ND	-	ND	-	ND	-	-	-	ND
Aroclor-1248	ND	-	ND	-	ND	-	ND	-	-	-	ND
Aroclor-1254	ND	-	ND	-	ND	-	ND	-	-	-	ND
Aroclor-1260	ND	-	ND	-	ND	-	ND	-	-	-	ND
Arsenic	6	6.3	4.8	5.8	9.1	-	3.9	3.6	5	4.8	10
Barium	180	210	210	220	380	-	130	170	150	160	190
Benzene	ND	ND	ND	ND	ND	-	2.4E-05	0.0003	ND	ND	ND
Beryllium	0.46	0.46	0.48	0.48	1.3	-	0.46	0.56	0.44	0.5	0.56

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d] (contd)

	Sample Locations[d,e]										
	Hood River			Biggs		McNary Dam		Lake Wallula			
	CR170[f]	CR187	CR198	CR208	CR245	CR270	CR298[f]	CR295	CR300	CR305	CR310
Beta-BHC	ND	-	ND	-	ND	-	ND	-	-	-	ND
Bromide	ND	ND	ND	ND	ND	-	ND	-	ND	ND	ND
Cadmium	0.27	ND	ND	ND	ND	-	1.4	ND	2.3	1.1	3
Calcium	10,000	13,000	13,000	12,000	27,000	-	9,600	11,000	8,600	7,500	15,000
Carbon tetrachloride	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
Chlordane	ND	-	ND	-	ND	-	ND	-	-	-	ND
Chloride	5.1	4.2	3.2	4.2	6.4	-	2.6	-	2.8	4.3	4
Chloroform	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
Chromium	31	50	39	42	31	-	24	31	31	25	52
cis-1,2-Dichloroethylene	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
Cobalt	15	23	16	21	37	-	13	17	16	12	22
Copper	27	28	27	29	38	-	21	22	21	24	56
Delta-BHC	0.000022	-	ND	-	ND	-	0.00011	-	-	-	ND
Dieldrin	ND	-	ND	-	ND	-	ND	-	-	-	ND
Endosulfan I	ND	-	ND	-	ND	-	ND	-	-	-	ND
Endosulfan II	ND	-	ND	-	ND	-	ND	-	-	-	ND
Endosulfan sulfate	ND	-	ND	-	ND	-	ND	-	-	-	ND
Endrin	ND	-	ND	-	ND	-	ND	-	-	-	ND
Endrin aldehyde	ND	-	ND	-	ND	-	ND	-	-	-	ND
Ethylbenzene	ND	ND	ND	ND	ND	-	4.5E-05	0.0002	ND	ND	ND
Fluoride	1.6	0.83	1.2	0.97	1.8	-	0.91	-	1.4	1.5	1.6
Gamma-BHC (Lindane)	0.00022	-	ND	-	ND	-	ND	-	-	-	ND
Heptachlor	ND	-	ND	-	0.0013	-	ND	-	-	-	ND
Heptachlor epoxide	ND	-	ND	-	ND	-	ND	-	-	-	ND
Iron	38,000	58,000	40,000	48,000	120,000	-	39,000	42,000	36,000	33,000	60,000

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d] (contd)

	Sample Locations[d,e]										
	Hood River			Biggs		McNary Dam		Lake Wallula			
	CR170[f]	CR187	CR198	CR208	CR245	CR270	CR298[f]	CR295	CR300	CR305	CR310
Lead	19	21	10	19	33	-	12	12	22	13	48
Magnesium	7,300	10,000	9,200	8,700	13,000	-	10,000	10,000	8,300	7,300	14,000
Manganese	590	830	520	940	1,700	-	650	500	610	580	720
Mercury	ND	ND	ND	ND	ND	-	0.14	0.05	0.081	ND	0.14
Methoxychlor	ND	-	ND	-	ND	-	ND	-	-	-	ND
Methylenechloride	ND	ND	0.0021	ND	ND	-	ND	ND	ND	ND	ND
Nickel	28	36	30	27	26	-	19	20	23	19	48
Nitrate	5.4	7.1	8.8	0.65	ND	-	ND	-	1.9	1.8	1.6
Nitrite	ND	ND	ND	ND	ND	-	ND	-	ND	ND	ND
PCDD	ND	-	ND	-	ND	-	ND	-	-	-	-
PCDF	ND	-	ND	-	ND	-	ND	-	-	-	-
Phosphate	ND	ND	3.2	2.9	3.6	-	ND	-	ND	ND	8
Potassium	1,800	2,000	2,600	2,100	4,000	-	2,700	4,200	3,100	3,300	3,100
Silver	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
Sodium	1,400	1,500	2,000	1,300	2,600	-	1,300	1,600	920	780	1,200
Sulfate	11	13	12	3.2	3.6	-	3.3	-	11	13	8
Tetrachloroethene	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
Thallium	0.58	0.75	0.72	0.87	2.3	-	0.63	1.2	1.1	0.68	0.88
Tin	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	-	0.00024	0.002	ND	ND	ND
Toxaphene	ND	-	ND	-	ND	-	ND	-	-	-	ND
trans-1,2-Dichloroethylene	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND
Vanadium	140	230	120	160	400	-	120	110	83	73	140
Vinyl chloride	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	ND

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d] (contd)

	Sample Locations[d,e]										
	Hood River			Biggs		McNary Dam		Lake Wallula			
	CR170[f]	CR187	CR198	CR208	CR245	CR270	CR298[f]	CR295	CR300	CR305	CR310
Xylenes (total)	ND	ND	ND	ND	ND	-	ND	0.0009	ND	ND	ND
Zinc	230	190	180	250	450	-	200	170	330	150	600

River Area	Walla Walla River			Snake River				Yakima River			
Sample No.	CR315	WWR0	CR320	SR1	SR3	CR325	CR329	CR335	YR2	CR338	SESP8
1,1,1-Trichloroethane	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
1,1,2-Trichloroethane	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
1,1-Dichloroethane	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
1,2-Dichloroethane	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
1,4-Dichlorobenzene	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
2,3,7,8-Tetrachlorodibenzo-p	-	-	-	ND	ND	-	-	-	ND	-	-
4,4'-DDD	-	-	-	0.0016	ND	-	-	-	0.0034	-	-
4,4'-DDE	-	-	-	0.0015	ND	-	-	-	0.012	-	-
4,4'-DDT	-	-	-	ND	ND	-	-	-	0.0013	-	-
Aldrin	-	-	-	ND	0.0007	-	-	-	0.0009	-	-
Alpha-BHC	-	-	-	ND	ND	-	-	-	ND	-	-
Aluminum	-	-	-	17,000	11,000	15,000	-	17,000	13,000	9,400	26,000
Antimony	-	-	-	ND	ND	ND	-	ND	ND	7.9	22
Aroclor-1016	-	-	-	ND	ND	-	-	-	ND	-	-
Aroclor-1221	-	-	-	ND	ND	-	-	-	ND	-	-
Aroclor-1232	-	-	-	ND	ND	-	-	-	ND	-	-
Aroclor-1242	-	-	-	ND	ND	-	-	-	ND	-	-
Aroclor-1248	-	-	-	ND	ND	-	-	-	ND	-	-
Aroclor-1254	-	-	-	ND	ND	-	-	-	ND	-	-

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d] (contd)

	Sample Locations[d,e]										
River Area	Walla Walla River			Snake River		Yakima River					
Sample No.	CR315	WWR0	CR320	SR1	SR3	CR325	CR329	CR335	YR2	CR338	SESP8
Aroclor-1260	-	-	-	ND	ND	-	-	-	ND	-	-
Arsenic	-	-	-	8	4.1	4.3	-	2.9	2.3	2.1	7.2
Barium	-	-	-	260	120	140	-	110	92	89	160
Benzene	-	-	-	ND	ND	0.0002	-	ND	ND	0.0002	ND
Beryllium	-	-	-	0.49	0.3	0.5	-	0.37	0.3	0.25	0.52
Beta-BHC	-	-	-	ND	ND	-	-	-	ND	-	-

River Area	Walla Walla River			Snake River		Yakima River					
Sample No.	CR315	WWR0	CR320	SR1	SR3	CR325	CR329	CR335	YR2	CR338	SESP8
Bromide	-	-	-	ND	ND	ND	-	ND	0.38	ND	ND
Cadmium	-	-	-	ND	ND	1.5	-	ND	ND	1.2	3.4
Calcium	-	-	-	6,900	5,500	8,800	-	7,500	5,100	14,000	16,000
Carbon tetrachloride	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
Chlordane	-	-	-	ND	ND	-	-	-	ND	-	-
Chloride	-	-	-	7.4	7.2	2.8	-	7.7	7	23	6.9
Chloroform	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
Chromium	-	-	-	29	23	27	-	24	18	17	48
cis-1,2-Dichloroethylene	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
Cobalt	-	-	-	17	12	17	-	13	8.9	6.4	17
Copper	-	-	-	17	14	26	-	21	17	14	41
Delta-BHC	-	-	-	ND	ND	-	-	-	ND	-	-
Dieldrin	-	-	-	ND	ND	-	-	-	0.001	-	-
Endosulfan I	-	-	-	ND	ND	-	-	-	ND	-	-
Endosulfan II	-	-	-	ND	ND	-	-	-	0.0011	-	-
Endosulfan sulfate	-	-	-	ND	ND	-	-	-	ND	-	-

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d] (contd)

	Sample Locations[d,e]										
River Area	Walla Walla River			Snake River				Yakima River			
Sample No.	CR315	WWR0	CR320	SR1	SR3	CR325	CR329	CR335	YR2	CR338	SESP8
Endrin	-	-	-	ND	ND	-	-	-	0.0006	-	-
Endrin aldehyde	-	-	-	0.0006	ND	-	-	-	ND	-	-
Ethylbenzene	-	-	-	ND	ND	0.0001	-	ND	0.0008	0.0001	ND
Fluoride	-	-	-	1.7	1.7	1.6	-	1.1	1.5	3	1.7
Gamma-BHC (Lindane)	-	-	-	ND	ND	-	-	-	ND	-	-
Heptachlor	-	-	-	ND	ND	-	-	-	ND	-	-
Heptachlor epoxide	-	-	-	ND	ND	-	-	-	ND	-	-
Iron	-	-	-	34,000	25,000	46,000	-	31,000	23,000	17,000	48,000
Lead	-	-	-	9.7	5.5	16	-	7.5	6.6	8.3	66
Magnesium	-	-	-	7,400	5,900	9,800	-	6,900	4,900	4,500	11,000
Manganese	-	-	-	570	320	480	-	600	680	170	520
Mercury	-	-	-	0.077	0.059	0.23	-	0.021	0.091	ND	0.18
Methoxychlor	-	-	-	0.0005	ND	-	-	-	0.0009	-	-
Methylenechloride	-	-	-	ND	0.0012	ND	-	ND	ND	ND	ND
Nickel	-	-	-	19	19	25	-	27	19	12	29
Nitrate	-	-	-	1.4	2.8	0.98	-	1.5	0.38	ND	ND
Nitrite	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
PCDD	-	-	-	ND	ND	-	-	-	ND	-	-
PCDF	-	-	-	ND	ND	-	-	-	ND	-	-
Phosphate	-	-	-	ND	3.4	ND	-	ND	ND	ND	ND
Potassium	-	-	-	2,900	1,700	2,300	-	1,900	1,500	1,400	3,800
Silver	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
Sodium	-	-	-	770	690	550	-	660	430	420	1,600
Sulfate	-	-	-	23	17	8	-	20	13	17	6.9
Tetrachloroethene	-	-	-	ND	ND	ND	-	ND	ND	ND	ND

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d] (contd)

	Sample Locations[d,e]										
River Area	Walla Walla River			Snake River				Yakima River			
Sample No.	CR315	WWR0	CR320	SR1	SR3	CR325	CR329	CR335	YR2	CR338	SESP8
Thallium	-	-	-	0.25	ND	2.4	-	0.17	ND	0.36	1
Tin	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
Toluene	-	-	-	ND	ND	0.0012	-	6.4E-05	0.0003	0.0006	0.0003
Toxaphene	-	-	-	ND	ND	-	-	-	ND	-	-
trans-1,2-Dichloroethylene	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
Trichloroethene	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
Vanadium	-	-	-	83	72	130	-	66	49	40	140
Vinyl chloride	-	-	-	ND	ND	ND	-	ND	ND	ND	ND
Xylenes (total)	-	-	-	ND	ND	ND	-	ND	ND	0.0004	ND
Zinc	-	-	-	86	59	280	-	71	57	130	660

River Area	Wooded Island					100-F Area			Priest Rapids Dam	
Sample No.	CR339	SESP7	CR350	CR354	SESP6	SESP5	SESP4	SESP3	CR389	SESP1
1,1,1-Trichloroethane	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3,7,8-Tetrachlorodibenzo-p	-	-	-	-	-	-	-	-	-	ND
4,4'-DDD	-	ND	-	-	-	ND	ND	-	-	0.0045
4,4'-DDE	-	0.0003	-	-	-	0.0004	0.0005	-	-	0.005
4,4'-DDT	-	ND	-	-	-	ND	ND	-	-	0.00045
Aldrin	-	ND	-	-	-	ND	ND	-	-	0.00064
Alpha-BHC	-	ND	-	-	-	ND	ND	-	-	ND
Aluminum	-	23,000	23,000	23,000	15,000	21,000	32,000	7,100	16,000	15,000

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d] (contd)

