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Hanford Site 1995 Environmental Report

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Hanford Site Environmental Report for Calendar Year 1995

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June 1996

Prepared by personnel from Pacific Northwest National Laboratory, Westinghouse Hanford Company, and Bechtel Hanford Incorporated for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830

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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 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 two hard copy formats and an electronic format. The hard copy documents include this large technical report and a smaller, less detailed summary report consisting of approximately 40 pages. The electronic versions of both hard copy documents are available on the Internet (the address is http://w3.pnl.gov:2080/hanford_envrpt95).

This report is prepared for the DOE Richland Operations Office, Environmental Assurance, Permits and Policy Division by the Pacific Northwest National Laboratory's Office of Health and Environment as part of the Public Safety and Resource Protection Program. Pacific Northwest National 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 National Laboratory (the Site research and development contractor) and Westinghouse Hanford Company (the Site management and operations contractor). Bechtel Hanford, Inc. (the Environmental Restoration contractor) 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, Environmental Assurance, Permits and Policy Division, P.O. Box 550, Richland, Washington 99352, or to Mr. Roger Dirkes, Pacific Northwest National Laboratory, P.O. Box 999, Richland, Washington 99352.

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 1995 of compliance with environmental regulations
- describe the environmental programs at the Hanford Site
- discuss estimated radionuclide exposure to the public from 1995 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)
- 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 until 1989 the Site 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 Plant, Plutonium Finishing Plant, Central Waste Complex, Low-Level Burial Grounds, B Plant/Waste Encapsulation Facility, 616 Non-Radioactive Hazardous Waste Storage Facility, Waste Receiving and Processing Facility, Transuranic Storage and Assay Facility, 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 DOE 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 Inc.

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 1995.

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, and DOE for achieving compliance with the remedial action provisions of the Comprehensive Environmental Response, Compensation, and Liability Act and with treatment, storage, and disposal unit regulation and corrective action provisions of the Resource Conservation and Recovery Act. From 1989 through 1995, a total of 460 enforceable Tri-Party Agreement milestones and 215 unenforceable target dates were completed on or ahead of schedule. Eighty-nine milestones scheduled for 1995 were completed.

Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act established a program to ensure that sites contaminated by hazardous substances are cleaned up by responsible parties or the government. The Comprehensive Environmental Response, Compensation, and Liability Act primarily covers waste cleanup of inactive sites.

Preliminary assessments conducted for the Hanford Site revealed approximately 2,100 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 operable units currently being studied were selected as a result of Tri-Party Agreement negotiations.

The Hanford Site was in compliance with Comprehensive Environmental Response, Compensation, and Liability Act requirements in 1995. Cleanup is underway at various sites in the 100, 200, and other Areas. Cleanup was completed in 1995 in the 1100 Area.

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. 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, the Act contains requirements for periodic reporting on hazardous chemicals stored and/or used near the community. The 1995 *Hanford Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1996c) was issued to the State Emergency Response Commission, local county emergency management committees, and local fire departments in March 1996. The report contained information on hazardous materials in storage across the Hanford Site. The Hanford Site was not required to submit a Toxic Chemical Release Inventory report in 1995. There were no toxic chemicals used in excess of applicable activity threshold levels. Accordingly, during 1995, the Hanford Site was in compliance with the reporting and notification requirements contained in this Act.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act establishes regulatory standards for the generation, transportation, storage, treatment, and disposal of hazardous wastes. Washington State Department of 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. Washington State Department of Ecology also implements the state's regulations, which are often more stringent. The Resource Conservation and Recovery Act 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 Resource Conservation and Recovery Act and Washington State regulations. These units are required to operate under Washington State Department of Ecology's interim-status compliance requirements. Approximately one-half of the units will be closed.

Subtitle I of the Resource Conservation and Recovery Act deals with regulation of underground storage tank systems. These regulations were added to the Resource Conservation and Recovery Act 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, Washington State Department of Ecology, Washington State Department of Health, and local air authorities.

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 applicable Hanford Site stacks emitting radiation have been registered in accordance with regulations.

Revised Clean Air Act requirements for radioactive air emissions were issued in December 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 within the EPA offsite emissions standard of 10 mrem/yr (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.

The local air authority, the Benton County 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 National Pollutant Discharge Elimination System (NPDES) permits governing effluent discharges to the Columbia River. The permits (No. WA-000374-3) specify discharge points (called outfalls), effluent limitations, and monitoring requirements. There were no instances of noncompliance in 1995 for this permit. NPDES permit No. WA-002591-7 was issued to the 300 Area Treated Effluent Disposal Facility and had six instances of noncompliance in 1995. Despite the use of best available technology, the facility is unable to meet the effluent levels specified in the permit. Permit renegotiation is expected.

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 1995, 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. The Hanford Site is currently in compliance with regulations for nonradioactive polychlorinated biphenyls. All radioactive polychlorinated biphenyl 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 17.21, "Washington Pesticide Application Act, 1961," as implemented by Washington Administrative Code 16-228, "General Pesticides Regulations," apply to storage and use of pesticides. In 1995, the Hanford Site was in compliance with the Act's requirements and Washington Administrative Code 16-228 regulations pertaining to storage and application of pesticides.

Endangered Species Act

Many 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 (federally listed). Others are listed by the Washington State Department of Fish and Wildlife as endangered, threatened, or sensitive species. The Site monitoring program is discussed in Section 6.2, "Wildlife." Hanford Site activities complied with the Endangered Species Act in 1995.

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 program, which is described in Section 6.3, "Hanford Cultural Resources Laboratory." In 1995, Hanford Site operations complied with these Acts.

National Environmental Policy Act

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

Several environmental impact statements 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 1995 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 1995. There were 23 unusual occurrence reports for 1995. There were 22 off-normal environmental release-related occurrence reports filed at the Hanford Site during 1995.

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 1995.

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 1995 are not significantly different from totals in 1994.

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 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 decontamination or decommissioning. Air, surface water and springs, surface contamination, soil and vegetation, vadose zone monitoring, investigative sampling (which can include wildlife), and

external radiation were sampled. Some of the parameters typically monitored are pH, radionuclide concentrations, radiation exposure levels, and concentrations of selected hazardous chemicals. 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.

Near-Facility Air Monitoring

Radioactivity in air was sampled by a network of continuously operating samplers at 47 locations near nuclear facilities: four were located in the 100-N Area, four were in the 100-K Area, 37 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 Pacific Northwest National Laboratory and the Washington State Department of Health at the Wye Barricade. 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. Of the radionuclide analyses performed, cesium-137, plutonium-239,240, strontium-90, and uranium were consistently detectable in the 200 Areas. Cobalt-60 and, infrequently, plutonium-239,240 were detectable in the 100-N Area. Air concentrations for these radionuclides were elevated near facilities compared to the concentrations measured offsite by Pacific Northwest National Laboratory.

Surface-Water Disposal Units and 100-N Springs Monitoring

Samples collected from surface-water disposal units included water, sediment, and aquatic vegetation. Only water samples were taken at 100-N shoreline springs. Radiological analyses of water samples from surface-water disposal units included plutonium-238, plutonium-239,240, uranium, tritium, strontium-90, and gamma-emitting radionuclides. 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.

Radiological analytical results for liquid samples from surface-water disposal units (ponds and ditches) located in the 200 Areas were less than the DOE Derived Concentration Guides and in most cases were equal to or less than the analytical detection limits. Although some elevated levels were seen in both aquatic vegetation and sediment, in all cases, the radiological analytical results were much less than the standards used for radiological control. 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 the Resource Conservation and Recovery Act. The analytical results for nitrates were all less than the 45-mg/L Drinking Water Standard for public water supplies.

Ground-water springs along the 100-N Area shoreline are sampled annually 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 at the facility effluent monitoring well. In 1995, with the exception of tritium, the concentrations detected in shoreline springs samples were highest in springs nearest the effluent monitoring well. Concentrations of tritium were highest in the two farthest downstream sampling locations.

Near-Facility Radiological Surveys

In 1995, there were approximately 2,531 ha (6,254 acres) of posted outdoor contamination areas and 1,025 ha (2,532 acres) of posted underground radioactive materials areas, not including active facilities, at the Hanford Site. These areas were typically associated with cribs, burial grounds, tank farms, and covered ditches. The posted contamination areas vary between years because of an ongoing effort to clean, stabilize, and remediate areas of known contamination. During this time, new areas of contamination were being identified. It was estimated that the external dose rate at 80% of the identified outdoor contamination areas was less than 1 mrem/h measured at 1 m (3.28 ft), 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 did not significantly add to dose rates for the public or Hanford Site workers in 1995.

Vadose Zone Monitoring

The inactive liquid effluent facilities vadose monitoring program tracks the movement of radioactive contaminants that were discharged to the soil. There are over 300 liquid waste disposal sites at Hanford that have received over 53 billion L (14 billion gal) of waste, excluding the 1,620 billion L (430 billion gal) that were discharged at the surface to ponds and ditches. During calendar year

1995, approximately 70 boreholes were logged around these facilities for radioactive plume identification and tracking. In addition, approximately 35 wells scheduled for decommissioning onsite were surveyed for gamma-ray radiation, to assure the wells were not contaminated, and for moisture and geologic data to help determine moisture migration pathways. The environmental restoration program also was supported by the collection of approximately 40 borehole logs for delineating subsurface radioactive contamination.

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

Near-Facility 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.

A hand-held micro-rem meter (to measure low-level radiation exposure) was used to survey points along the N-Springs Area, 1301-N Liquid Waste Disposal Facility, and the 1325-N Liquid Waste Disposal Facility. The radiation rates measured in the N Springs Area continued to decline in 1995, reflecting discontinued discharges to the 1301-N Liquid Waste Disposal Facility and the continuing decay of its radionuclide inventory.

The 1995 thermoluminescent dosimeter results indicate that direct radiation levels are highest near facilities that had contained or received liquid effluent from the N Reactor. These facilities primarily include the 1301-N and 1325-N Liquid Waste Disposal Facilities. While the results for these two facilities were noticeably higher than those for other 100-N Area thermoluminescent dosimeter locations, they were approximately 12% lower than exposure levels measured at these locations in 1994.

Two projects (the 1303-N Spacer Silo and the 1304-N Emergency Dump Tank) performed by the Environmental Restoration Contractor had a noticeable impact on radiation dose rates in the 100-N Area in 1995. Work to remove irradiated fuel spacers from the 1303-N Spacer Silo occurred in August. Dose rates around the 105-N Reactor building were significantly elevated during this period. The third quarter average for selected thermoluminescent dosimeters located near the silo reflected this increase. The overall affect of these two cleanup projects around the 105-N Reactor building was a decrease in dose rates to a level lower than those measured before these projects began. During the fourth quarter, reduction of the source term that was previously present in the 1304-N Emergency Dump Tank occurred. This facility was decontaminated during August and September.

This is the third year that thermoluminescent dosimeters have been placed in the 100-K Area, surrounding the 105-K East and 105-K West fuel storage basins and adjacent reactor buildings. Three of the thermoluminescent dosimeters have consistently shown elevated readings due to their proximity to radioactive waste storage areas or stored radioactive rail equipment.

The highest dose rates in the 200/600 Areas 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 1995 by thermoluminescent dosimeters was 120 mrem/yr, which was a decrease of 8% over the average dose rate of 130 mrem/yr measured in 1994.

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 1995 was 140 mrem/yr. This represents a decrease of 18% compared to the average dose rate of 170 mrem/yr measured in 1994. The average annual dose rate at the 300 Area Treated Effluent Disposal Facility in 1995 was 81 mrem/yr, which represents a decrease of 28% compared to the average dose rate of 110 mrem/yr measured in 1994.

The average annual dose rate measured in the 400 Area in 1995 was 77 mrem/yr, which represents an decrease of 32% compared to the average dose rate of 110 mrem/yr measured in 1994.

Investigative Sampling

Investigative sampling was conducted in the operations areas to confirm the absence or 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 that had indicated that radioactive contamination was present
- to conduct preoperational surveys that quantify the radiological/hazardous conditions 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) has created a potential for the spread of contaminants
- to determine the integrity of waste containment systems.

The maximum concentrations of radioactive isotopes from samples collected during these investigations are included in this report.

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 generally have not been identified above background levels in preoperational environmental monitoring samples.

Investigative samples collected in 1995 included air, water, soil (including sediment and radioactive specks), vegetation (e.g., cryptogams and tumbleweeds), a wasp nest, gopher snakes, western rattlesnake, rock doves (domestic pigeon), house finch, deer mice, bat, coyote feces and coyote jawbone.

Investigative samples were collected where known or suspected radioactive contamination was present, or to verify radiological conditions at project sites. In 1995, 41 such samples were analyzed for radionuclides, and 34 showed some level of contamination. In addition, 112 contamination incidents were reported and disposed without isotopic analyses, although field instrument readings were recorded for most, during cleanup operations.

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

Radioactive materials in air were sampled continuously at 40 locations onsite, at the Site perimeter and in nearby and distant communities. Eight of these locations were community-operated environmental surveillance stations that were managed and operated by local school teachers. At all locations, particulates were filtered from the air 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 worldwide from two other sources: naturally occurring radionuclides and radioactive fallout from historical nuclear activities not associated with Hanford. 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 1995, no differences were observed between the annual average total beta air concentrations measured at the Site perimeter and those measured at distant community locations. Air concentrations of total alpha are slightly elevated at the Site perimeter compared to the distant stations; however, the concentrations 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 1995 were slightly elevated at the Site perimeter compared to the distant station; however, the difference was not statistically significant.

Iodine-129 concentrations were statistically elevated at the Site perimeter compared to the distant locations indicating a measurable Hanford source; however, the average concentration at the Site perimeter was only 0.000002% of the DOE Derived Concentration Guide of 70 pCi/m^3. The DOE Derived Concentration Guide is

the air concentration that would result in a radiation dose equal to the DOE public dose limit (100 mrem/yr).

Strontium-90 was detected in 4 of 15 onsite air samples, with the maximum concentration at 0.003% of the DOE Derived Concentration Guide of 9 pCi/m^3. Strontium-90 air concentrations were below the detection limit for all perimeter and distant locations.

Air concentrations of plutonium-238 and americium-241 were below the detection limit for all samples collected in 1995.

Plutonium-239,240 concentrations were similar for air samples collected at the Site perimeter and the distant locations. The maximum plutonium-239,240 air concentration was 0.02% of the DOE Derived Concentration Guide of 0.1 pCi/m^3.

Twelve air samples were collected at several Hanford Site locations for polychlorinated biphenyls, polycyclic aromatic hydrocarbons, chlorinated pesticides, and phthalate plasticizers. The average total polychlorinated biphenyls concentrations ranged from 490 - 660 pg/m^3. Fourteen polycyclic aromatic hydrocarbons were found above the detection limit, with phenanthrene having the highest average values (800 - 2,500 pg/m^3). Fluoranthene, pyrene, fluorene, chrysene, and benzo(b)fluoranthene were the only other polycyclic aromatic hydrocarbons with average concentrations above 100 pg/m^3. Sixteen chlorinated pesticides were found above the detection limits, with Endosulfan I (550 - 3,500 pg/m^3) and Endosulfan II (65 - 750 pg/m^3) having the highest average concentrations. The average air concentrations for all other chlorinated pesticides were below 100 pg/m^3. No phthalate plasticizers were found above the detection limits.

There are no ambient air standards for these organic pollutants; therefore, the air concentrations measured on the Hanford Site were compared to risk-based concentrations. Air samples with concentrations below the risk-based concentrations have associated risks that are less than 1×10^{-6} for cancer risk and less than 1.0 of a hazard quotient for non-cancer risk. All polycyclic aromatic hydrocarbons and chlorinated pesticide concentrations were below the applicable risk-based concentrations. The detection limits for the phthalate plasticizers were well below the risk-based concentrations. All individual polychlorinated biphenyl concentrations and the average total polychlorinated biphenyls air concentrations were below the risk-based concentrations; however, the maximum total polychlorinated biphenyls concentrations exceeded the risk-based concentrations by a factor of two.

Surface Water and Sediment Surveillance

The Columbia River was one of the primary environmental exposure pathways to the public during 1995 as a result of past operations at the Hanford Site. Radiological and chemical contaminants entered the river along the Hanford Reach primarily through 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 identified routinely in Columbia River water during the year, concentrations remained extremely low at all locations and were well below standards. The concentrations of tritium and total uranium were significantly higher (5% significance level) at the Richland Pumphouse (downstream from the Site) than at Priest Rapids Dam (upstream from the Site), indicating contribution along the Hanford Reach. Transect sampling in 1995 revealed elevated tritium concentrations along the Benton County shoreline near the 100-N Area, old Hanford Townsite, 300 Area, and the Richland Pumphouse. Total uranium concentrations were elevated along both the Benton and Franklin Counties shorelines near the 300 Area and Richland Pumphouse. The highest total uranium concentration was measured near the Franklin County shoreline of the Richland Pumphouse transect and likely resulted from ground-water seepage and irrigation return canals east of the river.

Several metals and anions were detected both upstream and downstream of the Hanford Site. Copper concentrations were slightly elevated along the Benton County shoreline of the 300 Area transect. Lead and zinc concentrations were elevated along the Benton County shoreline of the Richland Pumphouse transect during sampling in June. Nitrate concentrations were elevated along the Franklin County shoreline of the old Hanford Townsite, 300 Area, and Richland Pumphouse transects and likely resulted from ground-water seepage associated with extensive irrigation north and east of the Columbia River. With the exception of nitrate, which had the highest average quarterly concentration at the Richland Pumphouse, no consistent differences were found between average quarterly contaminant concentrations in the Vernita Bridge and Richland Pumphouse transect samples. All metal and anion concentrations in Columbia River water collected in 1995 were less than Washington State ambient surface water quality criteria levels for acute toxicity. However, chronic toxicity levels for lead were

exceeded in all Columbia River transect samples with the exception of those collected along the 300 Area transect. Volatile organic compounds were not routinely detected in Columbia River water in 1995.

In 1995, samples of Columbia River surface sediments were collected from permanently-inundated monitoring sites above McNary Dam (downstream of the Site) and Priest Rapids Dam (upstream of the Site), and along the Hanford Reach. Regional median concentrations of beryllium-7, strontium-90, and plutonium-239,240 were highest in sediment collected above McNary Dam. The regional median concentration of cobalt-60 was highest in sediment collected along the Hanford Reach. Sediment samples were also collected from five periodically-inundated Columbia Riverbank springs in 1995. The highest concentrations of measured radionuclides were generally detected in sediment collected from the old Hanford Townsite riverbank spring. Exceptions include uranium-235 and -238, which were highest in sediment collected from the 300 Area riverbank spring, and europium-155, which was highest in sediment collected from the 100-K Area riverbank spring.

Levels of all measured metals were detected in all Columbia River sediment samples with the exceptions of silver, detected only above McNary Dam, and antimony, detected mainly in riverbank spring sediment. Regional median concentrations of most metals were highest in McNary Dam sediments. The highest median concentration of chromium, however, was found in riverbank spring sediment; maximum concentrations of chromium occurred in the 100-K Area, 100-B Area, and 100-F Area riverbank spring sediment.

Water samples were collected from eight Columbia River shoreline springs in 1995, contaminated as a result of past waste disposal practices at the Hanford Site. All radiological contaminant concentrations measured in riverbank spring water in 1995 were less than DOE Derived Concentration Guides. However, strontium-90 in the 100-H Area spring, and tritium in the 100-B Area and old Hanford Townsite riverbank springs, exceeded the Washington State ambient surface water quality criteria levels. There are currently no ambient surface water quality criteria levels directly applicable to uranium. However, total uranium exceeded the Site-specific proposed EPA drinking water standard in the 300 Area riverbank spring. Tritium concentrations were highest in the 100-B Area and old Hanford Townsite riverbank springs. Strontium-90 and technetium-99 concentrations were highest in the 100-H Area riverbank spring, iodine-129 concentrations were highest in the vicinity of the old Hanford Townsite, and total uranium concentrations were highest in the 300 Area riverbank spring.

All nonradiological contaminants measured in riverbank springs located on the Hanford shoreline in 1995 were below Washington State ambient surface water acute toxicity levels with the exceptions of copper and zinc in the 100-K Area spring. The chronic toxicity level of cadmium and the EPA standard for trichloroethylene were also exceeded at the 100-K Area spring. Note that riverbank spring sampling protocol does not lend itself to a direct comparison of most metal concentrations measured in riverbank springs to ambient surface water acute and chronic toxicity levels. The standards are used instead as a point of reference. Metal concentrations measured in riverbank springs in 1995 were highest in the 100-K Area riverbank spring with the exception of the chromium concentration, which was highest in the 100-D Area spring. Nitrate concentrations were highest in the 100-D, 100-H, and 100-F Area springs. Trichloroethylene concentrations were highest in the 100-K Area spring.

Water was collected from three onsite ponds located near operational areas in 1995. Although the ponds were not accessible to the public and did not constitute a direct offsite environmental impact during 1995, they were accessible to migratory waterfowl and other animals. As a result, a potential biological pathway existed for the removal and dispersal of onsite pond contaminants. With the exception of uranium-234 and -238 in the October sample of West Lake, radionuclide concentrations in the onsite pond water were below DOE Derived Concentration Guides. The average annual total beta concentration in West Lake exceeded the ambient surface water quality criteria level. Concentrations of most radionuclides in water collected from all three ponds during 1995 were similar to those observed during past years. However, the tritium concentration in the July sample from the Fast Flux Test Facility Pond was much higher than that observed previously. The elevated level most likely resulted from the use of a backup water supply in the 400 Area during June and July of 1995. The primary source of water to the Fast Flux Test Facility Pond is 400 Area sanitary water.

Offsite water, used for irrigation and/or drinking water, was sampled in 1995 to determine radionuclide concentrations in water used by the nearby public. All radionuclide concentrations measured in offsite water supplies were below DOE Derived Concentration Guides and drinking water standards. The proposed EPA drinking

water standard for total uranium, however, was exceeded at one location. Total uranium concentrations observed in offsite water supplies were comparable to those reported by the state of Washington elsewhere in Franklin county and were not attributable to Hanford operations. Radionuclide concentrations in offsite irrigation water were below DOE Derived Concentration Guides and ambient surface water quality criteria levels and were similar to those observed in Columbia River water.

Hanford Site Drinking Water Surveillance

Surveillance of Hanford Site drinking water was conducted to verify the quality of water supplied by Site drinking water systems and to comply with regulatory requirements. Radiological monitoring was performed by the Pacific Northwest National Laboratory and Westinghouse Hanford Company, and nonradiological monitoring was conducted by ICF Kaiser Hanford. Radiological results are discussed in this report, and nonradiological results are reported directly to the Washington State Department of Health.

During 1995, radionuclide concentrations in Hanford Site drinking water were similar to those observed in recent years and were in compliance with Washington State Department of Health and EPA annual average drinking water standards. Slightly elevated tritium levels (~20,000 pCi/L) were recorded in 400 Area drinking water during June and July 1995, when a backup water supply was used. However, the annual average tritium concentration for the 400 Area (8,424 pCi/L) was in compliance with the established standard.

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 around the Site. Samples were analyzed for cesium-137, cobalt-60, iodine-129, plutonium-238, plutonium-239,240, strontium-90, technetium-99, tritium, and uranium isotopes.

Most of the farm products sampled did not contain measurable concentrations of these radionuclides. Tritium levels in wine have been reported in the past at levels higher than could be confirmed at other laboratories where split samples were sent for analyses. This discrepancy was found to be caused by analyzing the initial distillates from the sample. These distillates also contained alcohol, which produces spuriously high results. By analyzing distillates obtained after the alcohol was distilled, the bias was eliminated. Other radionuclides that are infrequently detected at levels close to detection limits are generally considered background levels. Iodine-129 in milk and strontium-90 in alfalfa, which occur in their respective media in very small concentrations, may be linked to past Hanford operations. Their concentrations have been decreasing to background levels over the past six years.

Fish and Wildlife Surveillance

Analysis of wildlife for radionuclides indicated that some species had accumulated levels of radionuclides greater than background levels. Strontium-90 was detected in the offal of Columbia River whitefish and suckers at levels slightly exceeding levels found in a population of whitefish upstream in the Wenatchee River. Manmade radionuclides were not detected in fillets of whitefish. Similar levels of strontium-90 were also measured in goose eggshells collected from Hanford Reach islands and a background island located in the Priest Rapids dam impoundment upstream of the Site. Populations of geese were also sampled from the Reach. Strontium-90 was observed in bone at levels consistent with background levels of strontium-90 in the riverine ecosystem. Cesium-137 was intermittently detected in muscle samples. Collectively, the levels of radionuclides measured in Hanford fish and wildlife indicate accumulations of small amounts of specific radionuclides that possibly originated either from historic fallout or Hanford Site activities.

Soil and Vegetation Surveillance

Soil and vegetation samples were not collected in 1995. Sampling will be conducted periodically in the future consistent with ongoing Site cleanup activities.

External Radiation Surveillance

Radiological dose rates were measured at various locations, both on and off the Hanford Site, using thermoluminescent dosimeters. Contributors to the measured radiological doses included natural and artificial sources. In 1995, a new thermoluminescent dosimeter system, including new dosimeters and new readers, was employed to measure dose rates at the Hanford Site. In 1995, dose rates declined when compared to dose rates measured in 1994 (using the old system).

The average background radiological dose rate, calculated from thermoluminescent dosimeter results from Yakima and Sunnyside, and a new location at Heritage College in Toppenish (all locations are considered distant and upwind relative to Hanford), was 72 ± 8 mrem/yr as compared to the average downwind perimeter dose rate of 86 ± 8 mrem/yr. These represent an approximate 25% decrease in the background and a 23% decrease in the perimeter locations when compared to 1994 results. The decreases are attributable to changes in thermoluminescent dosimeter locations, natural variation between these locations, and the new thermoluminescent dosimeter system. The average dose rate measured onsite (86 ± 4 mrem/yr) was higher than either the average perimeter or the average background dose rates.

Dose rates at the Columbia River shoreline near the 100-N Area were approximately twice the typical shoreline dose rates. The higher 100-N shoreline dose rates may be attributable to radiation from the 100-N Area liquid waste disposal facilities and work done in the 100-N Area during the third quarter of the calendar year.

Ground-Water Protection and Monitoring

Radiological and chemical constituents in ground water were monitored during 1995 throughout the Hanford Site in support of the overall objectives described in Section 4.0, "Environmental Surveillance Information." 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 the Resource Conservation and Recovery Act, additional monitoring was conducted to assess the impact that specific facilities have had on ground-water quality. During 1995, approximately 800 Hanford Site wells were sampled to satisfy ground-water monitoring needs. As discussed in Section 4.2, "Surface Water Surveillance," 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 Maximum Contaminant Levels (or Drinking Water Standards) (Table C.2, Appendix C) and DOE's Derived Concentration Guides (Table C.5, Appendix C). Ground water beneath the Hanford Site is used for drinking at three locations. In addition, water supply wells for the City of Richland are located near 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 at levels greater than the Drinking Water Standard in one or more wells onsite. Concentrations of tritium greater than the DOE Derived Concentration Guide were detected in the 200 Areas. Concentrations of strontium-90 greater than the DOE Derived Concentration Guide were detected in the 100-K Area, 100-N Area, and 200-East Area. Concentrations of uranium greater than the DOE Derived Concentration Guide were detected in the 200-West Area. Plutonium concentrations greater than the DOE 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 at levels of more than one-half 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 recharge ponds associated with 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-B, 100-D, and 100-F Areas.

Cobalt-60 was detected in the 600 Area north of the 200-East Area at levels above the Drinking Water Standard.

The strontium-90 plume in the 100-N Area, which contains concentrations greater than the DOE Derived Concentration Guide, discharges to the Columbia River. Localized areas in both the 100-K Area and 200-East Area also contain strontium-90 at levels greater than the DOE Derived Concentration Guide. Strontium-90 is found at levels greater than the Drinking Water Standard in the 100-B, 100-D, 100-F, 100-H, 100-K, and 200-West Areas, and the 600 Area in the former Gable Mountain Pond area. These plumes extend to the Columbia River.

Technetium-99 at concentrations greater than the Drinking Water Standard was found in the northwestern 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 100-H Area and the 200-West Area and adjacent 600 Area. Ground water in one well completed in the upper-confined aquifer in the northern part of the 200-East Area had technetium-99 concentrations above Drinking Water Standards.

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. Iodine-129 exists in ground water above the Drinking Water Standard in the southern part of the 200-West Area and extends into the 600 Area. There is a less extensive iodine-129 plume at levels greater than the Drinking Water Standard in the northcentral part of the 200-West Area.

Cobalt-60 was detected above the Drinking Water Standard in the 600 Area north of 200-East Area in one well completed in the unconfined aquifer and in one well completed in the confined aquifer.

Cesium-137 was detected only in the 200-East Area. Concentrations greater than the Drinking Water Standard were restricted to one well.

Uranium was detected at levels greater than the Drinking Water Standard (proposed) in wells in the 100-F, 100-H, 200-East, 200-West, 300, and 600 Areas. Ground water with uranium concentrations greater than the Drinking Water Standard appears to be discharging to the Columbia River from the 300 Area. Wells near the U Plant in the 200-West Area had concentrations greater than the DOE Derived Concentration Guide.

Plutonium was detected in ground-water samples from two wells in the 200-East Area. The level in one of these wells exceeded the DOE Derived Concentration Guide.

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

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 also 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-B, 100-D, 100-F, 100-H, 100-K, 100-N, 200-East, 200-West, and 600 Areas.

Cyanide was detected above the Drinking Water Standard in one 600 Area well north of the 200-East Area.

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. A less extensive plume of chloroform, which may be a degradation product of the carbon tetrachloride, is associated with the carbon tetrachloride plume. 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 and near the Horn Rapids Landfill was also measured at levels greater than the Drinking Water Standard.

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 diskette included in this annual ground-water monitoring report.

Potential Doses from 1995 Hanford Operations

In 1995, 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, analyses, and the sample results used in these calculations are briefly described in the following summary sections discussing effluent monitoring and environmental surveillance.

The potential dose to the maximally exposed individual in 1995 from Hanford operations was 0.02 mrem (2×10^{-4} mSv), compared to 0.04 mrem (4×10^{-4} mSv) calculated for 1994. The radiological dose to the local population of 380,000 from 1995 operations was 0.3 person-rem (0.003 person-seivert), compared with the dose of 0.6 person-rem (0.006 person-Sv) calculated for 1994 operations. The average per capita dose from 1995 Hanford operations was 0.0009 mrem (9×10^{-6} mSv). The current DOE radiological dose limit for an individual member of the public is 100 mrem/yr (1 mSv/yr), and the national average dose from natural background sources is 300 mrem/yr (3 mSv). The average individual potentially received 0.001% of the standard and 0.0003% 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 a publicly accessible location with the maximum exposure rate. Doses from these sources also would have been small compared to the dose limit.

Dose through the air pathway was 0.06% of the EPA limit of 10 mrem/yr (40 CFR 61).

Meteorological measurements are taken at Hanford to support Site emergency preparedness, Site operations, and atmospheric dispersion calculations. Weather forecasting and the maintenance and distribution of climatological data are provided.

The Hanford Meteorological Station is located on the 200 Area Plateau where the prevailing wind direction is from the northwest during all months. The secondary wind direction is from the southwest. The average wind speed for 1995 was 12.6 km per hour (7.8 mph), which was slightly less than normal, and the peak gust for the year was 98 km per hour (61 mph).

Precipitation for 1995 totaled 31.3 cm (12.3 in.), 196% of normal, with 19.6 cm (7.7 in.) of snow recorded. 1995 was the wettest year on record.

Temperatures for 1995 ranged from -13.3°C (8°F) in January and February to 40.6°C (105°F) in July.

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 DOE Richland Operations Office in 1987 as part of the Pacific Northwest National 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.

The community-operated environmental surveillance program was initiated in 1990 to increase the public's involvement in and awareness of Hanford's surveillance program. Eight surveillance stations were operating in 1995.

Quality Assurance

Comprehensive quality assurance programs, which include various quality control practices and methods to verify data, are maintained to ensure data quality. The quality assurance programs are implemented through quality assurance plans designed to meet requirements in the American National Standards Institute/American Society of Mechanical Engineers NQA-1 quality assurance program document and DOE Orders. Quality assurance plans are maintained for all activities, and auditors verify conformance. 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.

Report Contributors

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Helpful Information

Helpful Information

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 and may be obtained by following directions given 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 by using scientific notation written 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 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 be 0.00002.

Metric Units

The primary units of measurement used in this report are metric. Table H.1 summarizes and defines the terms and corresponding symbols (metric and nonmetric). A conversion table is also provided (Table H.2).

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.3). 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, radioactivity values are expressed with two sets of units, one of which is usually included in parentheses 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.

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.4). 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 exposure to natural background radiation (see "Hanford Public Radiation Dose in Perspective" in Section 5.0 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.5

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 (or ft^3/s)	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 feet
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)
yd^3	cubic yard	lb	pound
		wt%	weight percent
		Concentration:	
		ppb	parts per billion
		ppm	parts per million

Chemical and Elemental Nomenclature

Chemical contaminants are also discussed in this report. Table H.6 lists many of the chemical (or element) names, and their corresponding symbols, used in this report.

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, which is an uncertainty term known as either the two-sigma counting error or the total propagated analytical uncertainty. 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 radioactive emissions. Such values are considered to be below detection. Each radioactive

Table H.2. 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	0.2642	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
yd^3	0.7646	m^3	m^3	1.308	yd^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
becquerel	27	pCi	pCi	0.03704	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
metric ton	1.1	ton	ton	0.9078	metric ton

Table H.3. 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

Table H.4. 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.5. 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	^{228}Ac	actinium-228	6.13 h
^{95}Nb	niobium-95	35 d	^{232}Th	thorium-232	1.4×10^{10} yr
^{95}Zr	zirconium-95	64 d	U or uranium[b]	uranium total	---
^{99}Mo	molybdenum-99	66 h	^{234}U	uranium-234	2.4×10^{5} yr
^{99}Tc	technetium-99	2.1×10^{5} yr	^{235}U	uranium-235	7×10^{8} yr
^{103}Ru	ruthenium-103	39.3 d	^{236}U	uranium-236	2.3×10^{7} yr
^{106}Ru	ruthenium-106	368 d	^{238}U	uranium-238	4.5×10^{9} yr
^{125}Sb	antimony-125	2.8 yr	^{238}Pu	plutonium-238	87.7 yr
^{129}I	iodine-129	1.6×10^{7} yr	^{239}Np	neptunium-239	2.4 d
^{131}I	iodine-131	8 d	^{239}Pu	plutonium-239	2.4×10^{4} yr
^{133}Ba	barium-133	10.7 yr	^{240}Pu	plutonium-240	6.5×10^{3} yr
^{134}Cs	cesium-134	2.1 yr	^{241}Pu	plutonium-241	14.4 yr
^{137}Cs	cesium-137	30 yr	^{241}Am	americium-241	432 yr

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

measurement must have the random background radioactivity of the measuring instrument subtracted; therefore, negative results are possible when background counts are high and there are few radioactive emissions from the sample.

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). If the data fluctuate randomly, then two times the 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 two times the 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

Graphs are useful when comparing numbers collected at several locations or at one location over time. Graphs

Table H.6. Elemental and Chemical Constituent 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		

make it easy to visualize differences in data where they exist. However, while graphs may make it easy 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 3,000 g/L (Figure H.1). A logarithmic plot of these same two numbers allows the reader to clearly see both data points (Figure H.2).

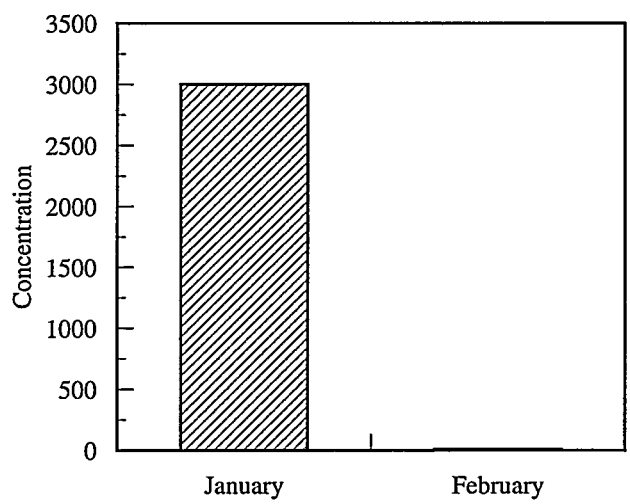

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Figure H.1. Data Plotted Using a Linear Scale

The mean (also called average) and median (the middle value when scores are arranged in increasing or decreasing

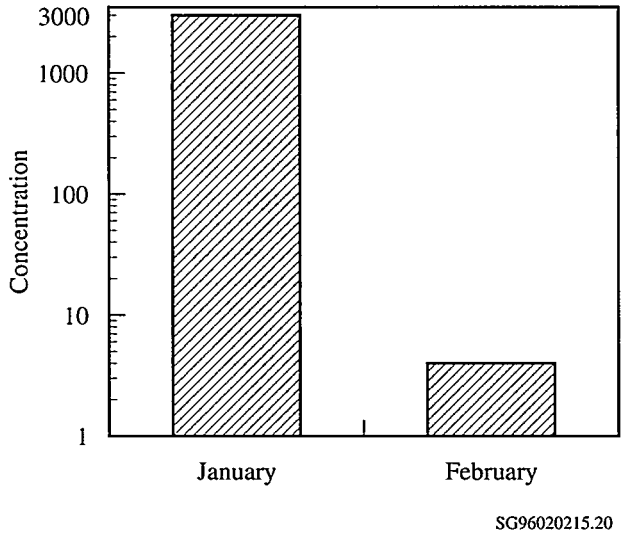


Figure H.2. Data Plotted Using a Logarithmic Scale

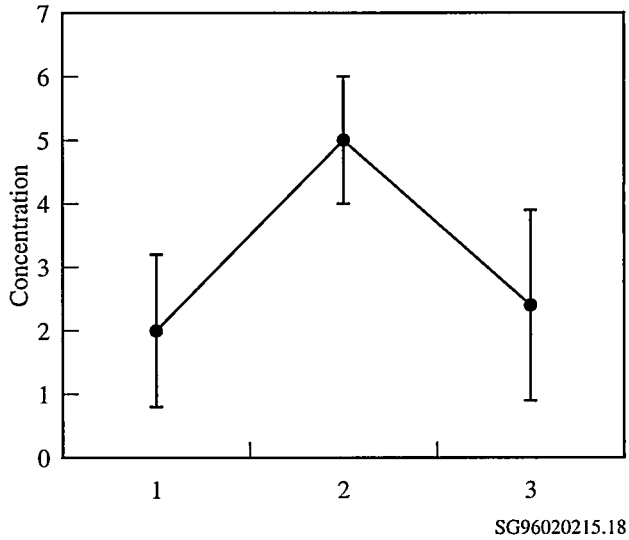


Figure H.3. Data with Error Bars Plotted Using a Linear Scale

order) values graphed in this report have vertical lines extending above and below the data point. When used with a mean value, these lines (called error bars) 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 ± 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 mean value. These bars provide a quick visual indication that one mean may be statistically similar to or different from another mean. If the error bars of two or more means overlap, as is the case with means 1 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.

When vertical lines are used with median values, the lower end of each bar represents the smallest (minimum) concentration measured, and the upper end of each bar represents the maximum concentration measured. Median, maximum, and minimum values are used in place of mean and standard error values when there are too few analytical results to accurately determine the error of the mean.

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. An inequality symbol used with an underscore (≤ or ≥) indicates that the actual value is less-than-or-equal-to or greater-than-or-equal-to the number given, respectively.

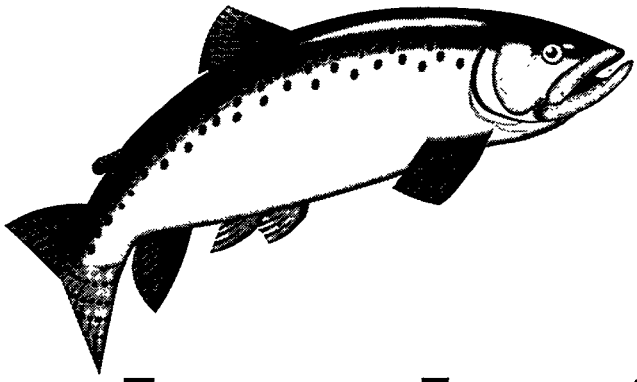
Acronyms and Abbreviations

Most acronyms and abbreviations have been deleted from this report. Commonly recognized acronyms that are used are defined in Table H.7.

(a) Assuming the Normal statistical distribution of the data.

Table H.7. Acronyms and Abbreviations

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CFR	Code of Federal Regulations
DDT	dichlorodiphenyltrichloroethane
DHHS	U.S. Department of Health and Human Services
DOE	U.S. Department of Energy
DOH	Washington State Department of Health
EPA	U.S. Environmental Protection Agency
FR	Federal Register
HAMMER	Hazardous Materials Management and Emergency Response (Training Center)
ICP	inductively coupled plasma (method)
ICRP	International Commission on Radiological Protection
IT	International Technology Corporation
LEPS	low-energy photon spectra
NASQAN	Natural Stream Quality Accounting Network
NCRP	National Council on Radiation Protection and Measurements
NRC	U.S. Nuclear Regulatory Commission
NTU	nephelometric turbidity unit
PCB	polychlorinated biphenyl
PSD	prevention of significant deterioration
PUREX	Plutonium-Uranium Extraction (Plant)
RCW	Revised Code of Washington
REDOX	Reduction-Oxidation (Plant)
SE	standard error
SEM	standard error of the mean
SI	International System of Units
TLD	thermoluminescent dosimeter
UNSCEAR	United Nations Science Committee on the Effects of Atomic Radiation
USGS	U.S. Geological Survey
VOC	volatile organic compound
WAC	Washington Administrative Code
WDSHS	Washington Department of Social and Health Services



Introduction

1.0 Introduction

The Hanford Site environmental report is produced through the joint efforts of the principal Site contractors (Pacific Northwest National Laboratory, Westinghouse Hanford Company, Bechtel Hanford Inc.) 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 and its history, discusses the current Site mission, and briefly highlights the Site's various waste management, effluent monitoring, environmental surveillance, and environmental compliance programs. Included are summary data and program descriptions for the site-wide Ground-Water Monitoring Program, the Near-Facility Environmental Monitoring Program, the Surface Environmental Surveillance Program, the Hanford Cultural Resources Laboratory, wildlife studies, climate and meteorological monitoring, and information about other programs. Also included are sections discussing environmental occurrences, current issues and actions, environmental cleanup activities, compliance issues, and descriptions of major operations and activities. 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 *Environmental Monitoring Plan* (DOE 1994a).

Overview of the Hanford Site

The Hanford Site lies within the semiarid Pasco Basin of the Columbia Plateau in southeastern Washington State (Figure 1.0.1). The Site occupies an area of about 1,450 km^2 (approximately 560 mi^2) located north of the city of Richland and the confluence of the Yakima River with the Columbia River. This large area has restricted public access and provides a buffer for the smaller areas onsite that historically were used for production of nuclear materials, waste storage, and waste disposal. Only 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 Site boundary. The Yakima River flows near a portion of the southern boundary and joins the Columbia River downstream from the city of Richland.

The cities of Richland, Kennewick, and Pasco (Tri-Cities) constitute the nearest population center and are located southeast of the Site. Land in the surrounding environs is used for 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.

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 (USBC 1994) revealed that the population of Benton and Franklin counties is young, with 57% of the total population under the age of 35, compared with 44% of the total state population. An examination of age groups reveals that the largest age group in Benton and

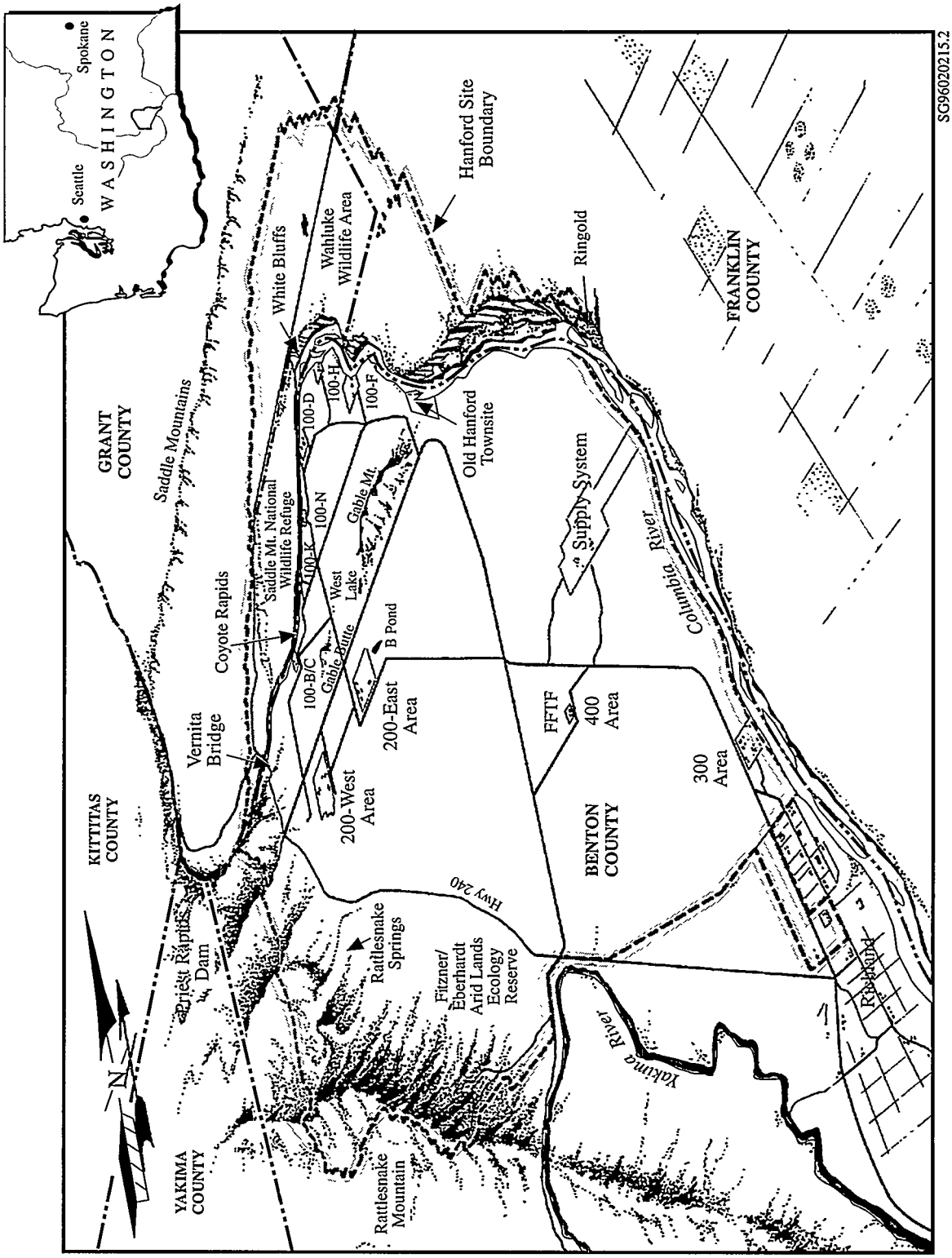


Figure 1.0.1. The Hanford Site and Surrounding Area

Franklin counties ranges from 5 to 17 years old, representing 23.2% of the total bicounty population; the largest age group in the state also ranges from 5 to 17 years and represents about 18.4% of the total state population. The bicounty Hispanic population is approximately 19% compared to the state average of 4.4%. Annual income for the bicounty area averages $28,600 while the state average is $31,000.

Site Description

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. 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. The 200 Areas cover about 16 km^2 (6 mi^2).
- The 300 Area is located just north of the city of Richland. 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.
- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, 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 facilities for ICF Kaiser Hanford Company and Boeing Computer Services. In 1995, both Kaiser and Boeing were in the process of vacating this area so that it can be made available for other uses. The Richland North Area includes the DOE and DOE contractor facilities, mostly office buildings, located between the 300 Area and the city of Richland that are not in the 1100 and 3000 Areas.

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 special designations. These include the Fitzner/Eberhardt Arid Lands Ecology 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 Fitzner/Eberhardt Arid Lands Ecology 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.

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 facility near Rattlesnake Mountain on the Hanford Site for gravitational wave studies.

Much of the above information is from Cushing (1995), where more detailed information can be found.

Historical Site Operations

The Hanford Site was established in 1943 to use technology that was developed at the University of Chicago and the Clinton Laboratory in Oak Ridge, Tennessee to produce plutonium for some of the nuclear weapons tested and used in World War II. Hanford was the first plutonium production facility in the world. Nearly all technology was developed as it was needed. The site was selected by the U.S. Army Corps of Engineers because it was remote from major populated areas. The site had ample electrical power from Grand Coulee Dam, a functional railroad, clean water available from the nearby Columbia River, and sand and gravel available onsite

that could be used for constructing large concrete structures. For security, safety, and functional reasons the Site was divided into numbered areas (Figure 1.0.1).

Hanford Site operations have resulted in the production of liquid, solid, and gaseous wastes. Most wastes resulting from Site operations have had at least the potential to contain radioactive materials. From an operational standpoint, radioactive wastes were originally categorized as "high level," "intermediate level," or "low level," which referred to the level of radioactivity present. Some high level solid waste, such as large pieces of machinery and equipment, were placed onto railroad flatcars and stored in underground tunnels. Both intermediate and low level solid wastes consisting of tools, machinery, paper, wood, etc., were placed into covered trenches at storage and disposal sites known as "burial grounds." Beginning in 1970, solid wastes were segregated according to the makeup of the waste material. Solids containing plutonium and other transuranium materials were packaged in special containers and stored in lined trenches covered with soil for possible later retrieval. High level liquid wastes were stored in large underground tanks. Intermediate level liquid waste streams were usually routed to underground structures of various types called "cribs." Occasionally, trenches were filled with the liquid waste and then covered with soil after the waste had soaked into the ground. Low level liquid waste streams were usually routed to surface impoundments (ditches and ponds). Nonradioactive solid wastes were usually burned in "burning grounds." This practice was discontinued in the late 1960s in response to the Clean Air Act, and the materials were instead buried at sanitary landfill sites. These storage and disposal sites, with the exception of high level waste tanks, are now designated as "active" or "inactive" waste sites, depending on whether or not the site currently is receiving wastes.

The 300 Area

From the early 1940s to the present, most research and development activities at the Hanford Site were carried out in the 300 Area, located just north of Richland (Figure 1.0.2). The 300 Area was also the location of nuclear fuel fabrication. Nuclear fuel in the form of pipe-like cylinders (fuel slugs) was fabricated from metallic uranium shipped in from offsite production facilities. Metallic uranium was extruded into the proper shape and encapsulated in aluminum or zirconium cladding. Copper was an important material used in the extrusion process, and substantial amounts of copper, uranium, and other heavy metals ended up in 300 Area liquid waste streams. Initially, these streams were routed to the 300 Area waste ponds, which were located near the Columbia River shoreline. In more recent times, the low level liquid wastes were shipped to a solar evaporation facility in the 100-H Area (100-H Area Basins).

The 100 Areas

The fabricated fuel slugs were shipped by rail from the 300 Area to the 100 Areas. The 100 Areas are located on the shore of the Columbia River, where up to nine nuclear reactors were in operation (see Figures 4.8.23, 4.8.24, 4.8.26, and 4.8.37 in Section 4.8, "Ground-Water Protection and Monitoring Program"). The main component of the nuclear reactors consisted of a large stack (pile) of graphite blocks that had tubes and pipes running through it. The tubes were receptacles for the fuel slugs while the pipes carried water to cool the graphite pile. Placing large numbers of slightly radioactive uranium fuel slugs into the reactor piles created an intense radiation field and a radioactive chain reaction that resulted in the conversion of some uranium atoms into plutonium atoms. Other uranium atoms were split into radioactive "fission products." The intense radiation field also caused some nonradioactive atoms in the structure to become radioactive "activation products."

The first eight reactors, constructed between 1944 and 1955, used water from the Columbia River for direct cooling. Large quantities of water were pumped through the reactor piles and discharged back into the river. The discharged cooling water contained small amounts of radioactive materials that escaped from the fuel slugs, tube walls, etc., during the irradiation process. The radiation fields in the piles also caused some of the impurities in the river water to become radioactive (neutron activation). The ninth reactor, N Reactor, was completed in 1963 and was a slightly different design. Purified water was recirculated through the reactor core in a closed-loop cooling system. Beginning in 1966, the heat from the closed-loop system was used to produce steam that was sold to the Washington Public Power Supply System to generate electricity at the adjacent Hanford Generating Plant.

When fresh fuel slugs were pushed into the front face of a reactor's graphite pile, irradiated fuel slugs were forced out the rear into a deep pool of water called a "fuel storage basin." After a brief period of storage in the basin and further storage in special freight cars on a railroad siding, the irradiated fuel slugs were transported by rail to the 200 Areas where the plutonium was recovered.