	Sample Locations[d,e]									
River Area		Wooded Island				100-F Area			Priest Rapids Dam	
Sample No.	CR339	SESP7	CR350	CR354	SESP6	SESP5	SESP4	SESP3	CR389	SESP1
Antimony	-	14	18	ND	10	18	24	ND	ND	ND
Aroclor-1016	-	ND	-	-	-	ND	ND	-	-	ND
Aroclor-1221	-	ND	-	-	-	ND	ND	-	-	ND
Aroclor-1232	-	ND	-	-	-	ND	ND	-	-	ND
Aroclor-1242	-	ND	-	-	-	ND	ND	-	-	ND
Aroclor-1248	-	ND	-	-	-	ND	ND	-	-	ND
Aroclor-1254	-	ND	-	-	-	ND	ND	-	-	ND
Aroclor-1260	-	ND	-	-	-	ND	ND	-	-	ND
Arsenic	-	7.3	9.3	6.2	7.6	7.6	9.5	5.1	7.5	4
Barium	-	180	150	180	130	150	230	51	110	110
Benzene	-	ND	0.0002	0.0004	ND	0.0002	0.0002	0.0001	ND	8.7E-05
Beryllium	-	0.57	0.5	0.43	0.36	0.48	0.57	0.11	0.34	0.37
Beta-BHC	-	ND	-	-	-	ND	ND	-	-	ND
Bromide	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	-	1.5	2.1	ND	1.9	2.6	3.2	1.6	2	4
Calcium	-	12,000	15,000	15,000	8,400	14,000	22,000	3,100	8,800	7,700
Carbon tetrachloride	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlordane	-	ND	-	-	-	ND	ND	-	-	ND
Chloride	-	13	5.7	1.4	5.3	4.1	1.9	0.73	2.8	3.6
Chloroform	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	-	47	57	42	31	62	130	15	38	25
cis-1,2-Dichloroethylene	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt	-	15	16	18	11	18	27	3.8	11	11
Copper	-	33	24	29	27	41	86	18	34	26
Delta-BHC	-	ND	-	-	-	ND	0.0003	-	-	ND
Dieldrin	-	ND	-	-	-	ND	ND	-	-	ND

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d] (contd)

	Sample Locations[d,e]									
River Area	Wooded Island					100-F Area			Priest Rapids Dam	
Sample No.	CR339	SESP7	CR350	CR354	SESP6	SESP5	SESP4	SESP3	CR389	SESP1
Endosulfan I	-	ND	-	-	-	ND	ND	-	-	0.00025
Endosulfan II	-	ND	-	-	-	ND	ND	-	-	0.001
Endosulfan sulfate	-	ND	-	-	-	ND	ND	-	-	ND
Endrin	-	ND	-	-	-	ND	ND	-	-	ND
Endrin aldehyde	-	ND	-	-	-	ND	ND	-	-	ND
Ethylbenzene	-	ND	0.0001	0.0002	ND	ND	0.0002	ND	ND	9.2E-05
Fluoride	-	2	1.8	1.4	1.1	9	1.4	0.91	1.9	1.1
Gamma-BHC (Lindane)	-	ND	-	-	-	ND	0.0015	-	-	ND
Heptachlor	-	ND	-	-	-	ND	ND	-	-	ND
Heptachlor epoxide	-	ND	-	-	-	ND	ND	-	-	ND
Iron	-	53,000	71,000	52,000	31,000	66,000	86,000	11,000	38,000	31,000
Lead	-	27	30	29	38	24	71	35	44	28
Magnesium	-	10,000	10,000	13,000	6,400	12,000	16,000	2,900	9,100	6,900
Manganese	-	570	640	570	600	930	1,000	130	410	370
Mercury	-	0.15	0.23	0.1	0.16	0.3	0.44	0.14	ND	0.11
Methoxychlor	-	ND	-	-	-	ND	ND	-	-	ND
Methylenechloride	-	ND	0.0005	ND	ND	ND	ND	ND	ND	ND
Nickel	-	33	26	35	20	38	47	11	29	20
Nitrate	-	ND	ND	ND	0.67	ND	ND	ND	0.94	ND
Nitrite	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCDD	-	-	-	-	-	-	-	-	-	ND
PCDF	-	-	-	-	-	-	-	-	-	ND
Phosphate	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potassium	-	3,200	3,100	2,700	2,100	2,400	3,600	1,000	1,900	2,000
Silver	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	-	1,300	1,700	1,000	980	1,300	2,200	310	590	750

Table A.9 Columbia River Comprehensive Impact Assessment (CRCIA) 1994 Preliminary Results for Organics, Pesticides, and Metal Concentrations (mg/kg) in Sediments[a,b,c,d] (contd)

	Sample Locations[d,e]									
River Area	Wooded Island				100-F Area				Priest Rapids Dam	
Sample No.	CR339	SESP7	CR350	CR354	SESP6	SESP5	SESP4	SESP3	CR389	SESP1
Sulfate	-	40	3.6	4.8	20	6.9	9.5	13	13	5
Tetrachloroethene	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	-	0.7	0.96	1	0.6	0.86	1.5	0.65	1.3	2
Tin	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	-	0.0002	0.0006	0.0009	0.0002	0.0007	0.001	0.0012	ND	0.0054
Toxaphene	-	ND	-	-	-	ND	ND	-	-	ND
trans-1,2-Dichloroethylene	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	-	130	220	130	76	170	240	24	91	88
Vinyl chloride	-	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylenes (total)	-	ND	ND	0.0012	ND	ND	0.0014	ND	ND	0.00024
Zinc	-	260	350	190	290	410	760	250	310	370

(a) Results are preliminary (draft), final results and data interpretation will be provided in a report by CRCIA.
(b) ND denotes analyte was below detection limit.
(c) - denotes no result obtained.
(d) River Area denotes the approximate location on the river where samples were taken; samples are ordered in downstream to upstream direction.
(e) Letters indicate river name (CR=Columbia River, SR=Snake River, YR=Yakima River, WW=Walla Walla River). Numbers indicate river mile.
(f) Values reported are transect means.

Table A.10 Radionuclide Concentrations Measured in Riverbank Spring Water During 1994. Concentrations are ± 2 total propagated analytical uncertainty.

Location/Radionuclide	No. of Samples	Concentration, pCi/L	
		Maximum	Minimum
100-B Area			
Alpha	2	1.78 ± 1.16	1.44 ± 1.10
Beta	2	38.1 ± 4.6	10.6 ± 2.5
^{3}H	2	14,300 ± 1,190	13,900 ± 1,140
^{90}Sr	2	0.027 ± 0.112	-0.111 ± 0.126
^{99}Tc	2	10.2 ± 1.5	10.0 ± 1.5
U-Total	2	1.64 ± 0.28	1.57 ± 0.24
100-N Area			
Alpha	1	8.07 ± 3.33	
Beta	1	8.79 ± 2.26	
^{3}H	1	30,900 ± 2,380	
^{90}Sr	1	0.129 ± 0.107	
^{99}Tc	1	2.42 ± 0.72	
U-Total	1	2.47 ± 0.37	
100-D Area			
Alpha	2	2.90 ± 1.91	2.54 ± 1.50
Beta	2	20.8 ± 3.33	17.5 ± 3.05
^{3}H	2	12,500 ± 1,040	8,010 ± 718
^{90}Sr	2	9.41 ± 1.78	7.00 ± 1.41
^{99}Tc	2	0.0299 ± 0.527	-0.0435 ± 0.510
U-Total	2	1.92 ± 0.22	1.39 ± 0.28
100-H Area			
Alpha	2	4.59 ± 1.93	4.40 ± 1.91
Beta	2	69.1 ± 7.05	49.9 ± 5.59
^{3}H	2	1,150 ± 251	691 ± 221

Table A.10 Radionuclide Concentrations Measured in Riverbank Spring Water During 1994. Concentrations are ±2 total propagated analytical uncertainty. (contd)

Location/Radionuclide	No. of Samples	Concentration, pCi/L	
		Maximum	Minimum
^{90}Sr	2	25.2 ± 4.5	12.5 ± 2.47
^{99}Tc	2	62.3 ± 7.15	43.7 ± 5.14
U-Total	2	8.35 ± 1.22	5.22 ± 0.616
100-F Area			
Alpha	1	2.61 ± 1.40	
Beta	1	2.04 ± 1.63	
^{3}H	1	623 ± 215	
^{90}Sr	1	0.0986 ± 0.0906	
^{99}Tc	1	-0.0303 ± 0.629	
U-Total	1	4.62 ± 0.67	
old Hanford Townsite			
Alpha	2	4.88 ± 2.17	3.00 ± 1.53
Beta	2	7.68 ± 2.20	4.75 ± 1.89
^{3}H	2	173,000 ± 12,700	6,340 ± 599
^{129}I	1	0.0435 ± 0.347	
^{90}Sr	2	0.123 ± 0.167	-0.324 ± 0.347
^{99}Tc	2	54.4 ± 6.29	2.04 ± 0.67
U-Total	2	4.03 ± 0.58	2.53 ± 0.49
300 Area			
Alpha	2	110 ± 21.2	94.5 ± 16.6
Beta	2	20.6 ± 3.3	16.2 ± 3.0
^{3}H	2	11300 ± 954	10,200 ± 878
^{129}I	1	0.00439 ± 0.00021	
^{90}Sr	2	0.198 ± 0.107	0.0136 ± 0.496

Table A.10 Radionuclide Concentrations Measured in Riverbank Spring Water During 1994. Concentrations are ±2 total propagated analytical uncertainty. (contd)

Location/Radionuclide	No. of Samples	Concentration, pCi/L	
		Maximum	Minimum
^{99}Tc	2	12.7 ± 2.04	1.30 ± 0.609
U-Total	2	113 ± 13	60.8 ± 7.6

Table A.11 Summary of Strontium-90 in Bass, Carp, and Whitefish Offal and Cesium-137 in Bass, Carp, and Whitefish Muscle, (pCi/g wet weight), 1994 Compared to Values from the Previous 5 Years

		1994			1989-1993		
	Location	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
^{90}Sr in Offal (MDC = 0.005 pCi/g)							
Bass	Sunnyside				0.032 ± 0.009	0.007 ± 0.003	2 of 20
	F Slough	0.026 ± 0.015	0.019 ± 0.006	0 of 5	0.066 ± 0.017	0.031 ± 0.007	0 of 15
Carp	100-N, 100-D	0.050 ± 0.012	0.040 ± 0.008	0 of 5	0.420 ± 0.077	0.100 ± 0.076	0 of 12
	300 Area	0.150 ± 0.035	0.049 ± 0.051	0 of 5	0.075 ± 0.015	0.030 ± 0.010	0 of 15
	Vantage[d]	0.110 ± 0.024	0.087 ± 0.017	0 of 10	0.110 ± 0.024	0.059 ± 0.013	0 of 13
Whitefish	100-N, 100-D	0.099 ± 0.029	0.034 ± 0.018	0 of 10	0.032 ± 0.007	0.012 ± 0.002	1 of 33
	300 Area	0.018 ± 0.006	0.010 ± 0.003	1 of 7	0.035 ± 0.032	0.014 ± 0.003	0 of 24
	Kettle River				0.048 ± 0.017	0.035 ± 0.006	0 of 9
	Priest Rapids-Vernita[e]				0.032 ± 0.007	0.017 ± 0.005	0 of 10
^{137}Cs in Muscle (MDC = 0.02 pCi/g)							
Bass	Sunnyside				0.09 ± 0.09	0.01 ± 0.02	20 of 20
	F Slough	0.05 ± 0.04	0.04 ± 0.01	0 of 5	0.06 ± 0.04	0.02 ± 0.01	8 of 15
Carp	100-N, 100-D	0.03 ± 0.02	0.00 ± 0.02	4 of 5	0.06 ± 0.00	0.02 ± 0.01	7 of 14
	300 Area	0.02 ± 0.01	0.01 ± 0.01	3 of 5	0.02 ± 0.02	0.01 ± 0.00	10 of 15
	Vantage[d]	0.02 ± 0.01	0.01 ± 0.00	6 of 10	0.02 ± 0.01	0.01 ± 0.00	6 of 13
Whitefish	100-N, 100-D	0.13 ± 0.04	0.02 ± 0.03	6 of 10	0.17 ± 0.04	0.02 ± 0.01	29 of 46
	300 Area	0.03 ± 0.03	0.01 ± 0.01	6 of 7	0.04 ± 0.04	0.01 ± 0.01	23 of 26
	Kettle River				0.04 ± 0.03	0.00 ± 0.01	8 of 9
	Priest Rapids-Vernita[e]				0.04 ± 0.04	0.01 ± 0.01	8 of 10

(a) Maximum is the concentration in pCi/g ±2 total propagated analytical uncertainty.
(b) Mean is pCi/g ±2 standard error of the mean. Not calculated for two or less samples.
(c) Number of samples with values less than the detection limit out of number of samples analyzed.
(d) Collected in 1990 and 1991; and in 1994.
(e) Discontinued in 1990.

Table A.12 Summary of Strontium-90 in Deer Bone and Cesium-137 in Deer Muscle (pCi/g wet weight), 1994 Compared to Values from the Previous 5 Years

	1994			1989-1993		
Location	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
^{90}Sr in Bone (MDC = 0.005 pCi/g)						
100-N	0.93 ± 0.24	0.51 ± 0.43	0 of 3	58 ± 11	11 ± 13	0 of 9
200 Area Ponds				3.3 ± 0.64	1.4 ± 1.9	0 of 3
Stevens County[d]	2.06 ± 0.41		0 of 1	0.81 ± 0.16	0.59 ± 0.44	0 of 2
Boardman	0.13 ± 0.04	0.11 ± 0.02	0 of 4			
^{137}Cs in Muscle (MDC = 0.02 pCi/g)						
100-N	0.007 ± 0.003	0.01 ± 0.00	1 of 3	0.03 ± 0.01	0.01 ± 0.01	6 of 9
200 Area Ponds				0.37 ± 0.05	0.12 ± 0.24	1 of 3
Boardman	0.03 ± 0.03	0.01 ± 0.02	3 of 4			
Onsite	0.01 ± 0.02	0.00 ± 0.01	4 of 4	0.008 ± 0.007[e]	0.003 ± 0.00[e]	17 of 21
Stevens County[d]	0.07 ± 0.03		0 of 1	0.52 ± 0.06	0.43 ± 0.19	0 of 2

(a) Maximum is the concentration in pCi/g ± 2 total propagated analytical uncertainty.
(b) Mean is pCi/g ± 2 standard error of the mean. Not calculated for two or less samples.
(c) Number of samples with values less than the detection limit out of number of samples analyzed.
(d) Collected in 1992 and 1994, Whitetail deer. Mule deer are collected at Hanford.
(e) Below detection.

Table A.13 Uranium Concentrations in Soil,[a] pCi/g (dry weight),[b] 1989 Through 1994

Location	1989[c]	1990[d]	1991[d]	1992[c]	1993[c]	1994[c]
Onsite						
Above 100-D Pumphouse				1.31 ± 0.0388	0.36 ± 0.26	0.8 ± 0.33
1 Mile NE of 100-N	0.35 ± 0.20		1.44 ± 0.159		0.53 ± 0.28	0.81 ± 0.52
1 Mile E of 100-N	0.67 ± 0.22		1.31 ± 0.137		1.45 ± 0.25	0.96 ± 0.51
100 Area Fire Station	0.97 ± 0.29		1.2 ± 0.108		0.59 ± 0.45	0.66 ± 0.5
200-East N Central	0.44 ± 0.26		1.17 ± 0.158		0.41 ± 0.30	0.67 ± 0.33
E of 200-East	0.40 ± 0.23		1.77 ± 0.29		0.39 ± 0.24	0.72 ± 0.29
200-East SE	0.91 ± 0.28		1.34 ± 0.132		0.42 ± 0.19	0.79 ± 0.52
SW of BC Cribs	80.85 ± 0.26		1.2 ± 0.148		0.60 ± 0.23	0.66 ± 0.55
S of 200-East	30.39 ± 0.23		1.89 ± 0.17		0.42 ± 0.26	0.78 ± 0.52
E of 200-West	10.97 ± 0.29	1.64 ± 0.156	1.5 ± 0.129		0.66 ± 0.26	1 ± 0.52
2 Miles S of 200-West	30.39 ± 0.22		1.31 ± 0.124		0.54 ± 0.23	0.79 ± 0.4
NE of FFTF	50.72 ± 0.29		1.31 ± 0.165			
SE of FFTF	20.56 ± 0.17		1.48 ± 0.165		0.56 ± 0.18	0.54 ± 0.24
N of 300 Area	70.34 ± 0.19		2.17 ± 0.145		0.85 ± 0.24	0.61 ± 0.26
S of 300 Area						0.8 ± 0.36
Hanford Townsite	60.42 ± 0.28		1.66 ± 0.121		0.75 ± 0.26	
Wye Barricade	50.66 ± 0.20		1.25 ± 0.0767		0.32 ± 0.19	
100-N Springs Shoreline			1.09 ± 0.104	1.07 ± 0.344	0.43 ± 0.28	
100-N Shore (HGP)				1.06 ± 0.453	1.16 ± 0.30	
100-K Area					0.71 ± 0.33	
400-E					0.45 ± 0.22	0.56 ± 0.26
Onsite Average	0.60 ± 0.12	1.64	1.44 ± 0.147	1.15 ± 0.142	0.61 ± 0.13	0.74 ± 0.069
Offsite						
Riverview	0.58 ± 0.20		1.75 ± 0.124	0.460 ± 0.176	0.45 ± 0.24	0.48 ± 0.41

Table A.13 Uranium Concentrations in Soil,[a] pCi/g (dry weight),[b] 1989 Through 1994 (contd)

Location	1989[c]	1990[d]	1991[d]	1992[c]	1993[c]	1994[c]
Byers Landing	0.42 ± 0.23	1.22 ± 0.131	1.46 ± 0.118	0.911 ± 0.224	0.89 ± 0.26	1 ± 0.41
Sagemoor	0.75 ± 0.29	1.56 ± 0.137	1.85 ± 0.127	0.742 ± 0.204	1.13 ± 0.50	0.78 ± 0.51
Taylor Flats No. 2	0.87 ± 0.24	1.88 ± 0.113			0.84 ± 0.48	
W End Fir Road	0.56 ± 0.21				0.90 ± 0.29	
Ringold	0.50 ± 0.19	1.44 ± 0.108	1.75 ± 0.13	0.752 ± 0.36	0.61 ± 0.20	0.66 ± 0.52
Berg Ranch	0.80 ± 0.24	1.23 ± 0.106			0.30 ± 0.46	
Wahluke Slope No. 2[e]	1.1 ± 0.3	1.09 ± 0.0945			0.15 ± 0.45	
Vernita Bridge[e]	0.58 ± 0.20				0.88 ± 0.45	
Yakima Barricade[e]	0.40 ± 0.19		1.5 ± 0.0811		0.61 ± 0.47	
Rattlesnake Springs	0.84 ± 0.25				0.51 ± 0.38	
ALE	1.5 ± 0.3				1.01 ± 0.49	
Prosser Barricade[e]	0.61 ± 0.22				0.51 ± 0.35	
S of 300 Area[e]	1.1 ± 0.3		1.56 ± 0.122		0.67 ± 0.19	
Benton City	0.45 ± 0.19				1.23 ± 0.66	
Sunnyside	1.0 ± 0.3	1.17 ± 0.138	1.29 ± 0.108	0.838 ± 0.287	0.73 ± 0.32	
Walla Walla	1.3 ± 0.3	1.43 ± 0.107				
McNary Dam	0.56 ± 0.21	1.76 ± 0.118				
Moses Lake	0.37 ± 0.19	0.99 ± 0.0955	1.23 ± 0.117			
Washtucna	0.72 ± 0.24	1.05 ± 0.0977				
Connell	0.69 ± 0.29	1.21 ± 0.113	1.16 ± 0.105			
Othello	0.64 ± 0.18	1.07 ± 0.101				
Yakima	0.45 ± 0.22	1.02 ± 0.0922	1.08 ± 0.0978	0.671 ± 0.260	0.66 ± 0.31	

Table A.13 Uranium Concentrations in Soil,[a] pCi/g (dry weight),[b] 1989 Through 1994 (contd)

Location	1989[c]	1990[d]	1991[d]	1992[c]	1993[c]	1994[c]
Offsite Average	0.73 ± 0.13	1.29 ± 0.1498	1.463 ± 0.169	0.729 ± 0.127	0.71 ± 0.14	0.73 ± 0.22

(a) Blank field indicates no data.
(b) Individual results are ±2 total propagated analytical uncertainty. Averages are ±2 times the standard error of the calculated mean.
(c) Uranium-238 analyzed by low-energy photon spectra (LEPS) method, which will detect all ^{235}U and ^{238}U in a soil sample.
(d) Uranium analyzed by alpha spectroscopy, which measures leached ^{234}U and ^{235}U, and ^{238}U from the sample matrix. Result is summation of ^{234}U, ^{235}U, and ^{238}U. LEPS and alpha spectroscopy activities are summed to produce a total uranium activity concentration. Soil samples receiving deposition of enriched uranium may have elevated activities of ^{235}U; however, the soil data do not indicate enriched ^{235}U concentrations (Bisping 1995).
(e) Perimeter location onsite near Site boundary.

Table A.14 Strontium-90 Concentrations in Soil,[a] 1989 Through 1994

Location	Concentration, pCi/g (dry weight)[b]					
	1989	1990	1991	1992	1993	1994
Onsite						
Above 100-D Pumphouse				0.0866 ± 0.00753	0.07 ± 0.006	0.055 ± 0.012
1 Mile NE of 100-N Area	0.18 ± 0.01		0.152 ± 0.012		0.08 ± 0.007	0.068 ± 0.014
1 Mile E of 100-N Area	0.17 ± 0.01		0.16 ± 0.012		0.08 ± 0.006	0.18 ± 0.036
100 Area Fire Station	0.31 ± 0.01		0.131 ± 0.011		0.22 ± 0.013	0.03 ± 0.0092
200-East N Central	0.58 ± 0.01		0.409 ± 0.0129		0.54 ± 0.018	0.7 ± 0.13
E of 200-East	0.41 ± 0.02		0.345 ± 0.013		0.35 ± 0.014	0.28 ± 0.055
200-East SE	0.13 ± 0.01		0.173 ± 0.0142		0.17 ± 0.010	0.18 ± 0.037
SW of BC Cribs	0.12 ± 0.01		0.102 ± 0.0096		0.10 ± 0.008	0.25 ± 0.048
S of 200-East	0.28 ± 0.01		0.214 ± 0.013		0.18 ± 0.011	0.12 ± 0.025
E of 200-West	0.50 ± 0.02	2.70 ± 0.0714	0.374 ± 0.018		0.58 ± 0.019	0.078 ± 0.016
2 Miles S of 200-West	0.14 ± 0.01		0.157 ± 0.0118		0.041 ± 0.006	0.084 ± 0.018
FFTF	0.05 ± 0.01			0.0959 ± 0.00718		
SE of FFTF	0.06 ± 0.01		0.0506 ± 0.00765		0.049 ± 0.007	0.028 ± 0.0079
N of 300 Area	0.15 ± 0.01		0.167 ± 0.00936		0.094 ± 0.008	0.11 ± 0.022
S of 300 Area						0.074 ± 0.015
Hanford Townsite	0.28 ± 0.01		0.0574 ± 0.0062		0.12 ± 0.009	
Wye Barricade	0.11 ± 0.01		0.23 ± 0.016		0.09 ± 0.008	
100-N Springs Shoreline			1.97 ± 0.063	0.235 ± 0.0125	0.19 ± 0.012	
Generating Plant (HGP)				0.0311 ± 0.00495	0.12 ± 0.008	
100-K Area					0.15 ± 0.013	
400-E					0.040 ± 0.006	0.04 ± 0.012
Onsite Average	0.23 ± 0.08	2.70	0.299 ± 0.229	0.118 ± 0.122	0.17 ± 0.071	0.15 ± 0.088

Table A.14 Strontium-90 Concentrations in Soil,[a] 1989 Through 1994 (contd)

Location	Concentration, pCi/g (dry weight)[b]					
	1989	1990	1991	1992	1993	1994
Offsite						
Riverview	0.07 ± 0.01		0.145 ± 0.0117	0.0623 ± 0.00781	0.031 ± 0.005	0.054 ± 0.015
Byers Landing	0.13 ± 0.01	0.122 ± 0.00956	0.121 ± 0.0081	0.146 ± 0.00855	0.087 ± 0.02	0.15 ± 0.029
Sagemoor	0.03 ± 0.01	0.0378 ± 0.00772	0.135 ± 0.00786	0.0851 ± 0.00806	0.073 ± 0.008	0.066 ± 0.018
Taylor Flats No. 2	0.16 ± 0.01	0.0229 ± 0.00488			0.046 ± 0.005	
W End Fir Road	0.20 ± 0.01				0.0202 ± 0.0043	
Ringold	0.15 ± 0.01	0.121 ± 0.0121	0.203 ± 0.014	0.132 ± 0.00815	0.059 ± 0.009	0.037 ± 0.01
Berg Ranch	0.09 ± 0.01	0.138 ± 0.012			0.14 ± 0.011	
Wahluke Slope No. 2[c]	0.07 ± 0.01	0.0628 ± 0.00766			0.051 ± 0.006	
Vernita Bridge[c]	0.12 ± 0.01				0.092 ± 0.012	
Yakima Barricade[c]	0.13 ± 0.01		0.143 ± 0.012		0.095 ± 0.016	
Rattlesnake Springs	0.09 ± 0.01				0.074 ± 0.008	
ALE	0.26 ± 0.01				0.105 ± 0.011	
Prosser Barricade[c]	0.24 ± 0.01				0.103 ± 0.012	
S of 300 Area[c]	0.30 ± 0.01		0.326 ± 0.0122		0.076 ± 0.007	
Benton City	0.17 ± 0.01				0.18 ± 0.011	
Sunnyside	0.13 ± 0.01	0.348 ± 0.0134	0.0293 ± 0.00314	0.0383 ± 0.00466	0.100 ± 0.010	
Walla Walla	0.01 ± 0.01	0.0455 ± 0.00584				
McNary Dam	0.09 ± 0.01	0.0789 ± 0.00804				
Moses Lake	0.05 ± 0.01	0.0612 ± 0.0086	0.0137 ± 0.00429			
Washtucna	0.12 ± 0.01	0.0496 ± 0.00599				
Connell	0.14 ± 0.01	0.204 ± 0.0125	0.094 ± 0.0106			
Othello	0.08 ± 0.01	0.0759 ± 0.0078				
Yakima	0.10 ± 0.01	0.126 ± 0.00852	0.119 ± 0.0111	0.0452 ± 0.00515	0.024 ± 0.011	0.094 ± 0.021

Table A.14 Strontium-90 Concentrations in Soil,[(a)] 1989 Through 1994 (contd)

Location	Concentration, pCi/g (dry weight)[(b)]					
	1989	1990	1991	1992	1993	1994
Offsite Average	0.13 ± 0.03	0.107 ± 0.0454	0.133 ± 0.0555	0.0848 ± 0.0369	0.079 ± 0.019	0.079 ± 0.038

(a) Blank field indicates no data.
(b) Individual results are ±2 total propagated analytical uncertainty. Averages are ±2 times the standard error of the calculated mean.
(c) Perimeter location onsite near Site boundary.