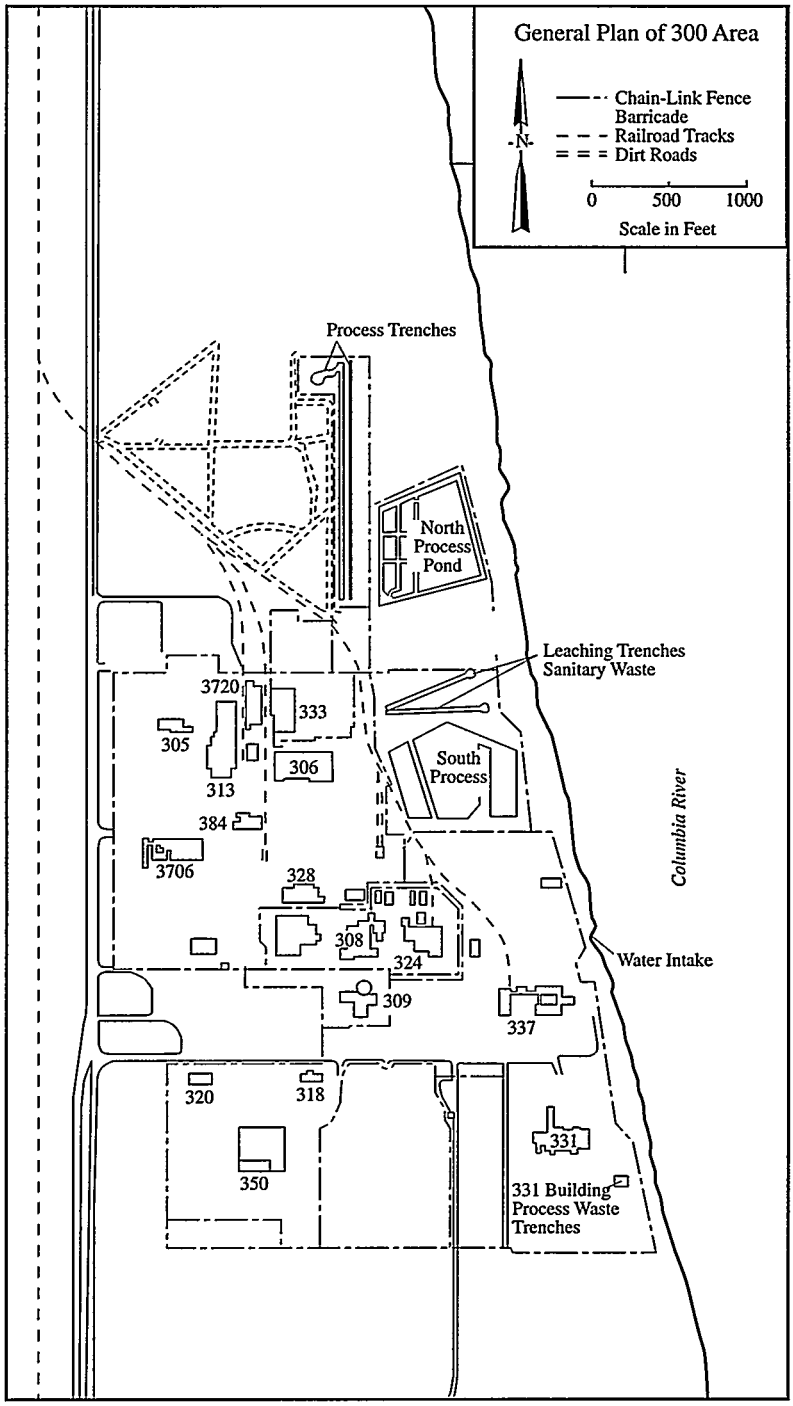


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Figure 1.0.2. The 300 Area, Located Just North of Richland

Most of the irradiated fuel slugs produced at N Reactor from the mid-1970s to late 1983 were transported by rail car to the 100-K East and 100-K West fuel basins for "temporary" storage, where they remain today.

The 200 Areas

The 200-East and 200-West Areas are located on a plateau about 11 km and 8 km (7 and 5 mi), respectively, south of the Columbia River. These areas housed facilities that received and dissolved irradiated fuel and then separated out the valuable plutonium (Figure 1.0.3). These facilities were called "separations plants." Three types of separations plants were used over the years to process irradiated fuel. Each of the plutonium production processes began with the dissolution of the aluminum or zirconium cladding material in ammonium hydroxide followed by the dissolution of the irradiated fuel slugs in nitric acid. All three separations plants therefore produced large quantities of waste nitric acid solutions containing high levels of radioactive materials. These wastes were neutralized and stored in large underground tanks. Fumes from the dissolution of cladding and fuel, and from other plant processes, were discharged to the atmosphere from tall smokestacks, that were filtered after 1950.

Both B Plant and T Plant used a "bismuth phosphate" process to precipitate and separate plutonium from acid solutions during the early days of Hanford operations. Leftover uranium and high level waste products were not separated and were stored together in large underground "single-shell" tanks, i.e., tanks constructed with a single wall of steel. The leftover uranium was later salvaged, purified into uranium oxide powder at the Uranium-TriOxide Plant, and transported to uranium production facilities in other parts of the country for reuse. This salvage process used a solvent extraction technique that resulted in radioactive liquid waste that was disposed to ground in covered trenches at the B-C Cribs Area south of the 200-East Area. Cooling water and steam condensates from B Plant went to B Pond, cooling water and steam condensates from T Plant went to T Pond, and cooling water and steam condensates from U Plant and the Uranium-TriOxide Plant were routed to U Pond.

After T Plant stopped functioning as a separations facility it was converted to a decontamination operation where large pieces of equipment and machinery could be cleaned up for reuse. B Plant was later converted into a facility to separate radioactive strontium and cesium from high level waste. The strontium and cesium were then concentrated into a solid salt material, melted, and encapsulated at the adjacent Encapsulation Facility. Canisters of encapsulated strontium and cesium were stored in a water storage basin at the Encapsulation Facility.

The REDOX (reduction oxidation) Plant (200-West Area) and PUREX (plutonium-uranium extraction) Plant (200-East Area) used solvent extraction techniques to separate plutonium from leftover uranium and radioactive waste products. Most of the irradiated fuel produced at Hanford was processed at either of these two facilities. The solvent extraction method separates chemicals based on their differing solubilities in water and organic solvents, i.e., hexone at the Reduction Oxidation Plant and tributylphosphate at the Plutonium-Uranium Extraction Plant. High level liquid wastes were neutralized and stored in single-shell tanks (Reduction Oxidation Plant) or double-shell tanks (Plutonium-Uranium Extraction Plant). Occasionally, organic materials such as solvents and resins ended up in high level liquid waste streams sent to the tanks. Because the solutions discharged to these tanks were not acidic, various chemicals and radioactive materials precipitated and settled to the bottom of the tanks. This phenomenon was later used to advantage—the liquid waste was heated in special facilities (evaporators) to remove excess water and concentrate the waste into salt cake and sludge, which remained in the tanks. The evaporated and condensed water contained radioactive tritium and was discharged to cribs. Intermediate and low level liquid wastes discharged to ground from the Reduction Oxidation and Plutonium-Uranium Extraction Plants typically contained tritium and other radioactive fission products as well as nonradioactive nitrate. Intermediate level liquid wastes discharged to cribs from the Reduction Oxidation Plant sometimes contained hexone used in the reduction oxidation process. Cooling water from the Reduction Oxidation Plant was discharged to the Reduction Oxidation Ponds. Cooling water from the Plutonium-Uranium Extraction Plant was discharged to Gable Mountain Pond and B Pond.

The Reduction Oxidation and Plutonium-Uranium Extraction Plants produced uranium nitrate for recycle and plutonium nitrate for weapon component production. Uranium nitrate was shipped by tank truck to the Uranium-TriOxide Plant for processing. The Uranium-TriOxide Plant used specially designed machinery to heat the uranium nitrate solution and boil off the nitric acid, which was recovered and recycled to the separation plants. The product, uranium oxide, was packaged and shipped to other facilities in the United States for recycle. Plutonium nitrate, in small quantities for safety reasons, was placed into special shipping containers (P-R cans) and hauled by truck to the Z Plant for further processing.

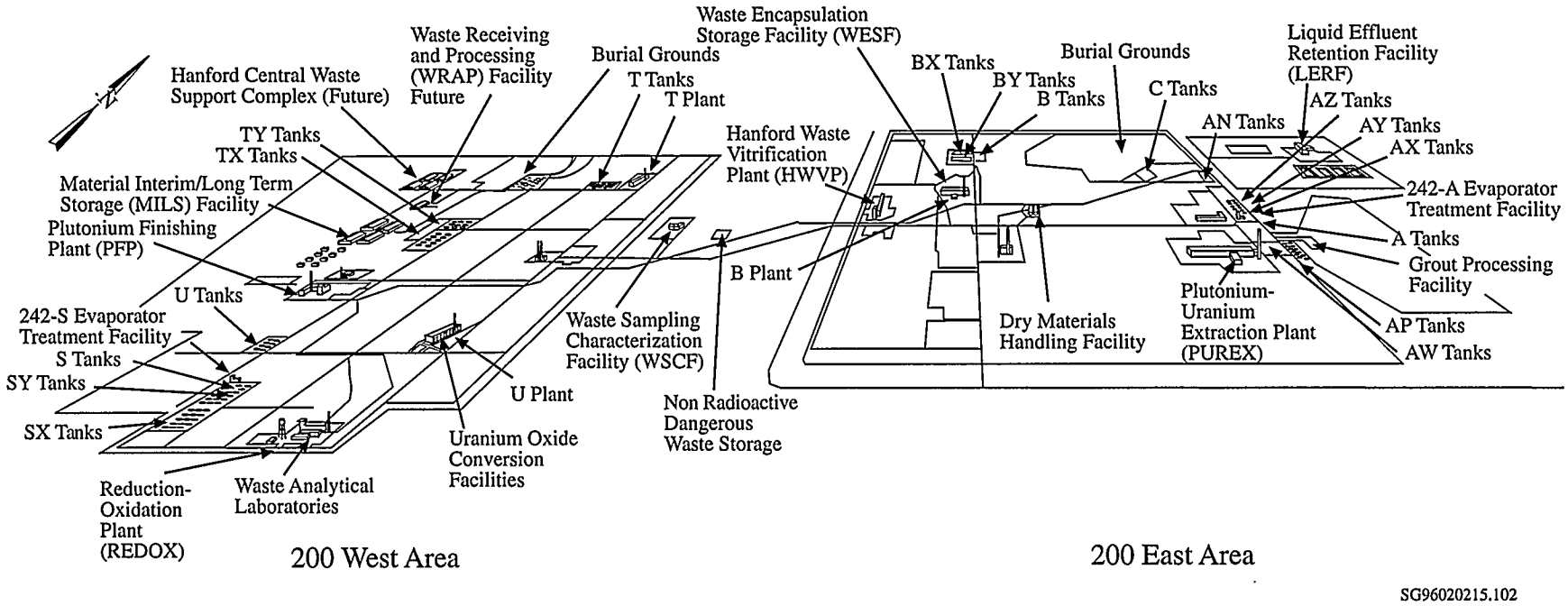


Figure 1.0.3. Waste Storage and Disposal Facilities in the 200 Areas

Plutonium was received at one of several buildings operated over the years that were collectively known as Z Plant, now called the Plutonium Finishing Plant. The purpose of Z Plant (now called the Plutonium Finishing Plant) operations was to convert the plutonium nitrate into plutonium metal blanks (buttons) that were manufactured into nuclear weapons components. The conversion processes used nitric acid, hydrofluoric acid, carbon tetrachloride, and various oils and degreasers. Varying amounts of all these materials ended up in the intermediate level liquid wastes that were discharged to cribs. Cooling water from the Z Plant was discharged via open ditch to U Pond. High level wastes containing plutonium were segregated and packaged for storage in special earth-covered trenches.

The 400 Area

In addition to research and development activities in the 300 Area, the Hanford Site has supported several test facilities. The largest was the Fast Flux Test Facility located in the 400 Area, about 8 km (5 mi) northwest of the 300 Area. This special nuclear reactor was designed to test various types of nuclear fuel. The facility operated for about 13 years and was shut down in 1993. The reactor was a unique design that used liquid metal sodium as the primary coolant. The heated liquid sodium was cooled with atmospheric air in heat exchangers. Spent fuel from the facility resides in the 400 Area, while other wastes were transported to the 200 Areas. With the exception of the spent fuel, no major amounts of radioactive wastes were stored or disposed of at the Fast Flux Test Facility site.

Current Site Mission

For more than 40 years, Hanford Site facilities were dedicated primarily to the production of plutonium for national defense and to the management of the resulting wastes. In recent years, efforts at the Hanford Site have been focused on developing new waste treatment and disposal technologies and cleaning up contamination left over from historical operations.

The current Site mission includes:

- **Management of Wastes** and the handling, storage, and disposal of radioactive, hazardous, mixed, or sanitary wastes from current operations
- **Environmental Restoration** of approximately 2,100 inactive radioactive, hazardous, and mixed waste disposal sites and about 117 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.

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.

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 activities or 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 management and operations contractor, which manages wastes, maintains the Fast Flux Test Facility, Plutonium-Uranium Extraction Plant, 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. Administration of the ICF Kaiser Hanford Company contract is 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 National 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. is the Hanford environmental restoration contractor, with responsibility for remedial action at past-practice waste sites, closure of Resource Conservation and Recovery Act land-based treatment, storage, and disposal units, and decontamination and decommissioning of facilities. The Bechtel Team includes three preselected subcontractors: CH2M Hill, IT Corporation, and ThermoAnalytical, Inc.

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

Major Operations and Activities

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 1.0.3) and the storage of irradiated fuel in the 100-K Area. Key facilities include the waste storage tanks, Low-Level Burial Grounds, 100-K Fuel Storage Basins, Plutonium-Uranium Extraction Plant, Plutonium Finishing Plant, B Plant/Waste Encapsulation Storage Facility, T Plant, 616 Non-Radioactive Hazardous Waste Storage Facility, the Central Waste Complex, the Transuranic Storage and Assay Facility, the Waste Receiving and Processing 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 and episodically released. 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 40-year-old 100-K East and 100-K West Fuel Storage Basins are currently being used to store N Reactor irradiated fuel. In 1995, the strategy for transitioning irradiated fuel from wet storage in the K Basins to dry interim storage in the 200-East Area was further developed. This strategy supports completion of fuel removal from the K Basins three years ahead of the target date of December 2002 stipulated in the Tri-Party Agreement.

The Plutonium-Uranium Extraction 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. After the stabilization run, the Plutonium-Uranium Extraction 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 nitric acid and process solutions have been recovered and the last of the organic component is being flushed from the facility.

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. A series of interim actions have been initiated to enhance safety features to reduce risks in the facility while the environmental impact statement is prepared. Sludge stabilization processing and 10-L container downloading and development testing were completed in 1995. Current plans are to complete stabilization and cleanout of the Plutonium Finishing Plant in accordance with a record of decision for the pending environmental impact statement expected in June 1996.

There are no production activities currently taking place at B Plant/Waste Encapsulation Storage Facility. The current mission is to provide for the safe deactivation of

the B Plant facilities and the safe management of approximately 75 million curies of cesium and strontium in the Waste Encapsulation and Storage Facility.

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 stored in liquid effluent retention basins until treated in the Liquid Effluent Treatment Facility, which started operations in November 1995. The concentrated waste from the evaporator is returned to the double-shell tanks. The Liquid Effluent Treatment Facility was constructed in the 200-East Area to remove regulated chemical constituents from the 242-A Evaporator process condensate. The recovered chemicals are packaged in 55-gal drums and transferred to the Central Waste Complex.

Solid waste is received at the Central Waste Complex from all radioactive waste generators at the Hanford Site and any offsite generators that are authorized by DOE to ship waste to the Hanford Site for treatment, storage, and disposal. The waste received at the Central Waste Complex is generated by ongoing Site operations and research and development activities conducted at the Site. Offsite waste has been primarily from DOE research facilities and other DOE sites. The characteristics of the waste received at the Central Waste Complex vary greatly, from waste that is nondangerous solid low-level waste to solid transuranic mixed waste.

The planned capacity of the Central Waste Complex to store low-level waste and transuranic mixed waste is 15,540 m^3 (20,330 yd^3). This capacity is adequate to store the current projected volumes of mixed waste to be generated through the year 1999, assuming no treatment of the stored waste. Current plans call for treatment of the mixed waste to begin in 1999, which will reduce the amount of waste in storage and make storage room available for newly generated mixed waste. The capacity of the Central Waste Complex to store mixed waste is continually evaluated and additional storage buildings will be constructed if necessary. The majority of waste shipped to the Central Waste Complex is generated in small quantities by routine plant operation and maintenance activities. The dangerous waste designation of each container of waste is determined at its point of generation based on process knowledge of the waste placed in the container or on sample analysis if sufficient process knowledge is unavailable.

The newly constructed Waste Receiving and Processing Facility (planned for operations in March 1997) will have the capability to process retrieved suspect transuranic solid waste (waste that may or may not meet transuranic criteria), certify newly generated and stored transuranic solid waste and low-level waste for either disposal or shipment to the Waste Isolation Pilot Plant in New Mexico (transuranic only), and process small quantities of radioactive mixed low-level waste for permanent disposal. Current funding only addresses low-level waste processing. These capabilities will be in accordance with Land Disposal Restrictions and Hanford Site disposal criteria for low-level waste and in accordance with waste acceptance criteria and transportation criteria for transuranic waste.

Three facilities are in the T-Plant area: the Transuranic Storage and Assay Facility for storage and assay of transuranic waste; the T Plant canyon building used for radiological decontamination of large equipment; and the 2706-T facility used for the repackaging of radioactive wastes and small equipment decontamination. T Plant was selected as the Hanford Site decontamination facility in 1994. Various activities were performed at the facility in 1995 including waste repackaging/processing, equipment decontamination, and verification that waste met acceptance criteria. Other activities that can be done in T Plant are Land Disposal Restriction determination for mixed waste soils; stabilization of toxic characteristic regulated soils; macroencapsulation of debris and contaminated equipment; neutralization and solidification of inorganic labpacks; and neutralization and repackaging of organic labpacks (specially packaged dangerous waste that may or may not originate from a laboratory).

Environmental Restoration

Environmental Restoration includes activities to decommission facilities, clean up inactive waste sites and prevent the spread of contamination. Cost estimates and schedules for all the facilities currently in the program are included in the *Hanford Site Environmental Restoration Project Plan* (DOE 1994b).

The Decontamination and Decommissioning Project conducts surveillance and maintenance of surplus facilities awaiting decommissioning, stabilizes large radioactive contaminated sites, provides for transition of surplus facilities from other programs into the Decontamination

and Decommissioning Project, conducts asbestos abatement Site wide and does the actual decommissioning/ demolition of the buildings.

The surveillance and maintenance activities associated with the inactive, surplus facilities include monitoring the condition of building structures until final decommissioning can be accomplished. These activities will continue for as long as necessary until the structures are successfully demolished. There are currently 117 facilities in the program.

The Site stabilization program is responsible for the decontamination/stabilization of approximately 870 ha (2,150 acres) on the Hanford site, including: inactive cribs; ponds; ditches; trenches; unplanned release sites and burial grounds. These sites have been maintained by performing periodic surveillances, radiation surveys and herbicide applications and by initiating timely responses to problems. The overall objective of this program is to prevent the exposure of the inventories contained within these sites to the natural forces of wind and erosion that would create contamination spread to the environment or personnel.

The facility transition group was set up to act as the gate for all facilities entering the surveillance and maintenance program. This group is tasked with ensuring the programmatic acceptance criteria are met and documented at each building prior to acceptance for long term surveillance and maintenance. In January, 1995, the Uranium-Trioxide Complex was accepted for long term surveillance and maintenance. This was the first application of a formal transition process and end point criteria at Hanford, and possibly the first of its size in the national DOE complex.

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 Richland North 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, cleanup, environmental protection, and Site restoration.

In 1994, the Environmental Restoration Program completed the prototype Hanford waste site barrier, which is instrumented to permit accurate measurement of surface subsidence, water balance, wind and water erosion, and vegetation changes under ambient and elevated precipitation. The first year of testing and monitoring was completed in October 1995. The barrier is intended to prevent the intrusion of water into underground waste sites. Despite an unusually wet year (twice normal precipitation) and an irrigation treatment that elevated the precipitation total to three times the annual average, there was no infiltration of water through the barrier to the underlying wastes. This demonstrates the prototype barrier is effective in preventing infiltration by retaining water above the barrier until it is recycled to the atmosphere by plants. In contrast, drainage was observed from the gravel and basalt side slopes, and there is evidence of a potential waste site infiltration at the periphery of barrier. Wind erosion was confined to the first three months of monitoring, before the soil surface was revegetated. The results of the first year of testing and monitoring of the prototype Hanford barrier represent a unique data set that will prove useful in the performance evaluation of surface barriers in arid and semiarid environments. Testing and monitoring of the prototype Hanford waste site barrier is scheduled to continue in 1996 with continued focus on water balance evaluation, evaluation of side slope performance, response to extreme precipitation events, and establishing an accurate basis for estimating the cost of long-term monitoring of engineered barriers.

Initial field testing of an in situ ground-water cleanup technology, redox manipulation, was performed during 1995. Redox manipulation involves changing the oxidation-reduction state of aquifer sediments so that contaminants dissolved in ground water are destroyed or immobilized. An injectable redox barrier using sodium dithionite as the reductant was successfully field tested in the 100-H Area to address chromate contamination. Extensive monitoring and characterization activities were initiated in 1995. Initial results indicate that reduction of the aquifer sediments was achieved and dissolved chromate concentrations were significantly reduced.

DOE's Tanks Focus Area 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 at 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. A cold test facility for the Light Duty Utility Arm System has been completed in the Fuels and Materials Examination Facility in the 400 Area and is ready for testing activities to be initiated.

The Tanks Focus Area is also supporting the Confined Sluicing End Effector. This tool uses manipulators to position water jets inside waste tanks to dislodge stubborn wastes (e.g., rock-hard saltcake). The dislodged pieces are removed from the tanks using a pneumatic transport system or jet pump transport.

The Pacific Northwest National Laboratory, in conjunction with DOE Richland Operations Office and Westinghouse Hanford Company, successfully completed two Cooperative Research and Development Agreements titled "Adaptation of Commercial Borehole Geophysics for Use at Arid DOE Sites" in 1995. The two largest providers of borehole geophysics for the petroleum industry, Halliburton Energy Services and Schlumberger Well Services, were the industry partners in the agreements. Each successfully adapted three different logging services to support the environmental mission at the Hanford Site and other arid DOE sites. The adapted technologies include: 1) scintillation spectral gamma ray logging for identifying and quantifying both naturally occurring and created radionuclides; 2) neutron-neutron logging for determining subsurface moisture concentrations; and 3) gamma-gamma density logging for determining the bulk density and porosity of the formation surrounding the borehole. Data from these three logging services are used to characterize environmental sites and monitor contaminant migration. Since completion of the agreements, these technologies were deployed by the Hanford Environmental Restoration Contractor in 1995 to characterize several waste sites (see Vadose Zone Characterization in Section 2.3).

Site Environmental Programs

Effluent Monitoring, Waste Management, and Chemical Inventory Programs

Liquid and airborne effluents are monitored or managed through contractor effluent monitoring programs. These programs are designed to monitor effluents at their point of release into the environment whenever possible. 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 1995 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 Programs

The Near-Facility Environmental Monitoring Program is responsible for facility-specific environmental monitoring immediately adjacent to facilities on the Site. 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 1995 programs are summarized in Section 3.2, "Near-Facility Environmental Monitoring."

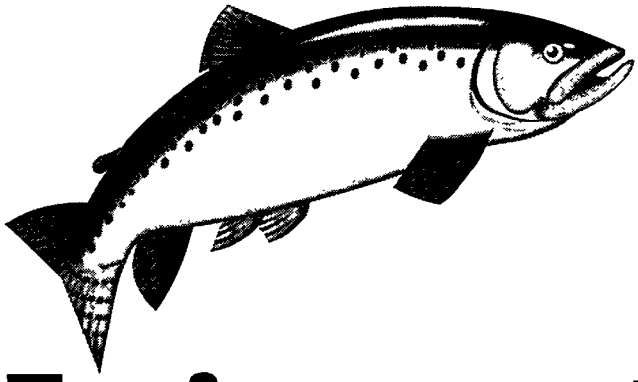
Sitewide Environmental Surveillance Program

The Sitewide environmental surveillance program is conducted by Pacific Northwest National Laboratory 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 to monitor for contaminants from the entire Hanford Site, rather than from specific contractor-owned or managed facilities. Results for the 1995 Sitewide environmental surveillance program are summarized in Section 4.0, "Environmental Surveillance Information."

Other Environmental Programs

Other 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 6.0, "Other Hanford Site Environmental Programs."



Environmental Compliance Summary

2.0 Environmental Compliance Summary

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

2.1 Stakeholder and Tribal Involvement

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 private 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, Washington State Department of Health, 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 the Washington State Department of 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 Washington State Department of Health has direct authority under the Clean Air Act to implement its 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 direct regulatory authority 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, Washington State Department of Ecology, and DOE for achieving environmental compliance at the Hanford Site with the Comprehensive Environmental Response, Compensation, and Liability Act including the Superfund Amendments and Reauthorization Act remedial action provisions, and with Resource Conservation and Recovery Act treatment, storage, and disposal unit regulation and corrective action provisions. The Tri-Party Agreement 1) defines the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act 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 the Washington State Department of 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 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 fishing rights on the Columbia River. The tribes reserved 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 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.

The Hanford Site and its' environment supports a number of Native American foods, medicines, and sacred places that are important in sustaining tribal cultures. The tribes hope to make use of these resources in the future and want to assure themselves that the Hanford environment is clean and healthy.

The DOE American Indian Policy states, "American Indian Tribal Governments have a special government-to-government relationship with the Federal Government of the United States, defined by history, treaties, statutes, court decisions, and the U.S. Constitution." In recognition of this government-to-government relationship, DOE and each tribe interact and consult on a direct basis. The tribes also participate in formal groups such as the State and Tribal Government Working Group, the Hanford Environmental Dose Reconstruction Project's Native American Working Group as well as informal groups working on issues such as the Columbia River Impact Assessment, land use planning, and cultural resources. The tribes have made presentations for DOE and the contractors on treaty rights, tribal sovereignty, the U.S. Government's trust responsibility, and the unique status of tribal governments.

The Tribes' active participation in Hanford plans and activities is guided by DOE's American Indian Policy. The policy states that among other things, "The Department shall: Consult with Tribal governments to assure that Tribal rights and concerns are considered prior to DOE taking actions, making decisions, or implementing programs that may affect Tribes." In addition to the American Indian Policy, 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 require consultation with Tribal governments. The combination of the Treaties of 1855, Federal policy, and laws and regulations provide the basis for Tribal participation in Hanford plans and activities.

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 on the Hanford Site.

Comprehensive Environmental Response, Compensation, and Liability Act Natural Resource Damage Assessment Trustee Activities

The Comprehensive Environmental Response, Compensation, and Liability Act 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 a state lead trustee to coordinate all state trustee responsibilities. 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 that 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 Indian Reservation; the Nez Perce Tribe; the state of Washington represented by the Washington State Department of 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 Comprehensive Environmental Response, Compensation, and Liability Act release. As part of this coordination requirement, DOE meets regularly with the trustees. The objectives of these meetings include the sharing of information about releases of hazardous substances and planned studies and response actions to address those releases. The meetings are further designed to assist the trustees in the determination and mitigation of actual or potential natural resource injuries. The trustees have signed a memorandum of agreement formally establishing the collaborative working group.

Public Participation

Individual citizens of Washington State and neighboring states may influence Hanford Site cleanup decisions through public participation activities. The public has opportunities to provide their input and influence decisions through many forums, including Hanford Advisory Board meetings, Tri-Party Agreement activities, National Environmental Policy Act public meetings covering various environmental impact statements and environmental assessments, and many other outreach programs.

A Site-wide public involvement strategy outlines the DOE Richland Operations Office commitment to, and plan for, involving the public in decisions. The DOE Office of External Affairs is responsible for establishing the planning and scheduling for conducting public participation activities for the Hanford Site.

The Tri-Party Agreement provides a means for Hanford to become compliant with environmental regulatory requirements. The Community Relations Plan, a companion to the Tri-Party Agreement, describes how information and involvement activities are conducted for Tri-Party Agreement decisions. The Community Relations Plan was developed and negotiated among DOE, the Washington State Department of Ecology, and EPA Region 10 with public comment and was jointly approved in 1990. The community relations plan is updated on an as-needed basis, the most recent revision occurring in early 1996.

To apprise the public of upcoming opportunities for public participation, the *Hanford Update*, a synopsis of all ongoing and upcoming Tri-Party Agreement public involvement activities, is published bimonthly. In addition, the *Hanford Happenings* calendar, which highlights Tri-Party Agreement 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 4,500 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 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 information repositories have been established. They are located in Richland, Seattle, and Spokane, Washington, and Portland, Oregon.

The three parties respond to questions that are received via a toll-free telephone line (1-800-321-2008). Members of the public can request information about any public participation activity and receive a response by contacting the DOE Richland Operations Office of External Affairs.

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

national DOE complex. The Board comprises 32 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 four committees: 1) Dollars and Sense, which deals with DOE budget issues, 2) Health, Safety, and Waste Management, 3) Environmental Restoration, and 4) the Board's internal executive 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.

Hanford Site Technology Coordination Group

In November 1989, DOE's Office of Environmental Restoration and Waste Management was established as the central authority for cleaning up the DOE Complex and preventing further environmental contamination. When the Office of Environmental Restoration and Waste Management found that its mission could not be achieved using existing technologies without incurring unreasonable costs, risks, and/or schedule impacts, it implemented a new approach to environmental research and technology development.

The new approach is focused on five major problem areas (plumes, landfills, tanks, mixed waste, and decontamination and decommissioning) that were targeted for action based on risk, prevalence, and need for technology development to meet environmental regulations. The new approach mandates: 1) directly linking research and development to specific site cleanup needs, and 2) engaging regulators, stakeholders, and potential users in the technology development process.

A Site technology coordination group was created at each DOE site to consolidate technology needs, enhance communications, and provide technology-transfer functions. The Hanford group consists of a management council and four subgroups: 1) plumes and landfills, 2) tanks, 3) mixed waste, and 4) decontamination and decommissioning.

The Management Council is chaired by the DOE Richland Operations Office Deputy Manager, and includes five assistant managers (Tank Waste Remediation System, Environmental Restoration, Waste Management, Facility Transition, and Technology) and representatives from the EPA, the Washington State Department of Ecology, the Hanford Advisory Board, the Yakama Indian Nation, the Nez Perce Indian Nation, and the Confederated Tribes of the Umatilla Indian Reservation. Each of the Hanford contractors has one ex officio member on the Management Council, as do industry and regional economic development interests.

The vision of the Hanford Site Technology Coordination Group is to be an effective decision-making body and a strong, unified voice for technology activities that affect the Hanford Site. Its mission is to:

- Function by involving users, technology providers, regulators, American Indian Tribes, and stakeholders, and by promoting broad information exchange among all interested parties.
- Identify, prioritize, and achieve consensus on Hanford Site problems and technology needs.
- Assess and recommend potential technologies for application at Hanford.
- Facilitate demonstration of innovative, modified, or existing technologies at Hanford or elsewhere and share information with other sites to best leverage technology budgets.
- Advocate implementation of innovative, modified, or existing technologies at Hanford.
- Promote privatization and commercialization.
- Provide input to decision-makers on Hanford's highest-priority technology needs to ensure critical needs are funded.

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. It also discusses 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, the Washington State Department of Ecology, and DOE to achieve environmental compliance for the Hanford Site with the Comprehensive Environmental Response, Compensation, and Liability Act remedial action provisions and with the Resource Conservation and Recovery Act treatment, storage, and disposal unit regulations and corrective action provisions. At the end of 1995, a total of 460 enforceable milestones and 215 unenforceable target dates (including those from 1989 through 1995) had been completed on or ahead of schedule. The following are some of the more significant accomplishments for 1995, with the associated Tri-Party Agreement milestone numbers:

- Initiated sheet pile wall construction to abate underground water flow to the Columbia River at the 100-N Area (M-16-12B-T3)
- Completed 1100 Area remediation field activities (M-16-05A-T2)
- Completed implementation of radiation skyshine abatement program at the 100-N Area (M-16-12A)
- Completed construction/installation and initiated operations of N-Springs pump-and-treat facility in the 100-N Area (M-16-12D)
- Completed radiation dose reduction activities at the Columbia River shoreline by decontaminating of the 1304-N emergency dump tank in the 100-N Area (M-16-12F)
- Completed 1100 Area site revegetation (M-16-05A-T3)
- Began remediation activities on three liquid waste disposal sites located near 100 Area B and C Reactor Areas
- Completed the removal of the 107-K retention basins at the 100-K Area
- Began construction of the Environmental Restoration Disposal Facility outside of the 200 Area
- Removed approximately 68,000 kg (150,000 lb) of carbon tetrachloride from the soil using a soil vapor extraction system in the 200-West Area
- Treated over 64 million L (17 million gal) of ground water in the 100 and 200 Areas
- Completed emergency pumping (interim stabilization) of single-shell tank 241-T-111 (M-41-16A-T1)
- Prepared an improved single-shell tank emergency pumping capability for each non-interim stabilized tank (M-41-02)
- Commenced operation of a vapor treatment system in single-shell tank 241-C-103 (M-40-07)
- Started interim stabilization of single-shell tanks 241-BX-106, 241-BY-103, and 241-BY-106 (M-41-12)
- Upgraded temperature monitoring capabilities in ferrocyanide-containing tanks (M-40-12)
- Completed safety alternative test in high-heat tank 241-C-106 (M-40-05)

- Performed vapor characterization for all organic and ferrocyanide watch list tanks (M-40-03 and M-40-08)
- Started construction of the cross-site transfer line system replacement for transfer of tank waste between the 200 Areas (M-43-07A)
- Achieved compliance with interim status facility standards for mixed waste stored in the high-level vault at the 324 Building, 300 Area (M-89-03)
- Completed deactivation of the Plutonium-Uranium Extraction Plant R-Cell (M-80-01)
- Completed all Uranium-TriOxide Plant transition activities and initiated surveillance and maintenance phase (M-80-00-T02)
- Completed removal and disposal of nearly 44,000 fuel spacers from the 118-N-1/1301-N silo in the 100-N Area (M-16-01E-T01)
- Completed liquid effluent treatment facility upgrades for all Phase I effluent streams (M-17-00A)
- Initiated full-scale hot operations of the 200 Area Treated Effluent Disposal Facility, with permitted disposal of effluent to a state-approved land disposal structure (M-17-08)
- Implemented "best available technology/all known and reasonable treatment" for the 242-A Evaporator process condensate (M-17-29) and at the generating facilities that will discharge to the 200 Area Treated Effluent Disposal Facility (M-17-08B)
- Ceased liquid discharges to hazardous waste land disposal units (M-17-10)
- Initiated full-scale hot operations for the 242-A Evaporator/Plutonium-Uranium Extraction Plant Process Condensate Treatment Facility with permitted discharge of treated effluent to the soil column (M-17-14).

Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act 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 2,100 known individual waste sites where hazardous substances may have been disposed. These 2,100 sites have been grouped into 71 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 currently conducting 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 Comprehensive Environmental Response, Compensation, and Liability Act cleanup requirements. All milestones related to the Comprehensive Environmental Response, Compensation, and Liability Act process established for 1995 were achieved, and the Hanford Site was in compliance with the Act requirements.

100 Area Remedial Action Project

In 1995, real cleanup of 100 Area waste sites began. Feasibility studies that evaluated high-priority waste sites in the 100-B/C, 100-DR, and 100-HR Areas were completed in early 1995, and proposed plans describing the remedial alternatives for these sites were issued for public review and comment in June 1995. At mid-year, DOE began cleanup of three liquid waste disposal sites in the 100-B/C Area to collect additional information to support the remedy selection. Nearly 3,100 m^3 (4,100 yd^3) of contaminated soil were excavated and stored for ultimate disposal in the Environmental Restoration Disposal Facility. Using the public's input and information from this early cleanup, DOE, EPA, and the Washington State Department of Ecology signed Hanford's first large interim Record of Decision in September 1995. The Record of Decision selected the cleanup alternatives for 37 liquid waste disposal sites in the 100 Areas. Following remedial design, full-scale remediation of the waste sites is scheduled to start in the summer of 1996.

Progress was also made in 1995 on the final closeout of four contaminated areas that were previously addressed as expedited response actions. The four areas were the Riverland Rail Yard, the North Slope (also known as the Wahluke Slope), the Sodium Dichromate Barrel Landfill, and the White Bluffs Pickling Acid Cribs. Investigation and cleanup activities were conducted at these areas from 1990 through 1994. A proposed plan describing these investigations and activities, with a determination that no further action would be required, was issued for public review and comment in June 1995. A final record of decision was signed by DOE, EPA, and the Washington State Department of Ecology in February 1996.

During 1995 the 190-D complex, consisting of six buildings and a high tower, was demolished using a combination of conventional demolition techniques and explosives. The demolition of the 183-C building was started, and pre-demolition activities on the 190-C building were initiated. Final demolition of the 183-H Solar Basins in the 100-H Area was initiated. Scabbling of the basin walls was completed and demolition of the concrete basin walls was initiated. The riverlines at the 105-B and 105-D reactor buildings were characterized using robotics to determine levels of both radiological and hazardous materials. Preliminary engineering was initiated for the 105-C Reactor Safe Storage Project.

100-N Area

The 100-N Area projects have been established to coordinate the cleanup actions within the 100-N Area. The project includes deactivating and decommissioning the N Reactor and supporting facilities and remediating the 100-N Area.

Deactivation of N Reactor facilities began in May 1995, when the appropriate National Environmental Policy Act determination of a finding of no significant impact was issued. Radioactive materials were removed from the N Reactor fuel storage basin including 65 m^3 (85 yd^3) of waste and 662 fuel canisters. Design, procurement, and installation of a water filtration system in the fuel storage basin was completed, resulting in improved water clarity.

The removal of the nearly 44,000 radioactive fuel spacers from the 100-N Area underground storage silos was completed in August 1995, one month ahead of schedule. Thorough planning and innovative designs of the spacer shipping containers, transport shipping frames, and a lifting beam resulted in a cost-effective operation that also reduced worker exposure during handling of spacer shipping containers.

Deactivation of 32 facilities took place ahead of schedule and under budget. With deactivation work completed at these buildings, surveillance and maintenance costs are greatly reduced.

The September 1994 action memorandum for the 100-N Area N Springs required the implementation of a pump-and-treat system combined with a removable steel barrier wall. The construction of the 100-N Pump and Treat facility to remove strontium-90 contaminated ground water was completed in July 1995. Pump and treat operations began in September 1995.

In March 1995, the Washington State Department of Ecology and EPA agreed that a sheet pile construction test conducted in December 1994 showed that the installation of the jointed sheet pile wall could not be achieved in the manner specified. The Washington State Department of Ecology and EPA directed the DOE Richland Operations Office to proceed with the installation of the Expedited Response Action pump-and-treat system and to 1) continue assessing accurately the flux of strontium to the river, 2) further characterize geologic and hydrologic conditions, and 3) assess design and installation alternatives related to modified barriers and expected performance.

Carbon Tetrachloride Vapor Extraction

Vapor extraction from the contaminated vadose zone beneath the 200-West Area (specifically, the 200-ZP-2 Operable Unit) began in February 1992 and continued through 1995. This Expedited Response Action uses three vapor extraction systems to draw soil vapor laden with carbon tetrachloride from the unsaturated soil column. The carbon tetrachloride is collected above ground into granulated activated-charcoal, which is then shipped offsite for treatment. As of February 1996, about 68,225 kg (150,410 lb) of carbon tetrachloride has been removed from the soil. The systems are anticipated to operate for several more years. However, decreasing carbon tetrachloride concentrations may drive the response action to closure if agreements can be reached between DOE and the regulators.

Horn Rapids Landfill, Horseshoe and Nike Site Landfills

In the fall of 1995, DOE and the Hanford Natural Resource Trustees worked cooperatively in planning and conducting the restoration action necessary for these remediated sites. The Horn Rapids Landfill was replanted for the

purposes of stabilization. Non-native bunchgrasses were planted using two planting techniques (rangeland drilling and land imprinting with mycorrhizal fungi) in an attempt to determine which method would be more effective in the rocky, sandy soils of the Site. The Horseshoe and Nike Landfills on the Fitzner/Eberhardt Arid Lands Ecology Reserve were replanted using local native transplanted bunchgrasses in an effort to restore the sites to pre-existing native grassland.

1100 Area Remediation

Remedial actions for the 1100 Area National Priority List Site were completed in September 1995 by the U.S. Army Corps of Engineers. A total of 1,340 m^3 (1,750 yd^3) of PCB-contaminated soil was removed from two sites. The PCB-contaminated soil was shipped to a disposal facility in Arlington, Oregon. An additional 70 m^3 (92 yd^3) of soil contaminated with bis(2-ethylhexyl)phthalate was removed from a third site and was sent to an incinerator near Salt Lake City, Utah. The Horn Rapids Landfill, located west of the 300 Area, was capped with fill material to prevent exposure to asbestos dust. Five new monitoring wells were installed downgradient of the landfill to establish a point of compliance and to provide additional sampling points to track trichloroethylene plume migration. Additional soils removed from other 1100 Area operable units consisted of 1,220 m^3 (1,600 yd^3) of petroleum-contaminated soil, 54 m^3 (70 yd^3) of soil contaminated with lead, and 62 m^3 (80 yd^3) of soil contaminated with petroleum hydrocarbons, lead, and chromium. These soils were also shipped to Arlington, Oregon for disposal.

Asbestos Removal

In 1995, the Environmental Restoration/Decontamination and Decommissioning project completed abatement of 3,300 linear m (11,000 linear ft) of asbestos-containing pipe insulation and 2,000 m^2 (22,000 ft^2) of asbestos-containing duct insulation. Approximately 90% of the asbestos wastes generated from the asbestos projects were shipped and stock-piled in an above-ground storage area at the 400 Area Asbestos Conversion Compound.

Wastes generated from 1995 asbestos projects exceeded 760 m^3 (990 yd^3) and will be used as feed stock during the Asbestos Conversion Technology Demonstration Project. This technology converts typical asbestos wastes into non-hazardous recyclable material by way of a systematic shredding, soaking, and thermal conversion process that subjects the treated material to temperatures exceeding 1000°C (1800°F). The entire process is contained in two transportable tractor trailers for easy relocation. The benefits of conversion are two-fold: waste volumes are reduced from 70 to 80%, and the end-product is suitable for low-level waste void space filler, a material currently purchased on the open market.

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. The pump-and-treat system tested the removal of carbon tetrachloride, chloroform, and trichloroethylene from ground water using liquid phase activated carbon. Treated water is discharged into an injection well, back into the aquifer. Approximately 19 million L (5 million gal) of water have been treated through 1995. Removal efficiency of carbon tetrachloride is always better than 95% and may exceed 99%. 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. Regulator and public comments were addressed and an interim record of decision was issued in June 1995.

Uranium/Technetium Ground-Water Plume

Another ground-water plume in the 200-West Area contains uranium and technetium-99. The contamination is the result of historical 200-West Area U Plant uranium recovery operations. A pump-and-treat system was designed to test removal of these contaminants using ion exchange. The system also removes carbon tetrachloride using liquid phase granulated activated carbon. In 1995, the ground-water extraction system was expanded to

190 L/min (50 gal/min). An engineering evaluation cost analysis has been prepared and a proposed plan leading to an interim record of decision has been through public review. An interim record of decision is expected in 1996. During 1995, a total of 36.7 million L (9.7 million gal) of ground water were treated.

200-East Area Ground-Water Plumes

The radiological contaminants in two 200-East Area ground-water plumes include cesium-137, cobalt-60, plutonium, strontium-90, and technetium-99. They are the result of historical reprocessing operations in the 200-East Area at the B Plant. Two pump-and-treat test systems addressing these plumes through treatability testing were discontinued in May 1995. Further decisions on remediation of these plumes have been deferred until after the data are evaluated. In 1995, approximately 5 million L (1.3 million gal) of water were treated. A Resource Conservation and Recovery Act Facility Investigation/Corrective Measures Study addressing contaminants (tritium, iodine-129, and nitrate) associated with the Plutonium-Uranium Extraction Plant is being prepared.

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. Chromium concentrations are at levels of potential concern to the Columbia River ecosystem. This concern has prompted an interim remedial measure to address the movement of chromium into the river. In 1994, a ground-water extraction system was installed at the 100-D Area to test chromium removal using ion exchange technology. Through 1995, the system has treated 40.8 million L (10.8 million gal) of ground water and has removed 39.4 kg (86.9 lb) of chromium.

Environmental Restoration Disposal Facility

In June 1995, construction began on the Environmental Restoration Disposal Facility near the 200 Areas. Approximately 1.5 million m^3 (2.0 million yd^3) of material were excavated to construct two adjoining disposal cells. Work was started on the double liner, leachate collection system, and support structures. Together, the disposal cells are approximately 21 m (69 ft) deep, 120 m by 330 m (390 ft by 1080 ft) in surface area, and can be expanded as needed. The disposal system will be operated to support Hanford remediation efforts. Construction is scheduled to be completed by July 1996.

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

Community Right-To-Know Activities

The Emergency Planning and Community Right-To-Know Act of 1986 requires states to establish a process for developing chemical emergency preparedness programs and to distribute information on hazardous chemicals present at facilities within communities. The Act has four major components: emergency planning (Sections 301-303); emergency release notification (Section 304); inventory reporting (Sections 311-312); and toxic chemical release inventory reporting.

Section 301 of the Act requires the appointment of a state emergency response commission to coordinate the emergency planning process. The state was divided into local planning districts, and local emergency planning committees were established for each district. Section 302 requires facilities that use, produce, or store Extremely Hazardous Substances[a] in quantities equal to or greater than the listed threshold planning quantity to notify the state emergency response commission and local emergency planning committee. Covered facilities must also identify an emergency response coordinator to participate in local emergency planning committee activities, including the development of the local emergency response plans required under Section 303.

The Hanford Site has been identified as a covered facility to the Washington State Emergency Response Commission and to three local emergency planning committees; Benton County Department of Emergency Management, Franklin County Office of Emergency Management, and Grant County Department of Emergency Management. During calendar year 1995, information regarding the

(a) See 40 CFR 355, Appendix A or B.

storage of hazardous chemicals and associated hazards was provided to these organizations. In addition, Hanford Site representatives participated in local emergency planning committee meetings held by the Benton County Department of Emergency Management.

Under Section 304, a facility must immediately notify the state emergency response commission and local emergency planning committee if there is a release of a listed hazardous substance that is not federally permitted, that exceeds the reportable quantity established for the substance, and that results in exposure to persons outside the facility boundaries. The substances subject to these requirements consist of Extremely Hazardous Substances and Hazardous Substances subject to the notification requirements of the Comprehensive Environmental Response, Compensation, and Liability Act.[b]

During calendar year 1995, the Hanford Site had no releases that fell under the requirements of the Emergency Planning and Community Right-To-Know Act, Section 304.

Sections 311 and 312 require facilities that store hazardous chemicals in amounts above minimum threshold levels to report information regarding these chemicals to the state emergency response commission, local emergency planning committee, and local fire department. Both sections cover chemicals that are considered physical or health hazards by the Occupational Safety and Health Act Hazard Communication Standard.[c] The minimum threshold level is 4,545 kg (10,000 lb) for a hazardous chemical, or 227 kg (500 lb) or the listed Threshold Planning Quantity, whichever is lower, if the chemical is an Extremely Hazardous Substance. Section 311 calls for the submittal of an Material Safety Data Sheet for each hazardous chemical present above minimum threshold levels, or a listing of such chemicals associated hazard information. The listing must be updated within 3 months of any change to the list, including new hazard information or the addition of new chemicals. Section 312 requires the annual submittal of more detailed quantity and storage information regarding the same list of chemicals. This information is submitted in the form of a Tier Two report.

The Hanford Site provides appropriate hazardous chemical inventory information to the Washington State Emergency Response Commission, three local emergency planning committees, and to both the Richland and Hanford fire departments. Updated Material Safety Data Sheet listings were issued in April, July, and October 1995, and January 1996, covering changes occurring in calendar year 1995. The 1995 *Hanford Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1996c) was issued in March 1996.

Under Section 313, facilities must report total annual releases of certain listed toxic chemicals.[d] The Pollution Prevention Act of 1990 adds additional information requirements to the submittal, and Executive Order 12856, Federal Compliance with Right-To-Know Laws and Pollution Prevention Requirements, extends the requirements to all federal facilities, regardless of the types of activities conducted there. A Toxic Chemical Release Inventory report consists of release, waste transfer, and source reduction information for each toxic chemical that is manufactured, processed, or otherwise used in amounts over specific activity threshold levels.

The Hanford Site was not required to submit a Toxic Chemical Release Inventory report in July 1995, covering reporting year 1994. Evaluation of complete toxic chemical usage information resulted in the determination that there were no toxic chemicals used in excess of applicable activity threshold levels. The list of toxic chemicals subject to reporting under Section 313 was expanded significantly, effective for reporting year 1995. The list was nearly doubled to include 590 chemicals and 28 chemical categories. Toxic chemical usage information for calendar year 1995 will not be collected and evaluated until the end of April 1996. Until then, it will not be known exactly how the expanded list will affect Hanford Site Toxic Chemical Release Inventory reporting.

Table 2.2.1 provides an overview of 1995 Emergency Planning and Community Right-To-Know Act reporting.

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.

(b) See 40 CFR 302.6(a).
(c) See 29 CFR 1910.1200.
(d) See 40 CFR 372.65.

Table 2.2.1. Emergency Planning and Community Right-to-Know Act Compliance Table, 1995[a]

Emergency Planning and Community Right-to-Know Act Sections	Yes	No	Not Required
302-303: Planning Notification	X		
304: EHS[b] Release Notification			X
311-312: MSDS[c]/Chemical Inventory	X		
313: TRI[d] Reporting	X		

(a) See text in Section 2.2 for further information. In this table, "Yes" indicates that notifications were provided and/or reports were issued under the applicable provisions. "No" indicates that notifications or reports should have been provided, but were not. "Not Required" indicates that no actions were required under the applicable provisions, either because triggering thresholds were not exceeded or no releases occurred.
(b) Environment, Health, and Safety.
(c) Material Safety Data Sheet.
(d) Toxic Chemical Release Inventory.

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 1995.

The Hanford Site Pollution Prevention Program was designed to meet the requirements of DOE Orders 5400.1, and 5820.2A, the DOE *Waste Minimization/Pollution Prevention Cross Cut Plan* (DOE 1994d) 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 have been prioritized, schedules are developed, and the viable opportunities are implemented.

Resource Conservation and Recovery Act

Hanford Site Facility Resource Conservation and Recovery Act Permit

The Hanford Facility Resource Conservation and Recovery Act Permit was issued by the Washington State Department of Ecology and EPA in August 1994 and has been in effect since late September 1994. The permit provides the foundation for all future Resource Conservation and Recovery Act permitting at the Hanford Site in accordance with provisions of the Tri-Party Agreement.

Resource Conservation and Recovery Act/Dangerous Waste Permit Applications and Closure Plans

For purposes of the Resource Conservation and Recovery Act and the Washington State Department of 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 Resource Conservation and Recovery Act/dangerous waste permit applications and closure plans to the Washington State Department of Ecology and EPA. During 1995, 12 Part A Form 3s and two Part B applications were certified and submitted to the Washington State Department of Ecology. In addition, six Notices of Intent for expansion were filed with the Washington State Department of Ecology, and seven treatment, storage, and disposal units were certified as closed.

Resource Conservation and Recovery Act Ground-Water Monitoring Project Management

Table 2.2.2 lists all the Resource Conservation and Recovery Act facilities and waste management areas and their ground-water monitoring program status. Samples were collected from nearly 300 wells in 1995. The ground-water samples were analyzed for a variety of dangerous waste constituents and site-specific constituents. Some sites were also analyzed for selected radionuclides. The list of constituents analyzed in 1995 was trimmed to reduce costs. The new constituent list still meets regulatory requirements and is still sufficient to meet data objectives. No new Resource Conservation and Recovery Act wells were drilled during the year.

The 183-H Solar Evaporation Basins are included in the Sitewide Resource Conservation and Recovery Act Permit and are subject to final status regulations. A final status ground-water monitoring program for the 183-H Solar Evaporation Basins was initiated in September 1995. The other sites listed in Table 2.2.2 are subject to interim status regulations at this time.

Four wells are monitored for the Environmental Restoration Disposal Facility. The facility is a Comprehensive Environmental Response, Compensation, and Liability Act landfill but will follow Resource Conservation and Recovery Act monitoring requirements. This monitoring program is conducted in accordance with 40 CFR 264 final status Resource Conservation and Recovery Act regulations.

Resource Conservation and Recovery Act Inspections

DOE and its Hanford contractors are working to resolve outstanding notices of violation and warning letters of noncompliance from the Washington State Department of Ecology that were received during 1995. Each of these notices lists specific violations. There were seven letters in 1995. Of the seven, six have had all corrective actions completed and have been closed. One was a formal violation that resulted in a $7,000 penalty. Below is a brief summary of the most significant of these issues.

- The Washington State Department of Ecology issued a voluntary compliance letter to Pacific Northwest National Laboratory for noncompliant conditions at the 324 Building's Radiochemical Engineering Cells and High-Level Vault tanks. This inspection was conducted to support resolution of a dispute between the Tri-Parties. The DOE Richland Operations Office and Pacific Northwest National Laboratory responded to the Washington State Department of Ecology with a letter that outlined the measures that would be taken to resolve the issues. The Washington State Department of Ecology has closed this issue "subject to issues being resolved via the Tri-Party Agreement." New Tri-Party Agreement milestones were negotiated for removal of waste from the 324 Building.

Table 2.2.2. Status of Hanford Site Resource Conservation and Recovery Act Interim-Status Ground-Water Monitoring Projects as of September 1995

Project (Date Initiated)	Individual Parameter Evaluation[a]	Ground-Water Quality Assessment
100-D Ponds (4/92)	X	
183-H Basins (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
LERF[b] (7/91)	X	
2101-M Pond (8/88)	X	
LLBG[c] Waste Management Area 1 (9/88)	X	
LLBG Waste Management Area 2 (9/88)	X	
LLBG Waste Management Area 3 (10/88)	X	
LLBG Waste Management Area 4 (10/88)	X	
LLBG Waste Management Area 5 (3/92)	X	
SST[d] Waste Management Area A-AX (2/90)	X	
SST Waste Management Area B BX-BY (2/90)	X	
SST Waste Management Area C (2/90)	X	
SST Waste Management Area S-SX (10/91)	X	
SST Waste Management Area T (2/90)		X
SST Waste Management Area TX-TY (9-10/91)		X
SST Waste Management Area U (10/91)	X	
300 Area Process Trenches (6/85)		X
Nonradioactive Dangerous Waste Landfill (10/86)	X	

(a) Specific parameters (pH, specific conductance, total organic carbon, and total organic halogen) used to determine if a facility is affecting ground-water quality. Exceeding the established limits means that additional evaluation and sampling is required (ground-water quality assessment). An "X" in the table indicates whether an evaluation was needed, or an assessment was required.

(b) LERF = Liquid Effluent Retention Facility.

(c) LLBG = Low-Level Burial Grounds.

(d) SST = single-shell tank.

- The Washington State Department of Ecology issued a voluntary compliance letter, which was followed by a formal Notice of Penalty Incurred and Due, against the DOE Richland Operations Office and Pacific Northwest National Laboratory after a pressurized drum in the 331 Building was improperly opened causing damage to the facility, worker contamination, and release of radioactive material to the building. A $7,000 fine was imposed. The fine was paid and both the informal and formal notices have been closed.

- The Washington State Department of Ecology issued a voluntary compliance letter to the DOE Richland Operations Office and Pacific Northwest National Laboratory after an investigation into the acceptance of labpack wastes (specially packaged liquid dangerous wastes) at the Central Waste Complex from offsite. Six violations were noted. All corrective actions were completed, and the Washington State Department of Ecology has closed this issue.

- The Washington State Department of Ecology issued two separate voluntary compliance letters to the DOE Richland Operations Office and the Site Environmental Restoration Contractor Team for an incident in which a drum containing 183-H Solar Evaporation Basin waste blew its lid off while it was being opened at T Plant for verification before storage. The first letter noted violations associated with inventories and characterization, and the second letter noted violations of training requirements in the Hanford Facility Resource Conservation and Recovery Act Permit. This item remained open at the end of 1995.