Table A.15 Cesium-137 Concentrations in Soil,[a] 1989 Through 1994

Location	Concentration, pCi/g (dry weight)[b]					
	1989	1990	1991	1992	1993	1994
Onsite						
Above 100-D Pumphouse				0.764 ± 0.0346	0.52 ± 0.019	0.2 ± 0.051
1 Mile NE of 100-N Area	0.96 ± 0.05		0.652 ± 0.044		0.45 ± 0.017	0.21 ± 0.042
1 Mile E of 100-N Area	0.63 ± 0.05		0.768 ± 0.061		0.34 ± 0.014	0.19 ± 0.06
100 Area Fire Station	1.1 ± 0.1		0.312 ± 0.042		1.15 ± 0.047	0.29 ± 0.069
200-East N Central	18 ± 0.2		0.295 ± 0.029		10.9 ± 0.13	12 ± 1.3
E of 200-East	2.1 ± 0.1		1.13 ± 0.053		2.29 ± 0.058	1.1 ± 0.14
200-East SE	0.59 ± 0.04		0.408 ± 0.035		0.52 ± 0.033	0.42 ± 0.07
SW of BC Cribs	0.52 ± 0.04		0.346 ± 0.032		0.39 ± 0.036	0.21 ± 0.046
S of 200-East	0.80 ± 0.04		0.357 ± 0.041		0.17 ± 0.026	0.14 ± 0.042
E of 200-West	3.0 ± 0.1	3.86 ± 0.105	1.6 ± 0.065		1.47 ± 0.045	0.94 ± 0.12
2 Miles S of 200-West	0.63 ± 0.04		0.496 ± 0.043		0.16 ± 0.023	0.28 ± 0.056
NE of FFTF	0.19 ± 0.02		0.387 ± 0.038			
SE of FFTF	0.22 ± 0.03		0.142 ± 0.024		0.19 ± 0.027	0.0031 ± 0.029
N of 300 Area	1.2 ± 0.1		0.709 ± 0.043		0.39 ± 0.036	0.37 ± 0.061
S of 300 Area						0.25 ± 0.051
Hanford Townsite	1.2 ± 0.1		0.271 ± 0.028		0.68 ± 0.042	
Wye Barricade	0.39 ± 0.04		0.66 ± 0.04		0.35 ± 0.029	
100-N Springs Shoreline			0.11 ± 0.022	1.04 ± 0.0405	0.65 ± 0.069	
100-N Shore (HGP)				0.37 ± 0.0307	0.45 ± 0.017	
100-K Area					0.54 ± 0.037	
400-E						0.078 ± 0.048
Onsite Average	2.1 ± 2.3	3.86	0.540 ± 0.192	0.725 ± 0.0337	1.14 ± 1.11	1.1 ± 1.6

Table A.15 Cesium-137 Concentrations in Soil,[a] 1989 Through 1994 (contd)

Location	Concentration, pCi/g (dry weight)[b]					
	1989	1990	1991	1992	1993	1994
Offsite						
Riverview	0.45 ± 0.04		1.78 ± 0.105	0.197 ± 0.039	0.12 ± 0.045	0.17 ± 0.082
Byers Landing	0.68 ± 0.04	0.623 ± 0.0451	0.597 ± 0.038	0.852 ± 0.0377	0.58 ± 0.046	0.16 ± 0.054
Sagemoor	0.12 ± 0.02	0.106 ± 0.0244	0.473 ± 0.036	0.421 ± 0.0611	0.41 ± 0.068	0.32 ± 0.092
Taylor Flats No. 2	0.79 ± 0.06	0.102 ± 0.0206			0.14 ± 0.055	
W End Fir Road	1.3 ± 0.1				0.014 ± 0.026	
Ringold	1.7 ± 0.1	0.583 ± 0.0422	0.726 ± 0.05	0.947 ± 0.0717	0.45 ± 0.030	0.12 ± 0.05
Berg Ranch	0.53 ± 0.04	0.637 ± 0.0421			0.62 ± 0.038	
Wahluke Slope No. 2[c]	0.25 ± 0.03	0.224 ± 0.029			0.20 ± 0.027	
Vernita Bridge[c]	0.66 ± 0.05				0.50 ± 0.035	
Yakima Barricade[c]	0.54 ± 0.04		0.362 ± 0.033		0.30 ± 0.027	
Rattlesnake Springs	0.46 ± 0.03				0.29 ± 0.026	
ALE	0.96 ± 0.06				0.22 ± 0.027	
Prosser Barricade[c]	0.86 ± 0.05				0.27 ± 0.024	
S of 300 Area[c]	1.1 ± 0.1		0.751 ± 0.0514		0.16 ± 0.018	
Benton City	0.76 ± 0.05				1.08 ± 0.046	
Sunnyside	0.48 ± 0.04	1.22 ± 0.0641	0.0668 ± 0.0258	0.420 ± 0.0315	0.74 ± 0.036	
Walla Walla	0.07 ± 0.03	0.333 ± 0.0619				
McNary Dam	0.54 ± 0.04	0.276 ± 0.0398				
Moses Lake	0.18 ± 0.03	0.243 ± 0.0346	-0.0017 ± 0.0201			
Washtucna	0.91 ± 0.05	0.288 ± 0.0497				
Connell	0.67 ± 0.05	1.19 ± 0.0905	0.334 ± 0.0388			
Othello	0.54 ± 0.04	0.344 ± 0.0413				
Yakima	0.56 ± 0.04	0.599 ± 0.0459	0.334 ± 0.0353	0.445 ± 0.0271	0.49 ± 0.059	0.46 ± 0.059

Table A.15 Cesium-137 Concentrations in Soil,[a] 1989 Through 1994 (contd)

Location	Concentration, pCi/g (dry weight)[b]					
	1989	1990	1991	1992	1993	1994
Offsite Average	0.74 ± 0.27	0.483 ± 0.1902	0.542 ± 0.317	0.547 ± 0.2891	0.39 ± 0.13	0.25 ± 0.13

(a) Blank field indicates no data.
(b) Individual results are ±2 total propagated analytical uncertainty. Averages are ±2 times the standard error of the calculated mean.
(c) Perimeter location onsite near Site boundary.

Table A.16 Plutonium-239,240 Concentrations in Soil,[a] 1989 Through 1994

Location	Concentration, pCi/g (dry weight)[b]					
	1989	1990	1991	1992	1993	1994
Onsite						
Above 100-D Pumphouse				0.0133 ± 0.00128	0.0097 ± 0.0011	0.0049 ± 0.0011
1 Mile NE of 100-N Area	0.017 ± 0.002		0.0129 ± 0.00129		0.0097 ± 0.0011	0.0051 ± 0.001
1 Mile E of 100-N Area	0.013 ± 0.001		0.0177 ± 0.00197		0.0081 ± 0.0013	0.007 ± 0.0016
100 Area Fire Station	0.026 ± 0.003		0.00488 ± 0.000934		0.027 ± 0.0019	0.01 ± 0.0017
200-East N Central	0.031 ± 0.003		0.017 ± 0.0014		0.020 ± 0.0014	0.024 ± 0.0031
E of 200-East	0.018 ± 0.002		0.00895 ± 0.00121		0.023 ± 0.0015	0.012 ± 0.0021
200-East SE	0.011 ± 0.001		0.00799 ± 0.00114		0.011 ± 0.0011	0.014 ± 0.0018
SW of BC Cribs	0.014 ± 0.001		0.00844 ± 0.00151		0.0096 ± 0.00097	0.00038 ± 0.00076
S of 200-East	0.015 ± 0.002		0.0104 ± 0.00118		0.0035 ± 0.00056	0.0022 ± 0.0008
E of 200-West	0.53 ± 0.01	0.656 ± 0.0125	0.286 ± 0.00546		0.28 ± 0.0054	0.39 ± 0.38
2 Miles S of 200-West	0.022 ± 0.002		0.0214 ± 0.00289		0.0059 ± 0.00077	0.031 ± 0.0039
NE of FFTF	0.004 ± 0.001		0.0085 ± 0.00118			
SE of FFTF	0.006 ± 0.001		0.00395 ± 0.000731		0.0032 ± 0.00067	0.00078 ± 0.00073
N of 300 Area	0.024 ± 0.002		0.0173 ± 0.00161		0.01 ± 0.001	0.0082 ± 0.0013
S of 300 Area						0.0061 ± 0.001
Hanford Townsite	0.027 ± 0.003		0.00368 ± 0.000846		0.015 ± 0.0012	
Wye Barricade	0.007 ± 0.001		0.0168 ± 0.00255		0.0083 ± 0.00092	
100-N Springs Shoreline			0.000769 ± 0.000774	0.0204 ± 0.00177	0.016 ± 0.0018	
100-N Shore (HGP)				0.00434 ± 0.000799	0.011 ± 0.0013	
100-K Area					0.0081 ± 0.0011	
400-E					0.0027 ± 0.00055	0.0019 ± 0.00049
Onsite Average	0.051 ± 0.069	0.656	0.0279 ± 0.0691	0.0127 ± 0.00805	0.026 ± 0.029	0.035 ± 0.051

Table A.16 Plutonium-239,240 Concentrations in Soil,[a] 1989 Through 1994 (contd)

Location	Concentration, pCi/g (dry weight)[b]					
	1989	1990	1991	1992	1993	1994
Offsite						
Riverview	0.008 ± 0.001		0.0197 ± 0.00212	0.00427 ± 0.000659	0.002 ± 0.00053	0.0036 ± 0.00077
Byers Landing	0.014 ± 0.002	0.00901 ± 0.00139	0.0133 ± 0.00145	0.0204 ± 0.00155	0.013 ± 0.0015	0.003 ± 0.00087
Sagemoor	0.019 ± 0.001	0.00141 ± 0.000761	0.00936 ± 0.00105	0.00661 ± 0.000801	0.011 ± 0.0013	0.0061 ± 0.0015
Taylor Flats No. 2	0.015 ± 0.001	0.000381 ± 0.000285			0.0052 ± 0.0012	
W End Fir Road	0.028 ± 0.002				0.00057 ± 0.00034	
Ringold	0.029 ± 0.003	0.0112 ± 0.00117	0.0183 ± 0.00214	0.0214 ± 0.00175	0.0063 ± 0.00098	0.0018 ± 0.00057
Berg Ranch	0.009 ± 0.002	0.0124 ± 0.00144			0.013 ± 0.0011	
Wahluke Slope No. 2[c]	0.005 ± 0.001	0.00711 ± 0.00098			0.0040 ± 0.0081	
Vernita Bridge[c]	0.013 ± 0.002				0.011 ± 0.0011	
Yakima Barricade[c]	0.011 ± 0.001		0.00502 ± 0.000938		0.0092 ± 0.0011	
Rattlesnake Springs	0.011 ± 0.001				0.0073 ± 0.00084	
ALE	0.021 ± 0.002				0.0059 ± 0.00071	
Prosser Barricade[c]	0.018 ± 0.002				0.0071 ± 0.00088	
S of 300 Area[c]	0.025 ± 0.002		0.0201 ± 0.00173		0.0036 ± 0.00065	
Benton City	0.015 ± 0.001				0.025 ± 0.0034	
Sunnyside	0.011 ± 0.002	0.0291 ± 0.00327	0.000885 ± 0.000577	0.00766 ± 0.00119	0.017 ± 0.0013	
Walla Walla	0.001 ± 0.001	0.00306 ± 0.000546				
McNary Dam	0.009 ± 0.002	0.00607 ± 0.000783				
Moses Lake	0.002 ± 0.001	0.00412 ± 0.000596	0.00003 ± 0.00016			
Washtucna	0.017 ± 0.002	0.0026 ± 0.000573				
Connell	0.010 ± 0.002	0.0164 ± 0.00127	0.00399 ± 0.000778			
Othello	0.008 ± 0.002	0.00765 ± 0.000878				
Yakima	0.010 ± 0.001	0.0106 ± 0.00111	0.00861 ± 0.00153	0.00776 ± 0.00107	0.002 ± 0.00048	0.011 ± 0.0022

Table A.16 Plutonium-239,240 Concentrations in Soil,[a] 1989 Through 1994 (contd)

Location	Concentration, pCi/g (dry weight)[b]					
	1989	1990	1991	1992	1993	1994
Offsite Average	0.0134 ± 0.00155	0.00865 ± 0.004	0.00993 ± 0.00481	0.0114 ± 0.0075	0.0084 ± 0.003	0.0036 ± 0.0018

(a) Blank field indicates no data.
(b) Individual results are ±2 total propagated analytical uncertainty. Averages are ±2 times the standard error of the calculated mean.
(c) Perimeter location onsite near Site boundary.