Clean Air Act

The Washington State Department of Health, 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 Washington State Department of Health. 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 Site air operating permit, scheduled to be issued in 1997 in accordance with 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, 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. The asbestos is handled according to the Hanford Site asbestos abatement plan, which is controlled by Bechtel Hanford, Inc. The plan is updated annually and contains an inventory of all buildings on the Hanford Site that contain asbestos, as well as an annual projection of the amount of asbestos to be handled and disposed.

Revised Clean Air Act requirements for radioactive air emissions were issued in December 1989 under 40 CFR 61, Subpart H. The total emissions from the Hanford Site's DOE operations are within the State and EPA offsite emission standard 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.

Reporting and monitoring requirements necessitated 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. This evaluation has been completed. In February 1994, a National Emission Standards for Hazardous Air Pollutants 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 that is being followed to bring the Hanford Site into compliance with the Clean Air Act, as amended, and its implementing regulations in 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants: Radionuclides. The specific requirements are being addressed for continuous measurement of radionuclide emissions in accordance with 40 CFR Part 61.93.

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 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 Benton County Clean Air Authority enforces Regulation 1, which pertains to detrimental effects, fugitive dust, open burning, odor, opacity and asbestos handling. It has been delegated the authority to enforce EPA asbestos regulations under the National Emission Standards for Hazardous Air Pollutants. In 1995, the Site was in compliance with the regulations.

During 1995, 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.

State of Washington Department of Health Enforcement Inspections

DOE and its Hanford contractors are working to resolve outstanding compliance findings from Washington State Department of Health inspections. Each of these findings lists specific violations. There were eight notices in 1995, and four of these have been resolved and closed. A brief summary of the most significant of these issues follows.

- Washington State Department of Health identified two findings at the Waste Sampling Characterization Facility as a result of how air samples from an unplanned release were handled. This issue has been closed.

- A finding at the Central Waste Complex was identified after drums stored at the facility were found to use lids containing an activated charcoal filter, which allows a gas exchange. The drums are not considered sealed sources, and Washington State Department of Health required the facility to obtain a Notice of Construction permit. This was completed and approved by Washington State Department of Health. Washington State Department of Health issued a compliance letter that resulted when previously identified audit findings were not corrected to the satisfaction of inspectors. The problems were associated with monitoring equipment either being improperly calibrated or having out-of-date calibration stickers. A corrective action plan was prepared and submitted to Washington State Department of Health but no formal notification of closure was received by the end of 1995.

- A sitewide radioactive air emissions audit by Washington State Department of Health of dose assessment activities performed by Westinghouse Hanford Company, Pacific Northwest National Laboratory, and Quanterra Laboratories resulted in the identification of 18 Notices of Correction. These Notices of Correction represent issues that previously would have been identified as findings. A response to Washington State Department of Health was being prepared at the end of 1995.

Clean Water Act

The Clean Water Act applies to point source 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.

A request for minor modification was submitted to EPA in August 1995 for permit #WA-000374-3 to remove the 100-N Area inactive outfalls from the monitoring and reporting requirements in the permit. A formal response had not been received from the EPA by the end of the calendar year. The remaining outfalls include two located in the 100-K Area (outfall 003 and 004) and one in the 300 Area (outfall 013). There were no instances of noncompliance for this permit in 1995.

Permit #WA-002592-7 covers the 300 Area Treated Effluent Disposal Facility and had six instances of noncompliance in 1995. All six cases were the result of effluent levels exceeding the National Pollutant Discharge Elimination System permit limits. The 300 Area Treated Effluent Disposal Facility was in normal operations and meeting design specifications at the time of these events. All indications suggest that the 300 Area Treated Effluent Disposal Facility is unable to consistently meet the

restrictions of the facility's National Pollutant Discharge Elimination System permit, despite the use of the best available technology. Based on operating history, it has been determined that the Treated Effluent Disposal Facility cannot operate under the current limits. Preparations for permit renegotiations are underway in accordance with the one year operating history review period specified when the permit was issued.

The Site has also been covered by a general stormwater permit since February 1994. In compliance with this permit, the Annual Comprehensive Site Compliance Evaluation was performed and documented, and the pollution prevention plan was updated. No instances of noncompliance occurred in 1995.

Liquid Effluent Consent Order

Washington State Department of Ecology Liquid Effluent Consent Order DE 91NM-177, which regulates 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 the Washington State Department of Ecology for all liquid effluent streams required by the Consent Order.

Two State liquid waste discharge permits were issued by the Washington State Department of Ecology in 1995, one for the 200 Area Treated Effluent Disposal Facility and one for the 200 Area Effluent Treatment Facility. A noncompliance with an Effluent Treatment Facility permit requirement occurred when the Operational Maintenance Matrices document for the facility was submitted late to the Washington State Department of Ecology.

The Miscellaneous Streams Plan and Schedule was approved by the Washington State Department of Ecology in February 1995. 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 four years to ensure the efficient use of both state and federal resources in the permit development. A state waste discharge categorical permit application for hydrotest (pressure test), construction, and maintenance discharges was submitted to the Washington State Department of Ecology in November 1995. DOE Richland Operations Office and its contractors met with the Washington State Department of Ecology during 1995 to develop draft discharge permits. In accordance with the Plan and Schedule, all Class V injection wells were registered with the Washington State Department of Ecology in August 1995.

An inventory of miscellaneous streams was submitted to the Washington State Department of Ecology in September 1995 in accordance with the Miscellaneous Streams Plan and Schedule. In May 1995, a list identifying streams that require the selection of Best Management Practices was submitted to the Washington State Department of Ecology. The criteria for determining whether a stream was a candidate for a Best Management Practice was: 1) effluent discharge to a surface contamination area, 2) effluent discharge to the ground within 300 horizontal feet from a known active or inactive crib, ditch or pond, and 3) the potential of contamination within the effluent stream. A Best Management Engineering Report was initiated to address the listed streams in 1995.

Lawsuits Filed

Heart of America Northwest et al. filed a lawsuit against both the Site management and operations 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 United States Court of Appeals for the Ninth Circuit in October 1993. The United States Court of Appeals for the Ninth Circuit dismissed this case in January 1995.

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. The Hanford Site water supplies are monitored for the contaminants listed in the rules and regulations of the Washington State Department of Health regarding public water systems. In 1995, all drinking water systems on the Site were in compliance with requirements and agreements; however, tritium concentrations in two drinking water samples collected at the Fast Flux Test Facility in June and July were slightly elevated (see Section 4.3, "Hanford Site Drinking Water Surveillance").

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 concentrations, temperature, and pH.

A notice of violation was issued to DOE by the Washington State Department of Health in October 1995, alleging that, based on their records, the 100 Area water system was being operated without certified operators. DOE responded in December 1995, and provided a list of the certified operators and their certification test results.

Toxic Substances Control Act

The Toxic Substances Control Act requirements applied 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.

Electrical transformers have been sampled and characterized. Seventeen PCB transformers (those with a PCB concentration greater than 500 ppm) remain in service. Schedules have been developed for the replacement and disposal of these PCB transformers.

Defueled, decommissioned reactor compartments shipped by the U.S. Navy to the Hanford Site for disposal contain small quantities of PCBs. 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 Toxic Substances Control Act authorization for the disposal site after the State has issued a dangerous waste permit.

Nonradioactive PCB waste is stored and disposed of in accordance with the 40 CFR 761 requirements. Radioactive PCB waste remains in storage onsite 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 set forth in 40 CFR 761 has been developed and approved by DOE and the U.S. Navy. The agreement will be implemented when approved by the EPA.

Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act is administered by EPA. The standards administered by the Washington State Department of Agriculture to regulate the implementation of the act in Washington State include: Washington Pesticide Control Act, RCW 15.58; Washington Pesticide Application Act, RCW 17.21; and rules relating to general pesticide use codified in WAC 16-228, "Pesticide Regulations." At the Hanford Site, all pesticides are applied by commercial pesticide operators who are listed on one of two commercial pesticide applicator licenses. In 1995, the Hanford Site was in compliance with these state and federal standards regulating the storage and use of pesticides.

Endangered Species Act

Many 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 as federal candidate species, or by the Washington State Department of Fish and Wildlife as endangered, threatened, or sensitive species (see Appendix F). The Site wildlife monitoring program is discussed in Section 6.2, "Wildlife."

Bald eagles, a threatened species, are seasonal visitors to the Hanford Site. Over the past few years, several bald eagles have attempted to nest onsite, but none have been successful. 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 each year from January until the eagles abandon the site 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 1995.

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 1995.

National Environmental Policy Act

The National Environmental Policy Act requires preparation of an Environmental Impact Statement to review the effects and alternatives of major federal actions that have the potential to significantly affect the quality of the human environment. Other National Environmental Policy Act 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 environmental impact statement. Certain types of actions may fall into categories that have already been reviewed by DOE and are determined not to result in a significant environmental impact. Actions that fall within these categorical exclusions are exempt from further National Environmental Policy Act review.

The Council on Environmental Quality, which reports directly to the President, was established to oversee the National Environmental Policy Act process. National Environmental Policy Act documents are prepared and approved in accordance with the Council on Environmental Quality National Environmental Policy Act regulations (40 CFR 1500 to 1508), DOE National Environmental Policy Act implementation procedures (10 CFR 1021), and DOE Order 451.1.

Recently Approved Environmental Impact Statements

The final environmental impact statement, Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington (DOE 1992a, DOE/EIS-0212) has been approved. This environmental impact statement assessed potential environmental impacts of decommissioning eight water-cooled, graphite-moderated reactors on the Hanford Site. The environmental impact statement evaluated five alternatives including immediate one-piece removal, safe storage followed by deferred dismantlement, and in situ decommissioning. The scope of this environmental impact statement does not include decommissioning of the N Reactor. 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 environmental impact statement. Until decommissioning begins, 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.

A Safe Interim Storage environmental impact statement was completed for a proposed Multifunction Waste Tank

Facility (DOE 1995c). Potential environmental impacts are reviewed that are associated with the construction and operation of up to six new 3.8-million-L (1-million-gal) double-shell waste tanks and a cross-site transfer line. The transfer line would resolve safety concerns regarding hydrogen generation in two waste tanks. The Record of Decision, published in the *Federal Register* in December 1995, states that DOE intends to replace the existing cross-site transfer line between the 200-East and 200-West Areas of the Hanford Site. The Washington State Department of Ecology was a co-preparing agency for this environmental impact statement.

The Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement evaluated alternatives for the management of spent nuclear fuel within the DOE complex. The environmental impact statement evaluated the use of several sites, including Hanford, as potential sites for spent nuclear fuel storage. The environmental impact statement also evaluated environmental and waste management issues at the Idaho National Engineering Laboratory. In August 1993, Hanford was requested to support the preparation of this environmental impact statement. DOE issued the final environmental impact statement in April 1995 (DOE 1995a) and a Record of Decision in May 1995 (DOE 1995b).

A final environmental impact statement was issued in January 1996 (DOE 1996d) for spent nuclear fuel stored at the Hanford Site. The environmental impact statement analyzes potential environmental impacts associated with removal and subsequent management of spent nuclear fuel from the K Basins. This action is needed to reduce the risk of release of radionuclides through the soil column to the Columbia River in the event of failure of the existing K Basins. The environmental impact statement supports implementation of a final decision that was made in the Record of Decision for DOE's programmatic environmental impact statement on spent nuclear fuel.

The National Park Service released a final environmental impact statement in June 1994 (NPS 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.

Programmatic Environmental Impact Statements in Progress

A Programmatic Environmental Impact Statement is being prepared by the Office of Environmental Restoration and Waste Management. The purpose of this impact statement is to evaluate a broad range of alternatives for the configuration of new and expanded waste management facilities. It could include remediation actions, compliance with the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act, 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. The notice of availability of the draft impact statement was published in the *Federal Register* in August 1995. The public comment period was extended until February 1996.

A Weapons Complex Reconfiguration Modernization Programmatic Environmental Impact Statement is being prepared by the Office of Defense Programs. The purpose of this programmatic environmental impact statement 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. Significant changes could involve 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 of this impact statement is under review.

Site-Specific Environmental Impact Statements In Progress

The Tank Waste Remediation System Environmental Impact Statement has its origin in two DOE decisions. The first was an October 1990 commitment by the Secretary of Energy to prepare a supplemental impact

statement to the 1987 Hanford Defense Waste Environmental Impact Statement 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 environmental impact statement combines the scope of the originally planned supplemental environmental impact statement and the tank safety mitigation/ remediation issues environmental impact statement. The notice of intent was published in the *Federal Register* in January 1994. Public scoping was conducted during February and March 1994, and the draft environmental impact statement was issued in April 1996. The Record of Decision is scheduled for July 1996.

Potential environmental impacts of the Comprehensive Environmental Response, Compensation, and Liability Act and the Resource Conservation and Recovery Act past-practices remediation activities at the Hanford Site, particularly cumulative impacts, will be assessed in the Hanford Remedial Action Environmental Impact Statement. This environmental impact statement 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 National Environmental Policy Act documentation could be prepared, as needed, for specific remediation of individual operable units or construction of waste management facilities. The Hanford Remedial Action Environmental Impact Statement will not make site-specific level-of-cleanup decisions. Instead, the final decision on this environmental impact statement may establish objectives for future site use that will in turn support the regulatory framework for establishing cleanup levels for individual waste sites. The notice of intent was published in the *Federal Register* during August 1992. The draft environmental impact statement is targeted for completion in September 1996.

Preparation of an environmental impact statement to address stabilization and removal of readily retrievable plutonium-bearing materials stored at the Plutonium Finishing Plant is under way. An interim action environmental assessment was published in 1994 for the Plutonium Reclamation Facility stabilization.

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, knowledge gained in implementing Tri-Party Agreement milestones, 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-nine milestones scheduled for 1995 were completed. Included in these completed milestones were the activities listed in Section 2.2 as well as those below. The following were submitted to the regulators (Washington State Department of Ecology and/or EPA):

- Five closure plans for Hanford treatment, storage, and disposal facilities
- One interim remedial measure report and plan
- One limited field investigation
- Seven focused feasibility study reports
- Five interim remedial measures proposed plans
- The 100-B Area burial ground field work report
- One sitewide data management systems analysis
- Data management plans for each DOE Richland Operations Office program office
- 1100 Area site restoration construction completion notification.

In 1995, the following activities were begun:

- Cross-site transfer system construction for transfer of tank wastes between the 200 Areas
- Interim stabilization of three single-shell tanks
- Operation of the 200 Area Treated Effluent Disposal Facility and the Effluent Treatment Facility.

From 1989 through 1995, a total of 460 enforceable Tri-Party Agreement milestones and 215 unenforceable target dates had been completed on or ahead of schedule. Three enforceable 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 6 years, the Tri-Party Agreement has been changed as additional information has been acquired about the cleanup problems.

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

A summary of the significant changes follows.

Facility Transition Approved 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 Plutonium-Uranium Extraction Plant, the Uranium-TriOxide Plants, and the Fast Flux Test Facility. The negotiations also addressed the cleanout of the Plutonium Finishing Plant and the 324 Building radiochemical engineering cells and vault tanks.

These negotiations led to the development of Amendment Five, which was approved in July 1995, incorporating facility transition activities into the Tri-Party Agreement.

Amendment Five changes included:

- Establishing a safe and environmentally secure configuration for the Plutonium-Uranium Extraction Plant to achieve necessary preclosure actions and transition the facilities to the surveillance and maintenance phase.
- Establishing 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.
- Stabilizing 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.
- Revising the necessary permitting, closure, or preclosure actions related to transition efforts for the Plutonium-Uranium Extraction Plant, Fast Flux Test Facility, and Plutonium Finishing Plant.

Other Modifications Made to the Tri-Party Agreement

Language was 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 they are submitted to the Washington State Department of Ecology and EPA. New language was added 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 also have been added and other definitions have been modified in Appendix A, "Definition of Terms."

A new section, 14, was added to the Action Plan to detail the facility decommissioning process. It includes planning and action paths for all three decommissioning phases and addresses regulatory integration.

Amendment Six to the Tri-Party Agreement

During the spring and summer of 1995, the tri-party signatories met on several occasions to examine methods of fundamentally improving the ways of doing business at the Hanford Site. A number of commitments were made to change the Tri-Party Agreement, with the aim of becoming more efficient and cost-effective within the Agreement's framework. These changes will provide authority and control to the personnel who are most responsible for performing the actual cleanup, so that decisions will be made at lower levels of management and in less time. These efficiencies will be further enhanced by the adoption of a single regulator concept in which only one regulatory agency generally will be involved in the day-to-day oversight and decision making on individual cleanup activities.

Amendment Six changes were implemented in November 1995 and underwent a successful implementation period through the end of 1995. Final approval of Amendment Six occurred in February 1996.

Environmental and Molecular Science Laboratory

In 1995, construction of the Environmental and Molecular Science Laboratory continued. When finished, the 18,600 m^2 (200,200 ft^2) facility 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 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 national 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 1995, working closely with stakeholders and local Native American tribes, decisions were made that support acceleration of the strategy for interim storage of the K Basin fuel inventory. This strategy supports removal of the fuel from the K Basins 3 years ahead of the December 2002 target date stipulated in the Tri-Party Agreement. The Spent Nuclear Fuel Project is now in the process of implementing the strategy for acceleration of fuel removal from the K Basins.

A project to install isolation barriers in the basins was completed in 1995. These barriers isolate the spent fuel from a vulnerable construction joint in the discharge chute of the basins. They will prevent 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.

Plutonium Finishing Plant

The function of the Plutonium Finishing Plant was to extract plutonium from plutonium-bearing chemical solutions and convert it into metal and oxide. The plant 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 citizen groups about plans to operate the Plutonium Finishing Plant processes. DOE intended to run processes within the plant, the Plutonium Reclamation Facility, and portions of the Remote Mechanical "C" Line to stabilize some plutonium-bearing materials. 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 environmental impact statement, and consideration of alternate methods of plutonium stabilization. Based on these comments, DOE began preparing an environmental impact statement and approved a proposal to initiate several interim actions to reduce safety risks in the facility while waiting for the environmental impact statement. Many of the interim actions already have been completed, including downloading solutions from the Plutonium Reclamation Facility for disposal, decontaminating portions of the Plutonium Finishing Plant, removing plutonium-contaminated ducts and piping from the 232-Z incinerator building, stabilizing plutonium-bearing solutions stored in Plutonium Finishing Plant gloveboxes, and stabilizing and testing solutions stored in 10-L (2.64-gal) containers.

Current facility activities include remediation of plutonium-contaminated ductwork in 234-5Z; continued thermal stabilization of plutonium residues; and preparation for the implementation of the environmental impact statement Record of Decision, which is expected in June 1996.

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. The DOE Richland Operations Office has issued a change request to the Tri-Party Agreement in order to proceed with the planned privatization of the initial

pretreatment and immobilization function of the Tank Waste Remediation System program.

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 is scheduled to 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.

Radioactive Mixed Waste Disposal Facilities

The Radioactive Mixed Waste Disposal Facilities are the first facilities in DOE's national complex for disposal of radioactive mixed wastes. These facilities are located in the Hanford Site Low-Level Burial Ground and are designated as 218-W-5, Trench 31, and Trench 34. Construction was completed on Trench 34, and operational readiness was completed on both trenches in 1995.

The facilities consist of rectangular landfills with approximate base dimensions of 76 m by 30 m (250 ft by 100 ft). The bottom of the landfill excavations slope slightly, giving a variable depth of 9 to 12 m (30 to 40 ft).

These facilities are Resource Conservation and Recovery Act compliant, with double liners and leachate collection and removal systems. The bottom and sides of the facilities are covered with a 1-m (3-ft)-deep layer of soil to protect the liner system during fill operations. There is a recessed section at one end of the landfill excavations that houses the sumps for leachate collection. Access to the bottom of the landfills is provided by ramps along the perimeters.

Enhanced Radioactive Mixed Waste Storage Facility, Phase V

Construction was initiated on the Enhanced Radioactive Mixed Waste Storage Facility, Phase V to increase the Site's permitted mixed waste storage capacity and to provide interim storage for the Waste Receiving and Processing Facility planned to begin operations in March 1997. Construction is scheduled for completion in January 1997. This facility comprises three buildings that have a total storage capacity of about 2,800 m^3 (3,700 yd^3).

Thermal Treatment Contract

In an effort to involve the private sector in waste treatment activities on the Site, bids were solicited for processing stored and future generated solid waste that requires thermal treatment per Resource Conservation and Recovery Act regulations. In October 1995, the contract for this work was awarded to Allied Technology Group, Inc. The contract is for 5 years, with five 1-year renewal options. Waste processing is scheduled to begin in fiscal year 2001.

Stabilization Contract

A contract for waste stabilization is in the bid review process. This contract is scheduled to be awarded in June 1996, with treatment scheduled to begin in September

1999. The initial contract is for 5 years, with five 1-year renewal options. This contract will result in the replacement of the treatment capabilities previously planned for the Waste Receiving and Processing 2A facility, which was terminated by DOE in 1995.

Waste Tank Safety Issues

The Waste Tank Safety Program 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 Program serves as the focal point for identification and resolution of selected high-priority waste tank safety issues, with resolutions being completed in priority order. Tanks with the highest risk will be evaluated and mitigated first. The tasks to resolve safety issues 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 questions (DOE 1991), 3) mitigate any hazardous conditions to ensure safe storage of the waste, 4) store and monitor waste conditions, and 5) resolve the respective safety issues. Each of these steps has supporting functions of some combination of monitoring, mathematical analyses, laboratory studies, and in-tank sampling or testing. The path that is followed depends on whether the waste requires treatment or can be stored safely by implementation of strict controls.

The Waste Tank Safety Program 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 and categorized by safety issue. At the end of 1995, 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 the four categories listed above to ensure increased attention and monitoring. Two other safety concerns involving some or all of the tanks' criticality and noxious vapor safety issues have also been addressed.

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 (482°F) for a reaction to propagate. The hottest ferrocyanide tank temperature is 53°C (127°F) and decreasing. In October 1990, an unreviewed safety question was declared because safety was not adequately defined by 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 levels have decreased, because of hydrolysis and radiolysis (aging), to acceptable low levels (Lilga et al. 1994).

Because the ferrocyanide has been shown to age significantly under temperature, pH, and radioactive conditions present in the high-level waste tanks, it is not necessary to sample all 18 of the ferrocyanide tanks. Nine of the tanks have been sampled, and all show that the ferrocyanide has degraded to levels too low to support propagating reactions. The nine tanks that were sampled represent the remaining tanks in terms of the waste parameters that enhance the degradation (aging) process.

Flammable Gas

The flammable gas safety issue involves the generation, retention, and potential release of flammable gases by the waste. Previously, 25 tanks were identified and placed on the Flammable Gas Watch List. In prior years, work controls were instituted to prevent introduction of spark sources into 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 installation of a mixing pump. The pump is operated up to three times a week to mix the waste and release gases that are generated and retained in the waste. This mitigation technique has been completely successful, and no episodic releases of gas have occurred since the pump was installed. A spare mixer pump is available in case the original pump should fail.

Hydrogen monitors have been 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 for the SY tank farm was submitted to DOE in 1995 for closure action; approval is expected in 1996.

Additional instrumentation for determining waste properties and tank behavior have been developed for use in the flammable gas tanks. These instruments are the viscometer for measuring the viscosity of the waste in situ in the tanks, a void fraction meter that determines in situ the amount of gas in a given volume of waste by compression, a retained gas sampler that captures a waste sample in a gas tight chamber and allows the gas composition to be measured after the apparatus is brought into a hot cell, and a Gas Characterization System that allows a broad spectrum of domespace gases (including hydrogen, ammonia, and nitrous oxide) to be continuously monitored for selected tanks. All of these devices are scheduled to be operational in 1996.

In November 1995, flammable gas controls were placed on all 177 high-level waste storage tanks after several events occurred where hydrogen gas was found at significant levels in the waste tank undergoing interim stabilization and in another tank being core-sampled. All rotary-mode sampling using the sampling trucks was suspended until a safety assessment covering this method could be approved for tanks that might be retaining pockets of gas within the waste matrix.

The Tri-Party Agreement milestone for resolution of the Flammable Gas Safety Issue is scheduled for September 2001.

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 have to be severely restricted 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, starting the fourth quarter of 1996, and transfer of waste to a double-shell tank. Double-shell tanks are designed to better handle heat-bearing materials than single-shell tanks. As part of the accelerated retrieval program, a refrigerated chiller system is being installed to remove radioactive decay heat and the heat generated by the waste transfer pumps.

The Tri-Party Agreement milestone for resolution of the High-Heat Safety Issue is scheduled for September 2001, with an interim milestone to start sluicing retrieval of the waste in tank 241-C-106 by October 1997.

Organic Tanks

The organic tanks safety issue involves the potential for uncontrolled exothermic reactions of organic chemicals and nitrates/nitrites or organic solvents also present in some of the tanks. During 1995 as part of the vapor sampling program, it was shown that organic vapors in the organic tanks are too low in concentration to exceed even 25% of their lower flammability limits. Criteria to screen tanks for possible organic compounds were also established based on analyses and simulant testing. Tank waste was screened against these criteria using historic and recent sampling data (Webb et al. 1995). Concentrations and temperatures required to support propagating exothermic reactions are comparable to those for ferrocyanide (Fauske et al. 1995). In addition, moisture levels of 20 wt% and less, in some cases, will prevent reactions from propagating regardless of the fuel concentration. To determine if adequate moisture is present in the waste, special surface monitoring instrumentation is being developed, and full-depth core samples of waste in organic tanks is continuing.

Work controls were implemented in 1990 to prevent the introduction of ignition sources into 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 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 are water soluble in nitrate-nitrite salt solutions. Thus, a high percentage of reactive 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.

During 1995, waste samples were obtained from eleven organic tanks, and 16 of the tanks were vapor sampled. Tank characterization reports have been or are being prepared for each of the sampling events. These reports are available to the public. The Tri-Party Agreement milestone for resolution of the Organic Tanks Safety Issue is scheduled for September 2001.

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. A potential criticality safety issue still remains for waste transfers required as part of the retrieval and pre-treatment processes. The Tri-Party Agreement milestone for resolution of the Criticality Safety Issue is scheduled for September 1999.

Vapor Sampling Program

Some of the Hanford Site tanks contain chemicals that release noxious 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 using heated sampling tubes. 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. As of December 1995, 38 high-level waste tanks were vapor sampled using heated sampling tubes. The two sampling methods are extremely sensitive and can detect vapors down into the low parts per billion range for certain compounds and consequently a number of organic species are identified in each tank sample. The levels of noxious substances present are normally very low and usually within published guidelines. A separate report is prepared for every tank sampled; each will be available to the public.

Waste Tank Status

The status of the 177 waste tanks as of December 1995 is reported in *Waste Tank Summary for Month Ending December 31, 1995* (Hanlon 1996). 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 the Watch List
  - 18 single-shell tanks[a] (six tanks were removed from the Watch List in 1993 and 1994)
- Number of flammable gas tanks on the Watch List
  - 19 single-shell tanks[b]
  - 6 double-shell tanks
- Number of organic tanks on the Watch List
  - 20 single-shell tanks.

So far, 114 single-shell tanks have been stabilized, with the tank stabilization program to be completed in 2000. At the end of 1995, 98 single-shell tanks had intrusion prevention devices completed, and 51 single-shell tanks were disconnected and capped to avoid inadvertent liquid additions to the tanks.

The total estimated volume of radioactive waste leakage from single-shell tanks is 2,300,000 to 3,400,000 L (600,000 to 900,000 gal).

During 1995, pumping occurred in eleven single-shell tanks. Portions of tanks T-107, T-111, BX-106, BX-111, BY-102, BY-103, BY-106, BY-109, C-102, C-107, and C-110 were pumped.

Vadose Zone Characterization

The inactive liquid effluent facilities vadose zone (the vadose zone is the zone between the soil surface and the water table) monitoring program conducted radiological surveys of approximately 70 boreholes or wells during calendar year 1995. The surveys identified gamma emitting radionuclides in the soils that were created by the liquid discharges. These survey data will become the baseline for any further vadose zone monitoring at these facilities.

Wells that are scheduled for decommissioning onsite are also surveyed to assure that no radioactivity exists in the wells before they are filled in. These data add to the geologic data base used for determining moisture in the vadose zone.

The Tank Farms Vadose Zone Characterization Project is being conducted by Rust Geotech, a DOE contractor, to gain a better understanding of contaminated soil beneath Hanford's single-shell tanks. This 4-year effort began in April 1995 with a logging technique called spectral gamma analysis. To date, about 250 dry wells out of a total of about 750 have been logged.

Preliminary data from some of the wells in the SX Tank Farm in the 200-West Area show at least one radioactive isotope, cesium, exists deeper in the soil than reported earlier. Readings from several of the monitoring dry wells indicate that cesium is at the bottom of some of the shafts, which are up to 38 m (125 ft) deep. Currently, it is not known if cesium has migrated deeper than 38 m (125 ft) or the means by which cesium has reached this depth in the dry wells. A low-permeability confining bed is located at a depth of approximately 38 m (125 ft) below these tanks. The ground water at this tank farm is about 64 m (210 ft) below the surface.

These data will greatly improve our understanding of the contamination from single-shell tanks that are known or suspected to have leaked over the past several decades. This will lead to better management of the waste and is consistent with Hanford's priority of protecting the Columbia River and the environment.

Pollution Prevention Program

The Hanford Site Pollution Prevention Program is an organized, comprehensive, and continual effort to reduce systematically 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.

The program 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 quantity, toxicity, or mobility (or a combination of these) will be considered only when prevention

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

or recycling are not possible or practical. Environmentally safe disposal is the last option.

Hanford Site pollution prevention efforts in 1995 helped to prevent the generation of 2,907 m^3 (3,802 yd^3) of radioactive mixed waste, 207 metric tons (228 tons) of Resource Conservation and Recovery Act waste, 30,000 m^3 (39,000 yd^3) of process waste water, and 4,400 metric tons (4,800 tons) of sanitary waste. Total cost savings exceeded $26,000,000.

Numerous generator-specific initiatives were put into place that enabled these waste reductions and cost savings. To celebrate these pollution prevention activities, the "Hanford Pollution Prevention Accomplishments Book" (Betsch 1995) was published in October. The book outlines 63 initiatives that were implemented and are now in use at locations throughout the Hanford Site.

During 1995, the Hanford Site recycled 632 metric tons (695 tons) of office paper, 20 metric tons (22 tons) of cardboard, 3,574 metric tons (3,931 tons) of ferrous metal, 215 metric tons (236 tons) of non-ferrous metal, 57 metric tons (63 tons) of lead, 16 metric tons (18 tons) of solid chemicals, and 78,000 L (20,600 gal) of liquid chemicals.

A new centralized recycling center for used materials and products opened for business in May 1995. It has received more than 2,140 aerosol cans, more than 590 kg (1,300 lb) of fluorescent light ballasts, more than 11,000 linear m (36,000 linear ft) of intact spent fluorescent light tubes, and more than 50,000 kg (110,000 lb) of lead acid/gel cell batteries. The total savings since May 1995 are estimated to be almost $200,000.

Liquid Effluent Activities

242-A Evaporator

Available storage space to support remediation of the tank waste and cleanup of the Hanford Site is limited in the double-shell tanks. The 242-A Evaporator in the 200-East Area of the Hanford Site processes double-shell tank waste into a concentrate that is returned to the tanks and a process condensate stream. The 242-A Evaporator had one processing campaign in 1995. Dilute waste from three double-shell tanks was processed, resulting in an average waste volume reduction of 87.6% while producing 10 million L (2.7 million gal) of process condensate. Future campaigns are scheduled for 1996.

Effluent treatment and disposal capabilities are now available to support the continued operation of the 242-A Evaporator. The 200 Area Effluent Treatment Facility was constructed to treat the process condensate. The process condensate is temporarily stored in the Liquid Effluent Retention Facility while awaiting treatment in the Effluent Treatment Facility.

Liquid Effluent Retention Facility

The Liquid Effluent Retention Facility consists of three Resource Conservation and Recovery Act-compliant surface impoundments for storing process condensate from the 242-A Evaporator. The facility provides equalization of the flow and pH of the feed to the Effluent Treatment Facility. Each basin has a capacity of 24.6 million L (6.5 million gal). Two basins are used for normal operation, and the third is used as contingency in the event a leak develops in an operational basin. The basins are constructed of two flexible high-density polyethylene membrane liners. A system is provided to detect, collect, and remove leachate from between the primary and secondary liners. Beneath the secondary liner is a 1-m (3.3-ft)-thick soil/bentonite barrier should the primary and secondary liners fail. Each basin has a mechanically-tensioned floating membrane cover constructed of very low-density polyethylene to keep out unwanted material and to minimize evaporation of the basin contents. The facility began operation in April 1994 and is designed to operate for 20 years. A total of 33 million L (8.7 million gal) of process condensate was stored in the basins at the end of 1995.

200 Area Effluent Treatment Facility

The 200 Area Effluent Treatment Facility provides for 1) collection of liquid effluents, 2) a treatment system to reduce concentrations of radioactive and hazardous waste constituents in the effluent streams to acceptable levels, 3) tanks to allow for verification of treated effluent characteristics before discharge, and 4) a state-approved land disposal structure for effluent disposal. The treatment process constitutes best available technology and includes ultraviolet light/peroxide destruction of organic compounds, reverse osmosis to remove dissolved solids, and ion exchange to remove the last traces of contaminants. Treatment capacity of the facility is 570 L/min (150 gal/min). The Effluent Treatment Facility began hot operation in December 1995 and has a 30-year design life.

The treated effluent from the Effluent Treatment Facility is sampled to verify that the concentrations of radioactive

and hazardous waste constituents have been reduced to acceptable levels and discharged via a dedicated pipeline to a state-approved land disposal structure. The disposal facility consists of an underground drain field. The percolation rates for the field have been established by site testing and evaluation of disposal site soil characteristics. Tritium in the liquid effluent cannot be practically removed, and the location of the disposal facility maximizes the time for migration to the Columbia River to allow for radioactive decay. A delisting petition was approved by the EPA and exempts the treated process condensate from the requirements of hazardous waste regulations under the Resource Conservation and Recovery Act and imposes certain effluent quality restrictions. High concentrations of ammonia in the process condensate also make this stream a dangerous waste subject to Washington Administrative Code (WAC) 173-303, *Dangerous Waste Regulations*. After treatment in the facility, the discharged effluent is not a dangerous waste. The disposal facility was permitted in June 1995 by the Washington State Department of Ecology under the WAC 173-216, *State Waste Discharge Permit Program*. The discharge permit requires monitoring of the effluent ground water to ensure that concentrations for certain constituents are not exceeded.

Secondary waste from treating the process condensate is a low-level mixed waste that will be concentrated, dried, and packaged in 0.21-m^3 (55-gal) drums. The Effluent Treatment Facility is a Resource Conservation and Recovery Act permitted storage facility, and this secondary waste material is temporarily stored until it is transferred to the Central Waste Complex for subsequent treatment (if needed to meet Land Disposal Restriction treatment standards) and disposal in the Mixed Waste Trench.

200 Area Treated Effluent Disposal Facility

The 200 Area Treated Effluent Disposal Facility is a collection and disposal system for non-Resource Conservation and Recovery Act permitted waste streams that already meet discharge requirements. Implementation of regulatory required "best available technology/all known and reasonable treatment" is the responsibility of the generating facilities. Facilities that discharge to the 200 Area Treated Effluent Disposal Facility currently include the Plutonium Finishing Plant, 222-S Laboratory, T Plant, 284-W Power Plant, Plutonium-Uranium Extraction Plant, B Plant, and 242-A-81 Water Services Building. Each facility must comply with discharge limits in the WAC 173-216 State Waste Discharge Permit without further treatment.

The 200 Area Treated Effluent Disposal Facility began operation in April 1995 and is designed to operate for 30 years. The design capacity of the facility is 8,700 L/min (2,300 gal/min), although the discharge permit presently limits the average monthly flow to 2,400 L/min (actually specified as 640 gal/min). Approximately 490 million L (130 million gal) of treated effluent was discharged in 1995. The effluent is discharged to two 2 ha (5 acre) disposal ponds located east of the 200-East Area. The discharge permit requires monitoring of the effluent ground water to ensure that concentrations for certain constituents are not exceeded.

300 Area Treated Effluent Disposal Facility

Waste water from laboratories, research facilities, office buildings, and former fuel fabrication facilities in the 300 Area is treated in the 300 Area Treated Effluent Disposal Facility. The waste water consists of once-through cooling water, steam condensate, and other liquid wastes generated in non-contact radioactive processes. The laboratory services are particularly critical to Hanford Site cleanup activities, including tank waste remediation efforts.

The 300 Area Treated Effluent Disposal Facility is designed for continuous receipt of waste waters, with a storage capacity of up to 5 days at the design flow rate of 1,100 L/min (300 gal/min). The facility treats the waste water using best available technology. The treatment process includes iron co-precipitation to remove heavy metals, thiol functional resin ion exchange to remove mercury, and ultraviolet light/hydrogen peroxide oxidation to destroy organics and cyanide. Sludge from the iron co-precipitation process is dewatered and used for backfill in the low-level waste trench. The treated liquid effluent is monitored and discharged through an outfall to the Columbia River under a National Pollutant Discharge Elimination System permit. The permit contains a reopener clause such that the permit conditions can be renegotiated after one year of operation. Capability exists to divert the treated effluent to holding tanks before discharge, if needed, until a determination can be made for final disposal based on sampling. The 300 Area Treated Effluent Disposal Facility began operating in December 1994 and treated about 310 million L (83 million gal) of waste water in 1995.

340 Waste Handling Facility

The 340 Facility provides receipt, storage, and loadout capability for low-level liquid waste generated during laboratory operations in the 300 Area. The waste is accumulated and stored in two 57,000-L (15,000-gal) tanks located in a covered, below-grade vault in the 340 Building. Six additional 30,000-L (8,000-gal) tanks in the adjacent 340-A building provide backup storage capability. The waste is pumped into rail cars and transported to the 200-East Area 204-AR Unloading Facility for neutralization and transfer to double-shell tanks in the 200 Area for storage. The 340 Facility does not have a Resource Conservation and Recovery Act permit, and wastes cannot be stored for more than 90 days.

The 340 Facility is scheduled to cease operation in about the year 2000. A new waste handling facility with storage and loadout capability will be provided for the 325 Building. This replacement facility will also serve any other generators that are still operating. Once shut down, the 340 Facility will be cleaned out and custody will be transferred to the Transition Projects Program for decontamination and decommissioning.

300 Area Process Sewer Upgrades

Until 1995, there were plans to replace the existing 300 Area gravity-draining process sewer system with a new pressure/vacuum system. However, the list of buildings that needed the process sewer was changing, and problems with a mechanical system became apparent. Approval by the regulators was obtained for a proposal to re-line the existing piping. The new approach will result in cost savings of more than $4 million. The process involves camera surveillance and clean-out of the piping, installation of a resin-impregnated polyester felt fiber on the pipe walls, and thermal curing by heating the water. Lateral pipelines were cut using robotics, and new manholes and clean-outs were constructed as needed for access. The work was approximately 60% complete at the end of 1995. Remaining work involves installation of additional process sewer lines and storm water connections, a pumping station to serve buildings in the southeast 300 Area, and disposal of drummed residue from pipe clean-out.

Phase II Liquid Effluent Streams

The DOE Richland Operations Office has committed to implement "best available technology/all known and reasonable treatment" for nine waste-water streams and to permit the streams under the WAC 173-216, *State Waste Discharge Permit Program* by October 1997. This activity is required by the Washington State Department of Ecology Consent Order No. DE 91NM-177 and Tri-Party Agreement milestone M-17-00B, and includes the elimination, minimization, or treatment of effluents being discharged to the 216-B-3 Expansion Ponds. One stream, the 241-AY/AZ Steam Condensate, is returned to the tank farms and is not planned to be discharged. Another stream, the 183-D Filter Backwash, was eliminated. A WAC 173-216 Discharge Permit application was submitted for the 400 Area Secondary Cooling Water stream in December 1992 and a final permit is expected to be issued by the Washington State Department of Ecology in 1996.

The project, "Phase II Effluent Treatment and Disposal," has been identified to provide the necessary construction activity for the following streams: 242-A Evaporator Cooling Water, the 242-A Evaporator Steam Condensate, the 244-AR Vault Cooling Water, the 284-E Powerplant (including 283-E and 282-E) Waste Water, and the B Plant/Waste Encapsulation and Storage Facility Cooling Water. Another stream, the 241-A Tank Farm Cooling Water, is to be connected to the 200 Area Treated Effluent Disposal Facility. Conceptual design for the project was completed in June 1993, advanced conceptual design was completed in January 1995, and definitive design started in February 1995.

In April 1995, the "best available technology/all known and reasonable treatment" determination was revised for the 200 Area Phase II waste-water streams based on additional sampling and better than expected effluent quality. As a result, only the cooling towers at B Plant remain in the construction project scope. The remaining 200 Area Phase II waste-water streams will now be routed to the 200 Area Treated Effluent Disposal Facility, and the existing WAC 173-216 Discharge Permit will be revised; a separate 200 Area Phase II Waste-Water Discharge Permit application submitted in December 1993 will not be acted upon. The 244-AR Vault Cooling Water stream was discontinued.

Miscellaneous Streams

Miscellaneous streams are lower priority waste-water streams that discharge to the soil column throughout the Hanford Site and are subject to requirements in Washington State Department of Ecology Consent Order No. DE 91NM-177. The *Plan and Schedule for*

Disposition and Regulatory Compliance for Miscellaneous Streams, (DOE 1994c), was approved by the Washington State Department of Ecology in February 1995. This document provides a plan and schedule for ensuring that miscellaneous streams will be in compliance with the applicable state regulations (e.g., WAC 173-216 and WAC 173-218). The commitments established in the plan and schedule include annually updating the miscellaneous streams inventory, registering injection wells, submitting four categorical permit applications, and implementing best management practices.

The inventory of miscellaneous streams includes more than 640 streams. Streams that already have discharge permits in place, streams for which permit applications have been submitted, or streams that are covered under a National Pollutant Discharge Elimination System permit are not included. All injection wells were registered under WAC 173-218 in August 1995, including injection wells that were previously registered. This ensured that the registrations were current, complete, and in the same format.

Use of categorical permits provides a vehicle to easily permit miscellaneous streams with similar characteristics. Four categorical permit applications are scheduled to be submitted through September 1998 for

- Hydrotesting, maintenance, and construction discharges (application submitted November 1995)
- Cooling-water discharges and uncontaminated steam condensate
- Surface-water discharges and safety shower discharges
- Storm-water discharges.

A best management practices report due to the Washington State Department of Ecology by August 1996 will include selection of preferred options and an implementation schedule.

Submarine Reactor Compartments

Eleven defueled submarine reactor compartment disposal packages were received and placed in Trench 94 in the 200-East Area during 1995. This brings the total number received to 54.

The reactor compartment disposal packages are being regulated by the Washington State Department of 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

DOE and the Hanford Natural Resource Trustees are working cooperatively to plan and execute effectively necessary restoration and mitigation actions for the proposed remediation sites. Revegetation/mitigation plans will use native plant species (seeds and shrubs) to restore the areas disturbed by remediation activities.

Bechtel Hanford, Inc. and its subcontractors CH2M Hill and IT Corp. are working cooperatively with the Natural Resource Trustees on the Mitigation Action Plan for the 100 Areas. The plan describes the planning and implementation of appropriate mitigation measures for areas disturbed during remediation. Mitigation measures include avoidance, minimization, rectification, or compensation of impacted resources.

2.4 Environmental Occurrences

R. L. Smithwick and D. G. Black

Onsite and offsite environmental releases of radioactive and regulated materials during 1995 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 1995, 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 232.1, emergency occurrences "are the most serious occurrences and require an increased alert status for onsite personnel and, in specified cases, for offsite authorities." There were no emergency occurrence reports filed in 1995.

An unusual occurrence is defined as "a nonemergency occurrence that exceeds the Off-Normal Occurrence threshold criteria, is related to safety, environment, health, security, or operations, and requires immediate notification to DOE." There were two unusual occurrence reports filed during 1995 for Site contractors. The unusual occurrences 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, safeguards and security, environmental or health protection, performance or operation of a facility." There were 22 off-normal environmental release-related occurrence reports filed at the Hanford Site during the year, most of which involved minor releases of hydraulic and diesel oils during excavation or earthmoving activities (most of which were nonregulated). The "Nature of Occurrence" for these occurrences was determined to be either "Hazardous Substance/Regulated Pollutants/Oils" or "Hazardous Material Contamination." The more significant of these off-normal occurrences are summarized below.

Unusual Occurrences

Notice of Penalty Assessed by the Washington State Department of Ecology

In May 1995, Pacific Northwest National Laboratory received a notice that the Washington State Department of Ecology had assessed a penalty against DOE and Pacific Northwest National Laboratory in the amount of $7,000. The assessment was for a failure to designate a container of solid waste in violation of Washington Administrative Code (WAC) 173-303-170(1)(a) and the procedures of WAC 173-303-170. This assessment was a result of field inspection, personnel interviews, and record reviews performed by the Washington State Department of Ecology.

Spill Plan Reference Not Submitted Within Required Time-Frame

The 200 Area Effluent Treatment Facility State Waste Discharge Permit requires the submittal of a spill plan or references of existing plans to the Washington State Department of Ecology within 60 days of the effective permit date. The submittal of the spill plan was not transmitted by its due date in August 1995. The reference to the final spill plan was transmitted to the Washington State Department of Ecology on the following day.

Off-Normal Occurrences

Contamination Discovered in Laboratory Sink

During a routine survey of Lab 416 in the 325 Building, 300 Area, the Radiological Control Technician discovered removable contamination reading 10,000 disintegrations per minute beta-gamma in the laboratory sink, which is connected to the retention process sewer. The sink was decontaminated to nonremovable levels and then replaced.

Treated Effluent Disposal Facility Failure to Meet Release Limits

The 300 Area Liquid Effluent Facilities received laboratory analysis results for effluent samples taken in 1995. On several occasions, the sample results indicated that the levels for copper, suspended solids, bis(2-ethylhexyl) phthalate, or cyanide exceeded the maximum daily limits set in the National Pollutant Discharge Elimination System permit.

The violations have not been gross or consistent. The facility was operating normally and within design specifications at the time of each event. The permit release limits established for the facility are stringent and set a precedent for waste-water treatment standards. The discharge permit for this facility is open to renegotiation after one year of operation. The management and operation contractor will use the permits re-opener clause to adjust any limits that operating data show to be too restrictive. The proposed modifications are to be submitted to DOE Richland Operations Office by August 1996.

Unplanned Discharge of Waste Water to the City of Richland Sewer System

The water processing equipment for the vehicle steam cleaning waste-water accumulation tank was stored in the bus wash area of the 1171 Building. This equipment is normally located outside, but due to potential freezing temperatures is located inside the building during winter months. During routine unattended waste-water processing, a seal ring on the pump failed, causing the circulation pump to shut down. When this occurred, it caused a syphon effect on the discharge side of the pump, which drained approximately 6,800 L (1,800 gal) of partially processed waste water through the defective seal ring from the holding tank directly to the city sewer system. Based on the pH test and visual inspection of the water and system, the City of Richland determined the discharge was within acceptable limits.

Effluent Monitoring Information

3.0 Effluent Monitoring, Waste Management, and Chemical Inventory Information

Environmental monitoring requirements at the Hanford Site are set forth in DOE Order 5400.1, "General Environmental Protection Program." By definition in the Order, environmental monitoring consists of two major activities: effluent monitoring and environmental surveillance. Effluent monitoring is the collection of samples and analyses, or measurements, of liquid and gaseous effluents for the purpose of characterizing and quantifying contaminants released to the environment, providing source terms for assessing potential exposures of the public, providing a means to control effluents at or near the point of discharge, and determining compliance with applicable standards and permit requirements. Environmental surveillance is the collection and analysis of samples, or direct measurements, of air, water, soil, vegetation, foodstuffs, terrestrial and aquatic biota and other environmental media from DOE sites and their environs for the purpose of assessing the potential exposure of members of the public, assessing the effects, if any, on the local environment, and determining compliance with applicable standards and permit requirements.

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 (Section 3.1). The effectiveness of effluent treatment and control and waste management practices are evaluated through near-facility monitoring (Section 3.2). Types, quantities, and locations of chemicals are also tracked (Section 3.3). This section summarizes the data collected in 1995 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 1995* (Schmidt et al. 1996), *1995 Hanford Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1996c), the *Hanford Site Annual Dangerous Waste Report for Calendar Year 1995* (DOE 1996b), and *Summary of Radioactive Solid Waste Received in the 200 Areas*

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* (DOE 1994a), 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 activity, total beta activity, and, as warranted, specific radionuclides. Nonradioactive constituents are also either monitored or sampled, as applicable.

Small quantities of the radionuclides tritium, colbalt-60, strontium-90, ruthenium-106, tin-113, antimony-125, iodine-129, cesium-134, cesium-137, europium-152, europium-154, europium-155, radon-220, radon-222, plutonium-238, plutonium-239,240, plutonium-241, americium-241, and uranium 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, 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 1995, releases of radioactive and nonradioactive constituents in effluents were less than applicable standards.

Effluent release data are documented in several reports in addition to this one, and all are available to the public. For instance, DOE's Richland Operations Office annually submits to EPA a report of radioactive airborne emissions from the Site, in compliance with National Emission Standards for Hazardous Air Pollutants (DOE 1996e). Data quantifying radioactive liquid and airborne effluents discharged from Westinghouse Hanford Company facilities and activities are reported to DOE annually (WHC 1996a). Monitoring results for liquid streams regulated by the National Pollutant Discharge Elimination System permit are reported monthly to EPA. Nonradioactive air emissions are reported yearly to the Washington State Department of 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. Emission sources 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 activity alpha, 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

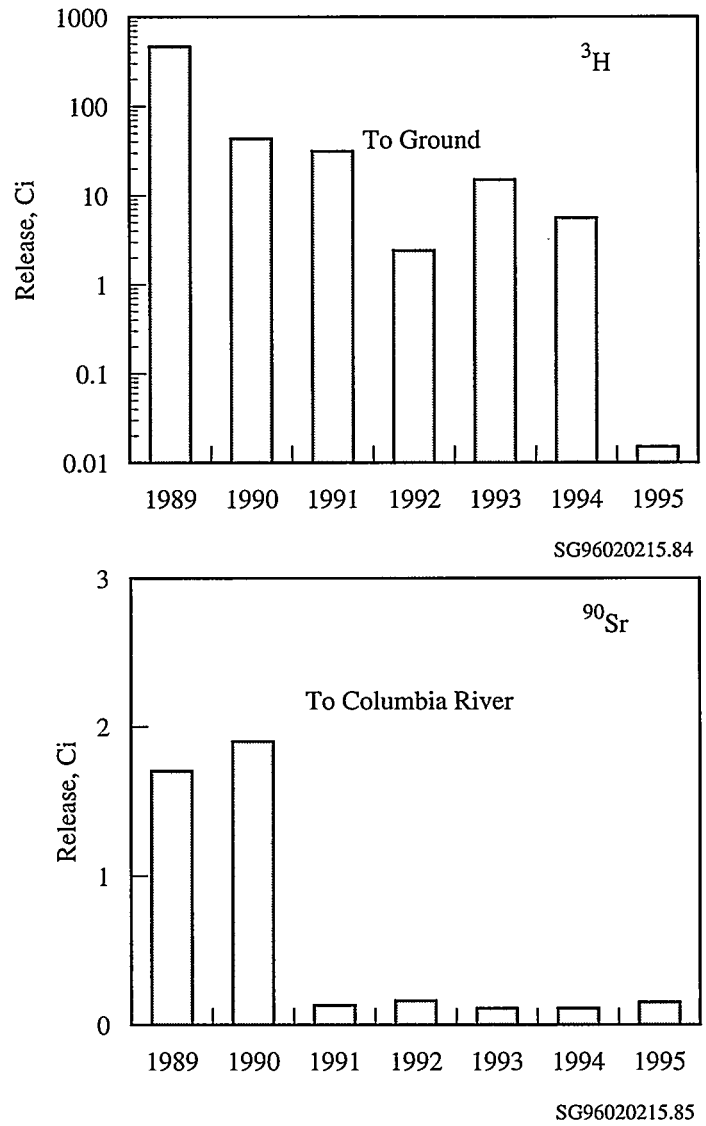


Figure 3.1.1. Liquid Releases of Selected Radionuclides from Site Facilities, 1989 Through 1995

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 of N Reactor, the two 100-K Area water-filled storage basins containing irradiated fuel, an inactive recirculation facility that filtered radioactive water from the N Reactor basin that was used for storage of irradiated fuel, a room used for cleaning contaminated tools and equipment, and a radiochemistry laboratory. Seven radioactive emission discharge points were active in the 100 Areas during 1995.

- 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 Plutonium-Uranium Extraction Plant, the Plutonium Finishing Plant, T Plant, the 222-S Analytical Laboratory, underground tanks for storage of high-level radioactive waste, and waste evaporators.

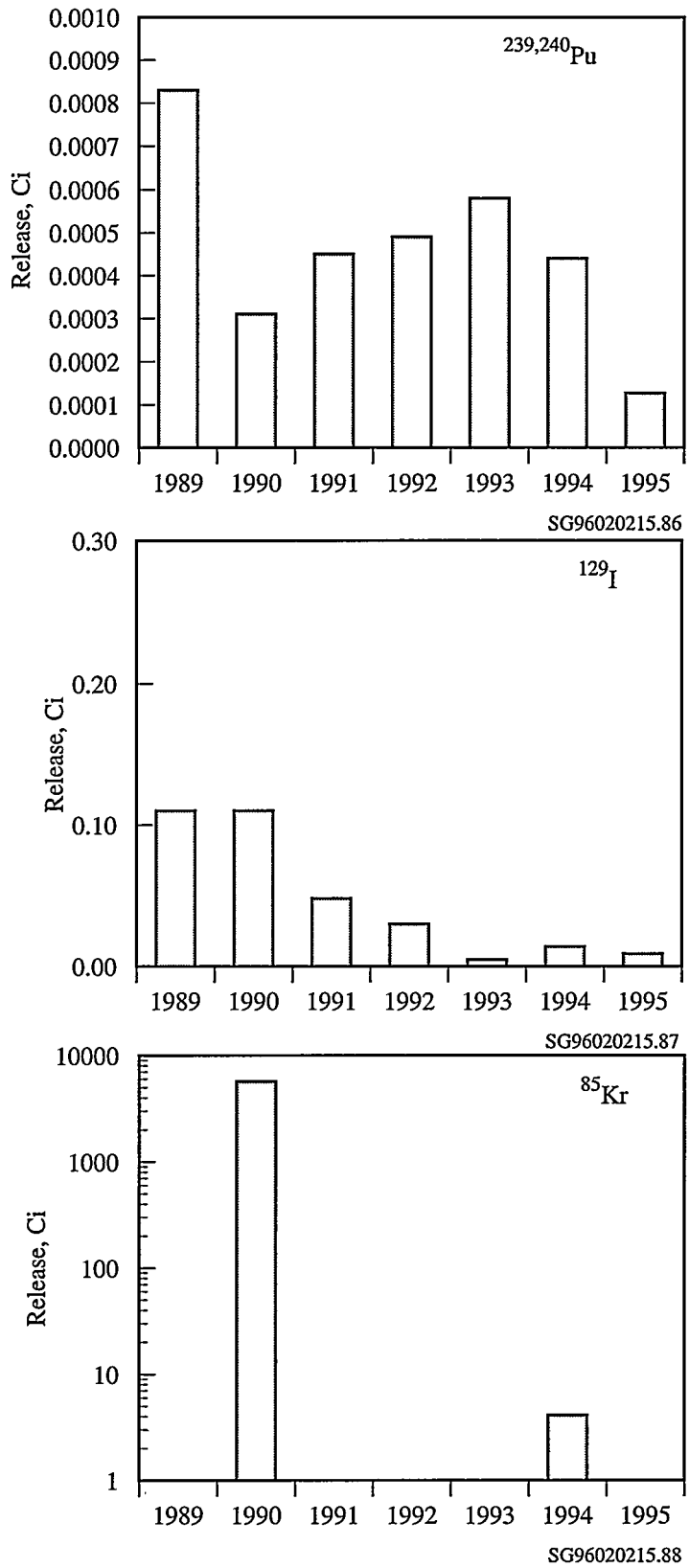


Figure 3.1.2. Airborne Releases of Selected Radionuclides from Site Facilities, 1989 Through 1995

During 1995, 61 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 1995, 37 radioactive emission discharge points were active in the 300 Area.