Appendix B

Glossary

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Appendix B

Glossary

absorbed dose - Amount of energy deposited by radiation in a given amount of material. Absorbed dose is measured in units of "rads" or "grays."

activation product - Material made radioactive by exposure to radiation from a source such as a nuclear reactor's neutrons.

air submersion dose - Radiation dose received from external exposure to radioactive materials present in the surrounding atmosphere.

alpha radiation - Least penetrating type of radiation. Alpha radiation can be stopped by a sheet of paper or the outer dead layer of skin, and can cause biological damage only if sufficient quantities are emitted inside the body.

aquifer - Permeable geologic unit that can hold and/or transmit significant quantities of water.

background radiation - Radiation in the natural environment, including cosmic rays from space and radiation from naturally occurring radioactive elements in the air, in the earth, and in our bodies. In the United States, the average person receives about 300 millirems (mrem) of background radiation per year.

bank storage - Hydrologic term that describes river water that flows into and is retained in permeable stream banks during periods of high river stage. Flow is reversed during periods of low river stage.

becquerel (Bq) - Unit of activity equal to one nuclear transformation per second (1 Bq = 1/s). The conventional unit of activity, the curie, is related to the becquerel according to
$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$.

beta radiation - One form of radiation emitted from a nucleus during radioactive decay. Beta radiation can be stopped by an inch of wood or a thin sheet of aluminum, and may cause biological damage if a sufficient amount is internal, or occasionally external, to the body.

boundary dose rate - Dose rate measured or calculated at publicly accessible locations on or near the Hanford Site.

collective effective dose equivalent - Sum of the effective dose equivalents for individuals composing a defined population. The units for this are "person-rem" or "person-sievert."

committed dose equivalent - Total dose equivalent accumulated in an organ or tissue in the 50 years following a single intake of radioactive materials into the body.

composite sample - Sample formed by mixing discrete samples taken at different points in time or from different locations.

confined aquifer - An aquifer bounded above and below by less permeable layers. Ground water in the confined aquifer is under a pressure greater than atmospheric pressure.

continuous sample - Sample formed by the continuous collection of the medium or contaminants within the medium during the entire sample period.

controlled area - An area to which access is controlled to protect individuals from exposure to radiation or radioactive and/or hazardous materials.

cosmic radiation - High-energy subatomic particles and electromagnetic radiation from outer space that bombard the earth. Cosmic radiation is part of natural background radiation.

curie (Ci) - A unit of radioactivity equal to 37 billion (3.7×10^{10}) nuclear transformations per second.

decay - The decrease in the amount of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of nucleons or either alpha or beta particles, often accompanied by gamma radiation. When a radioactive material decays, the material may be converted to another radioactive species (decay product) or to a nonradioactive material.

Derived Concentration Guides (DCG) - Concentrations of radionuclides in air and water that an individual could continuously consume, inhale or be immersed in at average annual rates, without receiving an effective dose equivalent of greater than 100 mrem/yr.

detection level - Minimum amount of a substance that can be measured with a 99% confidence that the analytical result is greater than zero.

dispersion - Process whereby effluents are spread or mixed as they are transported by ground water or air.

dose equivalent - Product of the absorbed dose, the quality factor, and any other modifying factors. The dose equivalent is a quantity for comparing the biological effectiveness of different kinds of radiation on a common scale. The unit of dose equivalent is the rem. A millirem is one one-thousandth of a rem.

dosimeter - Portable device for measuring the total accumulated exposure or absorbed dose from ionizing radiation fields.

Effective Dose - See "Effective Dose Equivalent" under "Radiation Dose."

effective dose equivalent - A value used for estimating the total risk of potential health effects from radiation exposure. This estimate is the sum of the committed effective dose equivalent (see above) from internal deposition of radionuclides in the body and the effective dose equivalent from external radiation received during a year.

effluent - Liquid or gaseous waste streams released from a facility.

effluent monitoring - Sampling or measuring specific liquid or gaseous effluent streams for the presence of pollutants.

exposure - Subjecting a target (usually living tissue) to radiation or chemicals. Also used as a term describing external radiation air ionization (see "Roentgen").

external radiation - Radiation originating from a source outside the body.

fallout - Radioactive materials that are released into the earth's atmosphere following a nuclear explosion or atmospheric release and that eventually fall to earth.

fission - A nuclear reaction involving the splitting or breaking apart of a nucleus into at least two other nuclei, accompanied with a release of various types of energy. For example, when a heavy atom, such as uranium, is split, large amounts of energy including radiation and neutrons are released along with the new nuclei (which are fission products).

fission products - Elements formed from fissioning. Many fission products are radioactive.

gamma radiation - Form of electromagnetic, high-energy radiation emitted from a nucleus. Gamma rays are essentially the same as x rays. They require heavy shielding, such as concrete or steel, to be stopped, and may cause biological damage when originating internally or externally to the body in sufficient amounts.

glaciofluvial sediments - Sedimentary deposits consisting of material transported by, suspended in, or laid down by the meltwater streams flowing from melting glacier ice.

grab sample - A sample that is randomly collected or "grabbed" from the collection site.

ground water - Subsurface water that is in the pore spaces of soil and geologic units.

gray (Gy) - Unit of absorbed dose in the International System of Units (SI) equal to 1 joule per kilogram. 1 Gy = 100 rad.

half-life - Length of time in which a radioactive substance will lose one half of its radioactivity by decay. Half-lives range from a fraction of a second to billions of years, and each radionuclide has a unique half-life.

internal radiation - Radiation originating from a source within the body as a result of the inhalation, ingestion, skin absorption, or implantation of natural or manmade radionuclides in body tissues (e.g., uranium dust in the lungs, radioiodine in the thyroid).

ion exchange - The reversible exchange of one species of ion for a different species of ion within a medium.

irradiation - Exposure to radiation.

isotopes - Different forms of the same chemical element that are distinguished by different numbers of neutrons in the nucleus. A single element may have many isotopes; some may be radioactive and some may be nonradioactive (stable). For example, the three isotopes of hydrogen are protium, deuterium, and tritium.

kurtosis - Measure of the degree of peakedness of a data distribution.

long-lived radioisotope - A radionuclide that decays at such a slow rate that a quantity will exist for an extended period (typically many years).

maximally exposed individual - A hypothetical member of the public residing near the Hanford Site who, by virtue of location and living habits, could receive the highest possible radiation dose from radioactive effluents released from Hanford.

mean - Average value of a series of measurements.

$$X = \frac{1}{n} \sum_{i=1}^{n} X_i$$

The mean, X, was computed as: where X_i is the ith measurement and n is the number of measurements.

median - Middle value in a set of results when the data are ranked in increasing or decreasing order.

millirem (mrem) - A unit of radiation dose equivalent that is equal to one one-thousandth (1/1000) of a rem. According to DOE standards, an individual member of the public may receive no more than 100 mrem per year from a site's operation. This limit does not include radiation received for medical treatment or the approximately 300 mrem that people receive annually from natural background radiation.

minimum detectable concentration - Smallest amount or concentration of a radioactive or nonradioactive element that can be reliably detected in a sample.

mode - The value of the piece of data that occurs with the greatest frequency.

noble gas - Any of a group of chemically and biologically inert gases that includes argon, krypton, and xenon. These gases are not retained in the body following inhalation. The principal exposure pathways from radioactive noble gases are direct external dose from the surrounding air (see "Air Submersion Dose").

offsite locations - Sampling and measurement locations outside the Hanford Site boundary.

onsite locations - Sampling and measurement locations within the Hanford Site boundary.

operable unit - A discrete area for which an incremental step can be taken toward comprehensively addressing site problems. The cleanup of a site can be divided into a number of operable units, depending on the complexity of the problems associated with the site.

outfall - End of a drain or pipe that carries waste water or other effluents into a ditch, pond, or river.

plume - The cloud of a pollutant in air, surface water, or ground water formed after the pollutant is released from a source.

plutonium - A heavy, radioactive, manmade metallic element consisting of several isotopes. One important isotope is ^{239}Pu, which is produced by the irradiation of ^{238}U. Routine analysis cannot distinguish between the ^{239}Pu and ^{240}Pu isotopes; hence, the term $^{239,240}Pu$ as used in this report is symbolic of the presence of one or both of these isotopes in the analytical results.

Quality Assurance - Actions that provide confidence that an item or process meets or exceeds that user's requirements and expectations.

Quality Control - Comprises all those actions necessary to control and verify the features and characteristics of a material, process, product, or service to specified requirements. Quality Control is an element of quality assurance.

radiation - The energy emitted in the form of rays or particles, such as those thrown off by transforming (disintegrating) atoms. For this report, radiation refers to ionizing types of radiation; not radiowaves, microwaves, radiant light, or other types of nonionizing radiation. The ionizing rays or particles typically consist of alpha, beta, or gamma radiation.

radiation dose - For the purpose of this report, radiation doses are defined as follows:

radioactivity - Property possessed by some isotopes of elements of emitting radiation (such as alpha, beta, or gamma rays) spontaneously in their decay process to stable element isotopes.

radioisotope - Radioactive isotope of a specified element. Carbon-14 is a radioisotope of carbon. Tritium is a radioisotope of hydrogen.

radionuclide - Radioactive atomic species or isotope of an element. There are several hundred known radionuclides, both manmade and naturally occurring. Radionuclide and radioisotope are terms that are sometimes used interchangeably, although they are theoretically different terms.

rem - Acronym for roentgen equivalent man; a unit of dose equivalent that indicates the potential for impact on human cells.

risk - The probability that a detrimental health effect will occur.

roentgen - Unit of x ray or gamma radiation exposure in air, typically used for describing external radiation levels. An exposure of 1 roentgen (R) is approximately equal to a 1-rem dose to human tissue.

short-lived radioisotope - A radionuclide that decays so rapidly that a given quantity is transformed almost completely into decay products within a short period (typically less than a few months).

sievert (Sv) - Unit of dose equivalent in the International System of Units (SI) equal to 100 rem.

skewness - Measure of the lack of symetry in a frequency distribution.

spent fuel - Nuclear fuel that has been exposed in a nuclear reactor; this fuel contains uranium, activation products, fission products, and plutonium.

standard deviation - An indication of the dispersion or variability of a set of results around their average.

standard error of the mean - An indication of the dispersion or variability of an estimated mean from the average of other estimates of the same mean. The standard error of X was computed as

$$SE = \sqrt{\frac{S^2}{n}}$$

where S^2, the variance of the n measurements, was computed as

$$S_M^2 = \frac{1}{n-1} \sum_{i=1}^{n} (X_i - X)^2$$

This estimator, S^2, includes the variance among the samples and the counting variance. The estimated S^2 may occasionally be less than the average counting variance.

taxon - A group of organisms constituting one of the categories or formal units in taxonomic classification (i.e., kingdom, phylum, class, order, family, genus, or species) and characterized by common characteristics in varying degrees of distinction.

thermoluminescent dosimeter (TLD) - A material that, after being exposed to beta and/or gamma radiation, emits light when processed and heated. The amount of light emitted is proportional to the amount of radiation (dose) to which the TLD has been exposed.

unconfined aquifer - An aquifer containing ground water that is not confined above by relatively impermeable rocks. The pressure at the top of the unconfined aquifer is equal to that of the atmosphere. At Hanford, the unconfined aquifer is the uppermost aquifer and is most susceptible to contamination from Site operations.

uncontrolled area - Area on or near a nuclear facility to which public access is not restricted.

vadose zone - Underground area from the surface to the top of the water table or aquifer.

water table - Theoretical surface represented by the elevation of water surfaces in wells penetrating only a short distance into the unconfined aquifer.

whole-body dose - Radiation dose that involves exposure of the entire body. Whole-body dose typically refers to external radiation exposure.

wind rose - Star-shaped diagram showing how often winds of various speeds blow from different directions, usually based on yearly averages.

Appendix C

Standards and Permits

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Appendix C

Standards and Permits

Operations at the Hanford Site must conform to a variety of governmental standards and permits designed to ensure the biological and physical quality of the environment for either public health, ecological, or aesthetic considerations. The primary environmental quality standards and permits applicable to Hanford operations in 1994 are listed in the following tables. The State of Washington has promulgated water quality standards for the Columbia River, Washington Administrative Code (WAC) 173-201. The Hanford Reach of the Columbia River has been designated as Class A (Excellent). This designation requires that the water be usable for substantially all needs, including drinking water, recreation, and wildlife. Class A water standards are summarized in Table C.1. Drinking water standards promulgated by the U.S. Environmental Protection Agency (EPA) in 40 Code of Federal Regulations (CFR) 141 are summarized in Tables C.2 and C.3. Benton-Franklin Counties Clean Air Authority air quality standards are shown in Table C.4.

Environmental radiation protection standards are published in U.S. Department of Energy (DOE) Order 5400.5, "Radiation Protection of the Public and the Environment." This DOE order establishes limits for public radiation dose and gives guidance for keeping radiation exposures to members of the public as low as reasonably achievable (ALARA). These standards are based on guidelines recommended by authoritative organizations, such as the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. The DOE has initiated a policy for creating and implementing public radiation protection standards that are generally consistent with the standards used by the U.S. Nuclear Regulatory Commission (NRC) in regulating and licensing non-DOE nuclear facilities (i.e., nuclear power plants). Table C.5 shows the radiation standards from DOE Order 5400.5. These standards govern allowable public exposures to ionizing radiation from DOE operations.

In Order 5400.5, the DOE established Derived Concentration Guides (DCGs) that reflect the concentrations of individual nuclides in water or air that would result in an effective dose equivalent of 100 mrem per year caused by ingestion of water or inhalation of air at average annual intake rates. Derived Concentration Guides are not exposure limits, but are simply reference values that are provided to allow for comparisons of radionuclide concentrations in environmental media. Table C.6 lists selected DCGs for radionuclides of particular interest at the Hanford Site. The DCGs are useful reference values but do not generally represent concentrations in the environment that ensure compliance with either the DOE, the Clean Air Act, or drinking water dose standards.

Permits required for regulated releases to water and air have been issued by the EPA under the National Pollutant Discharge Elimination System (NPDES) of the Clean Water Act and the Prevention of Significant Deterioration (PSD) requirements of the Clean Air Act. Also, under authority granted by the Clean Air Act, the Washington State Department of Health has issued a permit for Hanford radioactive air emissions. Permits for collecting wildlife for environmental sampling are issued by the Washington State Department of Fish and Wildlife and the U.S. Fish and Wildlife Service. Current permits are listed in Table C.7.