- The 400 Area contains the Fast Flux Test Facility, the Maintenance and Storage Facility, and the Fuels and Materials Examination Facility. Operations and support activities at the Fast Flux Test Facility and the Maintenance and Storage Facility released small quantities of radioactive material to the environment, even though the reactor did not operate in 1995. The 400 Area had four active radioactive emission discharge points during 1995.

- The 600 Area encompasses the remaining portions of the Hanford Site not assigned to other areas. One minor radioactive emission point was active during 1995 (the 6652-H Ecology Laboratory on the Fitzner/Eberhardt Arid Lands Ecology Reserve).

A summary of the Hanford Site's 1995 radioactive airborne emissions from point sources is provided in Table 3.1.1. The Hanford Site also produces radioactive airborne emissions from diffuse and fugitive sources. Estimates of the radioactive airborne emissions from these sources can be found in the report *Radionuclide Air Emissions Report for the Hanford Site Calendar Year 1995* (DOE 1996e).

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 Plutonium-Uranium Extraction Plant, 242-A Evaporator, 200-East Area Tank Farms, and 200-West Area Tank Farms. Ammonia emissions are monitored only when activities at these facilities are capable of generating them. In 1995, the 242-A Evaporator operated during April, June, and July producing reportable ammonia emissions. The 200-East Area and 200-West Area Tank Farms also produced reportable ammonia emissions in 1995. The ammonia releases from the 242-A Evaporator, and 200 Areas Tank Farms are provided in Table 3.1.2.

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 are reported in accordance with the air quality standards established by the Washington State Department of Ecology. Powerhouse emissions are calculated from the quantities of fossil fuel consumed, using EPA-approved formulas.

Should activities lead to chemical emissions in excess of quantities reportable under the Comprehensive Environmental Response, Compensation, and Liability Act, 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 1995 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 activity, total beta activity, and selected radionuclides.

Only facilities in the 200 Areas discharged radioactive liquid effluents to ground disposal facilities in 1995. A summary of radioactive liquid effluents discharged to the 200 Areas' ground disposal facilities in 1995 is provided 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 4.2, "Surface Water and Sediment Surveillance"). These measurements are used with the direct effluent measurements to determine potential public doses.

Table 3.1.1. Radionuclides Discharged to the Atmosphere from the Hanford Site, 1995

Radionuclide	Half-Life	Release, Ci[a]				
		100 Areas	200-East Area	200-West Area	300 Area	400 Area[b]
^{3}H (as HTO)[c]	12.3 yr	NM[d]	NM	NM	2.80	2.5×10^{-2}
^{3}H (as HT)[e]	12.3 yr	NM	NM	NM	3.84	NM
^{60}Co	5.3 yr	9.2×10^{-6}	ND[d]	ND	ND	NM
^{65}Zn	244.4 d	ND	ND	ND	ND	NM
^{90}Sr	29.1 yr	6.1×10^{-5}	6.8×10^{-5}[f]	1.0×10^{-4}[f]	1.8×10^{-5}[f]	6.1×10^{-8}[f]
$^{95}ZrNb$	64.02 d	ND	ND	ND	ND	NM
^{106}Ru	368 d	1.1×10^{-5}	6.7×10^{-6}	1.0×10^{-8}	ND	NM
^{113}Sn	115.1 d	ND	8.0×10^{-7}	1.4×10^{-7}	ND	NM
^{125}Sb	2.77 yr	2.8×10^{-6}	9.1×10^{-6}	1.2×10^{-7}	ND	NM
^{129}I	1.6×10^{7} yr	NM	8.9×10^{-3}	NM	ND	NM
^{131}I	8.040 d	NM	ND	NM	ND	ND
^{134}Cs	2.1 yr	1.3×10^{-6}	2.4×10^{-8}	1.1×10^{-7}	2.7×10^{-8}	NM
^{137}Cs	30 yr	2.5×10^{-4}	3.8×10^{-4}	1.9×10^{-5}	1.5×10^{-6}	5.9×10^{-6}[g]
^{152}Eu	13.6 yr	ND	3.7×10^{-7}	1.6×10^{-7}	ND	NM
^{154}Eu	8.8 yr	8.3×10^{-6}	4.6×10^{-7}	2.6×10^{-7}	ND	NM
^{155}Eu	5 yr	1.5×10^{-6}	2.2×10^{-7}	1.2×10^{-7}	4.3×10^{-8}	NM
^{220}Rn	56 s	NM	NM	NM	79	NM
^{222}Rn	3.8 d	NM	NM	NM	0.4	NM
Uranium, depleted	$\geq 2.445 \times 10^{5}$	NM	NM	NM	2.2×10^{-8}[h]	NM
^{238}Pu	87.7 yr	2.3×10^{-6}	6.9×10^{-7}	2.6×10^{-6}	2.5×10^{-9}	NM
$^{239,240}Pu$	2.4×10^{4} yr	1.5×10^{-5}[i]	7.9×10^{-6}[i]	1.0×10^{-4}[i]	2.1×10^{-6}[i]	1.7×10^{-6}[i]
^{241}Pu	14.4 yr	2.1×10^{-4}	1.2×10^{-4}	2.0×10^{-4}	NM	NM
^{241}Am	432 yr	5.7×10^{-6}	1.6×10^{-5}	1.7×10^{-5}	1.1×10^{-8}	NM

(a) 1 Ci = 3.7×10^{10} Bq.
(b) Releases from the 400 Area contain emissions from one stack in the 600 Area.
(c) HTO = tritiated water vapor.
(d) NM = not measured; ND = none detected.
(e) HT = elemental tritium.
(f) This value includes total beta release data. Total beta and unspecified beta results are assumed to be ^{90}Sr for dose calculations.
(g) The 400 Area's ^{137}Cs value is derived fully from total beta measurements.
(h) 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).
(i) This value includes total alpha release data. Total alpha and unspecified alpha results assumed to be $^{239,240}Pu$ for dose calculations.

Table 3.1.2. Nonradioactive Constituents Discharged to the Atmosphere, 1995[a]

Constituent	Release, kg		
	200-East Area	200-West Area	300 Area
Particulate matter	1.70×10^3	3.19×10^2	1.60×10^4
Nitrogen oxides	1.77×10^5	2.82×10^4	4.69×10^4
Sulfur oxides	2.25×10^5	3.53×10^4	2.34×10^5
Carbon monoxide	6.43×10^4	1.01×10^4	4.25×10^3
Lead	1.62×10^2	2.53×10^1	2.52×10^1
Volatile organic compounds[b]	6.43×10^2	1.00×10^2	2.38×10^2
Ammonia[c]	6.18×10^3	1.53×10^3	NM
Arsenic	1.73×10^2	2.70×10^1	1.48×10^1
Beryllium	2.33×10^1	3.64×10^0	5.46×10^{-1}
Cadmium	1.37×10^1	2.18×10^0	2.74×10^1
Carbon tetrachloride[d]	NM	9.07×10^1	NM
Chromium	5.01×10^2	7.83×10^1	1.67×10^1
Cobalt	NE	NE	1.57×10^1
Copper	3.15×10^2	5.02×10^2	3.62×10^1
Formaldehyde	7.05×10^1	1.25×10^1	5.27×10^1
Manganese	6.93×10^2	1.08×10^2	9.63×10^0
Mercury	5.11×10^0	8.08×10^{-1}	4.16×10^0
Nickel	4.12×10^2	6.43×10^1	3.03×10^2
Polycyclic organic matter	NE	6.00×10^2	7.14×10^3
Selenium	6.26×10^1	9.84×10^0	4.94×10^0
Vanadium	4.31×10^1	7.79×10^0	3.93×10^2

(a) The estimate of volatile organic compound emissions do not include emissions from certain laboratory operations; NM = not measured; NE = no emissions.
(b) Produced from burning fossil fuels for steam generation.
(c) Ammonia releases are from the 200-East Area Tank Farms, 200-West Area Tank Farms, and the operation of the 242-A Evaporator.
(d) Does not include CCl_4 Vapor Extraction Project releases from passively ventilated wells.

Table 3.1.3. Radionuclides in Liquid Effluents Discharged to Ground Disposal Facilities from the 200 Areas, 1995

Radionuclide	Half-Life	Release, Ci[a]
^{3}H	12.3 yr	1.5×10^{-2}
^{60}Co	5.3 yr	9.5×10^{-3}
^{90}Sr	29.1 yr	1.2×10^{-1}
^{99}Tc	2.1×10^{5} yr	2.3×10^{-4}
^{106}Ru	368 d	1.9×10^{-1}
^{113}Sn	115 d	1.0×10^{-1}
^{125}Sb	2.8 yr	3.8×10^{-3}
^{134}Cs	2.1 yr	1.2×10^{-3}
^{137}Cs	30 yr	4.5×10^{-2}
^{152}Eu	13.3 yr	1.1×10^{-3}
^{154}Eu	8.8 yr	3.3×10^{-2}
^{155}Eu	4.96 yr	2.3×10^{-2}
Total uranium	$>2.4 \times 10^{5}$ yr	5.5×10^{-4}
^{238}Pu	87.7 yr	7.5×10^{-4}
$^{239,240}Pu$	2.4×10^{4} yr	7.2×10^{-3}
^{241}Am	432 yr	1.2×10^{-3}

(a) 1 Ci = 3.7×10^{10} Bq.

Table 3.1.4. Radionuclides in Liquid Effluents Discharged to the Columbia River from the 100 Areas, 1995

Radionuclide	Half-Life	Release, Ci[a]
^{3}H	12.3 yr	1.5×10^{-1}
^{60}Co	5.3 yr	1.1×10^{-4}
^{90}Sr	29.1 yr	2.1×10^{-1}
^{106}Ru	368 d	ND[b]
^{125}Sb	2.8 yr	2.7×10^{-4}
^{134}Cs	2.1 yr	ND
^{137}Cs	30 yr	2.1×10^{-3}
^{154}Eu	8.8 yr	4.1×10^{-3}
^{238}Pu	87.7 yr	ND
$^{239,240}Pu$	2.4×10^{4} yr	4.3×10^{-7}
^{241}Am	432 yr	1.2×10^{-5}

(a) 1 Ci = 3.7×10^{10} Bq.
(b) ND = not detected.

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 permits for the Site. Should chemicals in liquid effluents that exceed quantities reportable under the Comprehensive Environmental Response, Compensation, and Liability Act, the release totals are reported immediately to EPA. If emissions remain stable at predicted levels, they may be reported annually with EPA's permission. Table 3.1.5 contains a synopsis of the National Pollutant Discharge Elimination System permit violations in 1995.

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.

Comprehensive Environmental Response, Compensation, and Liability Act and Washington Administrative Code Chemical Releases

Chemical releases are hazardous chemicals discharged directly to the environment, rather than through a liquid effluent stream. These releases almost entirely consist

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 Comprehensive Environmental Response, Compensation, and Liability Act as amended.

There were 18 releases reported under the Comprehensive Environmental Response, Compensation, and Liability Act-reportable quantity and Washington Administrative Code requirements by Hanford contractors in 1995. Effective July 1995, the reportable ethylene glycol quantity was increased from 0.454 kg (1 lb) to 2270 kg (5,005 lb), by the final rule for *Federal Register* 60FR30926. The number of reportable ethylene glycol releases have been significantly reduced as a result of the change in the reportable quantity. Table 3.1.6 contains a synopsis of 1995 Comprehensive Environmental Response, Compensation, and Liability Act reportable spills.

Table 3.1.5. National Pollutant Discharge Elimination System Permit Violations, 1995

Date	Facility	Material	Concentration
5/23/95	310 TEDF[a]	Copper solution	0.3 µg/L
6/06/95	310 TEDF	Copper solution	5.0 µg/L
7/07/95	310 TEDF	Copper solution	0.7 µg/L
7/11/95	310 TEDF	Total suspended solids	2.0 mg/L
8/22/95	310 TEDF	Bis'phthalate	9 µg/L

(a) TEDF = Treated Effluent Disposal Facility.

Table 3.1.6. Comprehensive Environmental Response, Compensation, and Liability Act and Washington Administrative Code Reportable Spills, 1995

Material	Occurrences	Quantity[a]
Ethylene glycol	11	67.6 kg
#6 fuel oil	1	4 kg
Sodium hydroxide	1	3.8 L
Freon R-12	1	79 g
Mercury (metallic)	1	190 g
Sulfur dioxide	1	Undetermined[b]
Diesel/unleaded fuel	1	Undetermined[c]
Waste oil	1	Undetermined[d]

(a) To convert kg to lb, multiply by 2.205; grams to lb, multiply by 0.002205; L to gal, multiply by 0.2642.
(b) Released to atmosphere, violated Washington Administrative Code air emission standard of 1,000 ppm/h.
(c) This spill was found while removing underground storage tanks.
(d) This spill was found while removing an underground storage tank.

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 contamination control in waste management and restoration activities, and effluent treatment and control practices. These media include air, surface water and springs, surface contamination, soil and vegetation, vadose zone monitoring, investigative sampling (which can include wildlife), and external radiation. Sampling and analysis information and analytical results for 1995 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 1995* (Schmidt et al. 1996).

Near-Facility Environmental Monitoring at the Hanford Site

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 Plutonium-Uranium Extraction 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 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; Washington State Code (WAC) 246-247; and 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants."

Routine monitoring activities include sampling and monitoring ambient air, water from surface-water disposal units, external radiation dose, the vadose zone, soil, sediment, vegetation, and animals. Some of the parameters typically monitored are pH, radionuclide concentrations, radiation exposure levels, and concentrations of selected hazardous chemicals. 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 routine activities of near-facility monitoring in 1995 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 the near-facility environmental monitoring report for 1995 (Schmidt et al. 1996).

Waste disposal sites and the terrain surrounding them are surveyed to detect and characterize 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 effluents and emissions; these systems also monitor diffuse source emissions.

Collection and Analysis of Air Samples

Radioactivity in air was sampled by a network of continuously operating samplers at 47 locations near nuclear facilities: four were located in the 100-N Area, four

Table 3.2.1. Near-Facility Routine Environmental Samples and Locations, 1995

Sample Type	Total Number of Sample Locations	100-K Area	100-N Area	200/600 Areas	300/400 Areas
Air	47	4	4	38[a]	1
Surface water	13	0	8	5	0
External radiation	199	11	104[b]	63	21
Soil	80	0	12	53	15
Vegetation	86	0	20	50	16

(a) Includes one station located at the Wye Barricade.
(b) Thirty thermoluminescent dosimeters and 74 survey points.

were in the 100-K Area, 37 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 Pacific Northwest National Laboratory and the Washington State Department of Health at the Wye Barricade in the 600 Area. To avoid duplication of sampling, the near-facility environmental monitoring program used existing Pacific Northwest National Laboratory air samplers in the 300 and 400 Areas. Results for these areas are reported in Section 4.1, "Air Surveillance," and are not discussed here. Air samplers were located primarily 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 direction.

Samples were collected according to a schedule established before the monitoring year (Schmidt 1994). 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 biannual samples for each location. Each composite sample was then sent to Quanterra Inc. (Richland, Washington) to be analyzed for plutonium-238, -239,240, -241; strontium-90; uranium-234, -235, -238; and gamma-emitting radionuclides (e.g., cesium-137, cobalt-60).

Radiological Results for Air Samples

Of the radionuclide analyses performed, cesium-137; plutonium-239,240; strontium-90; and uranium were consistently detectable in the 200 Areas. Cobalt-60, infrequently plutonium-239,240, were 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 1995 and the preceding 5 years for selected radionuclides compared to DOE Derived Concentration Guides and the background air concentration as measured by the Pacific Northwest National Laboratory in distant communities. The DOE Derived Concentration Guides are reference values that are used as indices of performance (see Appendix C, Table C.5). The data indicate a large degree of variability. In general, samples collected from air samplers located at or directly adjacent to nuclear facilities had higher concentrations than did those samples collected farther away. The data also show that concentrations 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. In 1995, plutonium-241 was included as an analyte for the first time to more completely account for the dose to the public. This also made the monitoring consistent with the facility effluent monitoring analytes. A more detailed data summary is provided in Schmidt et al. (1996).

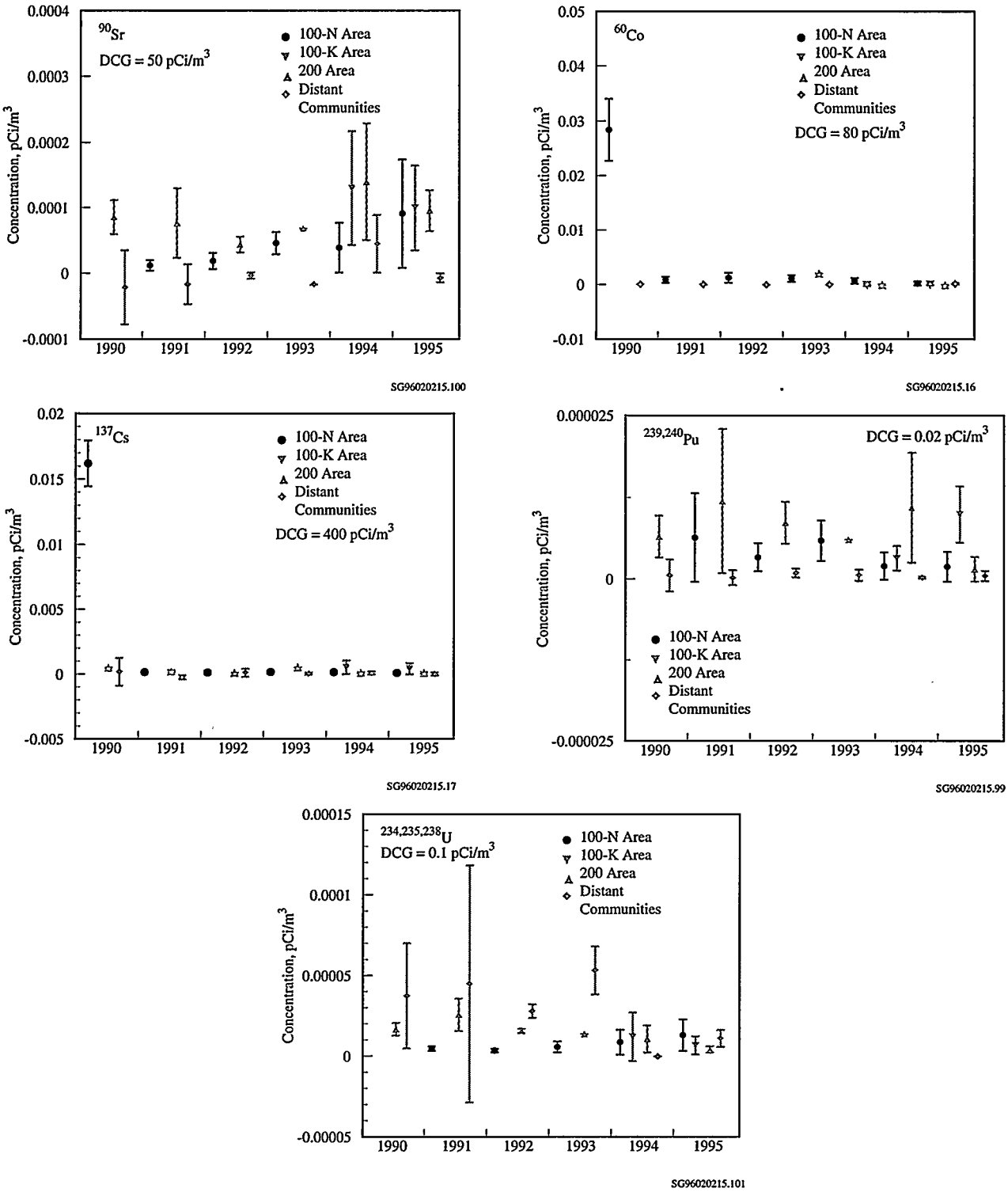

Figure 3.2.1. Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Air Samples Compared to Those in Distant Communities, 1990 Through 1995. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

100-N Area

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

100-K Area

Analytical results from 100-K ambient air samples show quantities of plutonium-239,240, and -241; americium-241; and cesium-137 that were slightly above detection levels (see Schmidt et al. 1996). These levels were much less than the DOE Derived Concentration Guides; however, they were greater than levels measured offsite. The results are slightly higher than 1994 values, which was expected due to higher facility emissions in 1995. Facility emissions have increased because the basins, which were used for spent nuclear fuel storage only, are being prepared for fuel removal.

200 Areas

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

Surface-Water Disposal Units and 100-N Riverbank 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 in the 200 Areas have declined from a maximum of five (216-2-21 Basin, 200-West Powerhouse Pond, 216-T-4 Ditch, 216-B-3C Pond, and 200-East Powerhouse Ditch) to two during 1995. These two are the 200-East Area Powerhouse Ditch and the 216-B-3C Pond. Water sampling in the 216-T-4 Ditch, located in the 200-West Area, was conducted from mid-January through March 1995. Sediment and aquatic vegetation samples were not collected from this ditch in 1995 because it was cleaned up and filled in prior to May, when these samples are normally collected. A more detailed description may be found in Schmidt et al. (1996).

Collection and Analysis of Surface-Water Disposal Unit and 100-N Riverbank Springs Samples

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. (1996). 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 Pacific Northwest National Laboratory for the 400 Area. Results for the 400 Area sampling are reported in Section 4.2, "Surface Water and Sediment Surveillance," and are not discussed here.

Radiological analyses of water samples from surface-water disposal units were performed by the Waste Sampling and Characterization Facility in 1995. Analyses included plutonium-238; plutonium-239,240; uranium; tritium; strontium-90; and gamma-emitting radionuclides. 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 for Surface-Water Disposal Units

Radiological analytical results for liquid samples from 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 DOE Derived Concentration Guides and in most cases were equal to or less than the analytical detection limit.

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 standards cited in the *Hanford Site Radiological Control Manual* (HSRCM 1994).

A more detailed data summary for samples taken to monitor surface-water disposal units is provided in Schmidt et al. (1996).

Radiological Results for 100-N Riverbank 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 at N Springs are calculated based on analysis of weekly samples collected from a monitoring well (well 199-N-46) located near the shoreline. A more detailed discussion of the release calculations may be found in the report, *Environmental Releases for Calendar Year 1995* (WHC 1996).

Table 3.2.2. Radiological Results for Liquid Samples from Surface-Water Disposal Units (pCi/L), 200 Areas, 1995

Sample Location[a]	Number of Samples		^{238}Pu	^{239}Pu	U Total	^{3}H	^{90}Sr	^{137}Cs
200-West Area Ditch	3	Mean	0.017	0.0036	2.1×10^{-5}	<450[b]	19.0	14.0
		Maximum	0.060	0.041	8.2×10^{-5}	<450	27.0	18.0
200-West Area Ponds	24	Mean	0.00031	0.074	6.0×10^{-5}	<450	0.77	-0.18[c]
		Maximum	0.032	0.18	1.7×10^{-4}	<450	6.0	1.3
200-East Area Ditch	12	Mean	0.014	0.042	1.9×10^{-4}	<450	0.90	-0.97
		Maximum	0.23	0.15	2.6×10^{-4}	<450	19.0	2.80
200-East Area Pond	12	Mean	1.2	1.1	2.2×10^{-4}	<450	-0.68	0.15
		Maximum	1.1	13	2.7×10^{-4}	<450	2.30	3.0
		DCG[d]	40	30	500[e]	2,000,000	1,000	3,000

(a) 200-West Area Ditch: 216-T-4 Pond.
200-West Area Ponds: 216-Z-21 Basin, 200-West Powerhouse Pond.
200-East Area Ditch: 200-East Powerhouse Ditch.
200-East Area Pond: 216-B-3C Pond.
(b) The detection limit for ^{3}H is 450 pCi/L .
(c) Negative values indicate results at or below background levels of radioactivity.
(d) DCG = DOE Derived Concentration Guide.
(e) Using ^{234}U as the most limiting DCG.

Table 3.2.3. Radiological Results for Aquatic Vegetation Samples from Surface-Water Disposal Units (pCi/g, dry wt), 200 Areas, 1995

Sample Locations[a]	Number of Samples		^{90}Sr	^{137}Cs	$^{239,240}Pu$	U Total (g/g)
200-West Area Ponds	2	Mean	2.4	2.0	2.1	4.4×10^{-8}
		Maximum	3.6	3.7	4.2	8.6×10^{-8}
200-East Area Pond	2	Maximum	0.56	4.0	0.91	1.0×10^{-8}
200-East Area Ditch	1	Maximum	1.6	2.3	2.9	4.9×10^{-9}

(a) 200-West Area Ponds: 216-Z-21 Basin, Powerhouse Pond.
200-East Area Pond: 216-B-3C Pond.
200-East Area Ditch: Powerhouse Ditch.

Table 3.2.4. Radiological Results for Sediment Samples from Surface-Water Disposal Units (pCi/g, dry wt), 200 Areas, 1995

Sample Locations[a]	Number of Samples		^{137}Cs	$^{239,240}Pu$	^{90}Sr	U Total (g/g)
200-West Area Ponds	2	Mean	NA[b]	0.28	0.78	1.7×10^{-7}
		Maximum	0.08	0.39	1.2	3.2×10^{-7}
200-East Area Pond	1	Maximum	6.6	2.0	0.57	1.6×10^{-7}
200-East Area Ditch	1	Maximum	NR[c]	0.52	0.41	3.8×10^{-8}

(a) 200-West Area Ponds: 216-Z-21 Basin, Powerhouse Pond.
200-East Area Pond: 216-B-3C Pond.
200-East Area Ditch: Powerhouse Ditch.
(b) NA = not available (^{137}Cs was reported for one 200-West Area Pond only).
(c) NR = not reported.

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 underreported). To verify releases, conservatively high radionuclide concentrations in samples collected from well 199-N-46 are used, 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 1995 releases from N Springs was 10 L per min (2.64 gal per min). The results of characterizing the radionuclide concentrations in the springs along the shoreline can then be compared to the concentrations measured in well 199-N-46 to ensure that the well is located in the ground-water migration route that has the highest concentrations of radionuclides.

In 1995, with the exception of tritium, the concentrations detected in shoreline springs samples were highest in springs nearest well 199-N-46. Concentrations of tritium

were highest in the two sampling locations farthest downstream. All of the springs concentrations were considerably lower than concentrations measured in the well. The data from shoreline springs sampling are summarized in Table 3.2.5. A more detailed data summary is provided in Schmidt et al. (1996).

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 the Resource, Conservation and Recovery Act. The analytical results for nitrates were all less than the 45-mg/L Drinking Water Standard for public water supplies.

Table 3.2.5. Concentration (pCi/L) of Radionuclides in 100-N Area Columbia River Shoreline Springs, 1995

Radionuclide	Facility Effluent Monitoring Well #199-N-46	Springs Maximum	Springs Mean	DCG[a]
^{3}H	NA[b]	500	90	2,000,000
^{60}Co	NA[b]	<1.9	<0.30	5,000
^{90}Sr	6,441	300	54	1,000

(a) DCG = DOE Derived Concentration Guide (see Appendix C).
(b) NA = not analyzed.

Radiological Surveys

Radiological surveys are used to monitor and detect radiological contamination on the Hanford Site. There are two main types of posted radiological controlled areas: underground radioactive materials areas and contamination areas. In 1995, the radiologically contaminated areas were reposted to meet the new requirements as outlined in the *Hanford Site Radiological Control Manual*, HSRCM-1. The posting includes Contamination, High Contamination (activity >100,000 dpm/100 cm^2 beta-gamma and/or >10,000 dpm/100 cm^2 alpha), Soil Contamination, Underground Radioactive Material, Radiological Buffer, and Radiation/High Radiation Areas. For continuity between annual reports issued before 1995, the use of Contamination areas in this report includes Contamination, High Contamination, and soil Contamination areas.

Underground radioactive material areas are posted when contamination occurs below the soil surface. 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.

Table 3.2.6. Nonradiological Results for Water Samples from Surface-Water Disposal Units, 200 Areas, 1995

Sample Locations[a]	pH No. of Samples	pH Mean	pH Maximum	pH Minimum	Nitrate (NO_3), mg/L No. of Samples	Nitrate Mean	Nitrate Maximum
200-West Area Ditch	12	6.3	6.7	5.9	1	NA[b]	1.3
200-West Area Ponds	40	8.0	9.0	7.3	2	0.36	0.60
200-East Area Ditch	52	8.5	9.6	6.7	4	0.62	1.3
200-East Area Pond	52	7.4	8.0	6.4	4	0.34	0.91

(a) 200-West Area Ditch: 216-T-4 Ditch.
200-West Area Ponds: 216-Z-21 Basin, 200-West Powerhouse Pond.
200-East Area Ditch: 200-East Powerhouse Ditch.
200-East Area Pond: 216-B-3C Pond.
(b) NA = not available.

These areas are routinely surveyed (at least annually) to document the current radiological status.

Contamination areas may or may not be associated with an underground radioactive material structure. A breech in the barrier of an underground radioactive materials area may result in the growth of contaminated vegetation. Insects or animals burrowing into an underground radioactive materials area may bring contamination to the surface. Vent pipes or risers from an underground structure may be a source of speck contamination. Fallout from stacks, or unplanned releases from previously operating facilities, may cause an area of contamination unrelated to a subsurface structure. All types of contamination areas may be susceptible to contamination migration. Contamination areas were routinely surveyed (at least annually) to document the current radiological status.

In 1995, there were approximately 2,531 ha (6,254 acres) of posted outdoor contamination areas and 1,025 ha (2,532 acres) of posted underground radioactive materials areas not including active facilities, at the Hanford Site. The number of hectares (acres) of contamination areas is 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 area was posted as a Radiologically Controlled Area in 1959 because of widespread speck contamination and currently encompasses approximately 1,000 ha (2,500 acres). Table 3.2.7 contains the hectares (acres) for contamination areas and underground radioactive material areas and shows the net change from 1994 to 1995. A global positioning system used to measure the surface areas enables greater accuracy than in past years. Area measurements for 1995 have been entered into the Hanford Geographical Information System (a computer database system), maintained by the Environmental Restoration Contractor.

The posted contamination areas vary between years because of an ongoing effort to clean, stabilize, and remediate areas of known contamination. During this time, new areas of contamination are being identified. Table 3.2.8 indicates the changes that resulted from stabilization activities during 1995. Approximately 50 ha (124 acres) were reclassified from contamination/soil contamination areas to underground radioactive materials areas, and 6 ha (15 acres) were posted as soil contamination 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 previously were undetected.

It was estimated that the external dose rate, measured at a height of 1 m, at 80% of the identified outdoor contamination areas was less than 1 mrem/h, although direct dose rate readings from isolated radioactive specks (a diameter less than 0.6 cm or [0.25 in.]) could have been considerably higher. Contamination levels of this magnitude did not significantly add to dose rates for the public or Hanford Site workers in 1995.

Vadose Zone Monitoring

The inactive liquid effluent facilities vadose monitoring program tracks the movement of radioactive contaminants discharged to the soils. There are over 300 liquid waste disposal sites at Hanford that have received over 53 billion L (14 billion gal) of waste, excluding the 1,620 billion L (430 billion gal) discharged at the surface to ponds and ditches. During calendar year 1995, approximately 70 boreholes were logged around these facilities for radioactive plume identification and tracking. The logging surveys of the boreholes identify gamma-ray emitting radionuclides in the soils and quantify the concentrations of these radionuclides as a function of depth. These survey data will become the baseline for any further vadose zone monitoring at these facilities. Additional characterization of subsurface radiological conditions took place at sites such as the 1301-N Trench. The sites of new boreholes and cone penetrometer emplacements also were surveyed to help delineate the subsurface wastes. Cone penetrometer emplacements are small diameter tubes with a cone tip that are forced into the ground; they do not generate drill cutting wastes.

Wells on the Hanford Site scheduled for decommissioning are surveyed with high-resolution (laboratory quality) gamma-ray and moisture logging equipment to assure that no radioactivity exists in the wells before they are filled in. These data add to the geologic data base that is used for determining the moisture migration pathways in the vadose and ground-water zones.

All boreholes associated with the 216-T-6 Crib, located to the west of T Plant in the 200-West Area, have been surveyed to identify radionuclides and define the extent of gamma-emitting radionuclides. Preliminary assessment of the subsurface plume from spectral gamma-ray

Table 3.2.7. Outdoor Contamination Status, 1995 (approximate surface area in hectares [acres])

Hanford Site Area	Contamination Areas[a]	Net Change[b]	Underground Radioactive Material Areas[c]	Net Change[b]
100-B/C	8 (20)	0	39 (96)	0
100-KE/KW	3 (7)	-8 (19)	60 (148)	8 (19)
100-N	29 (73)	0	0.3 (1)	0
100-D/DR	3 (8)	-3 (8)	36 (89)	3 (8)
100-H	0.4 (1)	0	13 (33)	0
100-F	8 (20)	0	30 (74)	0
200-East[d]	2,258 (5,580)	-12 (30)	151 (373)	12 (30)
200-West[e]	201 (497)	-21 (52)	677 (1,673)	21 (52)
300	21 (52)	0	13 (31)	0
400	0	0	0	0
600	0	0	6 (14)	0
Totals	2,531 (6,254)	-44 (109)	1,025 (2,532)	44 (109)

(a) Includes areas posted as "contamination/soil contamination" or as "Radiologically Controlled" and areas that had both underground and contamination/soil contamination.
(b) Increase or decrease from 1994 to 1995.
(c) Includes areas with only underground contamination. Does not include areas that had contamination/soil contamination as well as underground radioactive material.
(d) Includes tank farms, BC controlled zone, and waste disposal facilities outside the 200-East boundary which received waste from 200-East facilities (i.e., 216-A-25, 216-B-3-3, etc.).
(e) Includes tank farms and waste disposal facilities outside the 200-West boundary which received waste from 200-West facilities (i.e., 216-S-19, 216-U-11, etc.).

log surveys of the 15 boreholes associated with this crib determined that the concentration of cesium-137 exceeds 10,000 pCi/g in the soils near the crib structure, then slowly decreases to 1,000 pCi/g at several meters from the crib. Finally, at the 10 pCi/g concentration level the contamination plume extends over 30 m (100 ft) beyond the crib structures to a depth of 15 m (50 ft) below the ground surface (Figure 3.2.2).

Table 3.2.8. Zone Status Change by Area, 1995

Location	Zone Change[a]	Area[b]
100 Areas	CA to URM	11 (27)
200-East Area	CA to URM	18 (45)
200-East Area	URM to CA	6 (15)
200-West Area	CA to URM	21 (52)
300 Area	CA to URM	0
400 Area	CA to URM	0
600 Area	CA to URM	0

(a) CA = Contamination/Soil Contamination Area.
URM = Underground Radioactive Material Area.
(b) Area reported in hectares (acres).

Cobalt-60 has been found to be migrating laterally in the BY cribs, 40 years after the liquid waste discharges were terminated. In Well 299-E33-5, a 20% decrease in activity due to migration has been identified. The activity over a 3-year period decreased from 19 pCi/g to 10 pCi/g, including 6.3 pCi/g that would have been expected from natural decay and 2.6 pCi/g from the migration.

A more detailed summary of the subsurface radionuclide logging surveys is provided in Schmidt et al. (1996).

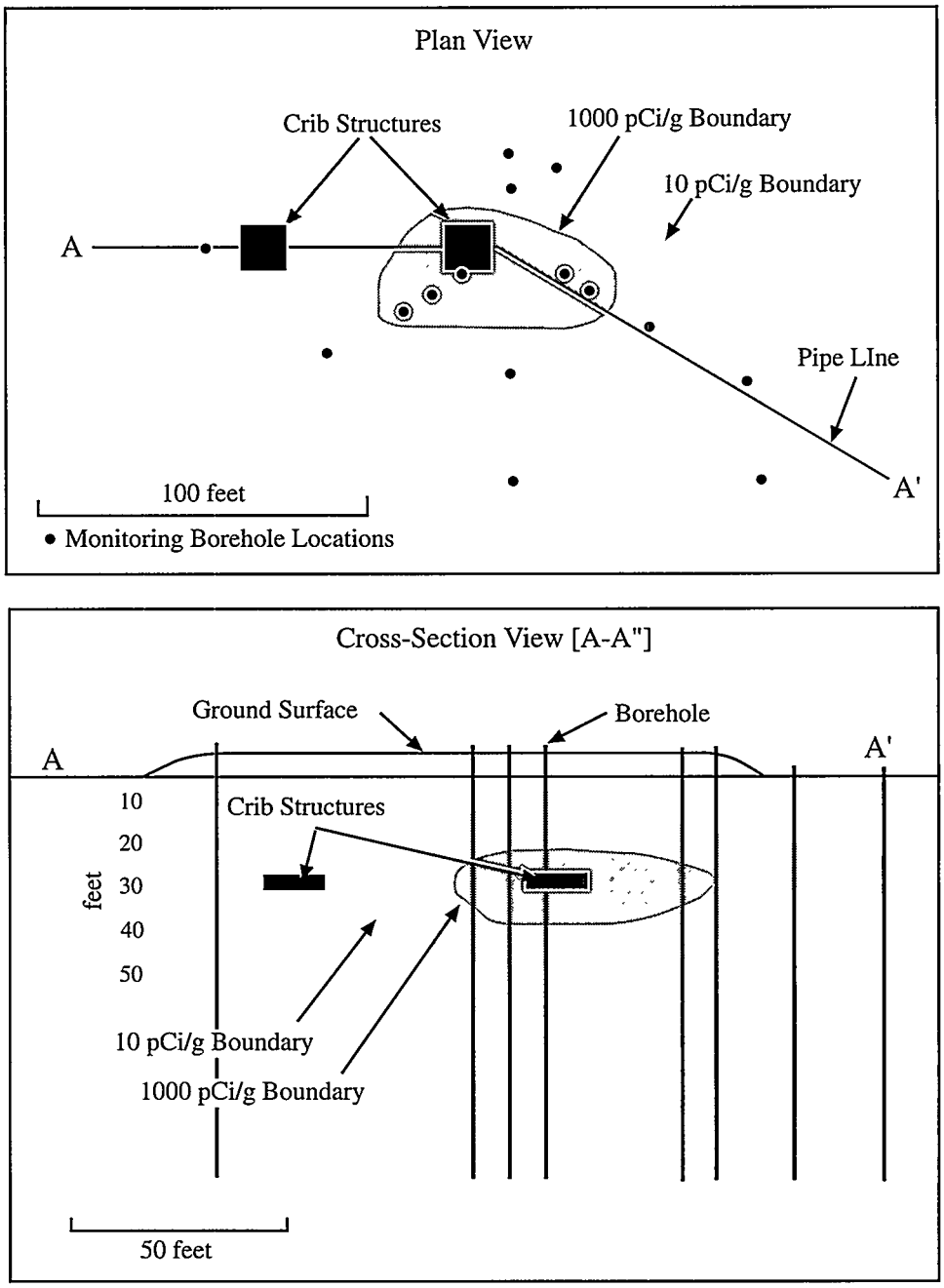

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Figure 3.2.2. Cesium-137 Contamination Plumes in the Vadose Zone Near the 216-T-6 Crib, 200-West Area

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. Special samples were also taken where physical or biological transport problems were identified. 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. Soil sampling in the 200 Areas was modified in 1994 to be more cost-effective. Fifty-five soil samples are collected at alternating locations each year. In 1995, only 53 samples were collected because two sample locations were destroyed by construction. The results of the sampling effort are discussed below.

Collection and Analysis of Soil and Vegetation Samples

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.

Radiological Results for Soil Samples

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 concentrations measured offsite in 1994. Figure 3.2.3 shows average soil values for 1995 and the preceding 5 years. The concentrations show a large degree of variability. In general, concentrations in 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 when compared to concentrations measured in distant communities in 1994. 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. (1996).

100-N Area

As a result of the shutdown of the 105-N Reactor and associated facilities and the implementation of more effective effluent controls, the analytical results from soil samples collected in the 100-N Area in 1995 generally exhibit concentrations at or near historical onsite levels. However, contamination levels were 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, better effluent controls, and improved waste management practices. However, for cesium-137; plutonium-239,240; and strontium-90, the results were greater than those measured offsite and were higher compared to values from the 100 and 300/400 Areas.

300/400 Areas

Analytical results from soil samples taken in the 300/400 Areas were compared to results for other operational areas and to those measured offsite. Uranium levels for the 300/400 Area were higher than those measured from the 100 Area and 200 Areas and higher than levels measured in previous years. Uranium was expected in these samples because it was used during past fuel fabrication operations in the 300 Area.

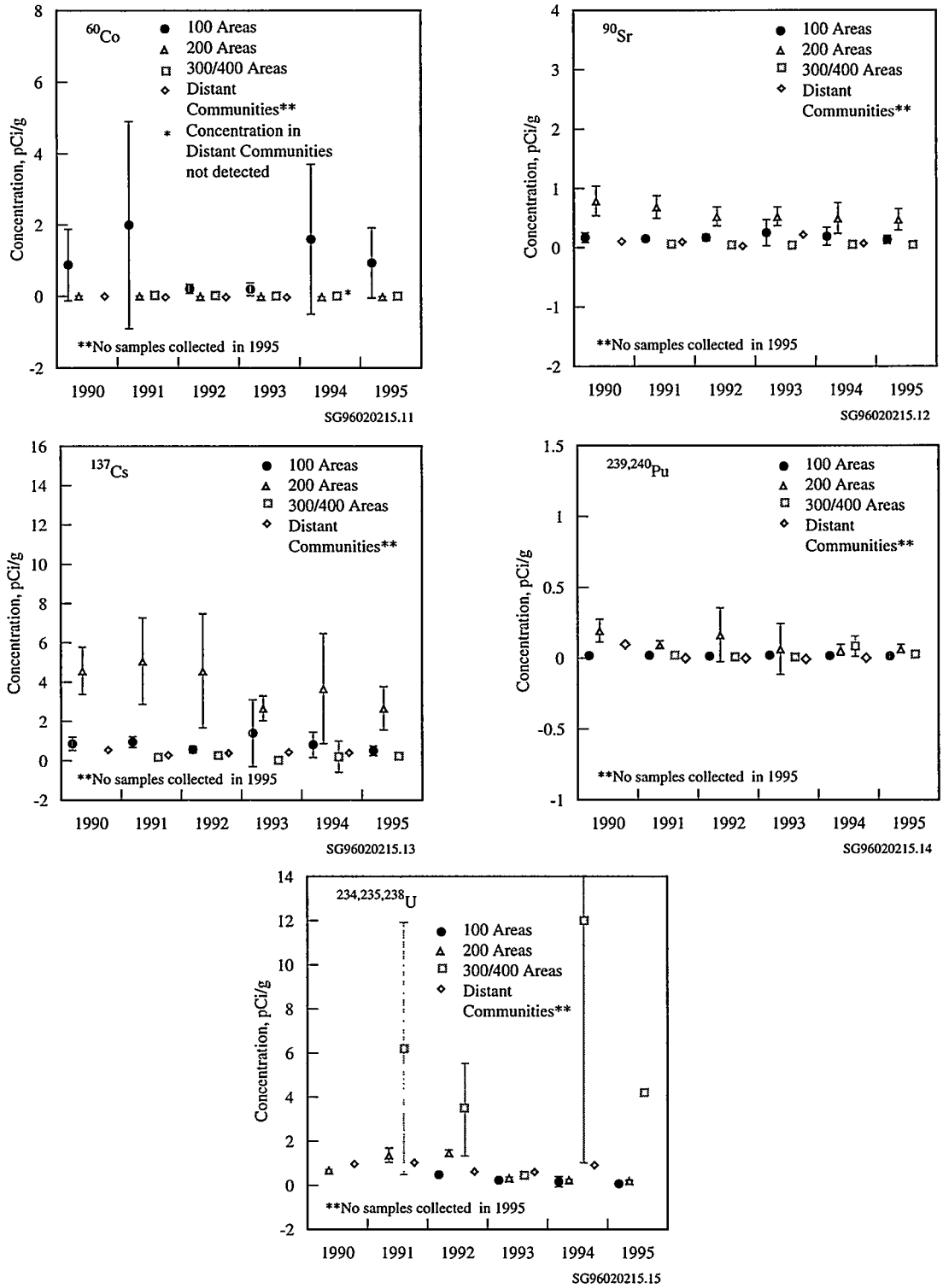


Figure 3.2.3. Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Soil Samples Compared to Those in Samples in Distant Communities, 1990 Through 1995. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols. The 1994 and 1995 100 Areas data includes the 100-N Area only.

Radiological Results for Vegetation Samples

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 in 1994. Figure 3.2.4 shows average vegetation values for 1995 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 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 when compared to concentrations measured in distant communities in 1994. 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. (1996).

100-N Area

Analytical results from vegetation samples collected in the 100-N Area in 1995 were generally lower than those seen in 1994. The maximum values observed were for strontium-90 in samples collected near the N Springs. The 1995 levels were 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 1995, the average concentrations for cesium-137 and plutonium-239,240 were similar 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 uranium levels were higher compared to the 100 Area and 200 Areas. The higher uranium levels were expected because uranium was released during past fuel fabrication operations 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.

Radiological Field Measurements and Analyses

Two methods are used for measuring external radiation fields. Hand-held meters are used at individual points of interest to give real-time assessments. Thermoluminescent dosimeters are used at numerous fixed locations over longer periods of time. Thermoluminescent dosimeter results can be used individually or averaged to determine dose rates in a given area for a particular sampling period. Specific information about external radiation sampling methods and locations can be found in the manual *Operational Environmental Monitoring* (WHC 1991b).

Results of Radiation Field Measurements

Radiation Surveys

A hand-held micro-rem meter was used to survey points along the N-Springs Area. Radiation measurements were taken at a height of approximately 1 m (3.28 ft).

In previous years, a micro-R meter was used for this survey. This instrument is known to overrespond to low-energy gamma radiation. In 1995, the micro-rem meter was used to provide a more accurate measurement of the exposure rate.

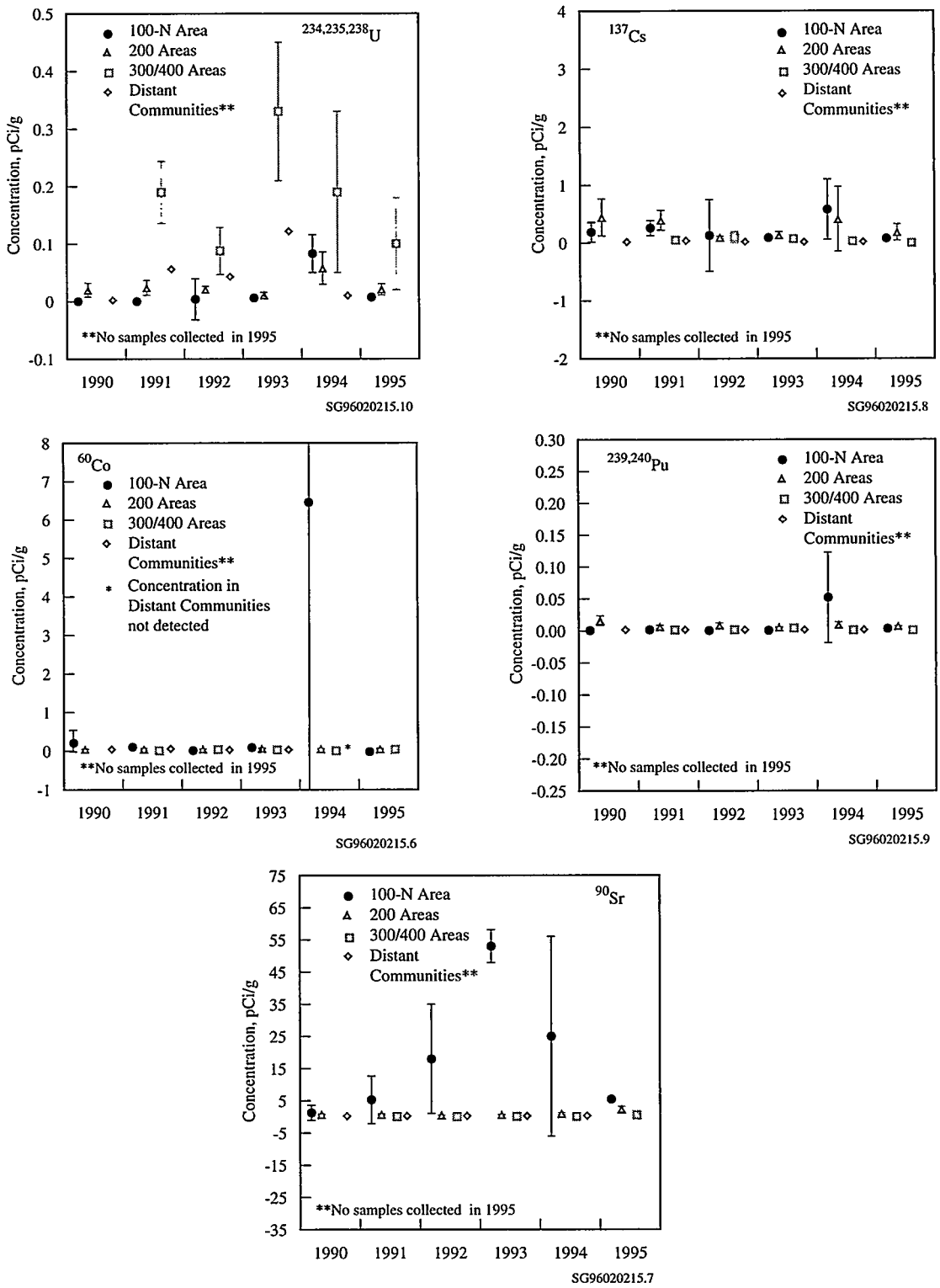


Figure 3.2.4. Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Vegetation Samples Compared to Those in Samples in Distant Communities, 1990 Through 1995. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols. The 1994 and 1995 100 Areas data includes the 100-N Area only.

Figure 3.2.5 shows the overall shape of the curve for 1995, which indicates that N-Springs shoreline areas with the highest exposure rate are, as in the past, juxtapositional with the 1301-N Liquid Waste Disposal Facility.

Surveys at the 1301-N and 1325-N Liquid Waste Disposal Facilities were discontinued this year. Data obtained from the thermoluminescent dosimeter stations located around the perimeters of these facilities provide adequate radiation assessment since neither of these facilities is active. More details on radiation surveys are provided in Schmidt et al. (1996).

Thermoluminescent Dosimeters

A decrease of up to 65% was noted in near-facility thermoluminescent dosimeter readings between 1994 and 1995. A percentage of this can be attributed to a difference in response between the old Hanford thermoluminescent dosimeter reader system used in 1994 and the Harshaw 8807 dosimeter and the Harshaw 8800 reader system used in 1995. This difference is the result of dissimilarities in readout methodologies and dosimeter designs between the two systems. With the old system, thermoluminescent dosimeters located in the field were not as well protected from light, heat, moisture, and dirt as the new system. The Harshaw thermoluminescent dosimeters are packaged in a holder that has an "O ring" seal and is more opaque. Also, the signal-to-noise ratio in the Harshaw system reader is much improved over the old system reader. Although the pre-issue 16-hour oven anneal has been retained for the Harshaw dosimeters, the new reader system provides the capability for various pre-read, read, and anneal options. These options are being used to improve the low-dose performance of the new dosimeters.[a]

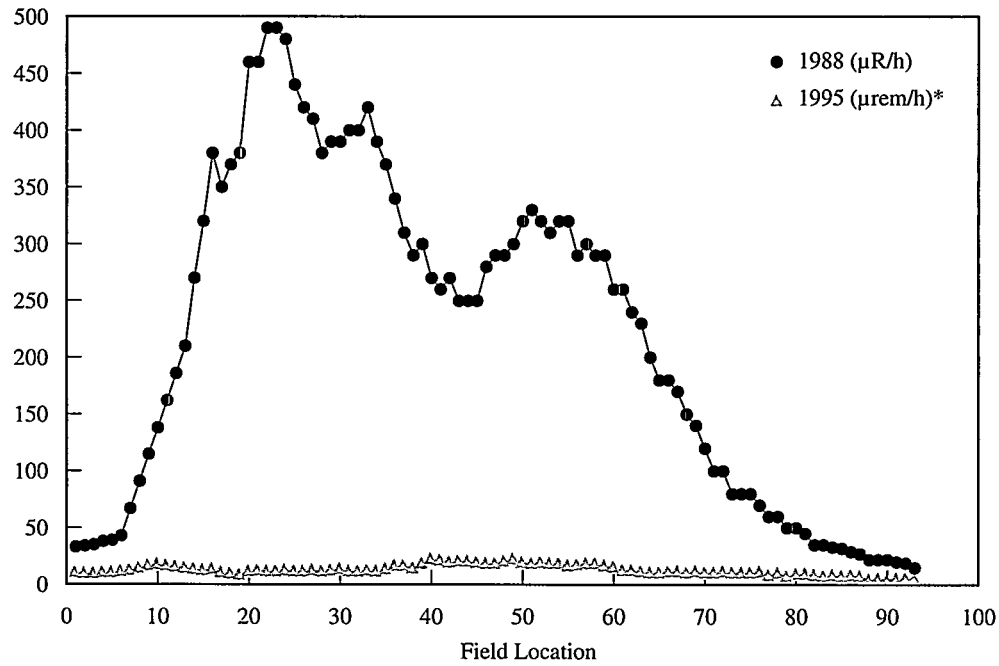
100-N Area. The results of the 100-N thermoluminescent dosimeters are presented in Table 3.2.9. The 1995 thermoluminescent dosimeter results indicate that direct radiation levels are highest near facilities that had contained or received liquid effluent from the N Reactor. These facilities primarily include the 1301-N and 1325-N Liquid Waste Disposal Facilities. While the results for these two facilities were noticeably higher than those for other 100-N Area thermoluminescent dosimeter locations, they were approximately 12% lower than exposure levels measured at these locations in 1994. Overall, dose rates measured at all locations in the 100-N Area in 1995 were approximately 17% lower than those measured in 1994. A historical summary of the dose rates measured around the Liquid Waste Disposal Facilities may be found in Schmidt et al. (1996). Decreases are the result of decay of the radionuclide inventories in the facilities.

Two projects (the 1303-N Spacer Silo and 1304-N Emergency Dump Tank) had a noticeable impact on radiation dose rates in the 100-N Area in 1995. Work to remove irradiated fuel spacers from the 1303-N Spacer Silo was performed in August. Dose rates around the 105-N Reactor building were significantly elevated during this period. The third quarter average for selected thermoluminescent dosimeters located near the silo reflected this increase. The overall affect of the two clean-up projects around the 105-N Reactor building was a decrease in dose rates to a level lower than that measured before the projects began. During the fourth quarter, the source term previously present in the 1304-N Emergency Dump Tank was reduced. This facility was decontaminated during August and September.

100-K Area. This is the third year that thermoluminescent dosimeters have been placed in the 100-K Area, surrounding the 105-K East and 105-K West fuel storage basins and adjacent reactor buildings. Three of the thermoluminescent dosimeters have shown consistently elevated readings due to their proximity to radioactive waste storage areas or stored radioactive rail equipment. A more detailed data summary and description is provided in Schmidt et al. (1996).

200 Areas. Three new thermoluminescent dosimeter monitoring sites were established in the 200 Area network to better evaluate the processes performed by the Central Waste Complex, the Solid Waste Operations Complex, and the Waste Receiving and Packaging Complex located on the west side of the 200-West Area. Table 3.2.9 summarizes the results for the 60 thermoluminescent dosimeter locations used in 1994 and 1995 in the 200/600 Areas. 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 1995 by thermoluminescent dosimeters was 120 mrem/yr, which was a decrease of 8% over the average dose rate of 130 mrem/yr measured in 1994. A more detailed data summary is provided in

(a) Personal communication April 4, 1995. Alan W. Endres, Research Scientist, Health Protection Department, Pacific Northwest National Laboratory, Richland, Washington.



* Surveys in 1995 utilized a micro-rem/h meter, as opposed to a micro-R/h meter used in previous surveys.

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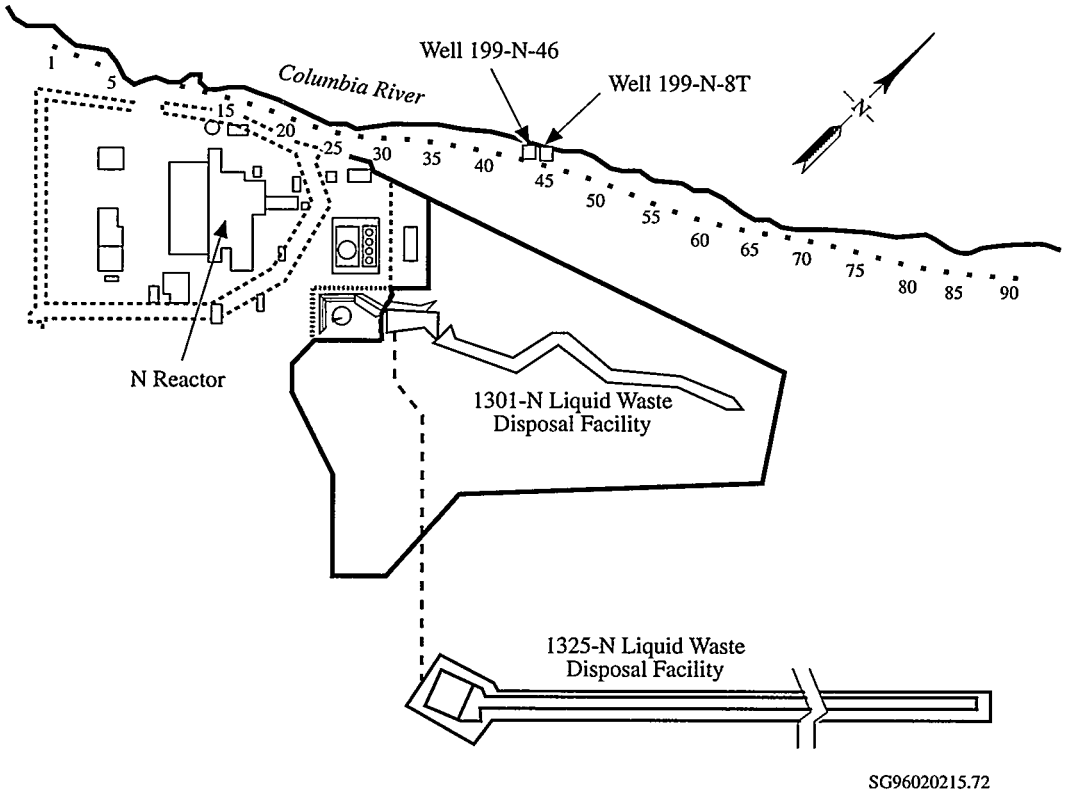

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Figure 3.2.5. Radiation Survey Measurements Along the 100-N Area Shoreline, 1988 and 1995

Table 3.2.9. Thermoluminescent Dosimeter Results for Waste-Handling Facilities in the Operations Areas (mrem/yr, based on 24 hours/day), 1994 and 1995

Area	Number of Locations, 1995	1994 Maximum	1994 Mean	1995 Maximum	1995 Mean	% Change[a]
100-K	11	14,700	1,100	2,800	390	-65
100-N	30	13,000	1,560	13,000	1,290	-17
200/600	63 (60)[b]	770	130	700	120	-8
300	8	540	170	310	140	-18
300 TEDF[c]	6	120	110	84	81	-28
400	7	210	110	81	77	-32

(a) Numbers indicate a decrease (-) or increase from the 1994 mean.
(b) Indicates 60 of 63 data points were applicable to this table.
(c) TEDF = Treated Effluent Disposal Facility.

300/300 Treated Effluent Disposal Facility/ 400 Areas. Table 3.2.9 compares 1995 thermoluminescent dosimeter results to those of 1994 for the 300 and 400 Areas. 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 1995 was 140 mrem/yr, which is a decrease of 23% compared to the average dose rate of 170 mrem/yr measured in 1994. The average annual dose rate at the 300 Area Treated Effluent Disposal Facility in 1995 was 80 mrem/yr, which is a decrease of 28% compared to the average dose rate of 110 mrem/yr measured in 1994. The average annual dose rate measured in the 400 Area in 1995 was 80 mrem/yr, which is a decrease of 31% compared to the average dose rate of 110 mrem/yr measured in 1994.

Investigative Sampling

Investigative sampling was conducted in the operations areas to confirm the absence or 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 that had indicated radioactive contamination was present,
- to conduct preoperational surveys that quantify the radiological/hazardous conditions 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) has created a potential for contaminants to spread, and
- to determine the integrity of waste containment systems.

The maximum concentrations of radioactive isotopes from samples collected during these investigations are included in this report. Complete results for these investigations, including field instrument and dose readings, where appropriate, are provided in Schmidt et al. (1996).

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 generally have not been identified above background levels in preoperational environmental monitoring samples.

Collection and Analysis of Investigative Samples

Investigative samples collected in 1995 included air, water, soil (including sediment and radioactive specks), vegetation (e.g., cryptogams and tumbleweeds), a wasp nest, gopher snakes, western rattlesnakes, rock doves (domestic pigeon), a house finch, deer mice, a bat, coyote feces and a coyote jawbone (Table 3.2.10).

Table 3.2.10. Investigative Samples Collected from the Operations Areas, 1995

Sample Type	Collection Area (Number of Samples)	Elevated Radionuclides	Maximum Concentrations (pCi/g)
Air	100 Areas (12)	^{60}Co	0.00011[a]
		^{90}Sr	0.00032[a]
		^{137}Cs	0.000097[a]
		$^{239,240}Pu$	0.000015[a]
		$^{Total}U$	0.00014[a]
Water	200-East (2)	^{90}Sr	47[b]
		^{137}Cs	<59[b]
		$^{239,240}Pu$	<7.8[b]
		$^{Total}U$	0.5[b]
Soil	200 Areas (7)	^{90}Sr	21
		^{137}Cs	630
		$^{239,240}Pu$	<11
		^{212}Pb	1
		^{214}Pb	1.4
		^{228}Ac	1.1
		$^{Total}U$	0.37
Soil (speck)	200-East (1)	^{90}Sr	1,900
		^{137}Cs	<1.9
		$^{239,240}Pu$	<1
		$^{Total}U$	0.21
Soil (sediment - greenish coloration)	200-East (1)	^{90}Sr	290
		^{137}Cs	68
		$^{239,240}Pu$	0.36
		$^{Total}U$	0.05
Ant mounds	200 Areas (2)	^{90}Sr	80
		^{137}Cs	7,900
		$^{239,240}Pu$	2,200
		$^{Total}U$	0.19
Cryptogams (baseline study)	200 Areas (37)	^{137}Cs	29.3
Tumbleweeds	200 Areas (3)	^{90}Sr	390
		^{137}Cs	14
		$^{239,240}Pu$	20
		$^{Total}U$	0.04
Wasp nest	100-N (1)	^{60}Co	2,500
		^{137}Cs	480
Rattlesnakes and gopher snakes	200 Areas (4)	^{90}Sr	35,000
		^{134}Cs	140
		^{137}Cs	960,000
		$^{239,240}Pu$	<2.8
		$^{Total}U$	0.009

Table 3.2.10. Investigative Samples Collected from the Operations Areas, 1995 (contd)

Sample Type	Collection Area (Number of Samples)	Elevated Radionuclides	Maximum Concentrations (pCi/g)
Pigeon	100-N (1)	^{90}Sr	0.05
		^{137}Cs	<0.03
		$^{239,240}Pu$	<0.05
		$^{Total}U$	0.04
Pigeon	200-West (2)	^{90}Sr	<0.31
		^{137}Cs	<0.34
		^{234}Th	9.4
		$^{239,240}Pu$	<0.14
		$^{Total}U$	9.1
House finch	200-East (1)	^{90}Sr	4,800
		^{137}Cs	270
		$^{239,240}Pu$	<3.2
Deer mouse	100-K (1)	^{90}Sr	220
		^{137}Cs	370
		$^{239,240}Pu$	1.3
		$^{Total}U$	0.005
Deer mice	200 Areas (11)	^{90}Sr	4,800
		^{137}Cs	1,200
		$^{239,240}Pu$	<3.2
		$^{Total}U$	0.05
Bat	100-D (1)	^{60}Co	1,600
		^{90}Sr	11,000
		^{137}Cs	220
		$^{239,240}Pu$	<7.6
		$^{Total}U$	2.6
Coyote jawbone	200-East (1)	^{90}Sr	130
		^{137}Cs	<12
		$^{239,240}Pu$	<10
		$^{Total}U$	0.008
Coyote feces	200-East (2)	^{90}Sr	330
		^{137}Cs	6.2
		$^{239,240}Pu$	<0.21
		$^{Total}U$	0.1
Coyote and deer feces (baseline study)	200 Areas (39)[c]	^{137}Cs	1,330

(a) Expressed in pCi/m^3.
(b) Expressed in pCi/L.
(c) Thirty-seven coyote samples, 2 deer samples.

Methods for collecting or otherwise obtaining investigative samples are described in the manual *Operational Environmental Monitoring* (WHC 1991b). Field monitoring was conducted to detect radioactivity before samples were collected. Field monitoring results are expressed as counts per minute when a Geiger-Mueller detector is used or as millirad per hour when an ion chamber is used. Laboratory sample analysis results are generally expressed in picocuries per gram. Maximum concentrations, rather than averages, are presented in this subsection.

Radiological Results for Investigative Samples

Investigative samples were collected where known or suspected radioactive contamination was present, or to verify radiological conditions at project sites. In 1995, 41 such samples were analyzed for radionuclides, and 34 showed some level of contamination. Another 112 contamination incidents were reported and disposed without isotopic analyses (although field instrument readings were recorded for most) during clean-up operations. A detailed data summary is provided in Schmidt et al. (1996).

A baseline investigation in the 200 Areas was initiated in 1995 to use vegetation and wildlife as indicators of radiological conditions in and around waste sites. Cryptogams (i.e., mosses and lichens), deer feces, and coyote feces were collected using a random block method and analyzed for gamma-emitting radionuclides.

Air

Investigative air samples were collected in 1995 to determine the fugitive and diffuse air emissions from five stabilization or operations sites. These sites were all Bechtel Hanford Inc. stabilization projects in the 100 Areas. 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 DOE Derived Concentration Guide values (Table 3.2.10).

Water

Investigative samples were collected from runoff water at two tank farms in the 200-East Area in 1995. Maximum concentrations of radionuclides are reported in Table 3.2.10 and included strontium-90 (47 pCi/L); cesium-137 (<59 pCi/L); plutonium-239,240 (<7.8 pCi/L); and total uranium (0.5 pCi/L).

Soil

In 1995, 11 investigative soil samples were collected. The highest cesium-137 concentration (7,900 pCi/g) was found in an ant mound near the 241-C Tank Farm; the highest plutonium-239,240 concentration (2,200 pCi/g) was also found near the 241-C Tank Farm; and the highest strontium-90 concentration (1,900 pCi/g) was found near Unplanned Release Site UN-216-E-6 in the 200-East Area. Analytical results are provided in Table 3.2.10. In addition, 62 incidents of contaminated soil or specks were found during cleanup operations and disposed of in low-level burial grounds. These incidents are summarized in Schmidt et al. (1996).

In 1995, the number of contamination incidents, the range of radiation dose levels, and radionuclide concentrations generally were within historical limits. Areas of special soil sampling that were outside radiological control areas and had radiation levels greater than Westinghouse Hanford Company radiological control limits (WHC 1991a) were posted as surface contamination areas.

Vegetation

In 1995, three tumbleweeds were analyzed for gamma-emitting radionuclides. Maximum radionuclide concentrations in the tumbleweeds are provided in Table 3.2.10 and include cesium-137 (390 pCi/g); plutonium-239,240 (20 pCi/g); strontium-90 (14 pCi/g); and total uranium (0.04 pCi/g). Analytical results were below Westinghouse Hanford Company radiological control limits (WHC 1991a). In addition, 36 instances of contaminated vegetation (mostly tumbleweeds) were recorded in the operational areas in 1995. This vegetation was discovered during remedial operations, surveyed with field instruments, and disposed to low-level burial grounds. The field-instrument readings for the vegetation ranged from less than 1 mrad/h (100 cpm) to 50 mrad/h (>1,000,000 cpm), which were within the ranges reported for the past few years (Schmidt et al. 1996).

During 1995, the numbers of contaminated vegetation, radioactivity levels, and range of radionuclide concentrations were all within historical limits. In the past, the greatest number of contaminated vegetation samples (42) were submitted for analyses in 1978 (Johnson et al. 1994). As part of the baseline investigation in the 200 Areas, 37 cryptogam samples were collected and analyzed for gamma-emitting radionuclides (Table 3.2.10). Cryptogams were selected because of their ability to act as highly sensitive indicators of environmental quality (Landeen et al. 1994), particularly for radionuclide contamination.

Wildlife

In 1995, wildlife and wildlife-related samples (e.g., feces, nests, etc.) were collected either as part of the Integrated Pest Management 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 potential 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 to be free of contamination, it was taken to an area of suitable habitat and released. If an animal was contaminated, a decision was made based on the level of contamination, sampling facility, and frequency of occurrence either to collect the animal as a sample or to dispose of the animal in a low-level burial ground.

Twenty-two of the 25 special animal samples (including nests and feces) analyzed in 1995 (Table 3.2.10) showed detectable levels of contamination. This compares to 16 contaminated samples that were analyzed in 1994 and 32 in 1993. The maximum radionuclide concentrations in 1995 were for cesium-137 (960,000 pCi/g) and strontium-90 (35,000 pCi/g) in a gopher snake from the 200-West Area and cobalt-60 (2,500 pCi/g) in a wasp nest from the 100-N Area (Table 3.2.10).

Additionally, there were 14 cases of contaminated wildlife or related samples found during cleanup operations, which were disposed without being analyzed. The numbers of animals found to be contaminated with radioactivity, the radioactivity levels, and the range of radionuclide concentrations were within historical limits (Johnson et al. 1994).

As part of a baseline investigation in the 200 Areas, 39 fecal samples (37 coyote and 2 deer) were collected and analyzed for gamma-emitting radionuclides. The feces were selected as an indicator of transport pathways for radionuclide contamination into the environment from waste sites. The maximum radionuclide concentration for cesium-137 (1,330 pCi/g) in a coyote feces sample was higher than expected for a randomly selected sample.

Special Characterization Sampling

Special characterization projects were conducted or completed in 1995 to verify the radiological, and in some cases, hazardous chemical status of several operations. These included the following:

- Monitored ambient air to determine the levels of diffuse fugitive air emissions at 116-B-1, 116-B-4, 116-B-5, 116-C-1, 183-H Solar Evaporation Basin, all in the 100 Areas. The 1301-N Liquid Waste Disposal Facility analytical data indicate that emissions from these activities were below regulatory concern

- Issued the *Preoperational Environmental Survey Report: 200 Areas Effluent Treatment Facility, State Approved Land Disposal Structure, and Liquid Effluent Retention Facility (C-018H)* (Johnson et al. 1995) completing the 2-year preoperational environmental monitoring survey for these projects. The analytical data did not identify any environmental concerns that would delay startup of the facilities

- Submitted the *Preoperational Environmental Survey Report: 200 Areas Cross-Site Transfer Line Replacement (W-058)* (Johnson et al. 1996) completing the 2-year preoperational environmental monitoring survey for this project. The analytical data did not identify any environmental concerns that would delay startup of this system

- Completed ambient air monitoring and issued a letter report for the Transuranic Waste Retrieval Pilot Project. The analytical data indicated elevated levels of plutonium-241 at one location; however, the concentrations were below the DOE Derived Concentration Guide

- Continued preoperational monitoring in support of Solid Waste Operations Complex projects (Waste Receiving and Packaging and the Central Waste Complex) in the 200-West Area. Preoperational monitoring in 1995 included collecting samples of surface soil, vegetation, and small mammals.

3.3 Waste Management and Chemical Inventories

B. P. Gleckler and D. E. Zalodek

Waste Management

Waste produced from Hanford cleanup operations is classified as either radioactive, nonradioactive, dangerous, nondangerous, toxic, 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 either dangerous waste or extremely hazardous waste or both, as defined in the Washington State Department of Ecology's Dangerous Waste Regulations. Hanford's hazardous wastes are managed in accordance with Washington Administrative Code (WAC) 173-303. Toxic wastes are managed in accordance with Toxic Substance Control Act 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 depends on the source, composition, and concentration of the waste. Transuranic waste is stored in vaults or on underground and aboveground 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 1996b). Dangerous wastes are treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous wastes generated at the Site are also shipped offsite for disposal, destruction, or recycling.

Nondangerous, nonradioactive wastes generated at the Hanford Site historically have been buried near the 200 Areas in Hanford's Solid Waste Landfill. In March 1996, this landfill was closed. Since December 1995, nondangerous, nonradioactive wastes have been disposed of at the Richland Landfill, which is located at the southern edge of the Hanford Site boundary. Since February 1996, medical wastes have been shipped to Waste Management of Kennewick and asbestos has been shipped to Basin Disposal, Inc. in Pasco. Since March 1996, nonradioactive drummed waste has been shipped to Waste Management of Kennewick.

These nondangerous, nonradioactive 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 are 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 wastes from 100 Areas decommissioning projects are buried in situ or in designated sites in the 100 Areas.

Annual reports document the quantities and types of solid wastes generated or received onsite, shipped offsite, and disposed of at the Hanford Site (WHC 1996a). Solid waste program activities are regulated by the Resource Conservation and Recovery Act and Toxic Substances Control Act, discussed in Section 2.0, "Environmental Compliance Summary." Solid waste quantities generated onsite, received from offsite, shipped offsite, and disposed of at the Hanford Site from 1990 through 1995 are shown in Tables 3.3.1 through 3.3.3. Table 3.3.4 provides a detailed summary of the radioactive solid wastes disposed of in 1995.

The quantities of liquid wastes generated in 1995 and stored in underground storage tanks are included in the annual dangerous waste report (DOE 1996b). Table 3.3.5 is a summary of the liquid wastes generated from 1990 through 1995, which are stored in underground storage tanks.

Table 3.3.1. Quantities of Solid Wastes[a] Generated on the Hanford Site, kg[b]

Waste Category	1990	1991	1992	1993	1994	1995
Mixed	1,025,084	475,370	48,641	150,012	567,670	131,755
Radioactive	1,325,045	1,069,703	682,684	1,116,616	1,390,647	1,892,636

(a) Solid waste includes containerized liquid waste.
(b) Multiply kg by 2.205 to convert to lb.

Table 3.3.2. Quantities of Solid Wastes[a] Received from Offsite, kg[b]

Waste Category	1990	1991	1992	1993	1994	1995
Mixed	0	23,605	40,897	207,905	96,409	52,796
Radioactive	239,669	629,686	1,010,439	1,587,884	1,355,653	1,306,194

(a) Solid waste contains containerized liquid waste. Solid waste quantities do not include naval reactor submarine compartments.
(b) Multiply kg by 2.205 to convert to lb.

Table 3.3.3. Quantities of Hazardous Wastes[a] Shipped Offsite, kg[b]

Waste Category	1990	1991	1992	1993	1994	1995
Containerized	92,811	89,354	181,305	123,754	267,113	224,003
Bulk Solids		0	433,330	250,235	2,872,661	477,648
Bulk Liquid		331,905	11,089	94,065	248,917	130,156
Totals	92,811	421,259	625,724[c]	468,054[d]	3,388,691[e]	831,807

(a) Does not include Toxic Substances Control Act wastes.
(b) Multiply kg by 2.205 to convert to lb.
(c) Includes 418,676 kg from demolition of 2727-S Building.
(d) Includes 250,235 kg from demolition of 190-B Building.
(e) Includes 2,658,788 kg from North Slope cleanup and 160,883 kg from carbon tetrachloride soil extraction.

Chemical Inventories

The types, quantities, and locations of hazardous chemicals are tracked through compliance activities associated with the Emergency Planning and Community Right-To-Know Act of 1986 (see Section 2.2, "Community Right-To-Know Activities"). The *1995 Hanford Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1996bc) was issued in March 1995, in compliance with Section 312 of the Act. Table 3.3.6 summarizes the information reported, listing the 10 chemicals stored in greatest quantity on the Hanford Site in 1995.

Table 3.3.4. Radioactive Solid Wastes Stored or Disposed of in 1995[a]

	Quantity, Ci					
Constituent	Low-Level	Low-Level Mixed	Low-Level Plus[b]	Low-Level Mixed Plus[c]	Transuranic	Transuranic Mixed
^{3}H	2.71×10^{4}	6.29×10^{-1}	0.00	0.00	0.00	0.00
^{54}Mn	8.25×10^{3}	2.30×10^{-2}	0.00	0.00	7.70×10^{-3}	0.00
^{55}Fe	1.43×10^{3}	7.32×10^{-4}	0.00	7.48×10^{4}	0.00	0.00
^{60}Co	3.43×10^{4}	6.93×10^{0}	0.00	6.20×10^{4}	1.48×10^{1}	2.24×10^{-2}
^{63}Ni	9.00×10^{1}	1.14×10^{0}	0.00	1.16×10^{5}	0.00	0.00
^{90}Sr	1.10×10^{4}	3.36×10^{1}	6.78×10^{-4}	3.64×10^{0}	3.40×10^{2}	9.99×10^{0}
^{90}Y	1.10×10^{4}	3.36×10^{1}	6.78×10^{-4}	3.64×10^{0}	3.40×10^{2}	9.99×10^{0}
^{99}Tc	0.00	1.61×10^{-1}	0.00	0.00	3.14×10^{-3}	0.00
^{137}Cs	6.36×10^{3}	1.38×10^{1}	5.20×10^{-4}	1.14×10^{1}	1.01×10^{3}	1.82×10^{0}
^{137m}Ba	6.02×10^{3}	1.31×10^{1}	4.92×10^{-4}	1.08×10^{1}	9.59×10^{2}	1.72×10^{0}
^{232}Th	4.03×10^{-2}	9.59×10^{-3}	0.00	0.00	0.00	0.00
^{233}U	4.65×10^{-2}	7.53×10^{-4}	0.00	0.00	6.49×10^{-1}	0.00
^{234}U	2.11×10^{-2}	1.39×10^{-2}	0.00	0.00	3.16×10^{-5}	0.00
^{235}U	6.79×10^{-1}	1.68×10^{-3}	0.00	0.00	5.55×10^{-3}	0.00
^{236}U	1.56×10^{-4}	2.37×10^{-5}	0.00	0.00	3.24×10^{-7}	0.00
^{238}U	5.04×10^{1}	1.45×10^{-2}	0.00	0.00	2.15×10^{-3}	0.00
^{238}Pu	(d)	(d)	(d)	(d)	9.70×10^{1}	3.00×10^{0}
^{239}Pu	(d)	(d)	(d)	(d)	4.29×10^{2}	5.22×10^{1}
^{240}Pu	(d)	(d)	(d)	(d)	1.60×10^{2}	1.17×10^{1}
^{241}Pu	(d)	(d)	(d)	(d)	7.59×10^{3}	3.57×10^{2}
^{242}Pu	(d)	(d)	(d)	(d)	4.72×10^{-2}	7.07×10^{-4}
^{241}Am	(d)	(d)	(d)	(d)	1.22×10^{2}	2.33×10^{0}
^{244}Cm	(d)	(d)	(d)	(d)	1.37×10^{2}	0.00

(a) Presently only low-level and low-level mixed plus wastes are permanently disposed of on the Hanford Site. Low-level mixed, transuranic, and mixed transuranic wastes are managed as stored wastes. This table does not include inventories of waste contained in temporary storage facilities. The "mixed" category identifies wastes that are regulated under the Resource Conservation and Recovery Act. The "plus" category identifies wastes that are regulated under the Toxic Substances Control Act (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.
(d) Since 1970, wastes containing transuranic elements have been segregated and managed in separate waste categories known as transuranic and transuranic mixed waste.

Table 3.3.5. Quantities of Bulk Liquid Wastes[a] Generated on the Hanford Site, L[b]

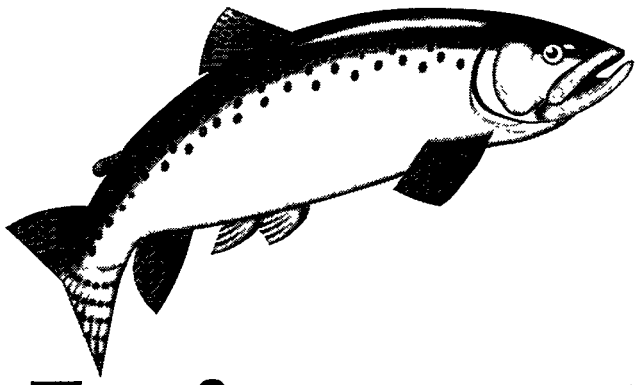
1990	1991	1992	1993	1994	1995
41,592,687	15,498,826	12,604,981	22,176,538	10,726,296	18,217,841

(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.
(b) Multiply L by 0.2642 to convert to gal.

Table 3.3.6. Average Balance of Ten Chemicals Stored in Greatest Quantity, 1995

Hazardous Material	Average Daily Balance, kg[a]
Coal	23,000,000
Mineral oil	1,900,000
Sodium	1,200,000
Diesel fuel	840,000
Bentonite	590,000
#6 Fuel oil	580,000
Nitric acid	340,000
Ethylene glycol	240,000
Unleaded gasoline	140,000
Aluminum sulfate dihydrate	94,000

(a) Multiply kg by 2.205 to convert to lb.



Environmental Surveillance Information

4.0 Environmental Surveillance Information

Environmental surveillance of the Hanford Site and the 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 DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991). The environmental surveillance program consists of the Surface Environmental Surveillance Project and the Ground-Water Surveillance Project at Hanford. The objectives, criteria, design, and description of the program are summarized below and provided in detail in the *Environmental Monitoring Plan* (DOE 1994a, Rev. 1).

Sections 4.1 through 4.8 of this report describe results of the Hanford Site surface environmental surveillance programs for 1995 and include, where applicable, information on both radiological and nonradiological constituents. Radiological doses associated with the surveillance results are discussed in Section 5.0, "Potential Radiation Doses from 1995 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." The ground-water surveillance activities discussed in the following sections were conducted by Pacific Northwest National Laboratory independent of ground-water programs managed and conducted by other contractors on the Site.

Many samples are collected and analyzed for the Hanford Site monitoring and surveillance programs, and data obtained from the analytical laboratories are compiled in large databases. It is not practical or desirable to list individual results in this report; therefore, only summary information emphasizing those radionuclides or chemicals of Hanford origin that are important to environmental or human health concerns are included. Supplemental data for some sections can be found in Appendix A.

More detailed results for specific surface environmental surveillance sampling locations are contained in a companion volume, *1995 Surface Environmental Surveillance Data* (Bisping 1996). Additional information on Hanford Site ground-water monitoring can be found in the annual Hanford Site ground-water monitoring report (Dresel et al. 1996). The intent of the summaries (Sections 4.1 through 4.8) is to provide current surveillance data, compare 1995 data to past data and existing and accepted standards so that concentrations can be viewed in perspective, and to present a general overview of Hanford Site surveillance activities.

Surface Environmental Surveillance

The Surface Environmental Surveillance Project is a multi-media environmental monitoring program conducted to measure the concentration of radionuclides and chemical contaminants in the environment and assess the integrated effects of these contaminants on the environment and the public. The monitoring program includes sampling air, surface water, sediments, soil, natural vegetation, agricultural products, fish, and wildlife. Analytical capabilities include the measurement of radionuclides at very low environmental concentrations as well as an extensive list of nonradiological chemicals including metals, anions, thioureas, volatile organic compounds, semivolatile organic compounds, pesticides, and polychlorinated biphenyls. In addition, the program includes the capability to measure ambient external radiation levels in the environment.

Activities inherent in the operation of the Surface Environmental Surveillance Project include environmental surveillance program design and implementation, sample collection, sample analysis, database management, data review and evaluation, exposure assessment, and reporting. Other elements of the project include project management, quality assurance/control, training, and records management.

Results of the sampling program are used to assess the fate, transport, and exposure of radionuclides and hazardous chemicals (non-radiological chemicals) to the public and determine compliance with applicable environmental quality standards, as well as assess the impacts of these contaminants on the environment. This includes the use of environmental data and mathematical models for the calculation of potential radiation doses to humans and aquatic biota, and the carcinogenic and non-carcinogenic risks to humans. Environmental surveillance data are also useful in dose reconstruction efforts, site characterizations performed in conjunction with ongoing Site environmental restoration activities, and in contaminant transport model verification and validation.

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 Environmental Assurance, Permits and Policy Division.

Surveillance Objectives

The general requirements and objectives for environmental surveillance are contained in DOE Orders 5400.1 and 5400.5. The broad objectives (DOE Order 5400.1) are to demonstrate compliance with legal and regulatory requirements, to confirm adherence to DOE environmental protection policies, and to support environmental management decisions.

These requirements are embodied in the surveillance objectives stated in the Orders and DOE/EH-0173T and include the following:

- determine compliance with applicable environmental quality standards and public exposure limits and applicable laws and regulations; the requirements of DOE Orders 5400.1 and 5400.5; and the environmental commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official DOE documents.

  Additional objectives that derive from the Orders and this primary objective include the following:

  - conduct preoperational assessments
  - assess radiological doses to the public and aquatic biota from Site operations
  - assess doses from other local sources
  - report alarm levels and potential doses exceeding reporting limits (DOE Order 5400.5, Chapter II, Section 7)
  - prepare an annual Site environmental report
  - maintain an environmental monitoring plan

- determine background levels and Site contributions of contaminants in the environment
- determine long-term accumulation of Site-related contaminants in the environment and predict trends; characterize and define trends in the physical, chemical, and biological condition of environmental media
- determine effectiveness of effluent treatment and controls in reducing effluents and emissions
- determine validity and effectiveness of models to predict the concentrations of pollutants in the environment
- detect and quantify unplanned releases
- identify and quantify new or existing environmental quality problems.

DOE/EH-0173T indicates that subsidiary objectives for surveillance should be considered. Subsidiary objectives applicable to the Site include the following:

- obtain data and maintain the capability to assess the consequence of accidents
- provide public assurance; address issues of concern to the public, stakeholders, regulators, and the business community.

- enhance public understanding of Site environmental impacts, primarily through public involvement and by providing public information

- provide environmental data and assessments to assist the DOE Richland Operations Office in environmental management of the site.

Surveillance Design

The Orders require that the content of surveillance programs be determined on a site-specific basis by the DOE Richland Operations Office. The surveillance programs must reflect facility characteristics; applicable regulations; hazardous potential; quantities and concentrations of materials released; extent and use of affected air, land, and water; and specific local public interest and concern. Environmental surveillance at Hanford was designed to meet the previously listed objectives while considering the environmental characteristics of the Site and potential and actual releases from Site operations. Surveillance activities focused on determining environmental impacts and compliance with public health and environmental standards or protection guides, rather than on providing detailed radiological and chemical characterization. Experience gained from environmental surveillance activities and studies conducted at the Hanford Site for more than 45 years provided valuable technical background for planning the surveillance design.

The Hanford Site environmental surveillance program historically has focused on radionuclides and nonradiological water quality parameters. In recent years, surveillance for nonradiological constituents, including hazardous chemicals, has been expanded significantly. A detailed chemical pathway and exposure analysis for the Hanford Site was completed in 1994 (Blanton et al. 1995a). The analysis helped guide the selection of chemical surveillance media, sampling locations, and chemical constituents.

Each year, a radiological pathway analysis and exposure assessment is performed. The 1995 pathway analysis was based on 1995 source-term data and on the comprehensive pathway and dose assessment methodology included in the Generation II (GENII) computer code (Napier et al. 1988a, 1988b, 1988c) used for estimating radiation doses to the public from Hanford operations. The CRITR computer code (Baker and Soldat 1992) was used to calculate doses to animals, and hand calculations were used to compute the doses not addressed in the computer codes. The results of the pathway analysis and exposure assessment serve as a basis for future years' surveillance program design.

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 on 1) examination of the types, location, and sources (contaminated soil, raw effluent, etc.) of contaminants; 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 influence the amount of exposure a person 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, travel through the atmosphere, or be carried offsite in contaminated wildlife)

- physically or chemically transformed (e.g., deposition, precipitation, volatilization, photolysis, oxidation, reduction, hydrolysis or radionuclide decay)

- biologically transformed (e.g., biodegradation)

- accumulated in the receiving media (e.g., sorbed strongly in the soil column, stored in organism tissues).

The primary pathways for movement of radioactive materials and chemicals from the Site to the public are the atmosphere and surface water. Figure 4.0.1 illustrates these potential primary routes and the possible exposure pathways to humans.

The significance of each pathway was determined from measurements and calculations that estimated the amount of radioactive material or chemical transported along each pathway and by comparing the concentrations or potential doses to environmental and public health protection standards or guides. Pathways were also evaluated

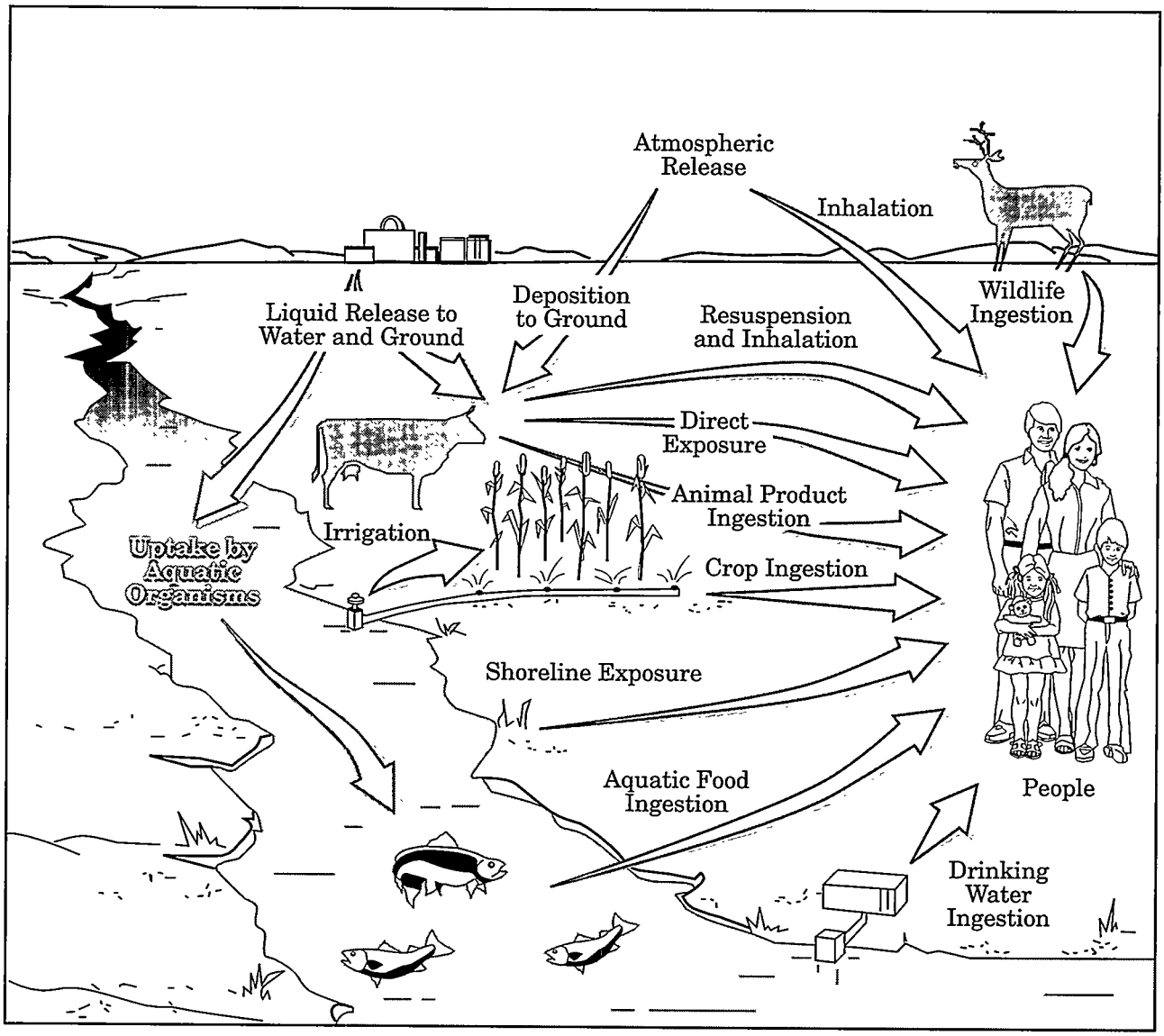


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Figure 4.0.1. Primary Exposure Pathways

based on prior studies and observations of radionuclide and chemical movement through the environment and food chains. Calculations based on effluent data showed the expected concentrations off the Hanford Site to be low for all Hanford-produced radionuclides and chemicals, and frequently below the level that could be detected by monitoring technology. To ensure that radiological and chemical analyses of samples were sufficiently sensitive, minimum detectable concentrations of key radionuclides and chemicals were established at levels well below applicable health standards.

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

The first surveillance zone extended 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) generally would be the highest and therefore most easily detected in this zone. The second surveillance zone consisted of a series of perimeter sampling stations positioned near or just inside the Site boundary and along State Highway 240, which runs through the Site from Richland to the Vernita Bridge. Exposures at these locations were typically the maximum that any member of the public could receive. The third surveillance zone consisted of nearby and distant community locations within an 80-km (50-mi) radius of the Site. Surveillance was conducted in communities to obtain measurements at locations where a large number of people potentially could be exposed to Hanford releases and to document that contaminant levels were well below standards established to protect public health. Table 4.0.1 summarizes the sample types and measurement locations in all three zones for 1995.

Background concentrations were measured at distant locations and compared with concentrations measured onsite and at perimeter and community locations. Background locations were essentially unaffected by Hanford operations, i.e., these locations could be used to measure ambient environmental levels of chemicals and radionuclides. Comparing background concentrations to concentrations measured on or near the Site indicated 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 generally have been too small to be measured directly once dispersed in the offsite environment. For the measurable radionuclides, often it was not possible to distinguish levels resulting from worldwide fallout and natural sources from those associated with Hanford releases. Therefore, offsite doses in 1995 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 (e.g., from resuspended contaminated soils) were estimated from measured airborne concentrations at Site perimeter locations

- Doses from fugitive liquid releases (e.g., ground water seeping into the Columbia River) were estimated by evaluating differences in measured concentrations upstream and downstream from the Hanford Site.

The surveillance design is reviewed annually based on the above considerations as well as an awareness of planned waste management and environmental restoration activities. The final sampling design and schedule are documented annually in the *Environmental Surveillance Master Sampling Schedule* (Bisping 1996). Results of the 1995 Surface Environmental Surveillance Project activities are presented in Sections 4.1 through 4.7 and Chapters 5.0 and 7.0.

Ground-Water Surveillance

Ground-water surveillance at the Hanford Site was conducted to assess the impacts of radiological and hazardous chemicals from Hanford on ground water, to provide an integrated assessment of quality of Hanford Site ground water, and to evaluate potential offsite impacts from the ground-water pathway. Additionally, near-field ground-water monitoring was conducted by Westinghouse Hanford Company to ensure that operations in and around specific waste-disposal facilities were in compliance with DOE Orders (Johnson 1993) and with 40 CFR 265 and WAC 173-303 and -304 (DOE 1996). The results from both the surveillance and compliance ground-water monitoring programs, along with data from Comprehensive Environmental Response, Compensation, and Liability Act investigations, were useful in determining the total impact of Hanford Site operations on ground water.

Surveillance Objectives

Ground-water surveillance objectives included 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.

Table 4.0.1. Environmental Surveillance Sample Types and Measurement Locations, 1995

		Sample Locations						
						Columbia River		
	Total Number	Onsite[a]	Site Perimeter[b]	Nearby Locations[c]	Distant Locations[c]	Upstream[c]	Hanford Reach[b]	Downstream[c]
Air	40	20	9	8[d]	3[e]			
Ground water[f]	499	499[g]						
Springs water	7						7	
Springs sediment	4						4	
Columbia River	7					2	4	1
Irrigation water	1		1					
Drinking water	12	7	5					
Columbia River sediments	6					1	3	2
Ponds	3	3						
Foodstuffs	11		7	1	3			
Wildlife	15	5	1		4	2	3	
Soil	0							
Vegetation	0							
TLDs[h]	69	25	33[i]	8[d]	3[e]			
Shoreline surveys	16		16					

(a) Surveillance Zone 1.
(b) Surveillance Zone 2.
(c) Surveillance Zone 3.
(d) Includes seven community-operated environmental surveillance stations.
(e) Includes one community-operated environmental surveillance station.
(f) Approximately 800 wells were sampled for all ground-water monitoring programs onsite.
(g) Some onsite wells along the Columbia River are referred to as perimeter locations in the text.
(h) TLDs = thermoluminescent dosimeters.
(i) Includes locations along the Columbia River.

Surveillance Criteria

The Ground-Water Surveillance Project was designed to monitor the effects of DOE activities on ground water beneath the Hanford Site in order 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, and predecessor projects, have monitored ground water at Hanford for more than 45 years. Hydrogeologic characterization and ground-water modeling were used to assess the monitoring network and to evaluate potential impacts of Hanford Site ground-water contamination on water users.

Surveillance Design

Specific chemicals and radionuclides in each monitoring well were selected for analysis based on past waste disposal activities (Stenner et al. 1988), ongoing waste disposal activities (Diediker and Rokkan 1993), and previous analyses from neighboring wells (Dresel et al. 1995). Selections also involved identifying contaminant sources and determining which chemicals and radionuclides were important to human dose and for understanding contaminant distribution and movement. Sampling locations and frequencies for 1995 were identified in the *Environmental Surveillance Master Sampling Schedule* (Bisping 1995a).

Ground-water surveillance was conducted using established quality assurance plans (see Section 7.0, "Quality Assurance") and written procedures (PNL 1992). Computerized data 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. The Hanford

Environmental Information System is the central consolidated database for storing and managing the ground-water results.

Ground-water samples were collected from both the unconfined and upper-confined aquifers. The unconfined aquifer was monitored extensively because it contains contaminants from Hanford operations (Dresel et al. 1994) and provides a potential pathway for contaminants to reach points of human exposure (e.g., water supply wells, Columbia River). The upper-confined aquifer was monitored, less extensively than the unconfined aquifer, because it also provides a potential pathway for contaminants to migrate off the Hanford Site. Some sampling was conducted at the request of the Washington State Department of Health.

Contaminant source areas were monitored to characterize and define trends in the condition of the ground water and to identify and quantify existing, emerging, or potential problems in ground water quality. Source areas included regions with active waste disposal facilities or with facilities that had generated or received wastes in the past. These included facilities within the 100, 200, and 300 Areas and the central landfill. Ground-water monitoring in these areas was performed primarily by the Resource Conservation Recovery Act compliance or operational monitoring programs conducted by the operating contractor. Additional sampling was conducted by the Environmental Restoration Contractor-Team as part of the Comprehensive Environmental Response, Compensation, and Liability Act activities on the Hanford Site. When necessary, the Ground-Water Surveillance Project supplemented these monitoring activities to meet the needs of DOE. Separate reports discuss the specific results and evaluations from these monitoring efforts (DOE 1996).

Wells located within known contaminant plumes were monitored to characterize and define trends in the concentrations of the associated radiological or chemical constituents. These wells were also monitored to quantify existing ground water quality problems and to provide a baseline of environmental conditions against which future changes can be assessed. These wells will continue to be monitored as releases of waste to disposal facilities are halted and cleanup of the Site begins. This will provide a continuing assessment of the effect of Hanford's remediation programs on ground water.

Water supplies on and near the Site potentially provide the most direct route for human exposure to contaminants in ground water. In 1995, three water supplies provided Hanford Site ground water for human consumption onsite. One supplied the staff at the Fast Flux Test Facility, one supplied personnel at the Yakima Barricade guard house, and one was located at the Hanford Patrol shooting range (see Section 4.3, "Hanford Site Drinking Water Surveillance"). Water supply wells for the City of Richland are near Hanford's southern boundary. Monitoring wells near these water systems were routinely sampled to ensure that any potential water quality problems would be identified long before regulatory limits were reached.

Wells along the Hanford Site perimeter were monitored to assess the quality of ground water at locations near the Site boundary, where access to the water is restricted by DOE. Wells in a region about 2 km wide (1.2 mi 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 that existed before Hanford operations began 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 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.

4.1 Air Surveillance

G. W. Patton

Atmospheric releases of pollutants from the Hanford Site to the surrounding region are a potential source of human exposure. Thus, radioactive and nonradioactive materials in air are monitored at a number of locations on and around the Site. The influence of Hanford emissions on local pollutant concentrations was evaluated by comparing air concentrations measured at distant locations within the region to concentrations measured at the Site perimeter. This section discusses sample collection techniques and analytical methods and summarizes the analytical results of the Hanford air surveillance program. A complete listing of all analytical results summarized in this section is reported separately by Bisping (1996). A detailed description of all radiological sampling and analytical techniques is provided in the *Environmental Monitoring Plan* (DOE 1994a).

Collection and Analysis of Radiological Air Samples

Airborne radionuclides were sampled by a network of 40 continuously operating samplers: 20 on the Hanford Site, 9 near the Site perimeter, 8 in nearby communities, and 3 in distant communities (Figure 4.1.1 and Table 4.1.1). Eight of the stations were community-operated environmental surveillance stations (see Section 6.4) that were managed and operated by local school teachers. 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 (see Figure 6.1.1). Continuous samplers located in Benton City, Richland, Kennewick, Mattawa, Othello, and Pasco provided data for the nearest population centers. Samplers in the distant communities of Sunnyside, Toppenish, and Yakima provided background data for communities essentially unaffected by Site operations.

Samples were collected according to a schedule established before the monitoring year (Bisping 1995a). Air sampling locations are listed in Table 4.1.1, 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 any unusual occurrences. 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. The samples were transported to an analytical laboratory and stored for at least 7 days. 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.

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 or annual composite samples. The quarterly composite samples were analyzed for specific gamma-emitting radionuclides (Appendix E). The quarterly composite samples were then used to form annual composite samples (Table 4.1.2). Annual composites were analyzed for strontium and plutonium isotopes, with selected annual composites also analyzed for uranium, americium, or gamma-emitting radionuclides.

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

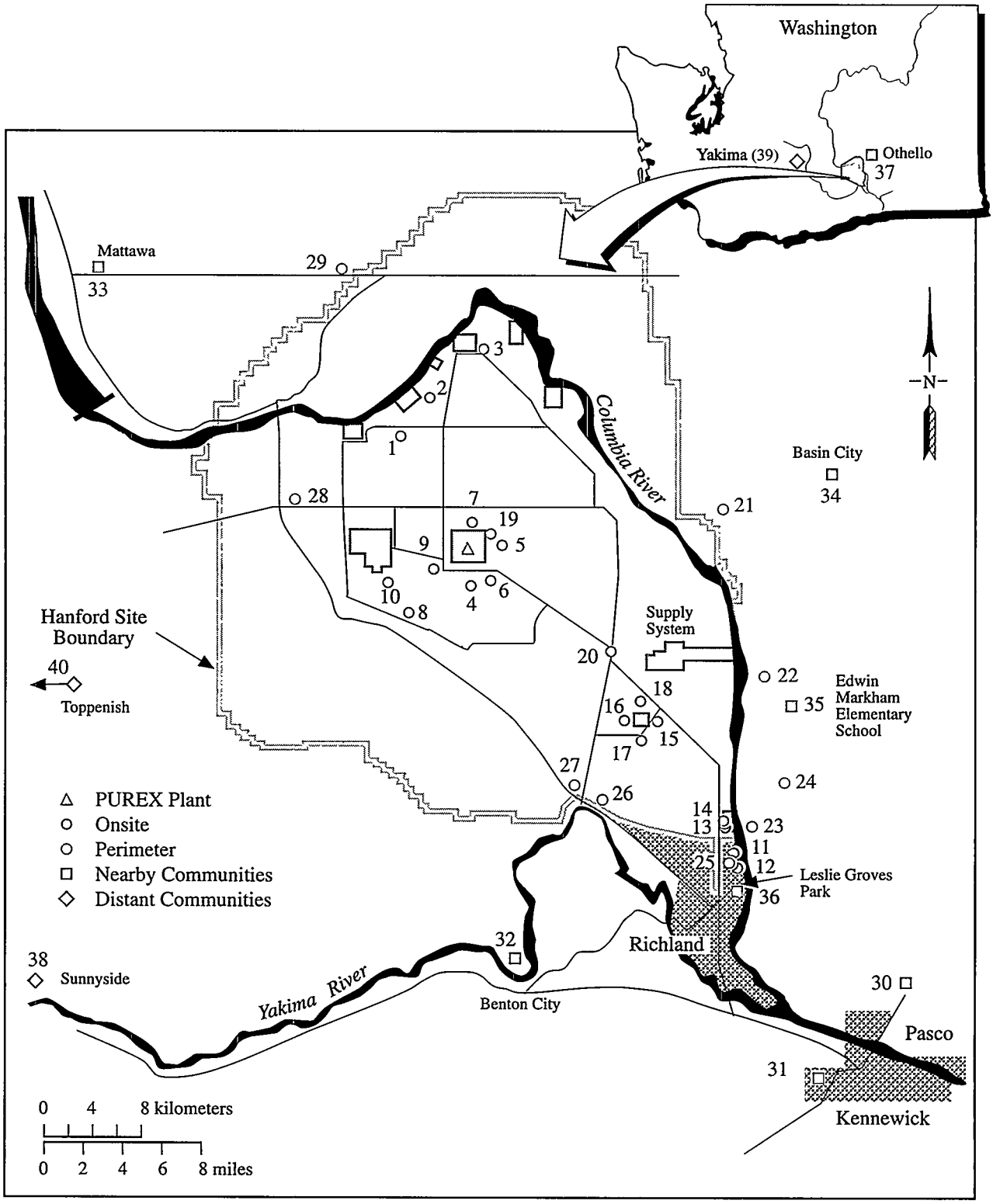

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Figure 4.1.1. Air Sampling Locations, 1995 (see Table 4.1.1 for location names)

Table 4.1.1. Air Sampling Locations, Sample Composite Groups, and Analyses, 1995

Map[a] Location	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	South of 200-East	Gamma, Sr, Pu, U
5	E of 200-East	Beta, alpha	East of 200-East	Gamma, Sr, Pu, U
6	200-East SE	Beta, alpha, ^{3}H, ^{129}I, SVOC[d]	200-East SE	Gamma, Sr, Pu, U, Am
7	N of 200-East	Beta	North of 200-East	Gamma - Annual
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	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 SVOC		
13	300 NE	Beta, alpha, ^{3}H	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	Ringold Met. Tower	Beta, alpha, ^{3}H, ^{129}I, ^{131}I	Ringold Met. Tower	Gamma, Sr, Pu
22	W End of Fir Road	Beta, alpha	W End of Fir Road	Gamma, Sr, Pu, U, Am
23	Byers Landing	Beta, alpha, ^{3}H, ^{129}I, ^{131}I	Byers Landing	Gamma, Sr, Pu, U, Am
24	Dogwood Met. Tower	Beta, alpha, ^{3}H	Dogwood Met. Tower	Gamma, Sr, Pu, U, Am
25	Battelle Complex	Beta	Battelle Complex	Gamma - Annual
26	Horn Rapids Road Substation	Beta, alpha	Prosser Barricade	Gamma, Sr, Pu, U
27	Prosser Barricade	Beta, alpha, ^{3}H		
28	Yakima Barricade	Beta, alpha, SVOC[e]	Yakima Barricade	Gamma, Sr, Pu

Table 4.1.1. Air Sampling Locations, Sample Composite Groups, and Analyses, 1995 (contd)

Map[a] Location	Sampling Location	Analyses[b]	Composite Group	Analyses[c]
29	Wahluke Slope	Beta, alpha, ^{3}H	Wahluke Slope	Gamma, Sr, Pu
Nearby Communities				
30	Pasco	Beta	Tri-Cities	Gamma, Sr, Pu
31	Kennewick	Beta, alpha		
32	Benton City	Beta	Benton City	Gamma - Annual
33	Mattawa	Beta	Mattawa	Gamma - Annual
34	Basin City	Beta, alpha, ^{3}H	Basin City Elem. School	Gamma, Sr, Pu, U
35	North Franklin County	Beta, alpha, ^{3}H, ^{131}I	Edwin Markham Elem. School	Gamma, Sr, Pu, U, Am
36	Richland	Beta, alpha, ^{3}H	Leslie Groves Park	Gamma, Sr, Pu, U
37	Othello	Beta	Othello	Gamma - Annual
Distant Communities				
38	Sunnyside	Beta, alpha, ^{3}H	Sunnyside	Gamma, Sr, Pu, U
39	Yakima	Beta, alpha, ^{3}H, ^{129}I, ^{131}I	Yakima	Gamma, Sr, Pu, U, Am
40	Toppenish	Beta, alpha, ^{3}H	Toppenish	Gamma, Sr, Pu, U

(a) See Figure 4.1.1.
(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.
(c) Gamma scans are performed on quarterly composite samples (or on annual composite samples [Gamma - Annual]); Sr, Pu, U, and Am analyses are performed on annual composite samples.
(d) SVOC = Semivolatile organic compounds.
(e) These semivolatile organic compound samples were actually collected at Rattlesnake Springs (Figure 1.0.1).

active nuclear reactors. 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 DOE operations would have decayed to undetectable amounts. Therefore, sampling for iodine-131 was discontinued in May 1995.