Table C.1 Washington State Water Quality Standards for the Hanford Reach of the Columbia River

Parameter	Permissible Levels
Fecal coliform	1) geometric mean value ≤ 100 colonies/100 mL 2) ≤ 10% of samples may exceed 200 colonies/100 mL
Dissolved oxygen	>8 mg/L
Temperature	1) ≤ 20°C (68°F) due to human activities 2) When natural conditions exceed 20°C, no temperature increases will be allowed that will raise the temperature of the receiving water by more than 0.3°C. 3) Incremental temperature increases resulting from point sources shall not, at any time, exceed 34/(T + 9), where T = background temperature. Incremental temperature increases resulting from non-point sources shall not exceed 2.8°C.
pH	1) 6.5 to 8.5 range 2) <0.5 unit induced variation
Turbidity	≤ 5 NTU[(a)] over background turbidity
Toxic, radioactive, or deleterious materials	Concentrations shall be below those of public health significance, or which cause acute or chronic toxic conditions to the most sensitive aquatic biota, or which may adversely affect characteristic water uses.
Aesthetic value	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

(a) NTU = nephelometric turbidity units.

Table C.2 Selected Radiological Drinking Water Standards

Radiological Constituent	Critical Organ	Maximum Contaminant Level (pCi/L)	Agency	EPA Status	Reference
Gross Alpha (excluding uranium)		15	DOH[a], EPA[b]	Final	WAC 246-290, 40 CFR 141.15
Radium-226		3	DOH		WAC 246-290
Beta and gamma radioactivity		4 mrem/yr[c]	DOH, EPA	Final	WAC 246-290, 40 CFR 141.16
Antimony-125	GI (LLI)[d]	300[e]	EPA		
Carbon-14	Fatty Tissue	2,000[e]	EPA		
Cesium-134	GI (S)[f]	20,000[e]	EPA		
Cesium-137	Whole Body	200[e]	EPA		
Cobalt-60	GI (LLI)	100[e]	EPA		
Iodine-129	Thyroid	1[e]	EPA		
Iodine-131	Thyroid	3[e]	EPA		
Ruthenium-106	GI (LLI)	30[e]	EPA		
Strontium-90	Bone Marrow	8[e]	EPA		
Technetium-99	GI (LLI)	900[e]	EPA		
Tritium	Whole Body	20,000[e]	EPA		

(a) Washington Department of Health.
(b) U.S. Environmental Protection Agency.
(c) Beta and gamma radioactivity from man made radionuclides. Annual average concentration shall not produce an annual dose from man made radionuclides equivalent to the total body or any internal organ dose greater than 4 mrem/yr. Compliance may be assumed if annual average concentrations of total beta, tritium, and strontium-90 are less than 50, 20,000, and 8 pCi/L, respectively.
(d) GI (LLI) = gastrointestinal tract (lower large intestine).
(e) Concentration assumed to yield an annual dose of 4 mrem/yr.
(f) (S) = stomach.

Table C.3 Selected Chemical Drinking Water Standards

Chemical Constituent	Maximum Contaminant Level (µg/L)	Agency	EPA Status	Reference
PRIMARY STANDARDS[a]				
Inorganic				
Antimony (Sb)	6	DOH[b], EPA[c]	Final	WAC 246-290, 40 CFR 141.62
Arsenic (As)	50	DOH	Under Review	WAC 246-290
Barium (Ba)	2,000	DOH, EPA	Final	WAC 246-290, 40 CFR 141.62
Beryllium (Be)	4	DOH, EPA	Final	WAC 246-290, 40 CFR 141.62
Cadmium (Cd)	5	DOH, EPA	Final	WAC 246-290, 40 CFR 141.62
Chromium (Cr)	100	DOH, EPA	Final	WAC 246-290, 40 CFR 141.62
Copper (Cu)	1,300[d]	EPA	Final	40 CFR 141.80
Cyanide (HCN)	200	DOH, EPA	Final	WAC 246-290, 40 CFR 141.62
Fluoride (F)	4,000	DOH, EPA	Final/Under Review	WAC 246-290, 40 CFR 141.62
Lead (Pb)	15[d]	EPA	Final	40 CFR 141.80
Mercury (Hg)	2	DOH, EPA	Final	WAC 246-290, 40 CFR 141.62
Nickel (Ni)	100	DOH, EPA	Final	WAC 246-290, 40 CFR 141.62
Nitrate (NO_3)	45,000	DOH, EPA	Final	WAC 246-290, 40 CFR 141.62
Selenium (Se)	50	DOH, EPA	Final	WAC 246-290, 40 CFR 141.62
Uranium (U)	20[e]	EPA	Proposed	
Organic				
Carbon tetrachloride	5	DOH, EPA	Final	WAC 246-290, 40 CFR 141.61
Trichloroethylene (TCE)	5	DOH, EPA	Final	WAC 246-290, 40 CFR 141.61
Tetrachloroethylene	5	DOH, EPA	Final	WAC 246-290, 40 CFR 141.61
SECONDARY STANDARDS[f]				
Aluminum (Al)	50-200	EPA	Final	40 CFR 143.3
Chloride (Cl)	250,000	DOH, EPA	Final	WAC 246-290, 40 CFR 143.3

Table C.3 Selected Chemical Drinking Water Standards (contd)

Chemical Constituent	Maximum Contaminant Level (µg/L)	Agency	EPA Status	Reference
Copper (Cu)	1,000	EPA	Final	40 CFR 143.3
Fluoride (F)	2,000	DOH,EPA	Final	WAC 246-290, 40 CFR 143.3
Iron (Fe)	300	DOH,EPA	Final	WAC 246-290, 40 CFR 143.3
Manganese (Mn)	50	DOH, EPA	Final	WAC 246-290, 40 CFR 143.3
Silver (Ag)	100	DOH, EPA	Final	WAC 246-290, 40 CFR 143.3
Zinc (Zn)	5,000	DOH, EPA	Final	WAC 246-290, 40 CFR 143.3

(a) Primary Drinking Water Standards define levels of water quality to protect the public health.
(b) Washington Department of Health.
(c) U.S. Environmental Protection Agency.
(d) Action level.
(e) Equivalent to a nationwide EPA standard of 30 pCi/L and a Sitewide standard of 13.4 pCi/L (see Section 5.8).
(f) Secondary Drinking Water Standards define levels of water quality to protect the public welfare from any known or anticipated adverse effects of a pollutant. Secondary Drinking Water Standards are based on factors other than health effects.

Table C.4 Benton-Franklin Counties Clean Air Authority Ambient Air Quality Standards[a]

Parameter	Type of Standard[b]	Sampling Period	Permissible Level
NO_2	Secondary and primary	Annual average	100 µg/m^3

(a) Benton-Franklin Counties Air Pollution Control Authority.
(b) Primary standards for ambient air quality define levels of air quality to protect the public health. Secondary standards define levels of air quality to protect the public welfare from any known or anticipated adverse effects of a pollutant.

Table C.5 Radiation Standards (Dose Limits[a]) for Protection of the Public from All Routine DOE Activities

All Pathways [limits from DOE Order 5400.5]

The effective dose equivalent for any member of the public from all routine DOE activities[b] shall not exceed the values given below.

	Effective Dose Equivalent[c]	
	mrem/yr	mSv/yr
Routine Public Dose	100	1
Potential Authorized Temporary Public Dose[d]	500	5

Dose to Native Aquatic Animal Organisms from Liquid Discharges [interim limits from DOE Order 5400.5]

Radioactive material in liquid wastes discharged to natural waterways shall not cause an absorbed dose[e] to native aquatic animal organisms that exceeds 1 rad per day (10 mGy per day).

Drinking Water Pathway Only [limits from 40 CFR 141 and DOE Order 5400.5]

Radionuclide concentrations in DOE-operated public drinking water supplies shall not cause persons consuming the water to receive an effective dose equivalent greater than 4 mrem (0.04 mSv) in a year. DOE activities shall not cause private or public drinking water systems downstream of the facility discharge to exceed the radiological drinking water limits in 40 CFR 141 (Table C.2).

Air Pathways Only [limits from 40 CFR 61]

	Effective Dose Equivalent[c]	
	mrem/yr	mSv/yr
Public Dose Limit at Location of Maximum Annual Air Concentration as a Consequence of Routine DOE Activities[b]	10	0.1

(a) Radiation doses received from natural background, residual weapons testing and nuclear accident fallout, medical exposures, and consumer products are excluded from the implementation of these dose limits.

(b) "Routine DOE activities" implies normal, planned activities and does not include actual or potential accidental or unplanned releases.

(c) Effective dose equivalent is expressed in rem (or millirem) with the corresponding value in sievert (or millisievert) in parentheses.

(d) Authorized temporary annual dose limits may be greater than 100 mrem/yr (but cannot exceed 500 mrem/yr) if unusual circumstances exist that make avoidance of doses greater than 100 mrem to the public impracticable. The Richland Operations Office is required to request and receive specific authorization from DOE Headquarters for an increase from the routine public dose limit to a temporary annual dose limit.

(e) Absorbed dose is expressed in rad (or millirad) with the corresponding value in gray (or milligray) in parentheses.

Table C.6 Selected Derived Concentration Guides[a,b,c]

Radionuclide	Water, pCi/L (10^{-9} µCi/mL)	Air, pCi/m^3 (10^{-12} µCi/mL)
^{3}H	2,000,000	100,000
^{14}C	70,000	500,000
^{51}Cr	1,000,000	60,000
^{54}Mn	50,000	2,000
^{60}Co	5,000	80
^{65}Zn	9,000	600
^{85}Kr	NS[d]	3,000,000
^{90}Sr	1,000	9
^{99}Tc	100,000	2,000
^{103}Ru	50,000	2,000
^{106}Ru	6,000	30
^{125}Sb	60,000	1,000
^{129}I	500	70
^{131}I	3,000	400
^{137}Cs	3,000	400
^{144}Ce	7,000	30
^{234}U	500	0.09
^{235}U	600	0.1
^{238}U	600	0.1
^{238}Pu	40	0.03
^{239}Pu	30	0.02
^{240}Pu	30	0.02
^{241}Am	NS	0.02

(a) Concentration of a specific radionuclide in water or air that could be continuously consumed or inhaled at average annual rates and not exceed an effective dose equivalent of 100 mrem/yr.
(b) Values in this table represent the lowest, most conservative derived concentration guides considered potentially applicable to Hanford operations, and may be adjusted upward (larger) if accurate solubility information is available.
(c) From DOE Order 5400.5.
(d) NS = No standard.

Table C.7 Environmental Permits

Clean Water Act Permit

NPDES Permit No. WA-000374-3, issued to the DOE, Richland Operations Office by Region 10 of the EPA, covers nonradioactive discharges to the Columbia River from eight outfalls. The following are measurements required for NPDES-permitted discharges at Hanford:

Measurement	Location		
	100-K Area (2 discharges)	100-N Area (5 discharges)	300 Area (1 discharge)
Flow rate	X	X	X
Suspended solids	X	X	X
Temperature	X	X	---(a)
pH	X	X	X
Chlorine	X	X	---
Oil and grease	---	X	---
Heat discharged	---	X	---
Settleable solids	---	---	X
Iron	---	X	---
Ammonia	---	X	---
Chromium	---	X	---

(a) Dashed line indicates no measurement required.

NPDES Permit No. WA-002591-7, issued to the DOE, Richland Operations Office by Region 10 of the EPA, covers organic and heavy metal discharges to the Columbia River from the 300 Area Treated Effluent Disposal Facility.

Clean Air Act Permits

PSD Permit No. PSD-X80-14, issued to the Richland Operations Office by Region 10 of the EPA, covers emission of NO_x to the atmosphere from the Plutonium Uranium Extraction (PUREX) Plant and the Uranium-TriOxide (UO_3) Plant. No expiration date.

Radioactive Air Emission Permit No. FF-01, issued to the Richland Operations Office by the Washington State Department of Health under authority granted by the Clean Air Act, covers operations on the Hanford Site having a potential to emit radioactive airborne effluents. Initially issued August 15, 1991, the permit was updated August 1993.

Table C.7 Environmental Permits (contd)

Wildlife Sampling Permits

Scientific Collection Permit No. 00114, issued by Washington State Department of Fish and Wildlife to Pacific Northwest Laboratory for 1994, covers the collection of food fish, shellfish, and wildlife, including gamefish, for environmental monitoring purposes. Renewed annually.

Federal Fish and Wildlife Permit No. 788930, issued by the U.S. Fish and Wildlife Service to Pacific Northwest Laboratory, covers the collection of migratory wildlife. Renewed annually.

Copies of the regulations concerning these permits may be obtained from the following organizations:

State of Washington Department of Ecology Olympia, WA 98504	U.S. Environmental Protection Agency Region 10 1200 Sixth Avenue Seattle, WA 98101	U.S. Department of Energy Richland Operations Office Richland, WA 99352

References

40 CFR 141. U.S. Government Printing Office, "National Primary Drinking Water Regulations." *Code of Federal Regulations*.

Benton-Franklin-Walla Walla Counties (Tri-Counties) Air Pollution Control Authority. 1980. *General Regulation 80-7*. Air Pollution Control Authority, Richland, Washington.

Clean Air Act. Public Law 88-206, as amended, 42 USC 7401 et seq.

Clean Water Act. Public Law 95-217, December 27, 1977, 91 Stat. 1566 and Public Law 96-148.

DOE Order 5400.5. 1990. "Radiation Protection of the Public and the Environment." Revised June 5, 1990 and January 7, 1993.