Iodine-129 (16,000,000-year half-life) was sampled at 4 locations 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 and combined to form quarterly composite samples for each location.

Atmospheric water vapor was collected for tritium analysis at 19 locations by continuously passing air through cartridges containing silica gel, which were exchanged every 4 weeks. The collection efficiency of the silica gel adsorbent is discussed in Patton et al. (1995). The collected water was distilled from the silica gel and analyzed for its tritium content.

Some of the environmental surveillance air samples were collected at eight community-operated environmental surveillance stations (see Section 6.4) located at Basin City Elementary School in Basin City, Edwin Markham Elementary School in Franklin County, Leslie Groves

Table 4.1.2. Airborne Radionuclide Concentrations in the Hanford Environs, 1995 Compared to Values from the Previous 5 Years

Radionuclide	Location Group[a]	1995 No. of Samples	1995 Maximum[b] pCi/m³	1995 Average[c] pCi/m³	1990-1994 No. of Samples	1990-1994 Maximum[b] pCi/m³	1990-1994 Average[c] pCi/m³	1995 Concentration Guide[d] pCi/m³
Total beta	Onsite	514	0.069 ± 0.0073	0.017 ± 0.00090	2,351	0.13 ± 0.012	0.020 ± 0.00053	
	Perimeter	205	0.065 ± 0.0069	0.017 ± 0.0014	1,291	0.15 ± 0.014	0.019 ± 0.00072	
	Nearby Communities	201	0.062 ± 0.0062	0.016 ± 0.0011	880	0.10 ± 0.0098	0.019 ± 0.00087	
	Distant Communities	71	0.061 ± 0.0064	0.015 ± 0.0025	387	0.12 ± 0.013	0.018 ± 0.0013	
			aCi/m³	aCi/m³		aCi/m³	aCi/m³	aCi/m³
^{90}Sr	Onsite	15	300 ± 96	47 ± 49	82	4,200 ± 810	100 ± 130	9,000,000
	Perimeter	7	0.32 ± 12	-1.6 ± 1.5	53	2,300 ± 430	170 ± 140	
	Nearby Communities	4	2.7 ± 16	-1.4 ± 3.2	44	6,300 ± 1,200	210 ± 300	
	Distant Communities	3	-1.8 ± 9.7	-7.1 ± 6.8	30	68 ± 120	-5.1 ± 9.2	
^{129}I	Onsite	4	50 ± 12	40 ± 11	20	110 ± 10	52 ± 10	70,000,000
	Perimeter	8	2.3 ± 0.28	1.1 ± 0.48	40	5.2 ± 0.39	1.5 ± 0.27	
	Distant Communities	4	0.056 ± 0.0054	0.035 ± 0.018	20	0.40 ± 0.046	0.10 ± 0.034	
^{131}I	Perimeter	22	5,900 ± 3,700	-3,300 ± 7,700	325	13,000 ± 11,000	5.0 ± 250	400,000,000
	Nearby Communities	10	2,700 ± 4,500	-210 ± 1,700	230	28,000 ± 19,000	470 ± 410	
	Distant Communities	10	4,000 ± 4,200	990 ± 1,500	161	7,200 ± 8,900	50 ± 330	
^{137}Cs	Onsite	45	550 ± 440	60 ± 64	203	1,200 ± 880	65 ± 42	400,000,000
	Perimeter	29	450 ± 250	-16 ± 97	161	1,400 ± 1,100	24 ± 68	
	Nearby Communities	19	300 ± 460	41 ± 47	120	990 ± 1,500	4.9 ± 62	
	Distant Communities	11	280 ± 410	3.2 ± 120	80	1,300 ± 1,200	36 ± 93	
U total[e]	Onsite	39	25 ± 4.3	10 ± 2.4	189	3,400 ± 330	66 ± 48	100,000
	Perimeter	12	36 ± 5.7	17 ± 7.9	78	64 ± 13	21 ± 3.9	
	Nearby Communities	9	26 ± 6.3	12 ± 6.3	54	44 ± 12	19 ± 3.9	
	Distant Communities	9	19 ± 3.7	11 ± 5.3	72	230 ± 30	21 ± 7.0	
^{238}Pu	Onsite	15	0.18 ± 0.33	-0.21 ± 0.20	82	2.0 ± 1.2	0.26 ± 0.14	30,000
	Perimeter	7	0.19 ± 0.37	0.078 ± 0.070	52	3.1 ± 4.1	0.078 ± 0.24	
	Nearby Communities	4	0.28 ± 0.62	0.096 ± 0.16	44	1.8 ± 1.6	0.029 ± 0.14	
	Distant Communities	3	0.047 ± 0.52	0.019 ± 0.030	30	5.3 ± 3.1	0.50 ± 0.44	

Table 4.1.2. Airborne Radionuclide Concentrations in the Hanford Environs, 1995 Compared to Values from the Previous 5 Years (contd)

Radionuclide	Location Group[a]	1995 No. of Samples	1995 Maximum[b] aCi/m³	1995 Average[c] aCi/m³	1990-1994 No. of Samples	1990-1994 Maximum[b] aCi/m³	1990-1994 Average[c] aCi/m³	1995 Concentration Guide[d] aCi/m³
$^{239,240}Pu$	Onsite	15	3.1 ± 1.2	0.92 ± 0.54	82	12 ± 3.0	1.7 ± 0.48	20,000
	Perimeter	7	1.5 ± 0.77	0.54 ± 0.42	52	2.5 ± 2.0	0.82 ± 0.20	
	Nearby Communities	4	0.41 ± 0.29	0.20 ± 0.17	44	3.3 ± 1.5	0.85 ± 0.26	
	Distant Communities	3	1.2 ± 1.2	0.46 ± 0.77	30	3.9 ± 1.3	0.53 ± 0.42	
^{241}Am[f]	Onsite	2	0.12 ± 1.1	0.11 ± 0.015	4	0.90 ± 1.2	0.44 ± 0.40	20,000
	Perimeter	3	0.33 ± 0.66	0.19 ± 0.14	5	0.43 ± 1.2	-0.27 ± 0.60	
	Nearby Communities	1	0.061 ± 0.56	0.061	2	-.032 ± 0.76	-0.48 ± 0.32	
	Distant Communities	1	-0.34 ± 0.38	-0.34	2	-0.47 ± 1.1	-0.77 ± 0.61	
Total alpha[g]	Onsite	463	2,100 ± 610	440 ± 25	988	8,300 ± 1,400	740 ± 63	
	Perimeter	179	1,900 ± 680	490 ± 43	537	12,000 ± 1,700	1,200 ± 120	
	Nearby Communities	101	1,200 ± 340	500 ± 48	236	6,200 ± 1,300	790 ± 110	
	Distant Communities	71	1,400 ± 480	380 ± 64	125[h]	6,500 ± 1,100	850 ± 180	

(a) Location groups are identified in Table 4.1.1.
(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) Summation of Uranium-234, -235, and -238.
(f) Americium-241 sampling was initiated in 1993.
(g) Total alpha values for 1991 and 1992 were not included 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).
(h) Two results from the distant communities were excluded as anomolous values through the use of a Q-test (26,000 ± 3,400 aCi/m³ at Yakima and 8,000 ± 1,000 aCi/m³ at Sunnyside (Skoog and West 1980).

Park in Richland, Pasco at Columbia Basin College, Kennewick, Othello, Mattawa, and Toppenish at Heritage College (see Table 4.1.1). These samples were collected by local teachers using the same equipment and procedures as the routine surveillance program. This work is part of an ongoing DOE-sponsored program to promote public awareness of Hanford environmental monitoring programs.

Radiological Results for Air Samples

Radiological air sampling results for onsite, Site perimeter, nearby communities, and distant communities for total beta, total alpha, and specific radionuclides are summarized in Table 4.1.2. Some specific radionuclides (cobalt-60, cesium-134, cesium-137, europium-154, and europium-155) were occasionally (≥88% of results were below detection limits) identified in the quarterly or annual composite gamma-scan analyses (Appendix E), but none of Hanford origin was detected consistently. In addition, naturally occurring beryllium-7 and potassium-40 were routinely identified by gamma-scan analyses.

Total beta concentrations in air for 1995, as shown in Figure 4.1.2, peaked during the winter, repeating a pattern of natural annual radioactivity fluctuations (Eisenbud 1987). 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 average concentration of total alpha radioactivity at the Site perimeter was elevated compared to the concentrations measured at the distant stations (Table 4.1.2), and the difference was statistically significant (log transformed, two-tailed t-test, 5% significance level). However, the concentrations were not beyond the range of measurements from previous years (Figure 4.1.3).

The airborne concentrations of tritium from 1990 to 1995 are given in Table 4.1.3. Table 4.1.3 provides a consistent treatment of the historical data because previous Hanford Site reports used differing methods to report suspect tritium results. Tritium concentrations measured in 1995 were similar to values reported for 1990 and did not show the highly elevated concentrations and widely

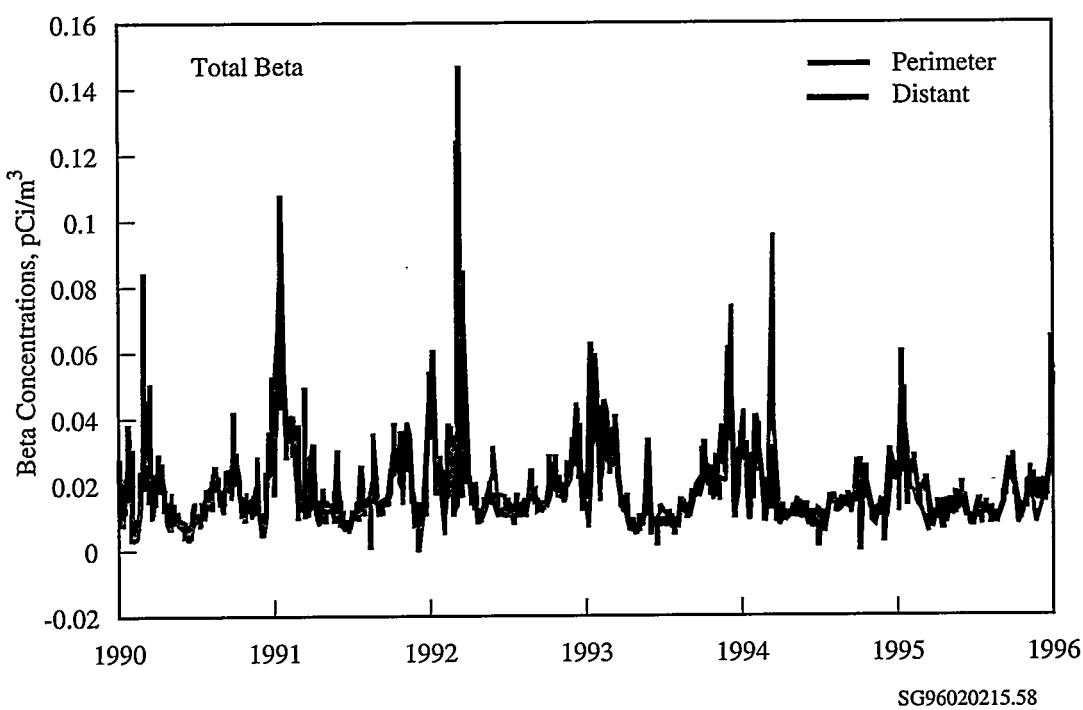

Figure 4.1.2. Total Beta Radioactivity in Airborne Particulate Samples, 1990 Through 1995

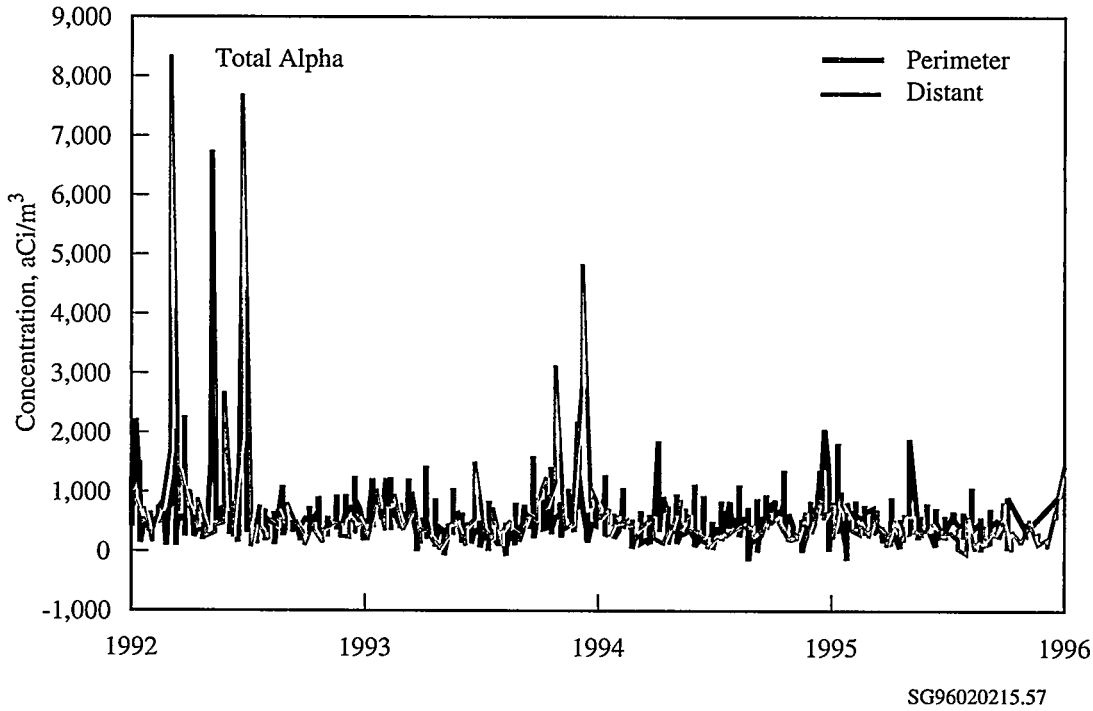

Figure 4.1.3. Total Alpha Radioactivity in Airborne Particulate Samples, 1992 Through 1995

variable results reported for 1991 and 1992 (Woodruff et al. 1993). The 1991 and 1992 results are highly suspect and are likely the result of cross-contamination at the analytical laboratory because even the concentrations at distant locations were high and variable. No individual tritium air concentrations for 1995 were above 100 pCi/m^3 and no sampling station measured consistently elevated concentrations. Even the highest individual concentration measured for 1995 (24 ± 20 pCi/m^3 [Location #9, Figure 4.1.1]) was only 0.02% of the 100,000 pCi/m^3 DOE Derived Concentration Guide. For 1995, the annual average tritium concentration measured at the Site perimeter (1.8 ± 0.71 pCi/m^3) was elevated compared to the annual average value at the distant locations (0.77 ± 0.42 pCi/m^3); however, the difference was not statistically significant (log transformed, two-tailed t-test, 5% significance level). The annual average tritium concentration at the Site perimeter in 1995 was 0.002% of the DOE Derived Concentration Guide.

Only 4 of 29 strontium-90 results (Table 4.1.2) for air samples for 1995 were above a nominal detection limit of 40 aCi/m^3, with all detectable concentrations occurring onsite. The highest concentration (300 ± 96 aCi/m^3) was measured at East of 200-E (Location #5, Figure 4.1.1) and this concentration is 0.003% of the 9,000,000 aCi/m^3 DOE Derived Concentration Guide.

Iodine-129 was sampled downwind of the Plutonium-Uranium Extraction Plant (onsite location #6, Figure 4.1.1), at two downwind perimeter locations, and at a distant location (Yakima) in 1995. Onsite concentrations in 1995 were elevated compared to those measured at the Site perimeter, and perimeter concentrations were higher than those measured at Yakima (Figure 4.1.4, Table 4.1.2). Iodine-129 concentration differences between these locations were statistically significant (log transformed, two-tailed t-test, 5% significance level) and showed a Hanford source. Onsite and perimeter air concentrations have remained at their respective levels from 1990 to 1995 (Figure 4.1.4). Onsite air concentrations of iodine-129 were influenced by minor emissions (0.0089 Ci, Table 3.1.1) from the Plutonium-Uranium Extraction Plant and possible releases from waste storage tanks and cribs. The annual average iodine-129 concentration at the downwind perimeter in 1995 (1.1 ± 0.48 aCi/m^3) was 0.000002% of the 70,000,000 aCi/m^3 DOE Derived Concentration Guide.

Plutonium-238 was not detected in any air samples for 1995 (nominal detection limit of 1 aCi/m^3). The detection

Table 4.1.3. Airborne Concentrations[a] of Tritium in the Hanford Environs (pCi/m³), 1990 to 1995

Location Group[b]	No. of Samples	Maximum[c]	Average (All Data)[d]	No. of Samples	Average Excluding Data ≥ 100 pCi/m³[e]
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
Nearby Comm.	30	4,900 ± 420	210 ± 340	28	1.9 ± 0.86
Distant Comm.	29	350 ± 31	18 ± 25	27	2.2 ± 2.2
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
Nearby Comm.	40	1,600 ± 8.4	120 ± 100	31	6.0 ± 5.6
Distant Comm.	26	380 ± 5.4	43 ± 43	23	5.0 ± 6.0
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
Nearby Comm.	34	120 ± 3.6	4.5 ± 7.2	33	0.95 ± 0.40
Distant Comm.	26	3.8 ± 4.1	0.83 ± 0.52	26	0.83 ± 0.51
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
Nearby Comm.	39	21 ± 2.2	1.2 ± 1.1	39	1.2 ± 1.1
Distant Comm.	26	2.2 ± 1.5	0.54 ± 0.29	26	0.54 ± 0.29
1995					
Onsite	101	24 ± 20	1.6 ± 0.61	101	1.6 ± 0.61
Perimeter	65	12 ± 22	1.8 ± 0.71	65	1.8 ± 0.71
Nearby Comm.	40	16 ± 15	2.4 ± 1.3	40	2.4 ± 1.3
Distant Comm.	35	5.2 ± 5.0	0.77 ± 0.42	35	0.77 ± 0.42

(a) 1995 DOE Derived Concentration Guide = 100,000 pCi/m³.
(b) Location groups are provided in Table 4.1.1.
(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/m³ 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 (Dirkes and Hanf 1995).

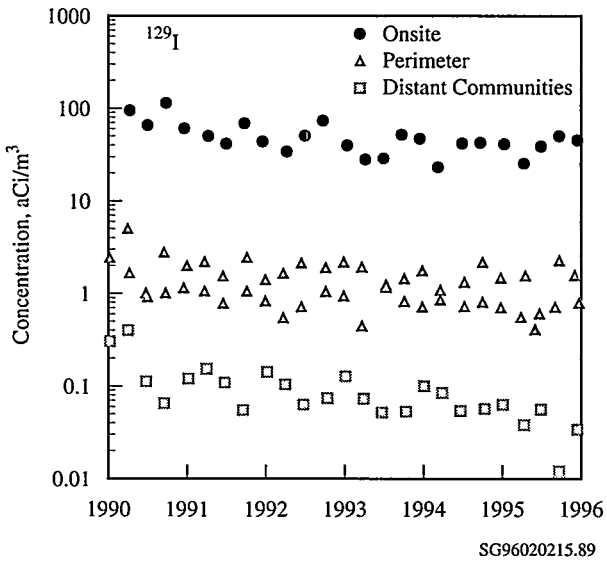

Figure 4.1.4. Concentrations of Iodine-129 in Air, 1990 Through 1995

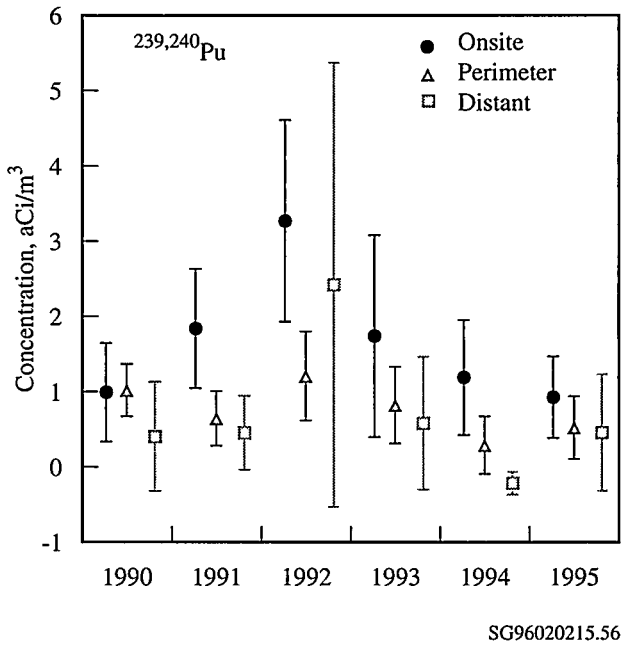

Figure 4.1.5. Annual Average Concentrations (±2 standard error of the mean) of Plutonium-239,240 in Air, 1990 Through 1995. As a result of figure scale, some uncertainties are concealed by point symbol.

limit represents 0.003% of the 30,000 aCi/m³ DOE Derived Concentration Guide for plutonium-238.

The average plutonium-239,240 concentrations for Hanford Site and offsite air samples are shown in Table 4.1.2 and Figure 4.1.5. The annual average air concentration of plutonium-239,240 at the Site perimeter was 0.54 aCi/m³ ± 0.042, which is 0.003% of the 20,000 aCi/m³ DOE Derived Concentration Guide. The annual average air concentration was slightly higher for the Site perimeter locations compared to the distant locations; however, this difference was not statistically significant (log transformed, two-tailed t-test, 5% significance level). The maximum Hanford Site plutonium-239,240 air concentration was measured at the 200-West Area (3.1 ± 1.2 aCi/m³ or 0.02% of the DOE Derived Concentration Guide).

Uranium concentrations (sum of uranium-234, -235, and -238) in airborne particulate matter in 1995 were similar at the Site perimeter and at distant communities (Table 4.1.2 and Figure 4.1.6). The 1995 annual average concentration for the Site perimeter was 17 ± 7.9 aCi/m³, which was 0.02% of the 100,000 aCi/m³ DOE Derived Concentration Guide.

Seven annual air composite samples were analyzed for americium-241 in 1995 and all results (Table 4.1.2) were

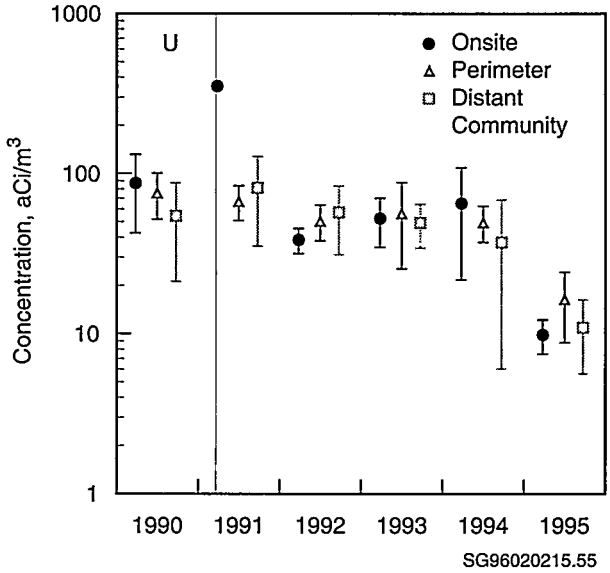

Figure 4.1.6. Annual Average Concentrations (±2 standard error of the mean) of Uranium in Air, 1990 Through 1995

below a nominal detection limit of 1 aCi/m^3. This concentration represents 0.005% of the 20,000 aCi/m^3 DOE Derived Concentration Guide. Americium-241 was added to the sampling schedule in 1993 to estimate the regional background air concentrations before the initiation of large-scale remediation work at Hanford; none of the 20 air samples analyzed since 1993 have had detectable concentrations.

Cesium-137 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 5 of 104 cesium-137 samples and 2 of 42 iodine-131 samples had concentrations above the detection limits. The cesium-137 and iodine-131 results for 1995 samples are included in Table 4.1.2. Even the maximum individual measurements for these radionuclides were less than 0.001% of their DOE Derived Concentration Guide.

Collection and Analysis of Nonradiological Air Samples

Samples for semivolatile organic compounds (PCBs, chlorinated pesticides, phthalate ester plasticizers, and polycyclic aromatic hydrocarbons) in air were collected at the 300 Area South Gate (Figure 4.1.1, location #12), at 200-East southeast (Figure 4.1.1, location #6), and at a background location near Rattlesnake Springs (Figure 1.0.1). The Rattlesnake Springs location is typically upwind of major Hanford Site facilities (Figure 6.1.1). Air samples for semivolatile organic compounds were collected using EPA Method TO-4 (EPA 1988), which uses high-volume air samplers equipped with glass-fiber filters and polyurethane-foam adsorbent traps. Air samples were analyzed by the Sequim Marine Laboratory using capillary gas chromatography with either electron capture detection or mass selective detection.

Nonradiological Results for Air Samples

A review of chemicals of concern for environmental surveillance at the Hanford Site (Blanton et al. 1995a) identified a PCB technical mixture (Aroclor 1254), a polycyclic aromatic hydrocarbon (benzo(a)pyrene), and a phthalate ester plasticizer (bis(2-ethylhexyl)phthalate as possible candidates for environmental monitoring. All of these compounds are classified as semivolatile organic compounds because they are found in both the gas phase (vapors) and associated with airborne particles. The PCBs and phthalate ester plasticizers have been widely used by modern society and are ubiquitous environmental contaminants. The polycyclic aromatic hydrocarbons are products from the incomplete combustion of fossil fuels and are common air pollutants. A set of twelve samples were collected in 1995 to evaluate the concentrations of semivolatile organic compounds in Hanford Site ambient air. The chlorinated pesticides were included in the list of compounds analyzed because of possible past use at Hanford. The samples were analyzed for 28 individual PCB congeners, 18 polycyclic aromatic hydrocarbons, 2 phthalate ester plasticizers, and 25 chlorinated pesticides. There are no ambient air standards for these semivolatile organic compounds; therefore, the ambient air concentrations measured on the Hanford Site are compared to carcinogenic and non-carcinogenic risk-based concentrations.[a] Ambient air concentrations below the risk-based concentrations have associated risks that are less than 1×10^{-6} for carcinogenic risk and less than 1.0 of a hazard quotient for non-carcinogenic risk. These risk-based concentrations are used as an initial screening tool to evaluate if additional monitoring or more detailed risk calculations should be undertaken.

Fourteen polycyclic aromatic hydrocarbons were found above the detection limits for the ambient air samples (Figure 4.1.7; Appendix A, Table A.9). Phenanthrene was the only polycyclic aromatic hydrocarbon with average air concentrations above 500 pg/m^3, with average values ranging from 800-2500 pg/m^3. Fluoranthene, pyrene, fluorene, chrysene, benzo(b)fluoranthene, and anthracene were the only other polycyclic aromatic hydrocarbon compounds with average concentrations above 100 pg/m^3. Benzo(a)pyrene (identified in the review of contaminates of concern) was not detected in any air samples with a nominal detection limit of 20 pg/m^3 for a 1,000 m^3 sample. The detection limit for benzo(a)pyrene was well below the risk-based concentration of 1,000 pg/m^3. Overall, the 300 Area had higher average concentrations of polycyclic aromatic hydrocarbons compared to the 200 Area and the background location near Rattlesnake Springs. The air concentrations at the 300 Area are influenced by sources on the Hanford Site

(a) U.S. EPA Region III Risk-Based Concentration Table, R. L. Smith, February 9, 1995.

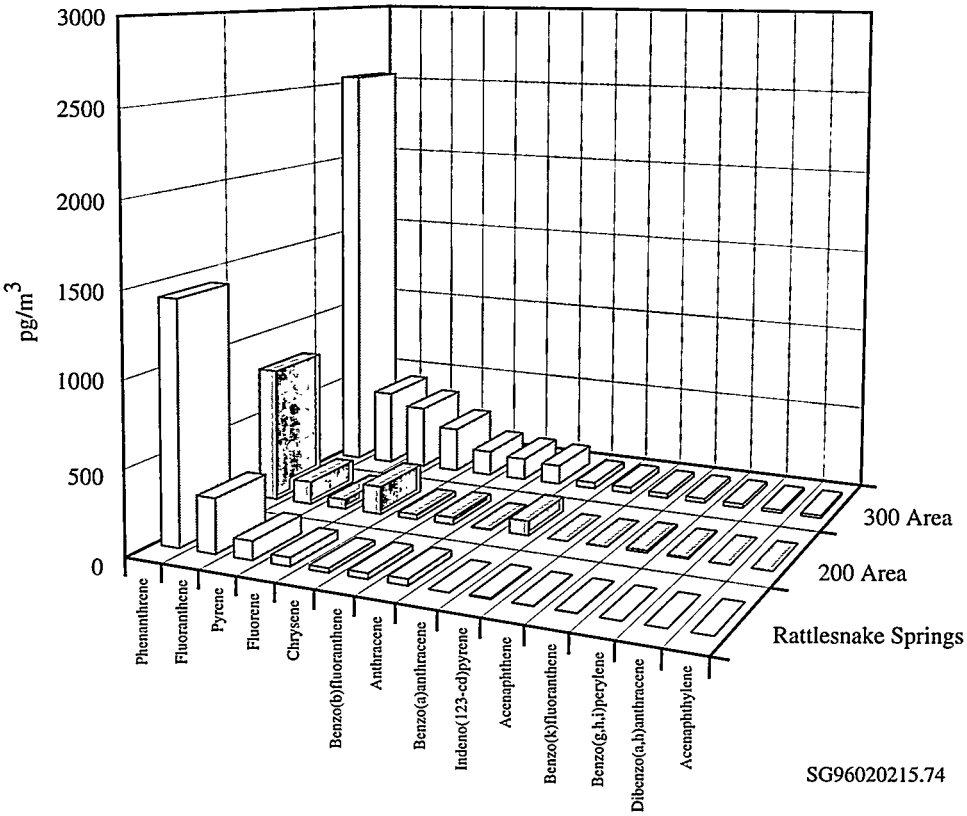

Figure 4.1.7. Annual Average Concentrations of Polycyclic Aromatic Hydrocarbons in Hanford Air, 1995

and from nearby communities. All polycyclic aromatic hydrocarbon concentrations measured in air were well below applicable risk-based concentrations (Appendix A, Table A.9).

The air samples were analyzed for two phthalate ester plasticizers [bis(2-ethylhexyl)phthalate and di-n-octyl phthalate]. Neither of these compounds were found above the detection limits; however, both of these compounds had high concentrations in the sample blanks which resulted in elevated detection limits of approximately 27,000 pg/m^3 for bis(2-ethylhexyl)phthalate and 720 pg/m^3 for di-n-octyl phthalate (assuming a 1,000 m^3 air sample). The detection limits for these compounds were well below their respective risk-based concentrations (450,000 pg/m^3 for carcinogenic risk for bis(2-ethylhexyl)phthalate and 73,000,000 pg/m^3 for non-carcinogenic risk for di-n-octyl phthalate.

Nineteen PCB congeners were found above the detection limits for the Hanford Site samples (Figure 4.1.8; Appendix A, Table A.10). Eight congeners (#101, #138, #87, #118, #105, #153, #28, and #52) accounted for over 80% of the average PCB concentrations at all three sampling locations. The average total PCB congener concentrations ranged from 490-660 pg/m^3, which were similar to values reported from a previous Hanford Site study (Patton et al. 1994). All individual congener PCB concentrations and all average total PCB concentrations were below the risk-based concentration of 810 pg/m^3 for carcinogenic risk. However, the maximum concentrations for total PCBs exceeded the risk-based concentrations by a factor of 2.

Sixteen chlorinated pesticides were found above the detection limits for Hanford Site air samples (Figure 4.1.9; Appendix A, Table A.11). Endosulfan I and Endosulfan II had the highest average air concentrations, with average concentrations for Endosulfan I ranging from 550-3,500 pg/m^3 and Endosulfan II ranging from 65-750 pg/m^3. The maximum concentrations of Endosulfan I and II were for an August 1995 sample from the 300 Area. This sample was re-analyzed using gas chromatography-negative ionization mass spectrometry,

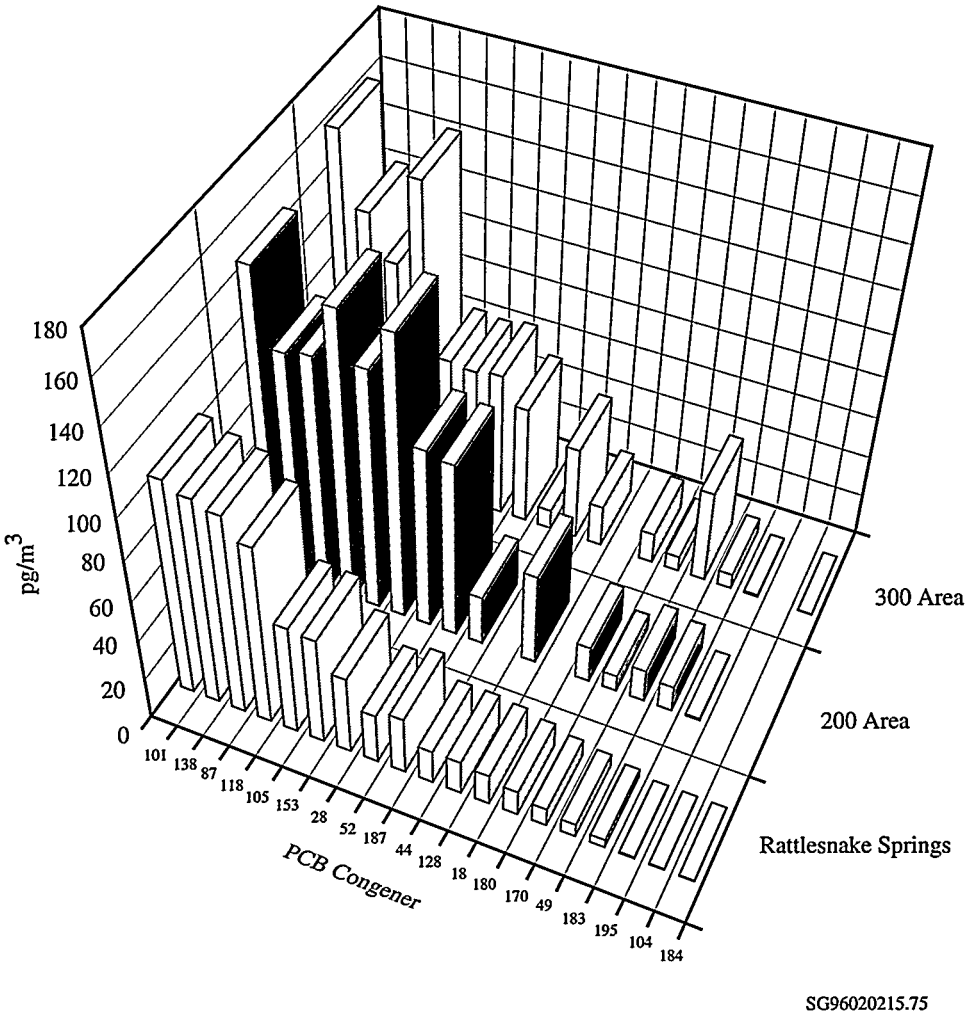

Figure 4.1.8. Annual Average Concentrations of PCBs in Hanford Air, 1995

which confirmed the elevated concentrations. All other average pesticide concentrations were below 100 pg/m³. The measured pesticide concentrations were orders of magnitude below the applicable risk-based concentrations (Appendix A, Table A.11).

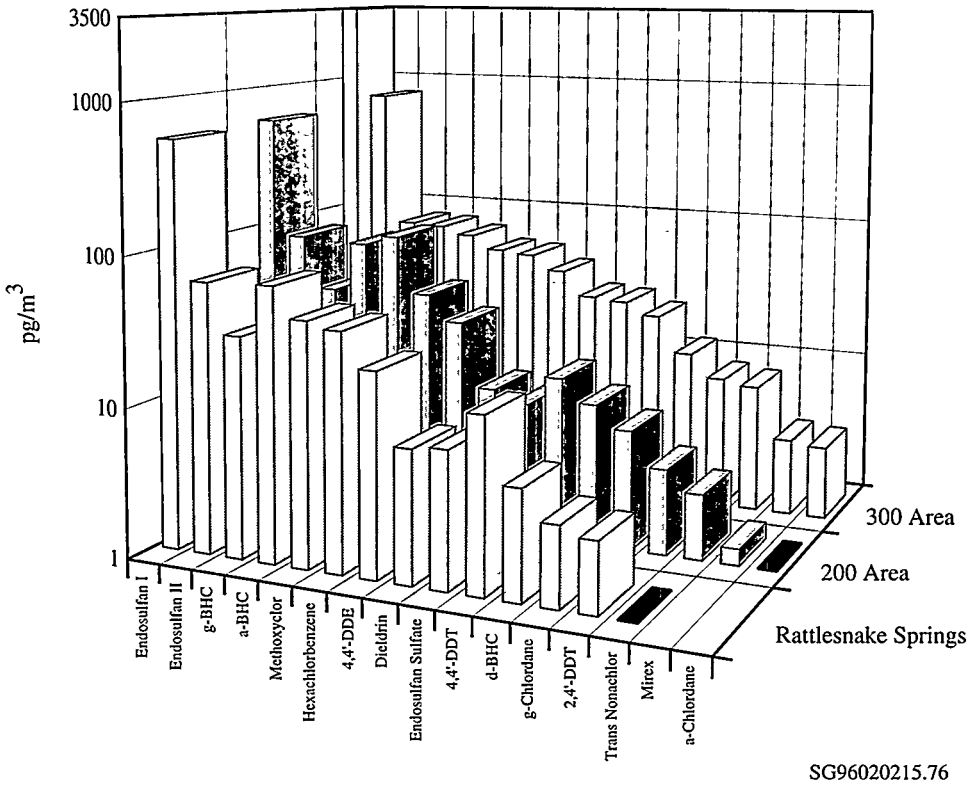

Figure 4.1.9. Annual Average Concentrations of Chlorinated Pesticides in Hanford Air, 1995

4.2 Surface Water and Sediment Surveillance

K. A. Saldi and R. L. Dirkes

Surface water and sediment on and near the Hanford Site are monitored to determine the potential impacts of Hanford-originated radiological and chemical contaminants to the public and to the aquatic environment. Surface-water bodies included in routine surveillance are the Columbia River, riverbank springs, onsite ponds, and offsite water systems directly east and across the Columbia River from the Hanford Site. Sediment quality surveillance is conducted on the Columbia River and riverbank springs. Tables 4.2.1 and 4.2.2 summarize the sampling locations, sample types, sampling frequencies, and sample analyses included in surface-water and sediment surveillance activities during 1995. Sample locations are also identified in Figure 4.2.1. This section describes the surveillance effort and summarizes the results for these aquatic environments. Detailed analytical results are reported by Bisping (1996).

Columbia River Water

The Columbia River is the second largest river in the continental United States in terms of total flow, and is the dominant surface-water body on the Hanford Site. The original selection of the Hanford Site for plutonium production and processing was based, in part, on the abundant water supply offered by the river. The Columbia River flows through the northern edge of the Site and forms part of the Site's eastern boundary. The river is used as a source of drinking water for onsite facilities and by communities located downstream from the Hanford Site. Water from the Columbia River downstream of Site operations is also used extensively for crop irrigation. 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.

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. Its flow is regulated by 11 dams within the United States, seven upstream and four downstream of 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. The Hanford Reach is the last stretch of the Columbia River in the United States above Bonneville Dam that remains unimpounded. The Hanford Reach is currently under consideration for designation as a National Wild and Scenic River as a result of congressional action in 1988.

Flows through the Hanford Reach fluctuate significantly and are controlled primarily by operations at Priest Rapids Dam. Annual flows of the Columbia River below Priest Rapids Dam over the last 77 years have averaged nearly 3,360 m^3/s (120,000 ft^3/s) (Wiggins et al. 1995). The annual average flow rate below Priest Rapids Dam in 1995 was 3,206 m^3/s (113,219 ft^3/s). The peak monthly average flow rate in 1995 occurred during December (4,624 m^3/s [163,295 ft^3/s]), following a rapid snow melt preceded by a large winter storm (Figure 4.2.2). A secondary high occurred in June as a result of spring runoff. The lowest monthly average flow rate occurred during September (2,040 m^3/s [72,042 ft^3/s]). Daily average flow rates varied from 1,339 to 5,805 m^3/s (47,286 to 205,002 ft^3/s) during 1995. As a result of fluctuations in discharges, the depth of the river varies significantly over time. River stage may change along the Reach by up to 3 m (10 ft) within a few hours (Dresel et al. 1996). Seasonal changes of about the same magnitude are also observed. River stage fluctuations measured at the 300 Area are only about half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam (Campbell et al. 1993), and the relative distance of each area from Priest Rapids Dam. The width of the river varies from approximately 300 m (984 ft) to 1,000 m (3,281 ft) along the Hanford Site.

Pollutants, both radiological and nonradiological, are known to enter the Columbia River along the Hanford Reach. In addition to direct discharges of liquid effluents from Hanford facilities, contaminants in ground water from past discharges to the ground are known to

Table 4.2.1. Surface-Water Surveillance, 1995

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 Cont [e] Q Cont	Gamma scan Pu[f]
Priest Rapids Dam and Richland	Soluble (resin)	M Cont Q Cont	Gamma scan ^{129}I, Pu
Vernita Bridge and Richland	Grab (transects)	Q	lo ^{3}H, ^{90}Sr, U
100-F and 300 Area	Grab (transects)	A	lo ^{3}H, ^{90}Sr, U
100-N	Grab (transects)	A	Alpha, beta, lo ^{3}H, ^{90}Sr, ^{99}Tc, U, gamma scan
Hanford Townsite	Grab (transects)	A	lo ^{3}H, ^{90}Sr, ^{99}Tc, U
Columbia River - Nonradiological			
Vernita and Richland[g]	Grab	Q	WQ-NASQAN, temperature, dissolved oxygen, turbidity, pH, fecal coliforms, suspended solids, dissolved solids, conductivity, hardness as $CaCO_3$, P, Cr, N-Kjeldahl, Fe, NH_3, $NO_3 + NO_2$
Vernita and Richland	Grab (transects)	Q	ICP[h] metals, anions, volatile organics, As, Pb
Vernita and Richland	Grab (transects)	A	CN, Hg
100-N, 100-F, and Hanford Townsite	Grab (transects)	A	ICP metals, anions, volatile organics, As, Pb
300 Area	Grab (transects)	A	ICP metals, anions, volatile organics, As, Pb, CN
Onsite Ponds			
West Lake	Grab	Q	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U, 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			
Drinking water	Grab	A	Alpha, beta, ^{3}H, U, gamma scan
Riverview Canal	Grab	3[i]	Alpha, beta, ^{3}H, ^{90}Sr, U, gamma scan
Riverbank Springs			
100-B, 100-K, 100-N, and 100-H	Grab	A	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U, gamma scan, ICP metals, anions, volatile organics
100-D	Grab	2[j]	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U, gamma scan, ICP metals, anions, volatile organics
Hanford Townsite and 300 Area	Grab	A	Alpha, beta, ^{3}H, ^{129}I, ^{90}Sr, ^{99}Tc, U, gamma scan, ICP metals, anions, volatile organics

(a) A = annually; M = monthly; Q = quarterly; Comp = composite.
(b) M Comp indicates river water was collected hourly and composited monthly for analysis.
(c) lo ^{3}H = low-level tritium analysis.
(d) Isotopic uranium.
(e) M/Q Cont indicates river water was sampled by continuous flow through a filter and resin column and composited monthly (M) or quarterly (Q) for analysis.
(f) Isotopic plutonium.
(g) 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.
(h) ICP = inductively coupled plasma analysis method.
(i) Three samples during irrigation season.
(j) Two samples during period of low river flow (August-September).

Table 4.2.2. Sediment Surveillance, 1995

Location[a]	Frequency	Analyses
River		
McNary Dam		
Oregon shore	A[b]	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
1/3 from Oregon shore	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
2/3 from Oregon shore	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
Washington shore	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
Priest Rapids Dam		
Grant County shore	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
1/3 from Grant County shore	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
2/3 from Grant County shore	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
Yakima County shore	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
White Bluffs Slough	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
100-F Slough	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
Hanford Slough	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
Richland	A	Gamma scan, ^{90}Sr, U,[c] Pu,[d] Pb, ICP[e] Metals
Springs		
100-B Spring	A	Gamma scan, ^{90}Sr, U,[c] ICP[e] Metals
Hanford Spring 28-2	A	Gamma scan, ^{90}Sr, U,[c] ICP[e] Metals
300 Area Spring 42-2	A	Gamma scan, ^{90}Sr, U,[c] ICP[e] Metals
100-K Spring	A	Gamma scan, ^{90}Sr, U,[c] ICP[e] Metals
100-F Spring	A	Gamma scan, ^{90}Sr, U,[c] ICP[e] Metals, Pb

(a) See Figure 4.2.1.
(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.

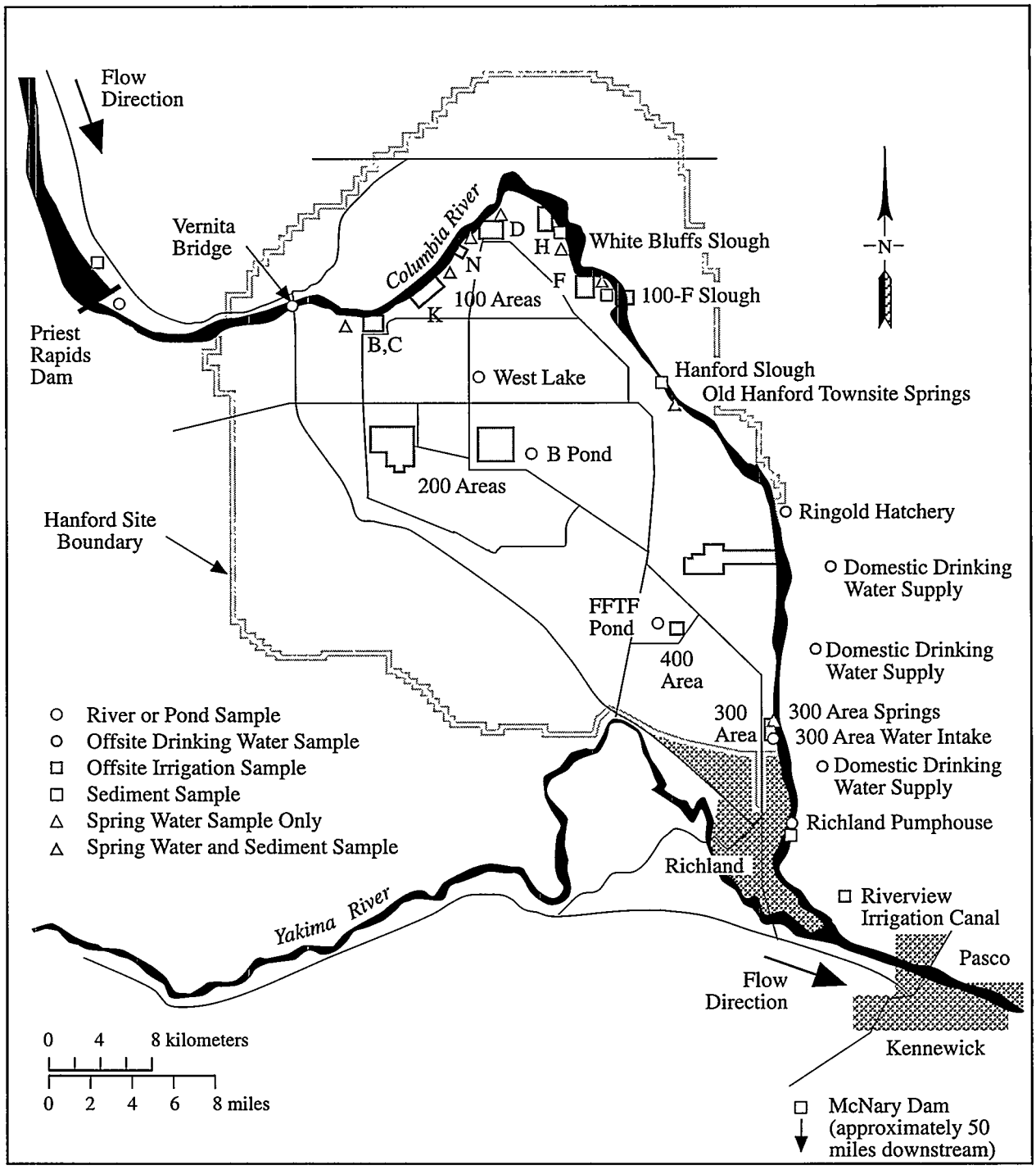

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Figure 4.2.1. Water and Sediment Sampling Locations, 1995

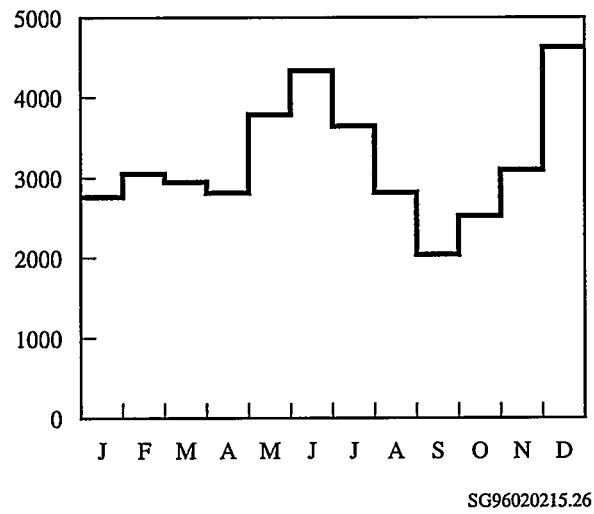

Figure 4.2.2. Mean Monthly Columbia River Flow Rates During 1995 (measured at Priest Rapids Dam)

seep into the river (Dirkes 1990, DOE 1992e, McCormack and Carlile 1984, Peterson 1992). Effluents from each direct discharge point are routinely monitored and reported by the responsible operating contractor; these 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 in compliance with the Clean Water Act. The National Pollutant Discharge Elimination System-permitted discharges at Hanford are summarized in Section 2.2, "Compliance Status."

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 and are provided in Appendix C, Table C.1.

Collection and Analysis of River Water Samples

Samples of Columbia River water were collected throughout 1995 at the locations shown in Figure 4.2.1. Samples were collected from fixed-location monitoring stations at Priest Rapids Dam and the Richland Pumphouse, and from Columbia River transects established near the Vernita Bridge, 100-N Area, 100-F Area, old Hanford Townsite, 300 Area, and the Richland Pumphouse. Samples were collected upstream from Hanford facilities at Priest Rapids Dam and the Vernita Bridge to provide background data from locations unaffected by Site operations. Samples were collected from all other locations to identify any increase in contaminant concentrations attributable to Hanford operations. The Richland Pumphouse is the first downstream point of river water withdrawal for a public drinking water supply.

The fixed-location monitoring stations at Priest Rapids Dam and the Richland Pumphouse consisted of both an automated sampler and a continuous flow system. Using the automated sampler, unfiltered samples of Columbia River water (cumulative samples) were collected hourly and composited monthly for radiological analyses (Table 4.2.1). Using the continuous flow system, particulate and soluble fractions of select Columbia River water constituents were collected in a filter and resin column, respectively. Filter and resin samples were composited monthly or quarterly for radiological analyses. The river sampling locations and the methods used for sample collection are discussed in detail in the *Environmental Monitoring Plan* (DOE 1994a).

A deviation from the environmental monitoring plan occurred from mid-March 1995 through early January 1996 due to construction at the Richland Pumphouse, which necessitated the removal of composite and continuous river water sampling equipment. Continuous-flow filter and resin samples of Columbia River water at the Richland Pumphouse were not collected during this time. Automated hourly grab samples of Columbia River water were replaced by manual weekly grab samples from the boat dock adjacent to the pumphouse and were composited monthly for analysis.

Radiological analyses of water samples collected from the Priest Rapids Dam and Richland Pumphouse fixed-location monitoring stations included total alpha, total beta, gamma scan, tritium, strontium-90, technetium-99, iodine-129, uranium-234, -235, and -238, plutonium-238, and plutonium-239,240. Alpha and beta measurements provided a general indication of radioactive contamination. Gamma scans provided the ability to detect numerous specific radionuclides (Appendix E). Sensitive radiochemical analyses and, in some cases, special sampling techniques were used to determine the concentrations of tritium, strontium-90, technetium-99, iodine-129, uranium-234, -235, and -238, plutonium-238, and plutonium-239,240 in river water during the year. Radionuclides of interest were selected for analysis based on their presence in effluents discharged from Site facilities or in near-shore ground-water underlying the Hanford Site, and their importance in determining water

quality, verifying effluent control and effluent monitoring systems, and determining compliance with applicable standards. Analytical detection levels for all radionuclides were less than 10% of their respective ambient water quality criteria levels (Appendix C, Table C.1).

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 Pacific Northwest National Laboratory 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 (see Section 4.3, "Hanford Site Drinking Water Surveillance") and the Richland Pumphouse. The cross sections at Vernita Bridge and the Richland Pumphouse were sampled quarterly during 1995. Annual transect sampling was conducted at the 100-N Area, 100-F Area, old Hanford Townsite, and 300 Area sampling locations.