Washington Administrative Code (WAC) 173-201A. 1992. "Water Quality Standards for Surface Waters of the State of Washington," Washington State Department of Ecology.

Washington Administrative Code (WAC) 246-290. 1994. "Group A Public Water Systems," Washington State Department of Health.

Appendix D

Dose Calculations

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Appendix D

Dose Calculations

J. K. Soldat

The radiation dose that the public could have potentially received in 1994 from Hanford operations was calculated in terms of the "effective dose equivalent." These dose quantities are given in units of millirem (mrem) (millisievert [mSv])[(a)] for individuals and in units of person-rem (person-Sv) for the collective dose received by the total population within an 80-km (50 mi) radius of the Site. These quantities provide a way to uniformly express the radiation dose, regardless of the type or source of radiation or the means by which it is delivered. The values given in this report may be compared to standards for radiation protection (Table C.5, Appendix C). This appendix describes how the doses in this report were calculated.

Releases of radionuclides from the Hanford Site activities are usually too low to be measured in offsite air, drinking water, and food crops. Therefore, in most cases, the dose calculations were based on measurements made at the point of release (stacks and effluent streams), and environmental concentrations were estimated from these effluent measurements by environmental transport models.

The transport of radionuclides in the environment to the point of exposure is predicted by empirical models of exposure pathways. These models calculate concentrations of radionuclides in air, water, and foods. Radionuclides taken into the body by inhalation or ingestion may be distributed among different organs and retained for various times. In addition, long-lived radionuclides deposited on the ground become possible sources for long-term external exposure and uptake by agricultural products. Dietary and exposure parameters were applied to calculate radionuclide intakes and radiation doses to the public. Standardized computer programs were used to perform the calculations. These programs contain internally consistent mathematical models that use site-specific dispersion and uptake parameters. These programs are incorporated in a master code, GENII (Napier et al. 1988a, 1988b, 1988c), which employs the dosimetry methodology described in International Commission on Radiological Protection (ICRP) Reports (1979a, 1979b, 1980, 1981a, 1981b, 1982a, 1982b, 1988). The assumptions and input data used in these calculations are described below.

Types of Dose Calculations Performed

Calculations of radiation doses to the public from radionuclides released into the environment are performed to demonstrate compliance with applicable standards and regulations.

The U.S. Department of Energy (DOE) requires that estimates of radiation exposure to the general public be in terms of the "effective dose equivalent." The effective dose equivalent is representative of the total risk of potential health effects from radiation exposure. The adoption and use of the effective dose equivalent was previously recommended by the ICRP (1977). In addition to implementing the effective dose equivalent requirement for offsite population dose calculations, the DOE has also adopted the biokinetic models and metabolic parameters for radionuclides given by the ICRP in 1977 for estimating radiation dose. As in the past, when concentrations of radionuclides in the environment are too low to measure, then DOE specifies that the doses are to be calculated from effluent data using environmental transport and dosimetry models.

The calculation of the effective dose equivalent takes into account the long-term (50-year) internal exposure from radionuclides taken into the body during the current year. The effective dose equivalent is the sum of individual committed (50-year) organ doses multiplied by weighting factors that represent the proportion of the total health-effect risk that each organ would receive from uniform irradiation of the whole body. Internal organs may

(a) 1 rem (0.01 Sv) = 1000 mrem (10 mSv).

also be irradiated from external sources of radiation. The external exposure received during the current year is added to the committed internal dose to obtain the total effective dose equivalent. In this report, the effective dose equivalent is expressed in rem (or millirem), with the corresponding value in sievert (or millisievert) in parentheses. The numerous transfer factors used for pathway and dose calculations have been documented in GENII (Napier et al. 1988a, 1988b, 1988c) and by Schreckhise et al. (1993).

The following types of radiation doses were estimated:

1. **"Boundary" Dose Rate (mrem/h and mrem/yr)**. The external radiation dose rates during the year in areas accessible by the general public were determined from measurements obtained near operating facilities.

2. **"Maximally Exposed Individual" Dose (mrem)**. The maximally exposed individual is a hypothetical member of the public who lives at a location and has a postulated lifestyle such that it is unlikely that other members of the public would receive higher doses. All potentially significant exposure pathways to this hypothetical individual were considered, including the following:

   - inhalation of airborne radionuclides
   - submersion in airborne radionuclides
   - ingestion of foodstuffs contaminated by radionuclides deposited on vegetation and the ground by both airborne deposition and irrigation water drawn from the Columbia River downstream of the N Reactor
   - exposure to ground contaminated by both airborne deposition and irrigation water
   - ingestion of fish taken from the Columbia River
   - recreation along the Columbia River, including boating, swimming, and shoreline activities.

3. **80-km Population Doses (person-rem)**. Regulatory limits have not been established for population doses. However, evaluation of the collective population doses to all residents within an 80-km (50-mi) radius of Hanford Site operations is required by DOE Order 5400.5. The 80-km (50-mi) population dose represents the summed products of the individual doses for the number of individuals involved for all potential exposure pathways.

The pathways assigned the maximally exposed individual were assumed to be applicable to the offsite population. Consideration was given, however, to the fraction of the offsite population actually affected by each pathway. The exposure pathways for the population are as follows:

- **Drinking Water**. The cities of Richland and Pasco obtain their municipal water directly, and Kennewick indirectly, from the Columbia River downstream from the Hanford Site. A total population of approximately 70,000 in the three cities drinks water derived from the Columbia River.

- **Irrigated Food**. Columbia River water is withdrawn for irrigation of small vegetable gardens and farms in the Riverview district of Pasco in Franklin County. Enough food is grown in this district to feed an estimated 2,000 people. Commercial crops are also irrigated by Columbia River water in the Horn Rapids area of Benton County.

- **River Recreation**. These activities include swimming, boating, and shoreline recreation. An estimated 125,000 people who reside within 80 km (50 mi) of the Hanford Site are assumed to be affected by these pathways.

- **Fish Consumption**. Population doses from the consumption of fish obtained locally from the Columbia River were calculated from an estimated total annual catch of 15,000 kg/yr (without reference to a specified human group of consumers).

Data

The data that are needed to perform dose calculations based on measured effluent releases include information on initial transport through the atmosphere or river, transfer or accumulation in terrestrial and aquatic pathways, and public exposure. By comparison, radiation dose calculations based on measured concentrations of radionuclides in food require data describing only dietary and recreational activities and exposure times. These data are discussed in the following sections.

Population Distribution and Atmospheric Dispersion

Geographic distributions of the population residing within an 80-km (50-mi) radius of the four Hanford Site operating areas are shown in the *Hanford Site Environmental Data for Calendar Year 1994—Surface and Columbia River* (Bisping 1995). These distributions are based on 1990 Bureau of Census data (Beck et al. 1991). These data influence the population dose by providing estimates of the number of people exposed to radioactive effluents and their proximity to the points of release.

Atmospheric dispersion data are also shown in the *Hanford Site Environmental Data for Calendar Year 1994—Surface and Columbia River* (Bisping 1995). These data describe the transport and dilution of airborne radioactive material, which influences the amounts of radionuclides being transported through the air to specific locations.

Terrestrial and Aquatic Pathways

Important parameters affecting the movement of radionuclides within potential exposure pathways, such as irrigation rates, growing periods, and hold-up periods, are listed in Table D.1. Certain parameters are specific to the lifestyles of either "maximally exposed" or "average" individuals.

Public Exposure

The potential offsite radiation dose is related to the extent of external exposure to or intake of radionuclides released from Hanford Site operations. Tables D.2 through D.4 give the parameters describing the diet, residency, and river recreation assumed for "maximally exposed" and "average" individuals.

Dose Calculation Documentation

The Hanford Dose Overview Panel has the responsibility for defining standard, documented computer codes and input parameters to be used for radiation dose calculations for the public in the vicinity of the Hanford Site. Only those procedures, models, and parameters previously defined by the Hanford Dose Overview Panel were used to calculate the radiation doses (Schreckhise et al. 1993). The calculations were then reviewed by the Dose Overview Panel. Summaries of dose calculation documentation for this report are shown in Tables D.5 through D.9 and *Hanford Site Environmental Data for Calendar Year 1994—Surface and Columbia River* (Bisping 1995).

Table D.1 Food Pathway Parameters Used in Dose Calculations, 1994

	Holdup, days[a]				
	Maximally Exposed Individual	Average Individual	Growing Period, days	Yield, kg/m^2	Irrigation Rate, $L/m^2/month$
Leafy vegetables	1	14	90	1.5	150
Other vegetables	5	14	90	4	170
Fruit	5	14	90	2	150
Cereal	180	180	90	0.8	0
Eggs	1	18	90	0.8	0
Milk	1	4			
Hay	(100)[b]	(100)	45	2	200
Pasture	(0)	(0)	30	1.5	200
Red meat	15	34			
Hay	(100)	(100)	45	2	200
Grain	(180)	(180)	90	0.8	0
Poultry	1	34	90	0.8	0
Fish	1	1	--	--	--
Drinking water	1	1	--	--	--

(a) Holdup is the time between harvest and consumption.
(b) Values in ( ) are the holdup in days between harvest and consumption by farm animals.

Table D.2 Dietary Parameters Used in Dose Calculations, 1994

	Consumption, kg/yr	
	Maximally Exposed Individual	Average Individual
Leafy vegetables	30	15
Other vegetables	220	140
Fruit	330	64
Grain	80	72
Eggs	30	20
Milk[a]	270	230
Red meat	80	70
Poultry	18	8.5
Fish	40	--[b]
Drinking water[a]	730	440

(a) Units L/yr.
(b) Average individual consumption not identified; radiation doses were calculated based on estimated total annual catch of 15,000 kg.

Table D.3 Residency Parameters Used in Dose Calculations, 1994

Parameter	Exposure, h/yr	
	Maximally Exposed Individual	Average Individual
Ground contamination	4,383	2,920
Air submersion	8,766	8,766
Inhalation[(a)]	8,766	8,766

(a) Inhalation rates: Adult 270 cm^3/s.

Table D.4 Recreational Parameters Used in Dose Calculations, 1994

Parameter	Exposure, h/yr[(a)]	
	Maximally Exposed Individual	Average Individual
Shoreline	500	17
Boating	100	5
Swimming	100	10

(a) Assumed river water travel times from 100-N to the point of aquatic recreation were 8 h for the maximally exposed individual and 13 h for the average individual. Correspondingly lesser times were used for other locations.

Table D.5 Documentation of 100-N Area Airborne Release Dose Calculations, 1994

Facility name	100-N Area
Releases	See Table 3.1
Meteorological conditions	1994 annual average, calculated from data collected at the 100-N Area and the Hanford Meteorology Station from January 1994 through December 1994, using the computer code HANCHI
$\overline{X}/Q'$	Maximally Exposed Individual at residence, 1.6×10^{-8} s/m^3 at 41 km SE; Maximally Exposed Individual at food source, 8.2×10^{-9} s/m^3 at 53 km SSE; 80-km population, 3.8×10^{-3} s/m^3 person-s/m^3
Release height	89-m effective stack height
Population distribution	375,000 (see Table D-1, Bisping [1995])
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

Table D.6 Documentation of 100-N Area Liquid Release Dose Calculations, 1994

Facility name	100-N Area
Releases	See Table 3.4
Mean river flow	94,700 cfs (2,680 m^3/s)
Shore-width factor	0.2
Population distribution	70,000 for drinking water pathway 125,000 for aquatic recreation 2,000 for consumption of irrigated foodstuffs 15,000 kg/yr total harvest of Columbia River fish
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to irrigated soil, to river water, and to shoreline sediments Ingestion of aquatic foods, and irrigated farm products
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90 Bioaccumulation Factor Library, Rev. 10-26-92

Table D.7 Documentation of 200 Area Airborne Release Dose Calculations, 1994

Facility name	200 Areas
Releases	See Table 3.1
Meteorological conditions	1994 annual average, calculated from data collected at the Hanford Meteorology Station from January 1994 through December 1994, using the computer code HANCHI
$\overline{X}/Q'$	Maximally Exposed Individual at residence, 1.3×10^{-8} s/m^3 at 34 km SE; Maximally Exposed Individual at food source, 9.7×10^{-9} s/m^3 at 45 km SE; 80-km population, 1.7×10^{-3} person-s/m^3
Release height	89-m effective stack height
Population distribution	376,000 (see Table D-2, Bisping [1995])
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

Table D.8 Documentation of 300 Area Airborne Release Dose Calculations, 1994

Facility name	300 Area
Releases	See Table 3.1
Meteorological conditions	1994 annual average, calculated from data collected at the 300 Area and the Hanford Meteorology Station from January 1994 through December 1994, using the computer code HANCHI
$\overline{X}/Q'$	Maximally Exposed Individual at residence, 8.6×10^{-7} s/m^3 at 1.5 km E; Maximally Exposed Individual at food source, 6.7×10^{-8} s/m^3 at 13 km SSE; 80-km population, 5.6×10^{-3} person-s/m^3
Release height	10 m
Population distribution	282,000 (see Table D-3, Bisping [1995])
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

Table D.9 Documentation of 400 Area Airborne Release Dose Calculations, 1994

Facility name	400 Area
Releases	See Table 3.1
Meteorological conditions	1994 annual average, calculated from data collected at the 400 Area and the Hanford Meteorology Station from January 1994 through December 1994, using the computer code HANCHI
$\overline{X}/Q'$	Maximally Exposed Individual at residence, 9.8×10^{-8} s/m^3 at 11 km SE; Maximally Exposed Individual at food source, 2.8×10^{-8} s/m^3 at 23 km SSE; 80-km population, 4.6×10^{-3} person-s/m^3
Release height	10 m
Population distribution	283,000 (see Table D-3, Bisping [1995])
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

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Beck, D. M., B. A. Napier, M. J. Scott, A. G. Thurman, M. D. Davis, D. B. Pittenger, S. F. Shindle, and N. C. Batishko. 1991. *Hanford Area 1990 Population and 50-Year Projections.* PNL-7803, Pacific Northwest Laboratory, Richland, Washington.