Columbia River transect water samples collected in 1995 were analyzed for both radiological and chemical contaminants (Table 4.2.1). Metals, anions, and volatile organics, listed in DOE (1994c), were selected for analysis following reviews of existing surface- and ground-water data, various Remedial Investigation/Feasibility Study work plans, and preliminary Hanford Site risk assessments (Blanton et al. 1995b, Dirkes et al. 1993, DOE 1992b, Evans et al. 1992, Napier et al. 1995). All radiological and chemical analyses of transect samples were performed on unfiltered water.

In addition to Columbia River monitoring conducted by Pacific Northwest National Laboratory in 1995, nonradiological water quality monitoring was also performed by the U.S. Geological Survey in conjunction with the National Stream Quality Accounting Network program. During 1995, U.S. Geological Survey samples were collected along Columbia River transects quarterly at the Vernita Bridge and three times at the Richland Pumphouse. Sample analyses were performed at the U.S. Geological Survey laboratory in Denver, Colorado for numerous physical, biological, and chemical constituents.

Radiological Results for Columbia River Water Samples

Results of the radiological analyses of Columbia River water samples collected at Priest Rapids Dam and the Richland Pumphouse during 1995 are reported by Bisping (1996) and summarized in Appendix A, Tables A.1 and A.3. Samples of Columbia River water were also collected by the Drinking Water Monitoring Program in 1995 at the 300 Area water intake. The 300 Area radiological monitoring results are reported in Section 4.3, "Hanford Site Drinking Water Surveillance," and are summarized in Appendix A, Table A.2. Tables A.1 through A.3 list the maximum and mean concentrations of select radionuclides observed in Columbia River water in 1995 and during the previous 5 years. All radiological contaminant concentrations measured in Columbia River water in 1995 were less than DOE Derived Concentration Guides and state of Washington ambient surface water quality criteria levels (Appendix C, Tables C.5 and C.1, 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 1995 at concentrations greater than two times their total propagated analytical uncertainty included tritium, strontium-90, iodine-129, uranium-234, and -238, and plutonium-239,240. The concentrations of all other measured radionuclides were less than two times their respective total propagated analytical uncertainties, and so were essentially not detectable in over 75% of samples collected. Tritium, strontium-90, iodine-129, and plutonium-239,240 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 4.2.3 and 4.2.4 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 1995 average total alpha and total beta concentrations were similar to those observed during recent years. Monthly total alpha and total beta concentrations measured at the Richland Pumphouse in 1995 were not significantly different (paired sample comparison and t-test of differences, 5% significance level) from those measured at Priest Rapids Dam. The average total alpha and beta concentrations in Columbia River water at Priest Rapids Dam and the Richland

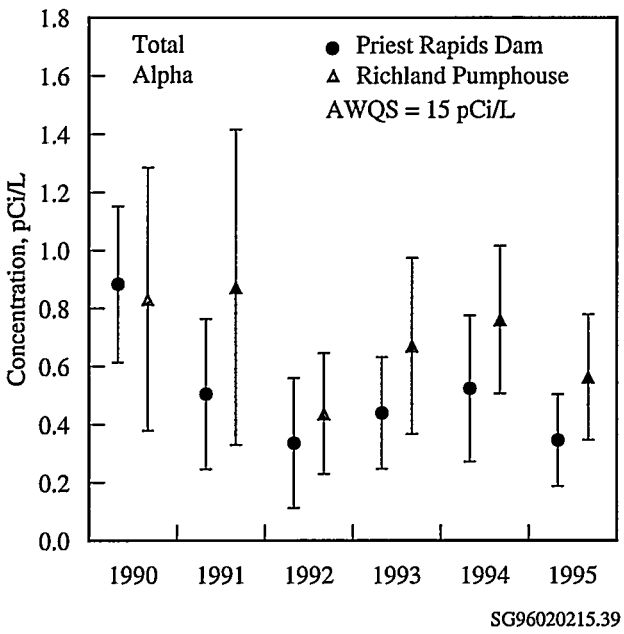

Figure 4.2.3. Annual Average Total Alpha Concentrations (±2 standard error of the mean) in Columbia River Water, 1990 Through 1995

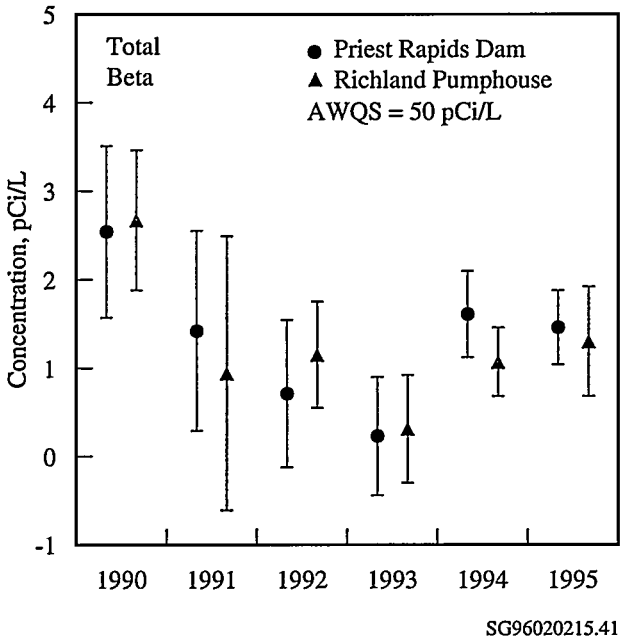

Figure 4.2.4. Annual Average Total Beta Concentrations (±2 standard error of the mean) in Columbia River Water, 1990 Through 1995

Pumphouse in 1995 were less than 5% of their respective Washington State ambient surface water quality criteria levels of 15 and 50 pCi/L.

Figure 4.2.5 compares the average annual tritium concentrations at Priest Rapids Dam and the Richland Pumphouse from 1990 through 1995. The 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 groundwater 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 river water used by the City of Richland for 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

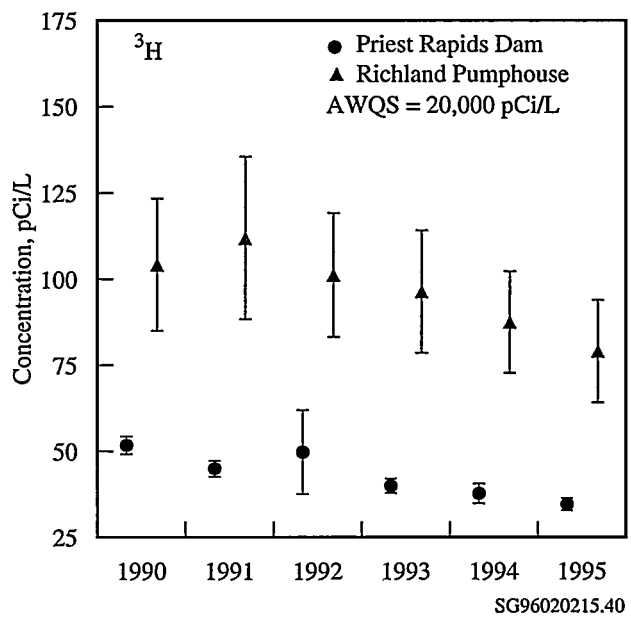

Figure 4.2.5. Annual Average Tritium Concentrations (±2 standard error of the mean) in Columbia River Water, 1990 Through 1995. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

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 1995 confirmed the existence of a concentration gradient in the river under certain flow conditions and is discussed subsequently in this section. 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. Average tritium concentrations in Columbia River water collected from Priest Rapids Dam and the Richland Pumphouse during 1995 were less than 1% of the state of Washington ambient surface water quality criteria level of 20,000 pCi/L.

The average annual strontium-90 concentrations of Columbia River water collected from Priest Rapids Dam and the Richland Pumphouse from 1990 through 1995 are presented in Figure 4.2.6. Concentrations observed in 1995 were similar to those observed previously. Ground-water plumes containing strontium-90 enter the Columbia River throughout the 100 Areas (Dresel et al. 1996). The highest strontium-90 concentrations in ground water onsite have been found in the 100-N Area as a result of past discharges to the 100-N liquid waste disposal facilities. Despite the Hanford source, the differences between monthly strontium-90 concentrations at Priest Rapids Dam and the Richland Pumphouse in 1995 were not significant (paired sample comparison, t-test of differences, 5% significance level). Average strontium-90 concentrations in Columbia River water were approximately 1% of the state of Washington ambient surface water quality criteria level of 8 pCi/L.

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 1990 through 1995 are shown in Figure 4.2.7. The large error associated with 1994 results was attributed to an unusually low concentration found in the December sample of each location. Total uranium concentrations observed in 1995 were similar to those observed during recent years. Monthly total uranium concentrations measured at the Richland Pumphouse in 1995 were significantly higher than those measured at Priest Rapids Dam (paired sample comparison, t-test of differences, 5% significance level). Although there is no direct

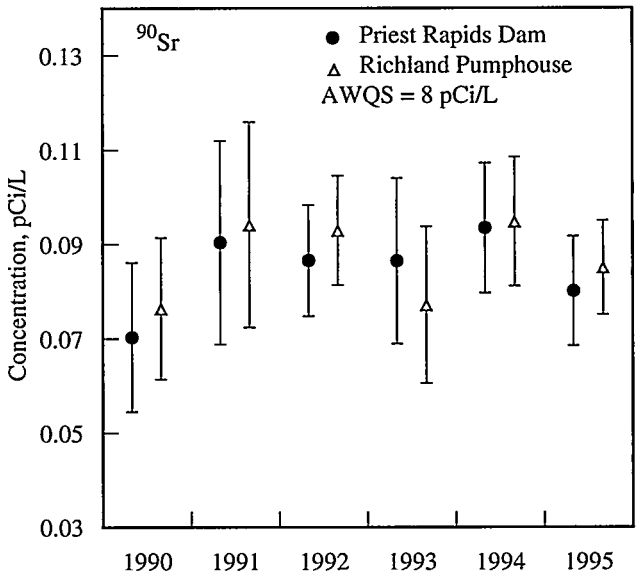

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Figure 4.2.6. Annual Average Strontium-90 Concentrations (±2 standard error of the mean) in Columbia River Water, 1990 Through 1995

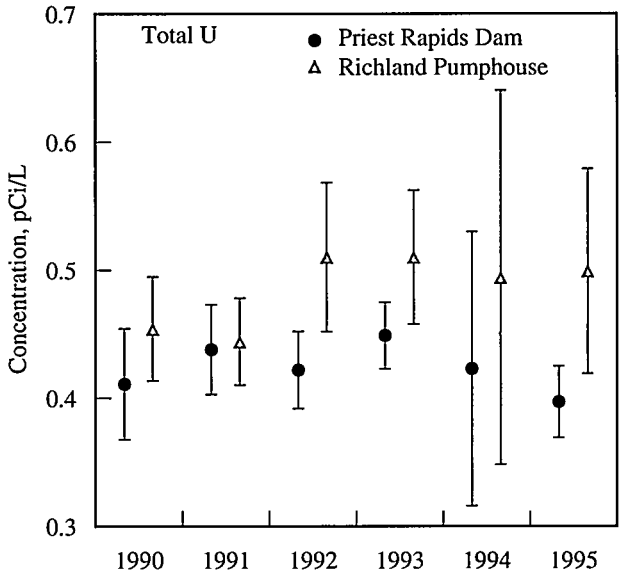

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Figure 4.2.7. Annual Average Total Uranium (Uranium-234 + Uranium-235 + Uranium-238) Concentrations (±2 standard error of the mean) in Columbia River Water, 1990 Through 1995

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 irrigation return water and ground-water seepage associated with extensive irrigation north and east of the Columbia River (Dirkes 1990). There are currently no ambient surface water quality criteria levels directly applicable to uranium. However, total uranium concentrations in the river during 1995 were well below the proposed EPA Drinking Water Standard of 20 µg/L (30 pCi/L).

Figure 4.2.8 presents the average annual iodine-129 concentrations (aCi/L) for Priest Rapids Dam and the Richland Pumphouse for 1990 through 1995. The large error observed at Priest Rapids Dam in 1994 is attributable to an unusually high third quarter result at that location. Only one quarterly iodine-129 result is available for the Richland Pumphouse during 1995 due to construction activities at the pumphouse. That single result is plotted in Figure 4.2.8 with its associated analytical uncertainty. The average concentration of iodine-129

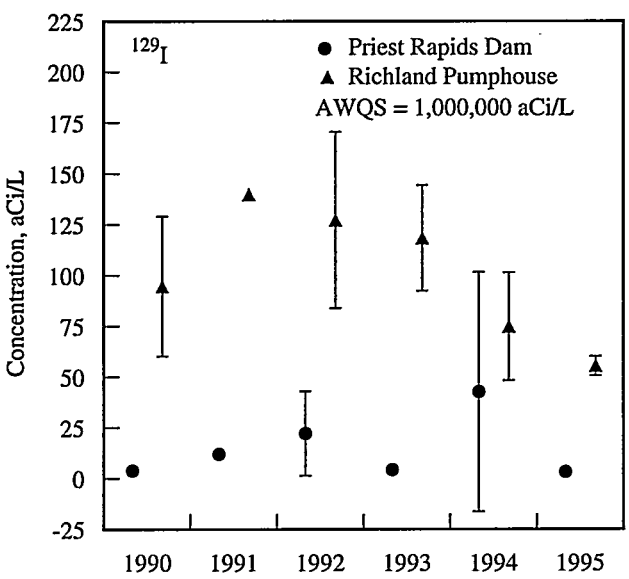

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Figure 4.2.8. Annual Average Iodine-129 Concentrations (±2 standard error of the mean) in Columbia River Water, 1990 Through 1995. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbols.

in Columbia River water was extremely low during 1995 (less than one-tenth of 1% of the Washington State ambient surface water quality criteria level 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 is the discharge of contaminated ground water along the portion of shoreline downstream of the old Hanford Townsite (Section 4.8, "Ground-Water Protection and Monitoring Program"). The iodine-129 plume originated in the 200 Area from past waste disposal practices. Due to the removal of continuous river sampling equipment at the Richland Pumphouse from March through December 1995, there were insufficient data to make a statistical comparison of iodine-129 concentrations in Columbia River water at the Richland Pumphouse and Priest Rapids Dam. With the exception of 1994 results, the quarterly iodine-129 concentrations at the Richland Pumphouse have been significantly higher than those at Priest Rapids Dam (paired sample comparison, t-test of differences, 5% significance level) (Dirkes and Hanf 1995, Dirkes et al. 1994).

During 1995, average plutonium-239,240 concentrations at Priest Rapids Dam and the Richland Pumphouse were 57.4 ± 40.2 aCi/L and 80.4 ± 73.8 aCi/L, respectively. Note that, due to construction activities, only one quarterly sample for plutonium analysis was collected at the Richland Pumphouse in 1995. No ambient surface water quality criteria levels currently exist for plutonium-239 or plutonium-240; however, if the DOE Derived Concentration Guides (Appendix C, Table C.5), which are based on a 100-mrem dose standard, are converted to a 4-mrem dose equivalent used to develop the Drinking Water Standards and ambient surface water quality criteria levels, 1.2 pCi/L (1,200,000 aCi/L) would be the relevant guideline for both plutonium-239 and plutonium-240. Due to the removal of continuous river sampling equipment at the Richland Pumphouse from March through December 1995, there were insufficient data to make a statistical comparison of plutonium-239,240 concentrations in Columbia River water at the Richland Pumphouse and Priest Rapids Dam. Historically, the difference in plutonium-239,240 concentrations at these locations has not been significant (paired sample comparison, t-test of differences, 5% significance level) (Dirkes and Hanf 1995).

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 1995 are presented in Appendix A, Table A.4 and in Bisping (1996).

Constituents that were consistently detected (in greater than 50% of river transect samples) at concentrations greater than two times their associated total propagated analytical uncertainty included tritium, strontium-90, and uranium-234, and -238. All measured radionuclide concentrations were less than applicable ambient surface water quality criteria levels.

Mean tritium concentrations measured along cross sections of the Columbia River during 1995 are depicted in Figure 4.2.9. The reported result is plotted for those transects that were sampled only once in 1995. 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 Benton County and Franklin/Grant Counties shorelines, respectively. The highest mean tritium concentrations observed in 1995 river transect water (Figure 4.2.9) were detected along the shoreline of the old Hanford Townsite where ground water containing tritium concentrations in excess of the ambient surface water quality criteria level of 20,000 pCi/L is known to discharge to the river (Dresel et al. 1996). The highest overall tritium concentration, however, was detected along the shoreline of the Richland Pumphouse in March. Elevated levels of tritium were also evident near the Hanford shoreline at the 100-N Area and 300 Area 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 gradient is most pronounced during periods of relatively low flow. As noted since transect sampling was initiated in 1987, the mean concentration of tritium measured along the cross section established at the Richland Pumphouse was less than that measured in monthly composited samples from the pumphouse, illustrating the conservative bias of the fixed-location monitoring station.

Mean strontium-90 levels in 1995 transect samples were fairly uniform across the width of the river and varied little between transects. Four slightly elevated results (maximum of 0.476 pCi/L) were reported along the Richland Pumphouse transect during 1995. These anomalies occurred sporadically in both time and space; no trends in strontium-90 distribution were noted.

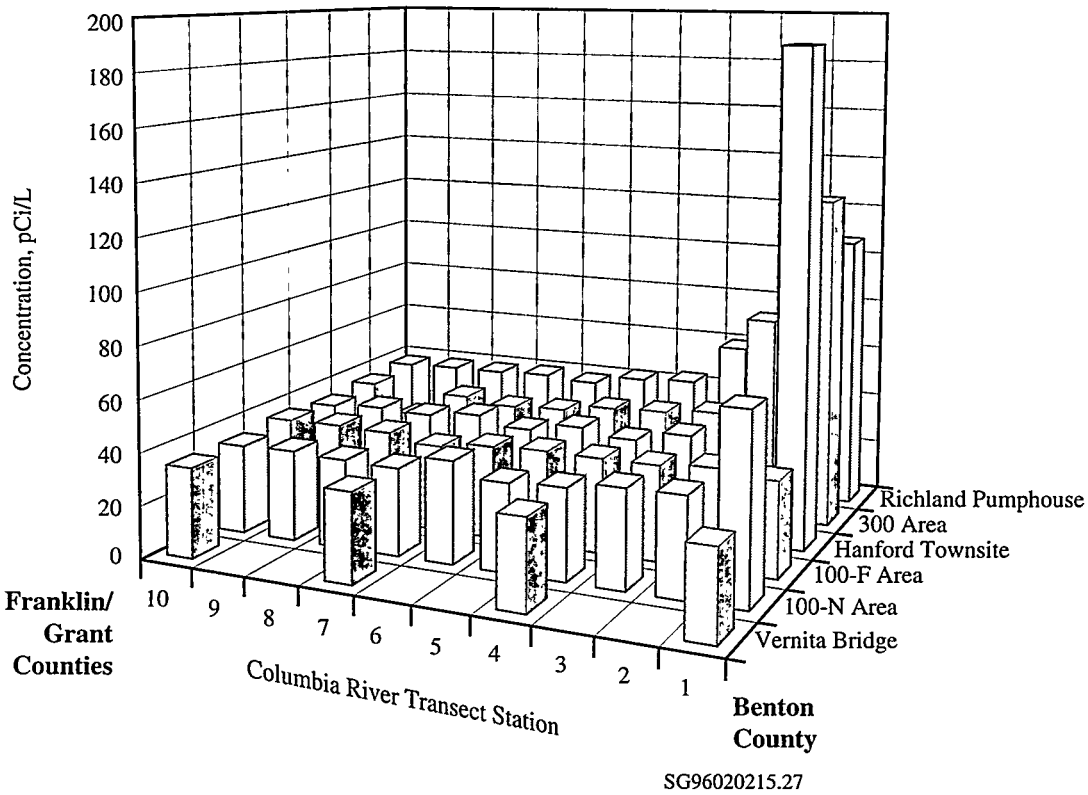

Figure 4.2.9. Mean Tritium Concentrations in Columbia River Transects During 1995

Reanalyses of the samples in question were not possible. The mean concentration of strontium-90 found during cross-sectional sampling at the Richland Pumphouse was similar to that measured in monthly-composited samples from the pumphouse. The similarity indicates that strontium-90 concentrations in water collected from the fixed-location monitoring station are representative of the average strontium-90 concentration of the river at this location.

Total uranium concentrations (i.e., the sum of uranium-234, -235, and -238 concentrations) in 1995 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 Richland Pumphouse transect and likely resulted from ground-water seepage, and irrigation return canals east of the river that contained naturally-occurring uranium (Dirkes 1990). The mean concentration of total uranium across the Richland Pumphouse transect was similar to that measured in monthly-composited samples from the pumphouse.

Nonradiological Results for Columbia River Water Samples

Nonradiological water quality data were compiled by the Pacific Northwest National Laboratory and the U.S. Geological Survey during 1995. A number of the parameters measured have no regulatory limits; however, they are useful as indicators of water quality and/or Hanford-originated 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 (Dirkes 1990).

Figure 4.2.10 shows the preliminary Vernita Bridge and the Richland Pumphouse U.S. Geological Survey results for 1990 through 1995 for several water quality parameters with respect to their 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 preliminary results obtained through the U.S. Geological Survey National Stream Quality Accounting Network program is documented in Bisping (1996) and is summarized in Appendix A, Table A.5. Final results will be published by the U.S. Geological Survey in an annual report entitled "Water Resources Data Washington Water Year 1995" (Wiggins et al. 1996). The 1995 U.S. Geological Survey results were comparable to those reported during the previous 5 years. Applicable standards for a Class A-designated surface-water body were met; however, the minimum detectable concentration of silver exceeded the Washington State acute toxicity standard. During 1995, 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 Pacific Northwest National Laboratory along cross sections of the Columbia River in 1995 at the Vernita Bridge, 100-N Area, 100-F Area, old Hanford Townsite, 300 Area, and the Richland Pumphouse are provided by Bisping (1996). The concentrations of volatile organics, metals, and anions observed in river water in 1995 were similar to those observed in the past. Volatile organic compounds were not routinely detected; those that were detected in greater than 5% of samples collected in 1995 included toluene and trichloroethylene. Neither compound displayed elevated concentrations along the Hanford shoreline of the Columbia River. All volatile organic compound concentrations were less than EPA ambient surface water quality criteria levels.

Several metals and anions were detected both upstream and downstream of the Hanford Site at levels comparable to those reported by the U.S. Geological Survey as part of their ongoing National Stream Quality Accounting Network program. The highest concentrations of most metals were detected during periods of relatively high river flow and were most likely associated with elevated levels of suspended sediment. Copper concentrations were slightly elevated along the Benton County shoreline of the 300 Area transect. Lead and zinc concentrations were elevated along the Benton County shoreline of the Richland Pumphouse transect during relatively low river flow in June. Nitrate concentrations were elevated along the Franklin County shoreline of the old Hanford Townsite, 300 Area, and Richland Pumphouse transects and likely resulted from ground-water seepage associated with extensive irrigation north and east of the Columbia River. Ground-water nitrate contamination associated with high fertilizer and water usage in Franklin County has been documented by the U.S. Geological Survey (1995). Numerous wells in western Franklin County exceed the EPA maximum contaminant level for nitrate. With the exception of nitrate, which had the highest average quarterly concentration at the Richland Pumphouse, no consistent differences were found between

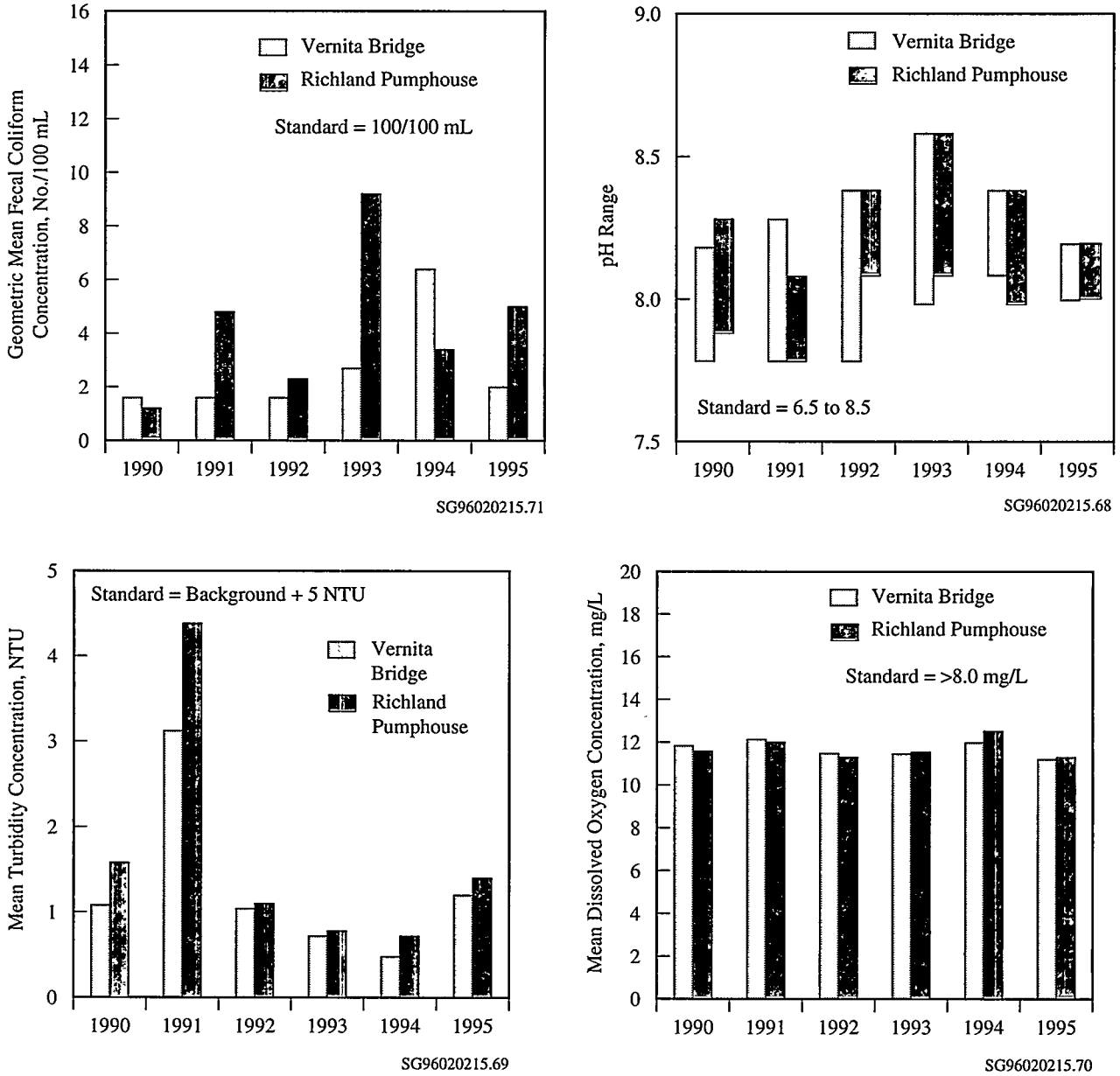

Figure 4.2.10. Preliminary USGS Columbia River Water Quality Measurements, 1990 Through 1995

average quarterly contaminant concentrations in the Vernita Bridge and Richland Pumphouse transect samples.

Washington State ambient surface water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total hardness-dependent (Appendix C, Table C.3). Criteria for Columbia River water were calculated using a total hardness of 51 mg/L as $CaCO_3$, the limiting value based on U.S. Geological Survey monitoring of Columbia River water near Vernita Bridge and the Richland Pumphouse over the past six years. The total hardness concentration reported by the U.S. Geological Survey at those locations from 1990 through 1995 ranged from 51 to 77 mg/L as $CaCO_3$. All metal and anion concentrations in river water were less than Washington State ambient surface water quality criteria levels for acute toxicity. However, chronic toxicity levels for lead were exceeded in all Columbia River transect samples with the exception of those collected along the 300 Area transect. Note that the chronic toxicity criteria for lead are based on a

4-day average concentration not to be exceeded more than once every 3 years; transect samples are grab samples and are therefore not directly comparable to the standard. The minimum detectable concentrations of antimony and arsenic exceeded EPA standards to protect human health for the consumption of water and organisms. The minimum detectable concentrations of cadmium and mercury exceeded chronic toxicity standards; that of silver exceeded the acute toxicity standard. Measures have been taken to ensure that analytical procedures capable of achieving adequate method detection levels for antimony, cadmium, and mercury will be employed on all 1996 Columbia River samples. Silver has not been identified as a Hanford-originated contaminant of concern to the Columbia River (Blanton et al. 1995b, Napier et al. 1995); no steps have been taken to lower its method detection level.

Columbia River Sediments

Sediments in the Columbia River contain low levels of radionuclides and metals of Hanford origin as well as radionuclides from nuclear weapons testing fallout (Beasley et al. 1981, Robertson and Fix 1977, Woodruff et al. 1992, Blanton et al. 1995b). Public exposures are well below the level at which routine surveillance of Columbia River sediments is required (Sula 1980, Wells 1994). However, periodic sampling is necessary to confirm the low levels and to ensure that no significant changes have occurred over time that may increase the potential exposure to the public through this pathway. The accumulation of radioactive materials in sediment can lead to human exposure through ingestion of aquatic species, through sediment resuspension into drinking water supplies, or as an external radiation source irradiating people who are fishing, wading, sunbathing, or participating in other recreational activities associated with the river and/or shoreline (DOE 1991).

As a result of past operations at the Hanford Site, large quantities of radioactive and nonradioactive materials were discharged to the Columbia River. On release to the river, the materials were dispersed rapidly, sorbed onto detritus and inorganic particles, incorporated into aquatic biota, and/or deposited on the riverbed as sediment. Fluctuations in the river flow rate, as a result of the operation of hydroelectric dams, annual spring freshets, and occasional floods, have resulted in the resuspension, relocation, and subsequent redeposition of the contaminated sediments (DOE 1994a).

Since the shutdown of the original single-pass cooling reactors, the contaminant burden in the surface sediments has been decreasing as a result of radioactive decay and the subsequent deposition of uncontaminated material. However, discharges of some pollutants from the Hanford Site to the Columbia River still occur via direct liquid effluent discharges from Hanford facilities (Section 3.1, "Facility Effluent Monitoring"), and via contaminated ground-water seepage (Dirkes 1990, DOE 1992e, McCormack and Carlile 1984, Peterson 1992).

A special study was conducted in 1994 to investigate the difference in sediment grain size composition and total organic carbon content at routine Pacific Northwest National Laboratory monitoring sites (Blanton et al. 1995b). Physicochemical sediment characteristics were found to be highly variable among monitoring sites along the Columbia River. Samples containing the highest percentage of silts, clays, and total organic carbon were collected above McNary Dam and from White Bluffs Slough. All other samples primarily consisted of sand-sized particles. Higher contaminant burdens were generally associated with sediments containing higher total organic carbon and finer grain-size distributions, which is consistent with other sediment investigations (Gibbs 1973, Karickhoff et al. 1978, Lambert 1967, Mudroch 1983, Nelson et al. 1966, Richardson and Epstein 1971, Sinex and Helz 1981, Suzuki et al. 1979, Tada and Suzuki 1982).

Collection and Analysis of Sediment Samples

Samples of Columbia River surface sediments (0-15 cm [0-6 in.]) were collected from six permanently-inundated and five periodically-inundated monitoring sites during 1995 (Figure 4.2.1, Table 4.2.2). Samples were collected upstream of Hanford facilities above Priest Rapids Dam (the nearest upstream impoundment) to provide background data from an area unaffected by Site operations. Samples were collected downstream of Hanford above McNary Dam (the nearest downstream impoundment) to identify any increase in contaminant concentrations. Note that any increases in contaminant concentrations found in sediment above McNary Dam relative to that found above Priest Rapids Dam do not necessarily reflect a Hanford source. The confluences of the Columbia River with the Yakima, Snake, and Walla Walla Rivers lie between the Hanford Site and McNary Dam. Several towns and factories in this area may also contribute to the contaminant load found in McNary Dam sediment.

In addition to sampling from Columbia River impoundments, sediment samples were also collected along the Hanford Reach of the Columbia River from areas in close proximity to contaminant discharges (e.g., riverbank springs), from slackwater areas where fine-grained material is known to deposit (e.g., the White Bluffs Slough, 100-F Slough, and Hanford Slough), and from areas commonly used by the public (e.g., the Richland shoreline).

Monitoring sites located at McNary and Priest Rapids Dams consisted of four stations spaced equidistant along a Columbia River transect. All other monitoring sites consisted of a single sampling location. Samples of permanently-inundated river sediment, herein referred to as river sediment, were collected using a Petite Ponar Grab sampler with a 235-cm^2 opening. Samples of periodically-inundated river sediment, herein referred to as riverbank spring sediment, were collected using a large plastic spoon, immediately following the collection of riverbank spring water samples. Sampling methods are discussed in detail in the *Environmental Monitoring Plan* (DOE 1994a). All sediment samples were analyzed for gamma emitters (see Appendix E), strontium-90, uranium-235, -238, and inductively coupled plasma (method) metals (DOE 1994a). River sediment samples were also analyzed for plutonium-238, plutonium-239,240, and lead. Sample analyses of Columbia River sediments were selected based on findings of previous Columbia River sediment investigations, reviews of past and present effluents discharged from Site facilities, and reviews of contaminant concentrations observed in near-shore groundwater monitoring wells.

Radiological Results for River Sediment Samples

Results of the radiological analyses on river sediment samples collected during 1995 are reported by Bisping (1996) and summarized in Appendix A, Table A.6. Radionuclides consistently detected in river sediment adjacent and downstream of Hanford during 1995 at concentrations greater than two times their total propagated analytical uncertainty included cobalt-60, strontium-90, cesium-137, europium-154, europium-155, uranium-235 and -238, and plutonium-239,240. The concentrations of all other measured radionuclides were less than two times their respective total propagated analytical uncertainties in over 50% of samples collected. Strontium-90 and plutonium-239,240 exist in worldwide fallout, as well as in effluents from Hanford facilities. Uranium occurs naturally in the environment in addition to being present in Hanford effluents. Comparisons of contaminant concentrations between sediment sampling locations are made below. Due to the variation in the bioavailablity of contaminants in various sediments, no state or federal freshwater sediment criteria are currently available to assess the sediment quality of the Columbia River (EPA 1994).

Radionuclide concentrations reported in river sediment in 1995 were similar to those reported previously, with the exceptions of uranium-235 and uranium-238 (Appendix A, Table A.6). Uranium-235 and -238 concentrations were slightly higher at McNary and Priest Rapids Dams in 1995 than in recent years. No appreciable differences in isotopic uranium concentrations were noted between locations. Regional minimum, median, and maximum concentrations of select radionuclides measured in river sediment from 1990 through 1995 are presented in Figure 4.2.11. Regions include the sampling stations at Priest Rapids and McNary Dams as well as the Hanford Reach stations of the White Bluffs Slough, 100-F Area Slough, Hanford Slough, and the Richland Pumphouse. Strontium-90 is the only radionuclide to exhibit consistently higher regional median concentrations at McNary Dam from 1990 through 1995. The regional rank of all other radionuclide concentrations varied from year to year. The regional median concentrations of beryllium-7, strontium-90, and plutonium-239,240 were highest in McNary Dam sediment in 1995. The regional median concentration of cobalt-60 was highest along the Hanford Reach. No other radionuclides measured in 1995 exhibited appreciable differences in concentrations between locations.

Radiological Results for Riverbank Spring Sediment Samples

Riverbank spring sediment sampling was initiated in 1993 at the old Hanford Townsite and 300 Area. The 100-B Area, 100-K Area, and 100-F Area riverbank springs were added in 1995. Sediments at all other riverbank spring sampling locations consisted of predominantly large cobble and were unsuitable for sample collection.

Radiological results for riverbank spring sediment collected in 1995 are presented in Bisping (1996) and are summarized in Appendix A, Table A.6. The highest concentrations of measured radionuclides were generally detected in sediment collected from the old Hanford Townsite riverbank spring. Exceptions include uranium-235

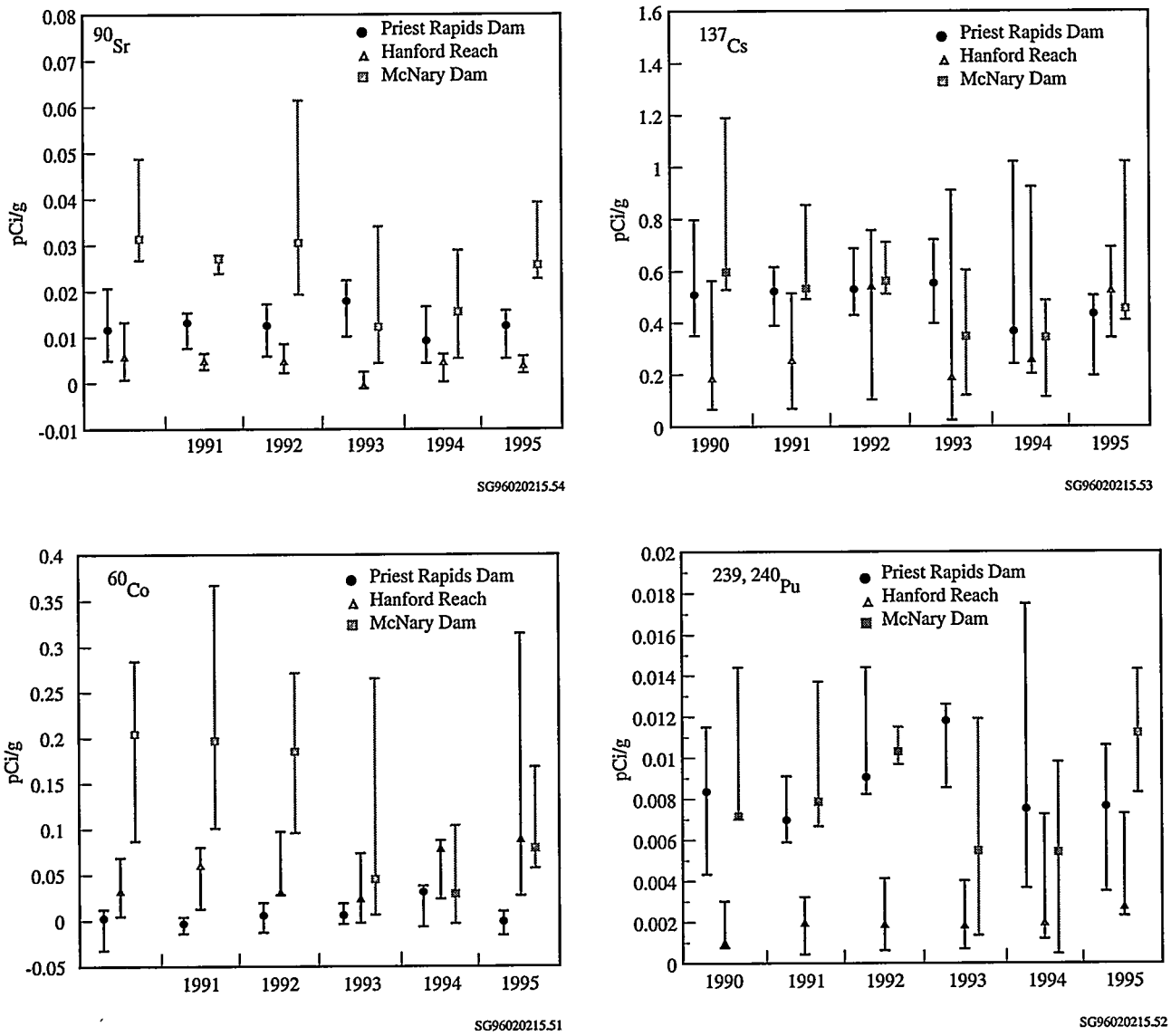

Figure 4.2.11. Minimum, Median, and Maximum Concentrations of Select Radionuclides Measured in Columbia River Sediments, 1990 Through 1995. As a result of figure scale, some minimum and maximum values are concealed by the point symbol.

and uranium-238, which were highest in sediment collected from the 300 Area riverbank spring, and europium-155, which was highest in sediment collected from the 100-K Area riverbank spring. The ranking of radionuclide concentrations in riverbank spring sediment in 1995 was generally consistent with that of riverbank spring water. Results for riverbank spring sediment collected from the old Hanford Townsite and 300 Area in 1995 were similar to those observed previously.

Radionuclide concentrations in riverbank spring sediment were similar to those observed in river sediment in 1995 with the exception of uranium, which was much higher in 300 Area riverbank spring sediment than elsewhere in the river. Elevated uranium concentrations exist 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 (Dresel et al. 1996).

Nonradiological Results for Columbia River Sediment Samples

Metal concentrations observed in Columbia River sediment in 1995 are reported by Bisping (1996) and are summarized in Appendix A, Table A.7. Levels of all measured metals were detected in all Columbia River sediment samples with the exceptions of silver, detected only in McNary Dam sediment, and antimony, detected mainly in riverbank spring sediment. Regional median concentrations of most metals were highest in McNary Dam sediments (Figure 4.2.12). The highest median concentration of chromium, however, was found in riverbank spring sediment; maximum concentrations of chromium occurred in the 100-K Area, 100-B Area, and 100-F Area riverbank springs. Maximum concentrations of antimony, calcium, cobalt, copper, iron, magnesium, manganese, nickel, sodium, tin, vanadium, and zinc were found in either Hanford Slough river sediment or old Hanford Townsite riverbank spring sediment.

Riverbank Springs Water

The Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site (Dresel et al. 1996). 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 (Dirkes 1990, DOE 1992e, McCormack and Carlile 1984, Peterson 1992).

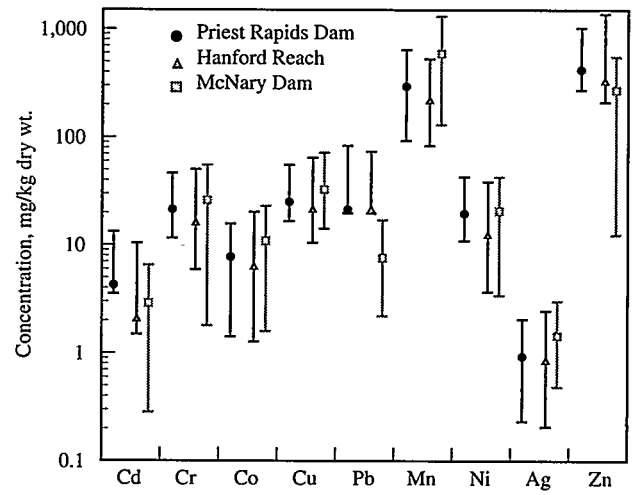

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Figure 4.2.12. Minimum, Median, and Maximum Concentrations of Select Metals Measured in Columbia River Sediments, 1995

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.

The seepage of ground water into the Columbia River has been known to occur for many years. Riverbank springs were documented along the Hanford Reach long before Hanford operations began during World War II (Jenkins 1922). McCormack and Carlisle (1984) walked the 41-mile stretch of shoreline of the Hanford Reach of the Columbia River in 1983 and identified 115 springs. They reported that the predominant areas of ground-water discharge at that time were in the vicinity of the 100-N Area, the old Hanford Townsite, and the 300 Area. The predominance of the 100-N Area may no longer be valid due to declining water-table elevations in response to the decrease in liquid-waste discharges from Hanford operations to the ground. In recent years, it has become increasingly difficult to locate springs in the 100-N Area.

The presence of springs varies with river stage. Dresel et al. (1996) reported that ground-water levels in the 100 and 300 Areas are heavily influenced by river-stage fluctuations. Water levels in the Columbia River fluctuate greatly on annual and even daily cycles and are controlled by the operation of Priest Rapids Dam, upstream

of the Site. Water flows into the aquifer (as bank storage) as the river stage rises, and flows in the opposite direction as the river stage falls. Following an extended period of low river discharge, ground-water discharge zones located above the water level of the river may cease to exist once the level of the ground water comes into equilibrium with the level of the river. Thus, springs are most readily identified immediately following a decline in river stage. Bank storage of river water also effects the contaminant concentration of the springs. When the river stage is high, river water flowing into the aquifer overlays and/or mixes with ground water. Spring discharge immediately following a river stage decline generally consists of river water or a river-ground-water mix. The percent contribution of ground water to spring discharge is believed to increase over time.

Due to the effect of bank storage on ground-water discharge and contaminant concentration, it is difficult to estimate the volume of radiologically and chemically contaminated ground water discharged to the Columbia River within the Hanford Reach. An unpublished estimate of total ground-water discharge from the upstream end of the 100 Areas to south of the 300 Area is approximately 66,500 m^3/day (2,350,000 ft^3/day).[(a)] This amount is 0.02% of the long-term average annual flow rate of the Columbia River, which illustrates the tremendous dilution potential offered by the river. Note that not all of the ground water discharged to the river contains contaminants originating from Hanford Site operations. Riverbank spring studies conducted in 1983 (McCormack and Carlisle 1984) and in 1988 (Dirkes 1990) noted that spring discharges had a localized effect on river contaminant concentrations. But both studies reported that the volume of ground water entering the river at these locations was very small relative to the flow of the Columbia River and that the impact of ground-water discharges to the river was minimal.

Collection and Analysis of Riverbank Spring Water Samples

Routine monitoring of select riverbank springs was initiated in 1988 at the 100-N Area, old Hanford Townsite, and 300 Area. The monitoring plan was expanded in 1993 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 1995 are identified in Figure 4.2.1. Sample collection methods are described in the *Environmental Monitoring Plan* (DOE 1994a).

Sampling is conducted once or twice annually during low river flow (August through September). The specific conductivities of samples collected from 100-N and 100-D Area springs in August 1995 were similar to that of the Columbia River water. This indicated that the samples were primarily composed of bank storage river water. This conclusion is supported by the unusually low contaminant concentrations observed in the samples (see subsequent discussion). A second riverbank spring sample from 100-D Area was collected in September. Further attempts to locate and sample a 100-N Area spring were unsuccessful.

Sample analyses of Columbia Riverbank springs water are selected based on findings of previous riverbank springs investigations, reviews of contaminant concentrations observed in nearby ground-water monitoring wells, and results of preliminary risk assessments. At a minimum, riverbank springs samples collected during 1995 were analyzed for gamma-emitting radionuclides, strontium-90, technetium-99, total alpha, total beta, tritium, and 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 Water

Hanford-origin contaminants continued to be detected in riverbank spring water entering the Columbia River along the Hanford Site during 1995. The locations and extent of contaminated discharges were consistent with recent ground-water surveys. Tritium, strontium-90, technetium-99, uranium-234, -235, and -238, cadmium, chloroform, chromium, copper, nitrate, trichloroethylene (TCE), and zinc were found to be entering the river along the 100 Area shoreline. Tritium, technetium-99, iodine-129, uranium-234, -235, and -238, chromium, nitrate, and zinc entered the river along the portion of shoreline extending from the old Hanford Townsite to below the 300 Area. Strontium-90 was discharged to

(a) Stuart Luttrell, Ground-Water Surveillance Project Manager, Pacific Northwest National Laboratory, Richland, Washington, January 1995.

the river along the 300 Area shoreline in addition to the other contaminants. The contaminant concentrations in spring water are typically lower than those found in near-shore ground-water wells due to bank storage effects.

The results of radiological and chemical analyses conducted on riverbank springs samples in 1995 are documented by Bisping (1996). Radiological results reported in 1995 are summarized in Appendix A, Table A.8, and compared to those reported in 1990 through 1994. 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 for Riverbank Springs Water Samples

All radiological contaminant concentrations measured in riverbank springs in 1995 were less than DOE Derived Concentration Guides (Appendix C, Table C.5). However, strontium-90 in the 100-H Area and tritium in the 100-B Area and along the old Hanford Townsite exceeded the Washington State ambient surface water quality criteria levels (Appendix C, Table C.1). There are currently no ambient surface water quality criteria levels directly applicable to uranium. However, total uranium (i.e., the sum of uranium-234, -235, and -238 concentrations) exceeded the Site-specific proposed EPA Drinking Water Standard in the 300 Area (Appendix C, Table C.2). All other radionuclide concentrations were less than ambient surface water quality criteria levels. The range of concentrations of select radionuclides measured in riverbank spring water from 1990 through 1995 is presented in Table 4.2.3.

Tritium concentrations vary widely with location. The highest concentrations are normally detected in the old Hanford Townsite riverbank spring, followed by the 100-B and 100-K Area springs. In 1995, however, the highest concentration of tritium was found in the 100-B Area spring. The tritium concentration of the old Hanford Townsite spring was lower than normally observed, probably as a result of bank storage (see subsequent discussion). The tritium concentration in the 100-B Area spring was slightly higher than the concentration previously found and was higher than that recently reported in 100-B Area ground water (Dresel et al. 1996).

Technetium-99 was detected in the 100-B, 100-N, 100-H, old Hanford Townsite, and 300 Area springs in 1995. The highest concentrations were found in the 100-H Area, which is consistent with past results and with recent ground-water reports. Uranium was found in all riverbank spring samples in 1995 but the highest total uranium and total alpha concentrations were found in the 300 Area spring, downgradient from the 316-5 Process Trenches. Iodine-129 was detected in the old Hanford Townsite and 300 Area riverbank springs; the highest concentrations were found in the vicinity of the old Hanford Townsite.

Strontium-90 was detected in the 100-D, 100-H, and 300 Area springs in 1995; the highest levels were found in the 100-H Area. Beta activity paralleled that of strontium-90. Results are consistent with those in 1993 and 1994. Before 1993, however, the highest levels of strontium-90 and total beta were found in the 100-N Area. These high concentrations were measured in samples collected from near-shore ground-water wells and not from riverbank springs.

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 Pacific Northwest National Laboratory in 1990 and 1991. In 1992, the Pacific Northwest National Laboratory sample was collected from well 199-N-46 (cassion), which is located slightly inland from well 199-N-8T. In 1993, 1994, and 1995, Pacific Northwest National Laboratory 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 sampling protocol at other riverbank spring locations and avoids duplicating efforts of the Westinghouse Hanford Company's Near-Facility Environmental Monitoring Program.

In 1993, 1994, and 1995, there was no visible shoreline seepage present directly adjacent to well 199-N-8T during sampling. The 100-N Area spring samples were instead collected from the nearest visible downstream riverbank spring. As a result of the relative proximity of the riverbank springs and monitoring wells to the contaminant plumes emanating from the 100-N Area, and as a result of bank-storage effects, some contaminant concentrations measured in the spring water were distinctly different from those previously measured in either of the two wells (Table 4.2.4). The concentrations of strontium-90 and total beta were much lower in riverbank spring water than in near-shore ground water. Tritium concentrations in riverbank spring water were similar to those found in well 199-N-8T and slightly higher than those found in

Table 4.2.3. Range of Radiological Data for Columbia Riverbank Springs, 1990-1995

	Ambient Surface Water Quality Criteria Level (pCi/L)	Concentration, pCi/L							
		100-B Area	100-K Area	100-N Area	100-D Area	100-H Area	100-F Area	Hanford Townsite	300 Area
No. of Samples		5	3	6	5	5	2	7	7
Total alpha	15[a]	1.14 - 3.54	ND - 1.63	ND	0.93 - 2.90	3.29 - 4.59	2.61 - 3.73	ND - 4.88	12.7 - 110
Total beta	50	7.69 - 38.1	1.84 - 3.60	ND - 24,100	2.14 - 20.8	39.4 - 69.1	1.74 - 2.04	ND - 33.2	3.31 - 29.3
Tritium	20,000	11,000 - 22,500	17,800 - 19,700	4,870 - 30,900	ND - 12,500	691 - 1,190	623 - 1,620	6,340 - 173,000	1,260 - 11,600
^{90}Sr	8	ND[b]	ND	ND - 10,900	ND - 9.41	12.4 - 25.2	ND - 0.0986	ND (5)	ND - 0.198 (5)
^{99}Tc	900	8.40 - 25.3	ND - 0.805	ND - 2.44	ND	43.7 - 136	ND (1)[c]	2.04 - 131	ND - 13.5 (6)
^{129}I	1							ND - 0.224 (3)	0.00187 - 0.00439 (2)
Total uranium		1.57 - 3.16	1.27 - 2.28	0.239 - 2.47	0.283 - 1.92	5.22 - 8.35	3.37 - 4.62	2.32 - 4.29 (5)	24.2 - 129

(a) Ambient surface water quality criteria level for total alpha excludes uranium.
(b) ND indicates result was less than 2 total propagated analytical uncertainty.
(c) Number in parentheses indicates number of samples used to calculate the range, if different from above.

Table 4.2.4. Selected Radionuclide Concentrations in 100-N Riverbank Spring Water During the Years 1990 Through 1995

Year	Concentration, pCi/L[a]		
	^{3}H	Total beta	^{90}Sr
1990[b]	38,500 ± 2,950	8,520 ± 603	3,990 ± 734
1991[b]	11,300 ± 1,040	7,140 ± 574	5,110 ± 1,000
1992[c]	4,870 ± 501	24,100 ± 1,730	10,900 ± 2,020
1993[d]			
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[d]	30,900 ± 2,380	8.79 ± 2.26	0.129 ± 0.107
1995[d]	12,000 ± 969	1.48 ± 1.49	0.079 ± 0.104

(a) Concentrations are ±2 total propagated analytical uncertainty.
(b) Samples collected from well 199-N-8T (see Figure 3.2.4).
(c) Sample collected from well 199-N-46 (see Figure 3.2.4).
(d) Sample collected from shoreline spring downstream of well 199-N-8T.

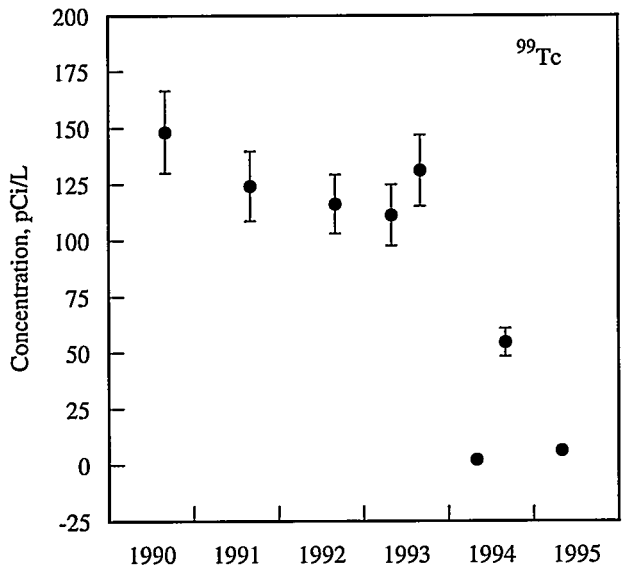
well 199-N-46. Tritium, technetium-99, and total uranium were the only measured contaminants with concentrations that were greater than two times their total propagated analytical uncertainty in 1995 (Table 4.2.3). The tritium and technetium-99 concentrations were 60% and 0.1% of the ambient surface water quality criteria levels, respectively. The total uranium concentration was 2% of the Site-specific proposed EPA Drinking Water Standard.