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Appendix E

Radionuclides Detected by Gamma Spectroscopy (Gamma Scan)

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Appendix E

Radionuclides Detected by Gamma Spectroscopy (Gamma Scan)

One of the several forms of radiation is gamma radiation. Gamma radiation is emitted by many radionuclides. Gamma spectroscopy, sometimes called a gamma scan, is used in the environmental surveillance program to detect the presence of the radionuclides shown in Table F.1. These radionuclides may be natural or result from Hanford activities. They include activation products formed by the absorption of a neutron by a stable element and fission products that occur following fission (splitting) of nuclear fuel radionuclides like plutonium-239 or uranium-235. These radionuclides may not be discussed in the main body of this report if they are below detection levels.

Table E.1. Radionuclides Analyzed by Gamma-Spectroscopy

Radionuclide	Symbol	Source
Beryllium-7	^{7}Be	Natural
Sodium-22	^{22}Na	Activation product
Sodium-24	^{24}Na	Activation product
Potassium-40	^{40}K	Natural
Manganese-54	^{54}Mn	Activation product
Cobalt-58	^{58}Co	Activation product
Cobalt-60	^{60}Co	Activation product
Iron-59	^{59}Fe	Activation product
Zinc-65	^{65}Zn	Activation product
Zirconium/Niobium-95	$^{95}Zr/Nb$	Activation product and fission product
Molybdenum-99	^{99}Mo	Activation product and fission product
Ruthenium-103	^{103}Ru	Activation product and fission product
Ruthenium-106	^{106}Ru	Fission product
Antimony-125	^{125}Sb	Activation product
Iodine-131	^{131}I	Fission product
Cesium-134	^{134}Cs	Activation product
Cesium-137	^{137}Cs	Fission product
Barium/Lanthanum-140	$^{140}Ba/La$	Fission product
Cerium-141	^{141}Ce	Activation product and fission product
Cerium/Praseodymium-144	$^{144}Ce/Pr$	Fission product
Europium-152	^{152}Eu	Activation product
Europium-154	^{154}Eu	Activation product
Europium-155	^{155}Eu	Activation product

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Appendix F

Threatened and Endangered Species

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Appendix F

Threatened and Endangered Species

L. L. Cadwell

Threatened and endangered plants and animals identified on the Hanford Site, as listed by the federal government [50 Code of Federal Regulations (CFR 17] and Washington State (Washington Natural Heritage Program 1990), are shown in Table G.1. No plants or mammals on the federal list are known to occur on the Hanford Site. Several species of plants and animals, however, are under consideration for formal listing by the federal government and Washington State (Table G.2). One species, eatonella *(eatonella nivea)* is listed by the State as threatened. However, it has not been sighted on Hanford. It is known to exist near the Site and occupies habitats similar to those found at Hanford. Surveys have not been completed for this species. Washington State plant species of concern are listed in Table G.3.

Table F.1 Threatened (T) and Endangered (E) Species

Common Name	Scientific Name	Federal	State
Plants			
Columbia milkvetch	*Astragalus columbianus*		T[(a)]
Columbia yellowcress	*Rorippa columbiae*		E[(a)]
Hoover's desert parsley	*Lomatium tuberosum*		T[(a)]
Northern wormwood	*Artemisia campestris borealis var. wormskioldii*		E
Dwarf evening-primrose	*Camissonia (Oenothera) pygmaea*		T[(a)]
Birds			
Aleutian Canada goose	*Branta canadensis leucopareia*	T	E
Peregrine falcon	*Falco peregrinus*	E	E
Bald eagle	*Haliaeetus leucocephalus*	T	T[(a)]
White pelican	*Pelecanus erythrorhychos*		E[(a)]
Sandhill crane	*Grus canadensis*		E
Ferruginous hawk	*Buteo regalis*		T[(a)]
Mammals			
Pygmy rabbit	*Brachylagus idahoensis*		E

(a) Occur on the Hanford Site.

Table F.2 Washington State Plant Species of Concern Occurring on the Hanford Site

Common Name	Scientific Name	Status[a]
Dense sedge	*Carex densa*	S
Gray cryptantha	*Cryptantha leucophaea*	S
Bristly cyptantha	*Cryptantha interrupta*	M2
Shining flatsedge	*Cyperus rivularis*	S
Piper's daisy	*Erigeron piperianus*	S
Southern mudwort	*Limosella acaulis*	S
False-pimpernel	*Lindernia anagallidea*	S
Dwarf evening primrose	*Oenothera pygmaea*	T
Tooth-sepal dodder	*Cuscuta denticulata*	M1
Thompson's sandwort	*Arenaria franklinii v. thompsonii*	M2
Robinson's onion	*Allium robinsonii*	M3
Squill onion	*Allium syscillioides*	M3
Columbia River mugwort	*Artemisia lindleyana*	M3
Stalked-pod milkvetch	*Astragalus sclerocarpus*	M3
Medic milkvetch	*Astragalus speirocarpus*	M3
Crouching milkvetch	*Astragalus succumbens*	M3
Rosy balsamroot	*Balsamorhiza rosea*	M3
Palouse thistle	*Cirsium brevifolium*	M3
Smooth cliffbrake	*Pellaea glabella*	M3
Fuzzy-tongue penstemon	*Penstemon eriantherus*	M3
Canadian St. John's wort	*Hypericum majus*	M1
Desert evening-primrose	*Oenothera caespitosa*	S
Geyer's milkvetch	*Astragalus geyeri*	S

The following species may inhabit the Hanford Site, but have not been recently collected, and the known collections are questionable in terms of location and/or identification.

Palouse milkvetch	*Astragalus arrectus*	S
Few-flowered blue-eyed Mary	*Collinsia sparsiflora*	S
Coyote tobacco	*Nicotiana attenuata*	S

(a) Abbreviations: S = Sensitive; taxa vulnerable or declining, and could become endangered or threatened without active management or removal of threats; M1 = Monitor Group 1, taxa for which there are insufficient data to support listing as threatened, endangered, or sensitive; M2 = Monitor Group 2, taxa with unresolved taxonomic questions; M3 = Monitor Group 3, taxa that are more abundant and/or less threatened than previously assumed.

Appendix G

Errata from 1993 Hanford Site Environmental Report

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Appendix G

Errata from 1993 Hanford Site Environmental Report

The following lists errors in the published 1993 environmental report (*Hanford Site Environmental Report for Calendar Year 1993*, Woodruff, R. K., R. W. Hanf, and R. E. Lundgren, editors. 1993. PNL-8682, Pacific Northwest Laboratory, Richland, Washington). Individuals, organizations, and agencies who were on the distribution list for the 1993 report have already received a copy of this errata.

On page xli in table H.4 column 3 for ^{90}Sr, change the half-life from 21.1 yr to 29.1 yr:

29.1 yr

On page 55 in the 1st column, 6th line of last bullet, replace with the following:

Irradiation Laboratory, and the 340 Vault and Tanks.

On page 56 in the 2nd column of table 3.1, across from $^{90}Sr^{(d)}$, replace 21.1 yr with 29.1 yr, and in the 6th column, across from ^{238}Pu, replace NM with 6.9 x 10^{-8}:

29.1 yr 6.9 x 10^{-8}

On page 58 in the 2nd column of table 3.3, across from ^{90}Sr, replace 21.1 yr with 29.1 yr, and in the 4th column, across from Uranium, total, replace 0.052[c] with 0.0052[c]:

29.1 yr 0.0052[c]

On page 58 in the 2nd column of table 3.4, across from ^{90}Sr, replace 21.1 yr with 29.1 yr, and in the 3rd column, across from ^{60}Co, replace 0.0036 with 0.00036:

29.1 yr 0.00036

On page 76 in the top artwork on figure 3.6, replace R/h with the following:

µR/h

On page 143 in table 5.13 replace the caption with the following new caption:

Table 5.13. Washington State Department of Health Tritium Concentrations (pCi/L) in Wine, 1993

On page 169 in the second column of text, the last paragraph, replace the 8th line of text with the following:

shoreline and ranged from 8 to 120 µrem/h using a

On page 209 in Figure 5.68, replace the vertical scale unit description of (ug/L) with (mg/L), and the horizontal scale description from Data to Date

Nitrate (mg/L) Collection Date

On page 238 in Table 7.8 replace with the following: in column 3 replace <193 block with new <193[f] block and replace <194 block with new <194[f] block, in column 4 replace 0.30 ± 0.1 column with 300 ± 100 new column, Replace footnote with new footnote below (for space reasons the footnote was turned on its side, but when inserting into document you can put in correct position.

<193[f]	300 ± 100
<0.00289	0.0024 ± 0.0009
<0.0457[b]	ND
NA[c]	ND[d]
<0.00540	ND
<194[f]	500 ± 710
<0.00200	ND
<0.0462	ND
NA	ND
<0.00481	ND
	ND
	0.022 ± 0.005
	ND
	ND
	ND
	ND
	ND
	ND
	ND
	ND
	300 ± 140
	ND
	ND
	ND
	ND
	ND
	0.0046 ± 0.0004
	ND
	ND
	ND

(a) 2 sigma Total Propogated Uncertainty; PNL = Pacific Northwest Laboratory.
(b) <values are 2 sigma total propogated uncertainies.
(c) NA = not analyzed (PNL did not request analysis).
(d) ND = not detected.
(e) Analysis requested but data not received from laboratory.
(f) Reported in pCi/l.

On page A.5 in table A.4 replace 0.5 ± 3 block under 3rd column, across from ^{3}H with the following 95 ± 3 new block:

95 ± 3
0.20 ± 0.03
0.63 ± 0.18
0.03 ± 0.02
0.49 ± 0.16
1.15 ± 0.24

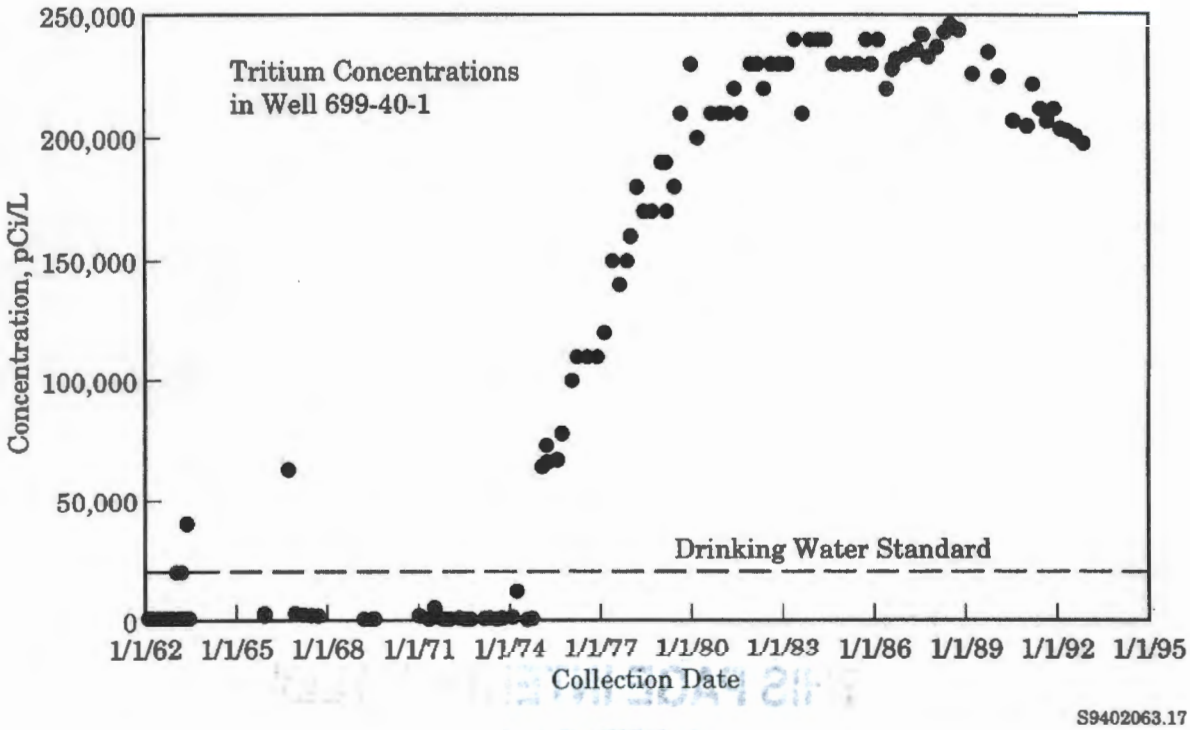

Figure 5.51. Tritium (^3H) Concentrations in Well 699-40-1, 1962 Through 1993

Take the information below the dashed line and paste it into the Environment Report behind the Title page (which is the first page in your report and is blank on the backside.) Place it on that blank page. Thank you.

Errata for the 1993 Hanford Site Environmental Report

On page 165, Figure 5.3.5, the arrow for Leslie Groves Park should be pointing to dot 12, not dot 4.

On page 175, figure 5.41, on the left hand side of the figure, the arrows should be labeled 148, 150, and 152 instead of 146, 148, and 150.

On page 222, Figure 6.1, the arrow indicating the Allied Technology Group corporation should be pointing at the green dot just below and to the right of the Siemens Power Corporation location.

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