Concentrations of selected radionuclides in riverbank springs near the old Hanford Townsite for 1990 through 1995 are provided in Figure 4.2.13. Total beta and technetium-99 concentrations in 1995 were similar to those observed in 1994 and slightly lower than those observed previously. The tritium concentration was lower than normal but similar to that observed in one sample collected in 1994. The lower contaminant concentrations in 1994 and 1995 may result from dilution of ground-water discharge by river water that entered the riverbank during higher flows. The specific conductivities of those samples that exhibited unusually low contaminant concentrations were between those normally found in river water and those found previously in the old Hanford Townsite riverbank spring water. With the exception of total uranium, all other measured contaminant concentrations in 1995 were rarely greater than two times their associated total propagated analytical uncertainty. Total uranium concentrations were less than 17% of the Site-specific proposed EPA Drinking Water Standard. The iodine-129 concentration measured in the old Hanford Townsite riverbank spring (0.0638 ± 0.0057 pCi/L) was 6% of the ambient surface water quality standard.

Figure 4.2.14 depicts the concentrations of selected radionuclides in the 300 Area riverbank spring from 1990 through 1995. Results in 1995 were similar to those observed previously. Elevated contaminant concentrations during 1992 are believed to have resulted from coordinated efforts with Priest Rapids Dam to control the water level of the river during the 1992 riverbank spring sampling activities. Maintaining a low river water level during sampling in 1992 maximized the contribution of ground water in the springs, and minimized the bank storage effect, to provide samples that reflected limiting water quality conditions. The elevated tritium concentrations measured in the 300 Area riverbank spring during the past 5 years reflects the expansion of the contaminated ground-water plume emanating from the 200 Areas (Dresel et al. 1996). Technetium-99 and iodine-129 are also contained in the 200 Area contaminated ground-water plume. Tritium, technetium-99, and iodine-129 concentrations in 300 Area riverbank spring water in 1995 were 58%, 2%, and 0.5% of their respective ambient surface water quality criteria levels. The highest total uranium concentrations in riverbank sping water from 1990 through 1995 were found in the 300 Area riverbank springs. Elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area in the vicinity of uranium fuel fabrication facilities and inactive waste sites. Total alpha and total beta concentrations in the 300 Area riverbank spring water from 1990 through 1995 parallel that of uranium and are likely associated with its presence. With the exception of strontium-90, the concentrations of all other measured contaminants in the 300 Area spring in 1995 were generally less than two times their associated total propagated analytical uncertainty. The concentration of strontium-90 was 3% of the ambient surface water quality criteria level. Potential sources of strontium-90 in 300 Area ground water are the research reactor and research buildings. Low levels of strontium-90 have been detected in 300 Area ground water (Dresel et al. 1996).

Nonradiological Results for Riverbank Springs Water Samples

The range of concentrations of selected chemical compounds measured in riverbank spring water in 1993



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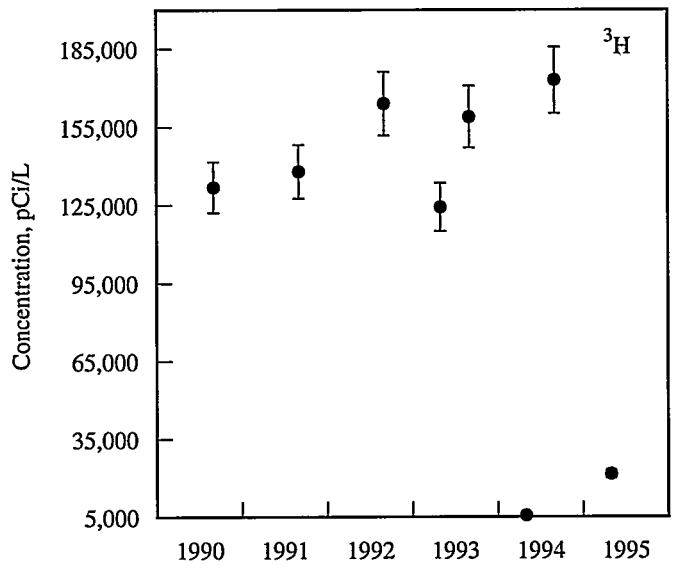

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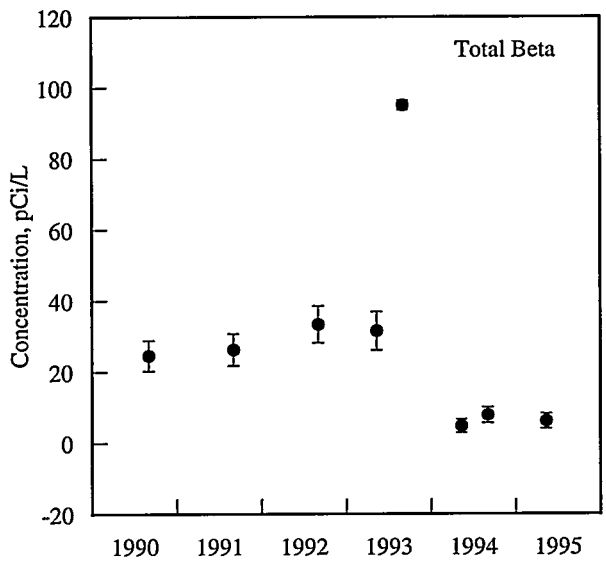

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Figure 4.2.13. Concentrations (±2 total propagated analytical uncertainty) of Constituents of Interest in the Riverbank Spring Near the Old Hanford Townsite, 1990 Through 1995. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

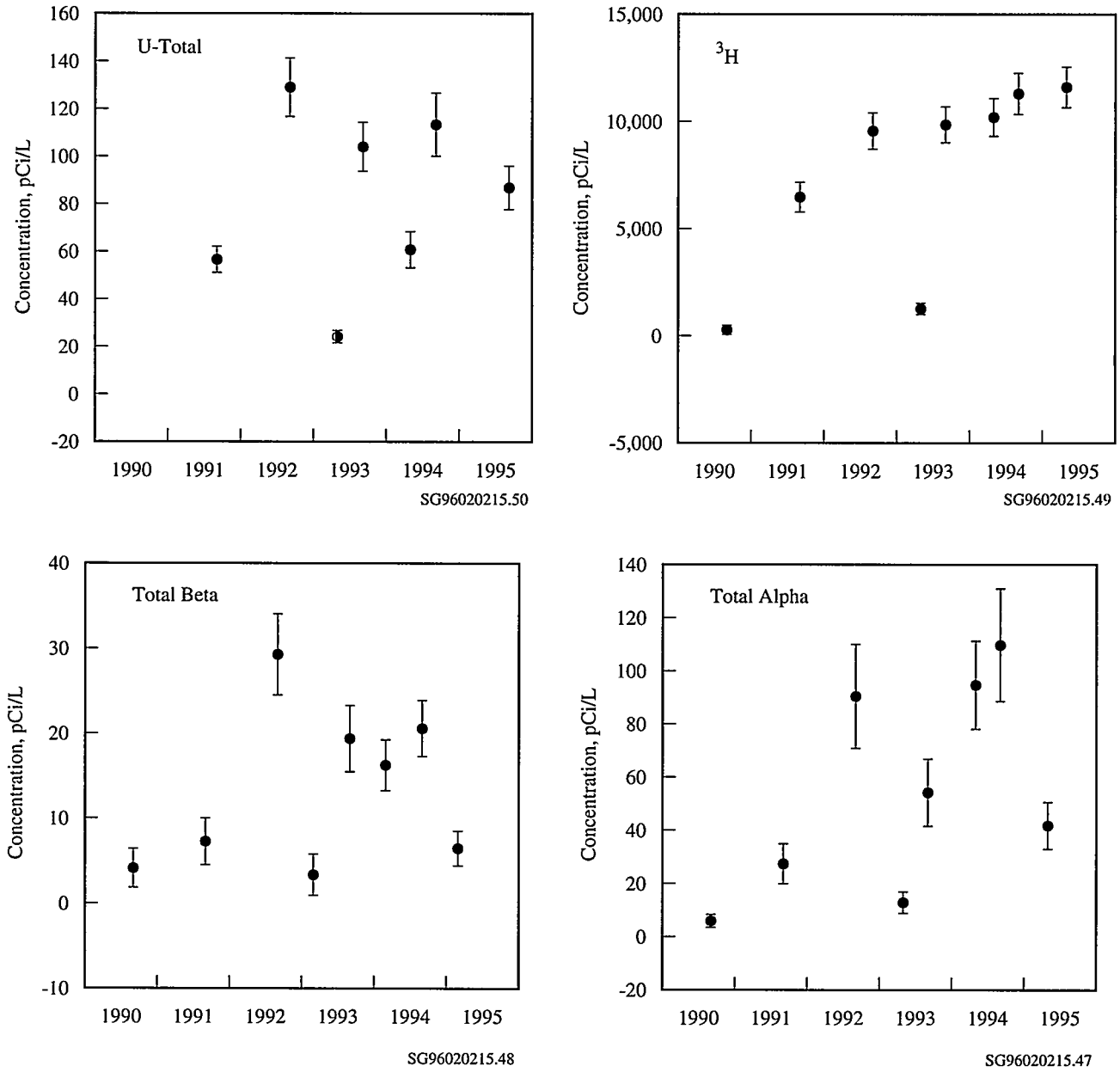


Figure 4.2.14. Concentrations (±2 total propagated analytical uncertainty) of Constituents of Interest in the 300 Area Riverbank Spring, 1990 Through 1995. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

Table 4.2.5. Concentration Ranges of Select Nonradiological Compounds in Columbia Riverbank Springs, 1993-1995

	Ambient Surface Water Quality Criteria Level (µg/L)	Concentration, µg/L							
		100-B Area	100-K Area	100-N Area	100-D Area	100-H Area	100-F Area	Hanford Townsite	300 Area
No. of Samples		3	1	2	4	3	2	3	2
Metals									
Aluminum		34-610	4,800	ND[a]-9,400	66-180	27-88	41-1,700	67-750	140-960
Barium		55-59	120	32-140	34-80	27-48	41-58	43-54	95-96
Cadmium	[b]	ND	2	ND	ND	ND	ND-1.1	ND	ND
Chromium	[b]	21-25	66	ND-45	ND-400	18-55	6-37	ND	ND-4.4
Copper	[b]	ND	37	ND-30	ND-6.4	ND-4.7	ND-3.9	ND-5.4	ND-3.5
Iron		25-860	9,300	60-12,000	93-250	52-180	18-2,500	100-1,200	190-1,200
Manganese		1.9-22	330	3.2-680	6.6-13	7.6-11	3.1-39	7.1-82	5.8-30
Nickel	[b]	ND	ND	ND-25	ND-26	ND	ND-20	ND-22	ND
Vanadium		ND-11	33	6.6-42	ND-5.3	ND-3.6	ND-9.3	ND-19	ND-4
Zinc	[b]	ND-45	410	3.8-460	7.3-11	7-15	7.3-62	5.4-32	9.6-30
Anions									
Nitrate		7,600-7,900	15,000	3,800-15,000	1,000-46,000	27,000-47,000	20,000-30,000	5,000-40,000	22,000-23,000
Volatile Organics									
Chloroform	5.7	ND-0.44 (4)[c]	ND-0.79 (3)	0.75-3 (4)	ND-4.1 (5)	3.7-14 (4)	ND	ND (4)	ND
Methylene chloride	4.7	ND-0.49 (7)	ND (5)	ND-1.3 (7)	ND-1.2 (8)	ND-1.2 (7)	ND-1.2 (3)	ND-0.52 (7)	ND (3)
Tetrachloroethylene	0.8	ND (4)	ND (3)	ND-1.4 (4)	ND (5)	ND (4)	ND	ND (4)	ND
Trichloroethylene	2.7	0.53-1.0 (4)	7.4-9.5 (3)	ND (4)	ND (5)	ND (4)	ND	ND (4)	ND

(a) ND indicates result was less than the minimum detection level.
(b) Ambient surface water quality criteria level is hardness-dependent (see Appendix C, Table C.3).
(c) Number in parentheses indicates number of samples used to calculate the range, if different from above.

through 1995 are presented in Table 4.2.5. The low concentrations of all compounds reported in the 100-N and 100-D Area springs were measured in August 1995 samples collected from those locations and are more representative of Columbia River water than of local ground water conditions. With the exceptions of August 1995 sample results for 100-N and 100-D Area springs, riverbank spring nonradiological results in 1995 were similar to those reported previously. Metal concentrations are typically highest in the 100-K and 100-N Area springs with the exception of the chromium concentration, which is highest in the 100-D Area spring. Nitrate concentrations are highest in the 100-D, 100-H, and old Hanford Townsite Area springs. Trichloroethylene is highest in the 100-K Area spring. Hanford ground-water monitoring results for 1995 indicate similar relationships between nonradiological contaminant concentrations in shoreline areas (Dresel et al. 1996).

Washington State ambient surface water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total hardness-dependent (Appendix C, Table C.3). Criteria for Columbia Riverbank spring water were calculated assuming the total hardness was attributable only to calcium and magnesium. Other multivalent cations typically comprise a small fraction of total hardness. Considering only calcium and magnesium in the caluculations provided the most limiting surface water quality criteria.

With the exception of trichloroethylene, the concentrations of all anion and volatile organic compounds measured in riverbank spring water collected from the Hanford shoreline in 1995 were below Washington State ambient surface water quality criteria levels. The concentration of trichloroethylene exceeded the EPA standard to protect human health for the consumption of water and organisms in the 100-K Area riverbank spring. Riverbank spring sampling protocol does not lend itself to a direct comparison of most metal concentrations measured in riverbank springs to ambient surface water acute and chronic toxicity levels. The standards are, instead, used as a point of reference. The ambient surface water acute and chronic toxicity levels of arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc are 1-hour and 4-day average concentrations, respectively, not to be exceeded more than once every 3 years on the average (Washington Administrative Code 173-201A-040). Riverbank spring samples are grab samples. Metal concentrations measured in riverbank springs located on the Hanford shoreline in 1995 were below Washington State ambient surface water acute toxicity levels, with the exceptions of copper and zinc in the 100-K Area spring. The chronic toxicity level of cadmium was also exceeded in the 100-K Area spring. The minimum detectable concentration of antimony exceeded EPA standards to protect human health for the consumption of water and organisms in all springs. The minimum detectable concentrations of cadmium and silver exceeded their chronic and acute toxicity standards, respectively, in the August 1995 samples collected from 100-N and 100-D Area springs.

Onsite Pond Water

Three onsite ponds (see Figure 4.2.1) located near operational areas were sampled periodically during 1995. 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. The Fast Flux Test Facility 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. West Lake, the only naturally occurring pond onsite, is located north of the 200-East Area (Gephardt et al. 1976). West Lake has not received direct effluent discharges from Site facilities; rather, its existence is caused by the intersection of the elevated water table with the land surface in the topographically low area south of Gable Mountain (and north of the 200-East Area). The artificially elevated water table occurs under much of the Hanford Site and reflects the artificial recharge from Hanford Site operations.

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 1995, they were accessible to migratory waterfowl, creating a potential biological pathway for the dispersion of contaminants (see Section 4.5, "Wildlife Surveillance"). Periodic sampling of the ponds also provided an independent check on effluent control and monitoring systems.

Collection and Analysis of Pond Water Samples

In 1995, grab samples were collected quarterly from B Pond, the Fast Flux Test Facility 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, and 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.

Radiological Results for Onsite Pond Water Samples

Analytical results from pond samples collected during 1995 are listed by Bisping (1996). With the exceptions of uranium-234 and -238 in the October sample of West Lake, radionuclide concentrations in onsite pond water were less than DOE Derived Concentration Guides (Appendix C, Table C.5). Average annual total beta concentrations exceeded the ambient surface water quality criteria level in West Lake. The average concentration of all other radionuclides was less than ambient surface water quality criteria levels (Appendix C, Table C.1).

Annual concentrations of selected radionuclides in B Pond for the years 1990 through 1995 are shown in Figure 4.2.15. B Pond comprises a series of four ponds: 216-B-3, -3A, -3B, and -3C (Figure 4.8.11). Before October 1994, B Pond samples were collected from 216-B-3. However, 216-B-3 and -3A Ponds were decommissioned in 1994, and 216-B-3B Pond was never active, although it did receive an accidental discharge one time. B Pond samples are currently collected from 216-B-3C. Contaminant concentrations found in samples collected from 216-B-3C Pond in 1995 are similar to those found previously in 216-B-3 Pond. Average total alpha, total beta, tritium, strontium-90, and cesium-137 concentrations in 1995 were 2%, 4%, 0.5%, 1%, and 1% of ambient surface water quality criteria levels, respectively. All other measured radionuclides were detected at concentrations greater than two times their total propagated analytical uncertainty in less than 25% of samples collected.

Figure 4.2.16 shows the annual total beta and tritium concentrations in Fast Flux Test Facility Pond from 1990 through 1995. Median concentrations of both constituents have remained stable in recent years. However, the tritium concentration in the July sample was 16,400 pCi/L, which is much higher than that observed previously. June and July samples of Fast Flux Test Facility drinking water also contained unusually high levels of tritium, comparable to those found in Fast Flux Test Facility Pond (see Section 4.3, "Hanford Site Drinking Water Surveillance"). During this time, backup water supply well 499-S0-7 was in use. Tritium levels in well 499-S0-7 are typically above 20,000 pCi/L, reflective of those observed in the local unconfined aquifer. The use of backup water supply well 499-S0-7 is most likely responsible for the high levels of tritium observed in Fast Flux Test Facility Pond in July as the primary source of water to Fast Flux Test Facility Pond is 400 Area sanitary water. Average total beta and tritium concentrations in Fast Flux Test Facility Pond water during 1995 were 28% and 42% of their respective ambient surface water quality criteria levels. The concentrations of all other measured contaminants in Fast Flux Test Facility Pond water were greater than two times their respective total propagated analytical uncertainties in less than 25% of samples collected.

The annual concentrations of selected radionuclides from 1990 through 1995 in West Lake are shown in Figure 4.2.17. Note that the peak total uranium concentration reported in 1995 (2,662 pCi/L) was calculated by summing uranium-234 and -238 concentrations only. The concentration of uranium-235 in this sample was not reported by the lab. Radionuclide concentrations in West Lake during 1995 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. Declines in ground-water levels in the 200 Areas have been recorded since the decommissioning of U Pond in 1984 and the shutdown of production facilities (Dresel et al. 1995). As a result, the water level in West Lake has dropped. 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. Average concentrations of tritium, strontium-90, and technetium-99 in West Lake in 1995 were 1%, 5%, and 2%, respectively, of ambient surface water quality criteria levels and were

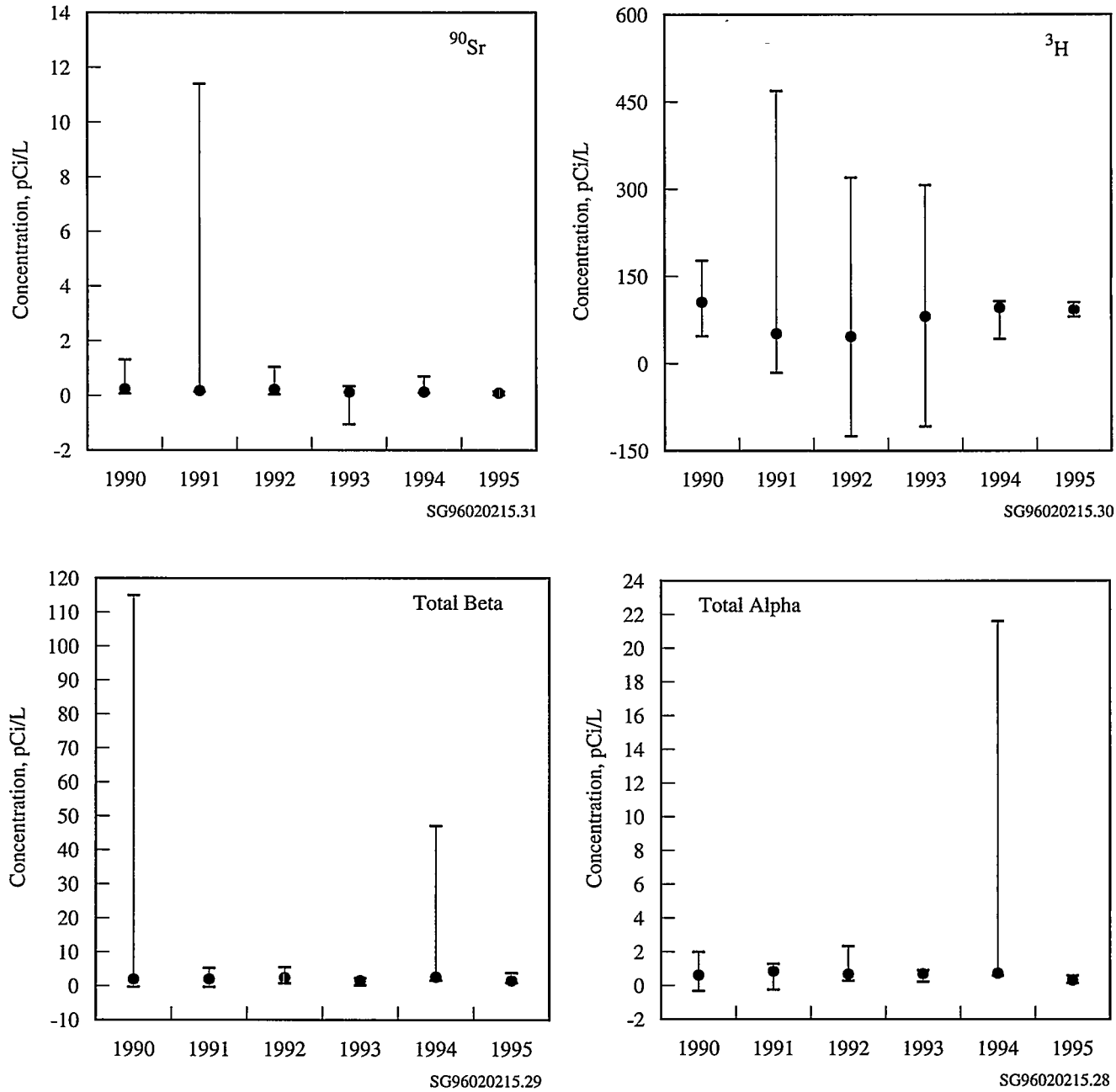
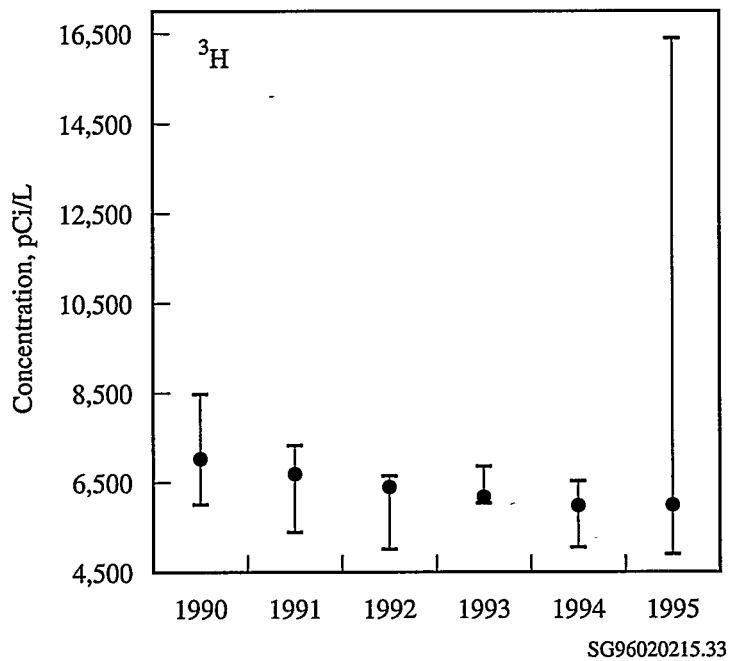


Figure 4.2.15. Minimum, Median, and Maximum Concentrations of Select Radionuclides in B Pond, 1990 Through 1995. As a result of figure scale, some maximum and minimum values are concealed by the point symbol.



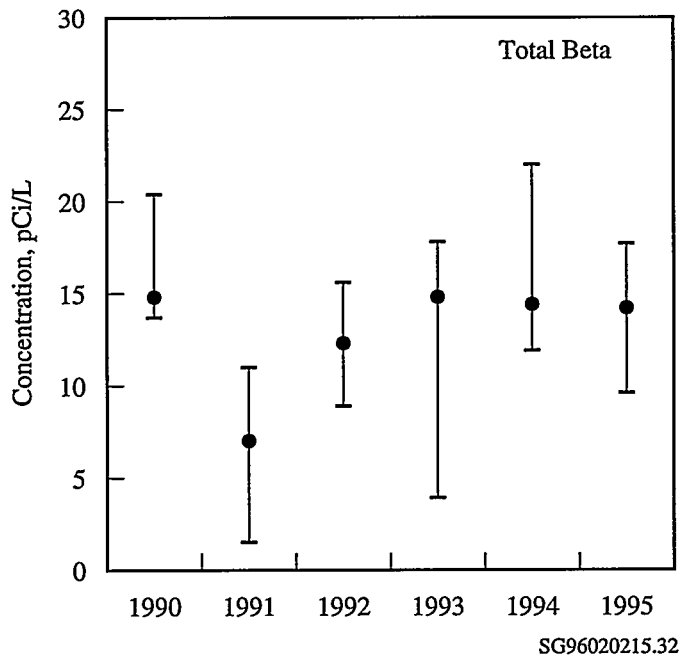


Figure 4.2.16. Minimum, Median, and Maximum Total Beta and Tritium Concentrations in the Fast Flux Test Facility Pond, 1990 Through 1995. As a result of figure scale, some maximum and minimum values are concealed by the point symbol.

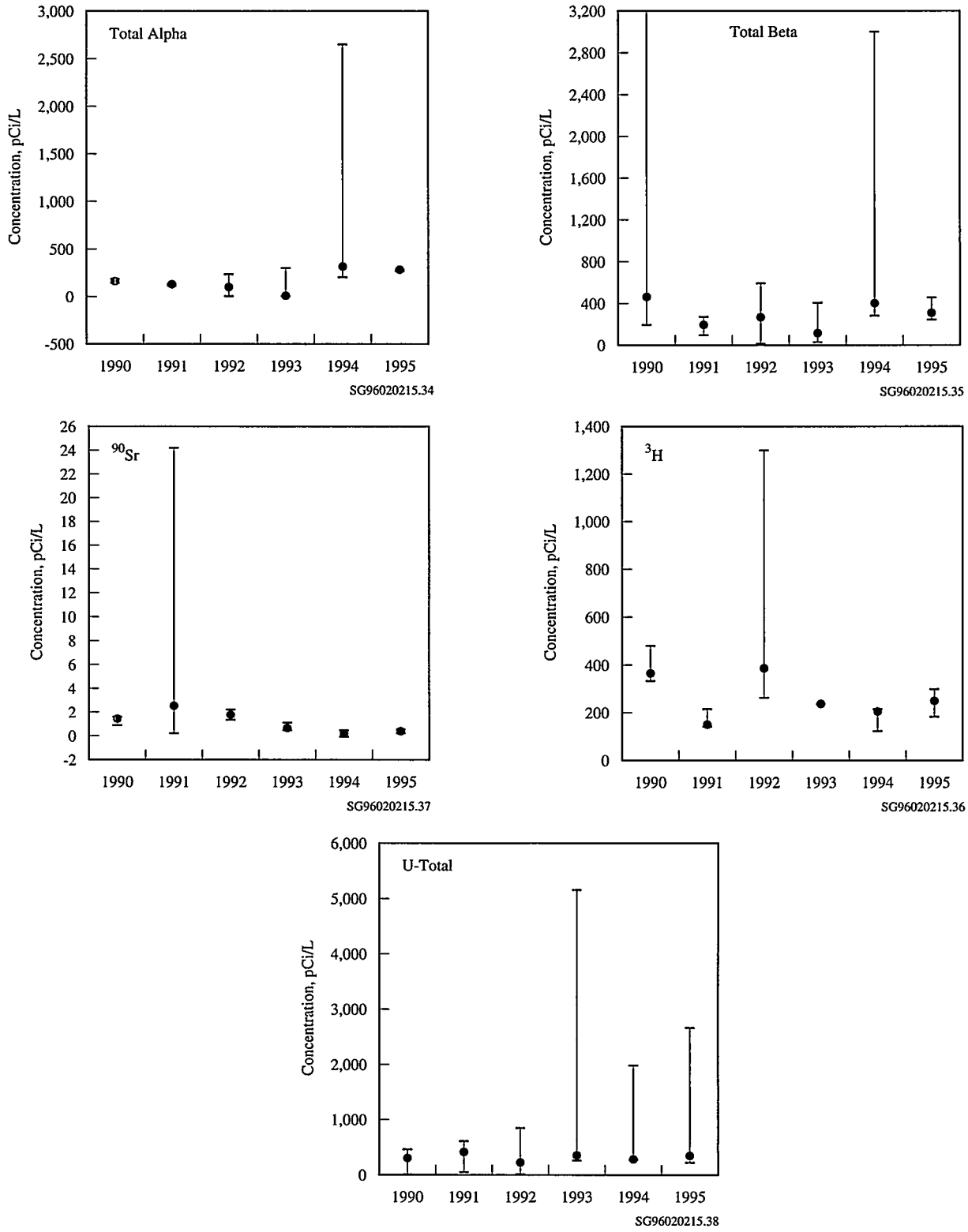


Figure 4.2.17. Minimum, Median, and Maximum Concentrations of Select Radionuclides in West Lake, 1990 Through 1995. As a result of figure scale, some maximum and minimum values are concealed by the point symbol. The maximum total beta concentration in 1990 was 271,000 pCi/L.

reflective of local ground-water concentrations. The concentrations of all other measured radionuclides were rarely higher than two times their associated total propagated analytical uncertainties.

Offsite Water

During 1995, water samples were collected from five water supplies that utilized ground water directly east of and across the Columbia River from the Hanford Site. Water samples were also collected from an irrigation canal downstream from Hanford that obtains water pumped from the Columbia River. As a result of 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 (see Section 5.0, "Potential Radiation Doses from 1995 Hanford Operations").

Collection, Analysis, and Radiological Results for Offsite Water Samples

Grab samples were collected once from five offsite domestic water supplies at four locations during 1995. Analyses of unfiltered aliquots of the samples included gamma scan, total alpha, total beta, tritium, and uranium-234, -235, and -238. All radionuclide concentrations measured in offsite water supplies in 1995, reported by Bisping (1996), were below DOE Derived Concentration Guides (Appendix C, Table C.5) and the Washington State and EPA Drinking Water Standards (Appendix C, Table C.2). The proposed EPA Drinking Water Standard for total uranium, however, was exceeded at one location. Total uranium concentrations observed in offsite water supplies were comparable to those reported by the state of Washington elsewhere in Franklin County (DSHS 1988) and were not attributable to Hanford operations. Uranium isotopes were detected at measurable concentrations in three of the five offsite domestic water supplies. The concentrations of all other measured radionuclides in offsite drinking water during 1995 were less than two times their associated total propagated analytical uncertainties. Elevated total alpha concentrations measured in offsite water supplies in 1995 were attributable to natural uranium concentrations in the ground water.

Water in the Riverview irrigation canal was sampled three times in 1995 during the irrigation season. Unfiltered samples of the canal water were analyzed for gamma emitters, strontium-90, total alpha, total beta, tritium, and uranium-234, -235, and -238. Results are presented by Bisping (1996). In 1995, 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 DOE Derived Concentration Guides and ambient surface water quality criteria levels. 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 1995 ranged from 0.01 to 0.08 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).

4.3 Hanford Site Drinking Water Surveillance

R. W. Hanf and R. L. Dirkes

The primary purpose of the Hanford Site drinking water surveillance program is to verify the quality of the drinking water supplied by Site drinking water systems. This is achieved by routinely collecting and analyzing drinking water samples and comparing the data with established drinking water standards and guidelines (Appendix C, Tables C.2 and C.5). In 1995, radiological surveillance of drinking water on the Site was conducted for ICF Kaiser Hanford primarily by Pacific Northwest National Laboratory. However, Westinghouse Hanford Company collected radiological data for one system as noted below. Chemical and microbiological surveillance was conducted by ICF Kaiser Hanford. In previous years, nonradiological sampling of Hanford Site drinking water was done by the Hanford Environmental Health Foundation. Their data were combined with radiological data supplied by other Site contractors and published by the Hanford Environmental Health Foundation in an annual Hanford sanitary water quality surveillance report (Thurman 1994, 1995). ICF Kaiser Hanford is not producing a 1995 drinking water report due in part to recent reductions in federal funding. Therefore, the 1995 radiological data for Hanford Site drinking water are summarized here, and the individual results are reported in *1995 Hanford Environmental Surveillance Data* (Bisping 1996). Nonradiological data will not be published at this time. Washington Administrative Code (WAC) 246-290, "Drinking Water Regulations," requires that all drinking water analytical results be reported to the state of Washington. Nonradiological results have been reported to the state by ICF Kaiser Hanford throughout the year; radiological results are provided to the state and to Site contractors in this report and by Bisping (1996).

Radiological Monitoring of Hanford Site Drinking Water Systems

Drinking water is supplied to the Site through a system of contractor operated water systems. Most of these systems use water from the Columbia River and consist of pumping stations and/or treatment and distribution facilities. A few systems use ground water from beneath the Site. Most of the systems are operated by ICF Kaiser Hanford. Westinghouse Hanford Company and Bechtel Hanford Inc. also each operate two and one system, respectively, although water for the Bechtel system is supplied by a pumping station operated by ICF Kaiser Hanford (Table 4.3.1). The City of Richland provides drinking water to the 300 (backup water supply), 700, 1100, 3000, and Richland North Areas of the Site; however, this water is not monitored through the Site drinking water surveillance program and is not discussed in this report. Pacific Northwest National Laboratory does collect water samples from the Columbia River at the Richland Pumphouse, which is the City of Richland's drinking water intake, and the analytical results for the river water samples are discussed in Section 4.2, "Surface Water and Sediment Surveillance."

Hanford Site drinking water systems are identified in Table 4.3.1. Ten of the systems used Columbia River water, and three used ground water. Sampling was discontinued at Pacific Northwest National Laboratory's observatory on Rattlesnake Mountain in late 1994 because the facility's water supply was no longer in use. The building is now supplied with bottled water on an as-needed basis.

In 1995, radionuclide concentrations were monitored at the locations shown in Figure 4.3.1, which represent the primary sources of water for the Site drinking water systems. The 100-B pumphouse continued to serve as the primary Columbia River pumping station for many areas on the Site (the 100-N, 200-East, and 200-West Areas, the 251 Building, and the 100 Area Fire Station), with the 100-D pumphouse available as an emergency backup. Water for the 100-K Area was supplied by the 100-K pumphouse. The Yakima Barricade, Patrol Training Academy, and the 400 Area obtained water from ground-water wells. As in past years, drinking water in buildings on the Fitzner/Eberhardt Arid Lands Ecology Reserve was supplied by bottled water in 1995 because

Table 4.3.1. Hanford Drinking Water Systems[a]

System Name/ ID Number	Source of Supply	Notes
100-D/001761	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 183-D. System is operated by ICF Kaiser Hanford.
100-B/04480U	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 182-B.
100-K/00177	Columbia River via 181-K Pump House	Filtered and chlorinated at 183-K. System is operated by Westinghouse Hanford Company.
100-N/418532	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 183-N. System is operated by Bechtel Hanford Inc.
200-E/41866V	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 283-E. System is operated by ICF Kaiser Hanford.
200-W/001004	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 283-W. System is operated by ICF Kaiser Hanford.
251 Bldg/001782 (Electrical Switching)	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 251 Building. System is operated by ICF Kaiser Hanford.
609 Bldg/001806 (100-Area Fire Station)	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 609 Building. System is operated by ICF Kaiser Hanford.
Yakima Barricade/ 001848	Well 699-49-100C	No treatment provided. System is operated by ICF Kaiser Hanford.
6652-C/001827 (PNNL Observatory)	Developed spring on side of Rattlesnake Mountain (Elev. 3,160 ft)	Chlorination only. System is operated by Pacific Northwest National Laboratory and maintained by ICF Kaiser Hanford. (Removed from service in 1994.)
Patrol Training Academy/00183Q	Well 699-S28-E0	Chlorination only. System is operated by ICF Kaiser Hanford.
400 Area/419470	Wells 499-S1-8J, 499-S0-7, and 499-S0-8	Supplied from 499-S1-8J (P-16); 499-S0-7 (P-15) is the emergency supply, 499-S0-8 (P-14) is the dire emergency supply. Chlorination only. System is operated by Westinghouse Hanford Company.
300 Area/418408	Columbia River via 312 Pump House or City of Richland	Filtered and chlorinated at 315 Building. System is operated by ICF Kaiser Hanford.

(a) Adapted from Thurman (1995).

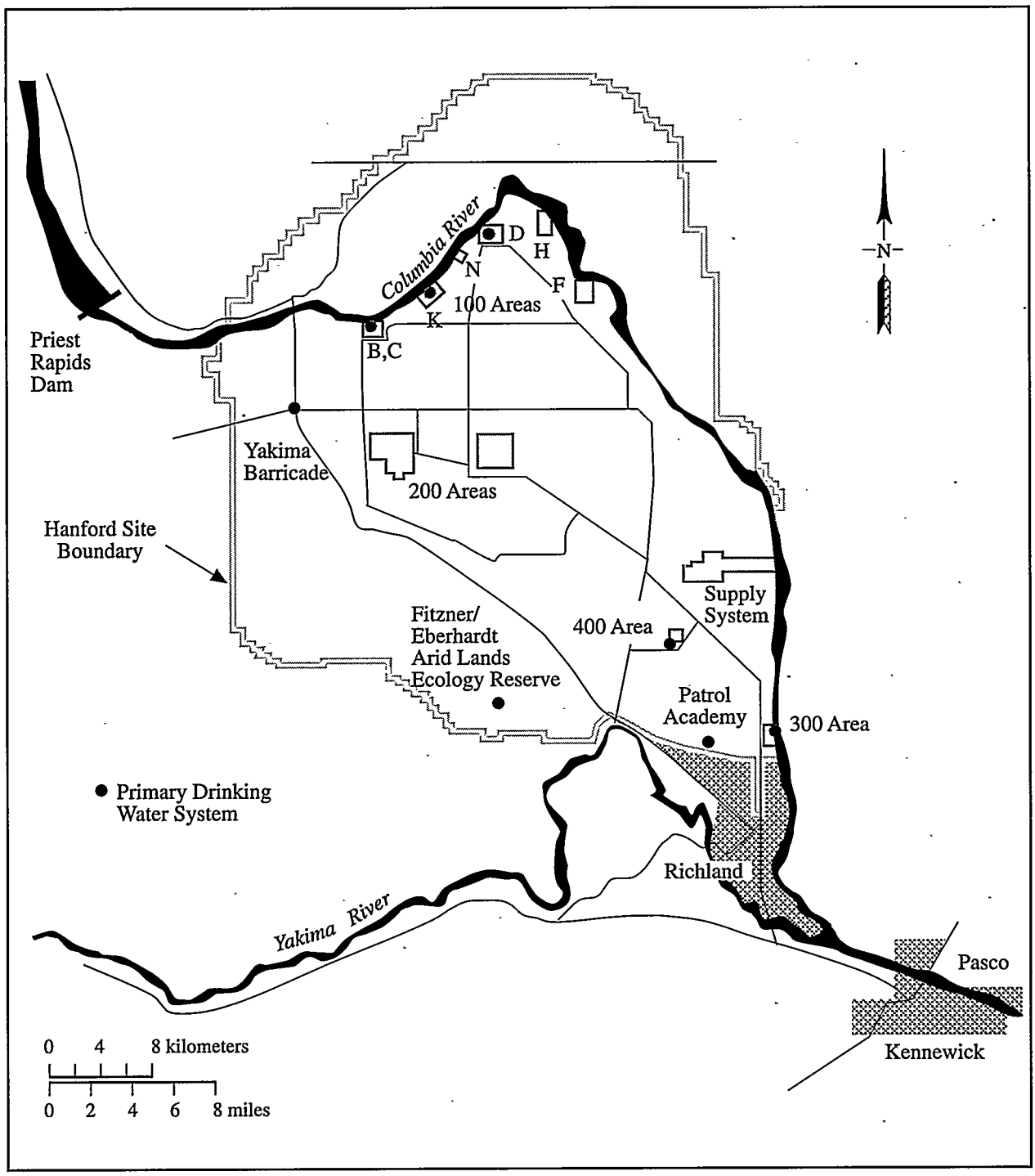


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Figure 4.3.1. Hanford Site Primary Drinking Water Systems

of naturally occurring elevated fluoride levels in the water supply well. However, radiological monitoring of the facility's well continued in 1995. The 400 Area continued to use well 499-S1-8J (P-16) for drinking water, with well 499-SO-7 (P-15) serving as the emergency supply. Well 499-SO-8, used in past years as the primary 400 Area drinking water supply, now functions as the emergency supply well. Water from well 499-SO-8 (P-14) was not used in 1995.

Collection and Analysis of Drinking Water Samples

Samples for radiological analysis were collected according to a schedule established at the beginning of the calendar year (Bisping 1995a). The majority of the samples were collected and analyzed quarterly. The 300 Area samples were collected monthly and composited for quarterly analysis. At the 400 Area, samples were collected monthly for tritium analysis, annually for iodine-129 analysis, or quarterly for other analyses. Samples from most locations were grab samples of treated water collected at the tap (Table 4.3.1). The 300 Area samples were cumulative raw river water samples that were collected at the water supply pumphouse before any water treatment (see Section 4.2, "Surface Water and Sediment Surveillance"). Tap water samples collected from the 400 and 100-D Areas during the second quarter of the year were collected in conjunction with the Washington State Department of Health. These duplicate samples were analyzed in different laboratories to provide a check on data quality. Results for the state samples will be available in the Washington State Department of Health Environmental Radiation Program annual report for 1995.

Radiological analyses of 1995 drinking water samples included total alpha, total beta, gamma scan, tritium or low level tritium, and strontium-90. Samples from the 400 Area were also analyzed for iodine-129. River samples from the 300 Area and the Richland Pumphouse were analyzed for technetium-99 and uranium. Radionuclides of interest were selected based on monitoring requirements, their presence in the source water, and their importance in determining compliance with applicable standards. Alpha and beta measurements provided a general indication of the radioactive contamination. Gamma scans provided the ability to detect numerous specific radionuclides (see Appendix E). Sensitive radiochemical analyses were used to determine the concentrations of iodine-129, technetium-99, tritium, and uranium.

Radiological Results for Hanford Site Drinking Water

The Hanford Site was in compliance with Washington State Department of Health and EPA annual average radiological drinking water standards in 1995, and results were similar to those observed in recent years (Thurman 1994, 1995). Results of radiological monitoring of Hanford Site drinking water during 1995 are summarized in Table 4.3.2. Concentrations of total alpha, total beta, tritium, and strontium-90 are included in the table to demonstrate compliance with drinking water standards. The maximum amount of beta-gamma radiation from manmade radionuclides allowed in drinking water by the Washington State Department of Health and U.S. EPA is an annual average concentration that will not produce an annual dose equivalent to the whole body or any internal organ greater than 4 millirem per year. If more than one radionuclide is present, the sum of their annual dose equivalents must not exceed 4 millirem. Compliance with this standard may be assumed if the annual average concentrations of total beta, total alpha, tritium, and strontium-90 are less than 50 pCi/L, 15 pCi/L, 20,000 pCi/L, and 8 pCi/L, respectively (see Appendix C, Table C.2).

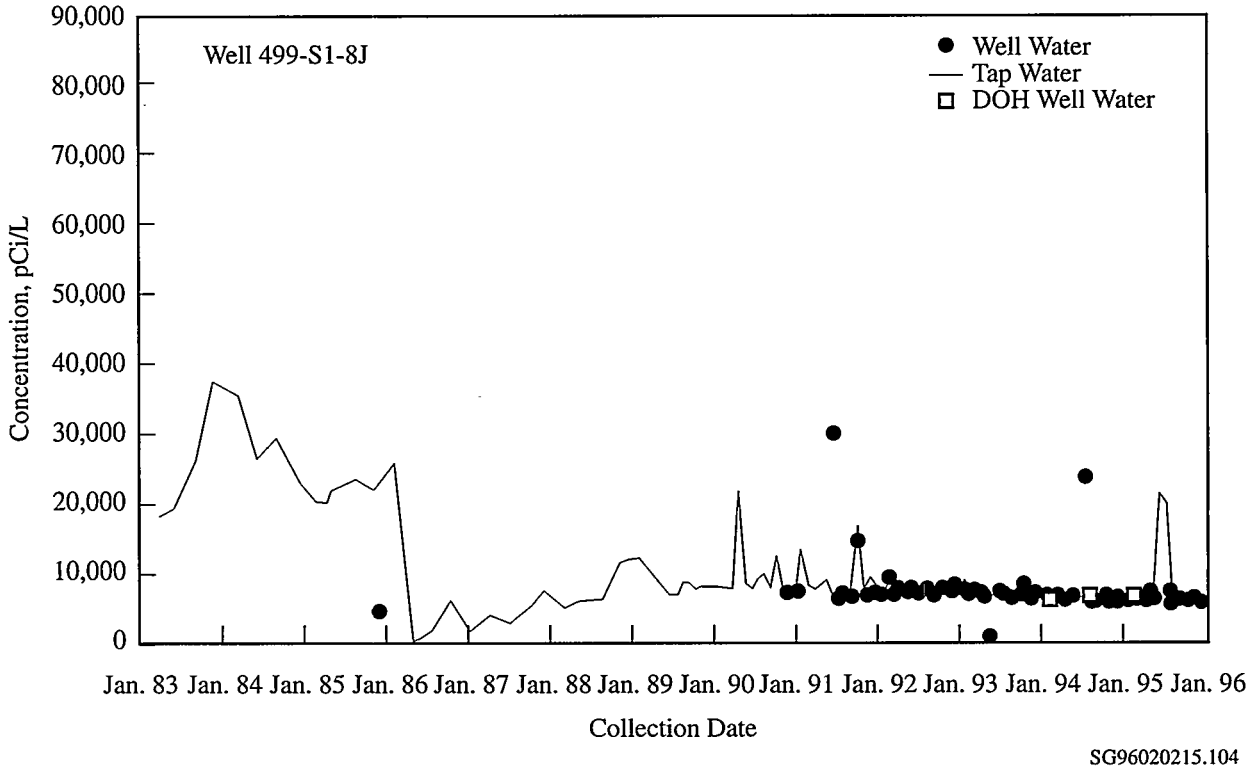
The annual average tritium concentration in 400 Area drinking water in 1995 (8,424 ± 304 pCi/L) was in compliance with the EPA annual average tritium standard of 20,000 pCi/L. However, tritium concentrations in monthly drinking water samples collected from the 400 Area in June and July were above 20,000 pCi/L (21,100 ± 1,640 pCi/L and 20,300 ± 1,580 pCi/L, respectively). The elevated tritium levels occurred when the principal drinking water supply well for the 400 Area (499-S1-8J) was shut down and water from the emergency well (499-SO-7), which draws water from a more contaminated portion of the aquifer, was substituted. The primary back-up well is used as a drinking water source when the principal well is inoperable. Figure 4.3.2 illustrates the tritium concentrations in the 400 Area drinking water supply wells used in 1995 for the period 1983 through 1995. Data were collected by Pacific Northwest National Laboratory's Ground-Water and Surface Environmental Surveillance Projects, and the Washington State Department of Health. The radiological doses associated with drinking this water are discussed in Section 5.0, "Potential Radiation Doses from 1995 Hanford Operations."

Iodine-129 was measured in one sample of 400 Area drinking water collected in August. The result (0.0095 ± 0.001 pCi/L) was well below the 1.0 pCi/L drinking water standard that would result in an annual dose equivalent of 4 millirem.

Table 4.3.2. Radiological Contaminants in Hanford Drinking Water Systems - 1995 Annual Average Concentrations,[a] pCi/L

System	No. of Samples	Total Alpha	Total Beta	^{3}H	^{90}Sr
100-B Area	4	0.41 ± 0.22	0.94 ± 1.98	45 ± 6[b]	0.64 ± 0.009
100-D Area	4	0.19 ± 0.19	0.24 ± 1.25	64 ± 16	0.08 ± 0.02
100-K Area[c]	4	0.115 ± 0.376	0.917 ± 2.71	61.5 ± 91.7	0.027 ± 0.142
300 Area	4	1.05 ± 0.30	1.95 ± 1.42	129 ± 52[b]	0.16 ± 0.17
Yakima Barricade	4	1.30 ± 0.71	7.92 ± 2.38	-18 ± 33	-0.10 ± 0.02
400 Area	4[d]	0.12 ± 0.44	6.72 ± 1.82	8,424 ± 304	0.004 ± 0.006
Patrol Academy	4	1.01 ± 0.72	4.29 ± 1.90	-2.83 ± 46	0.004 ± 0.01
Fitzner/Eberhardt Arid Lands Ecology Reserve	4	1.0 ± 0.86	9.76 ± 2.21	3.21 ± 40	-0.009 ± 0.02
Standards[e]	-	15	50	20,000	8

(a) Average value ±2 standard error of the calculated mean.
(b) Low-level tritium.
(c) Reported by Westinghouse Hanford Company.
(d) Thirteen ^{3}H samples.
(e) See Appendix C, Table C.2.



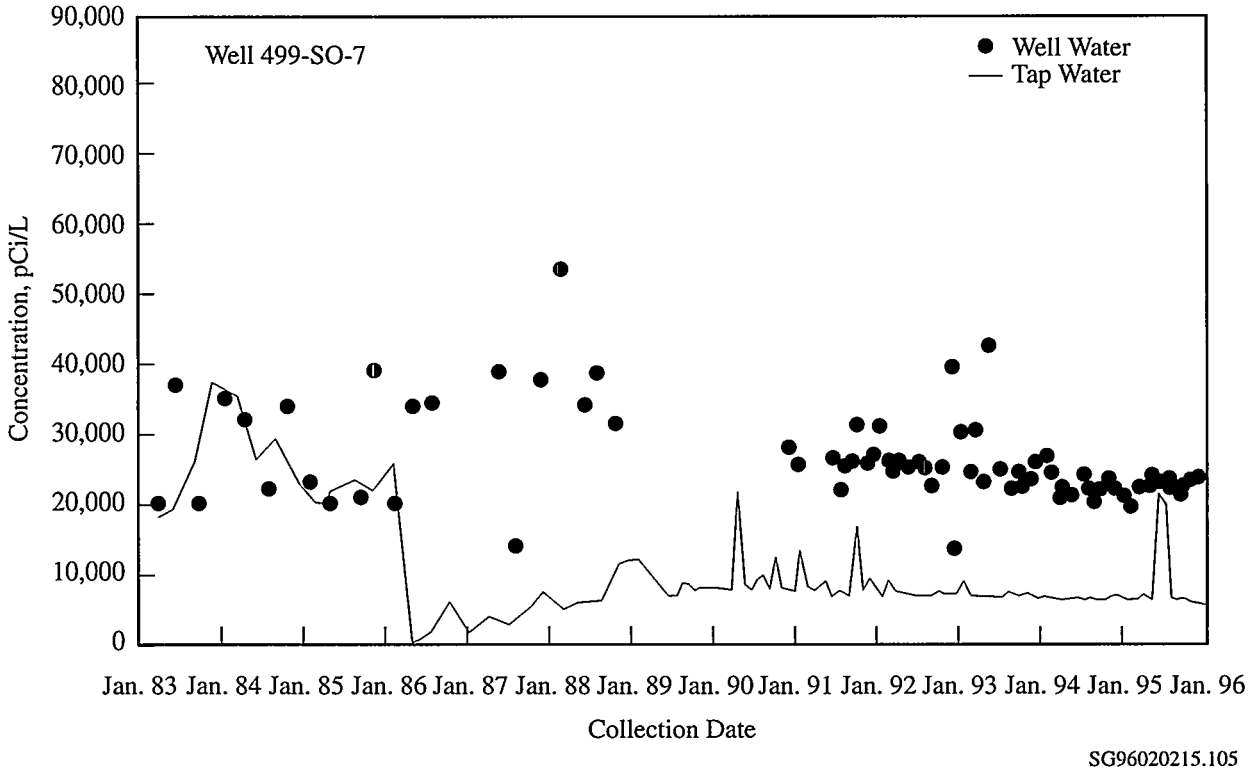


Figure 4.3.2. Tritium Concentrations in 400 Area Drinking Water

4.4 Food and Farm Product Surveillance

T. M. Poston

Alfalfa and a number of foodstuffs including milk, wheat, beef, chickens, eggs, vegetables, fruits, and wine were collected at several locations surrounding the Hanford Site (Figure 4.4.1). Samples were collected primarily from locations in the prevailing downwind directions (south and east of the Site) where deposition of airborne effluents from Hanford could be expected. 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 1995. Detailed analytical results are provided in Bisping (1996). The potential dose to the public from consuming local foods and farm products is addressed in Section 5.0, "Potential Radiation Doses from 1995 Hanford Operations." Results for fruits, vegetables, and animal products are reported in picocuries per gram wet weight. Results for wheat and alfalfa are reported in picocuries per gram 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 picocuries per liter 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 (1995a) and DOE (1994) and are summarized in Table 4.4.1. Gamma scans (cesium-137, cobalt-60, and other radionuclides; see Appendix E) and strontium-90 analyses were performed routinely for nearly all products. Selected food products were analyzed specifically for additional radionuclides including iodine-129, plutonium, technetium-99, tritium, and uranium. For many radionuclides, concentrations are below levels that can be detected by the analytical laboratory. When this occurs for an entire group of samples, a nominal detection limit is determined by using two times the total propagated analytical error. This value is used as an estimate of the lower level of detection for that analyte and particular media. The total propagated analytical error includes all sources of analytical error associated with the analysis, e.g., counting errors and errors associated with weight and volumetric measurements. Theoretically, reanalysis of the sample should yield a result falling between the upper and lower error for the analysis. Propagated errors not reported in this report may be found in Bisping (1996).

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 food grown outside of their sampling locations. Fallout radioactivity in feed may be a significant source of monitored levels in animal products; observed levels are very near levels considered to be background. Generally, levels of fallout radioactivity in environmental media correlate positively with the amount of precipitation that an area receives.

Collection and Analysis of Milk Samples

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 4.4.1). Milk samples were also collected from a Sunnyside dairy to indicate general background radionuclide concentrations at a generally upwind location. Samples were collected monthly throughout the year from the Sagemoor Area and collected quarterly from the other areas.

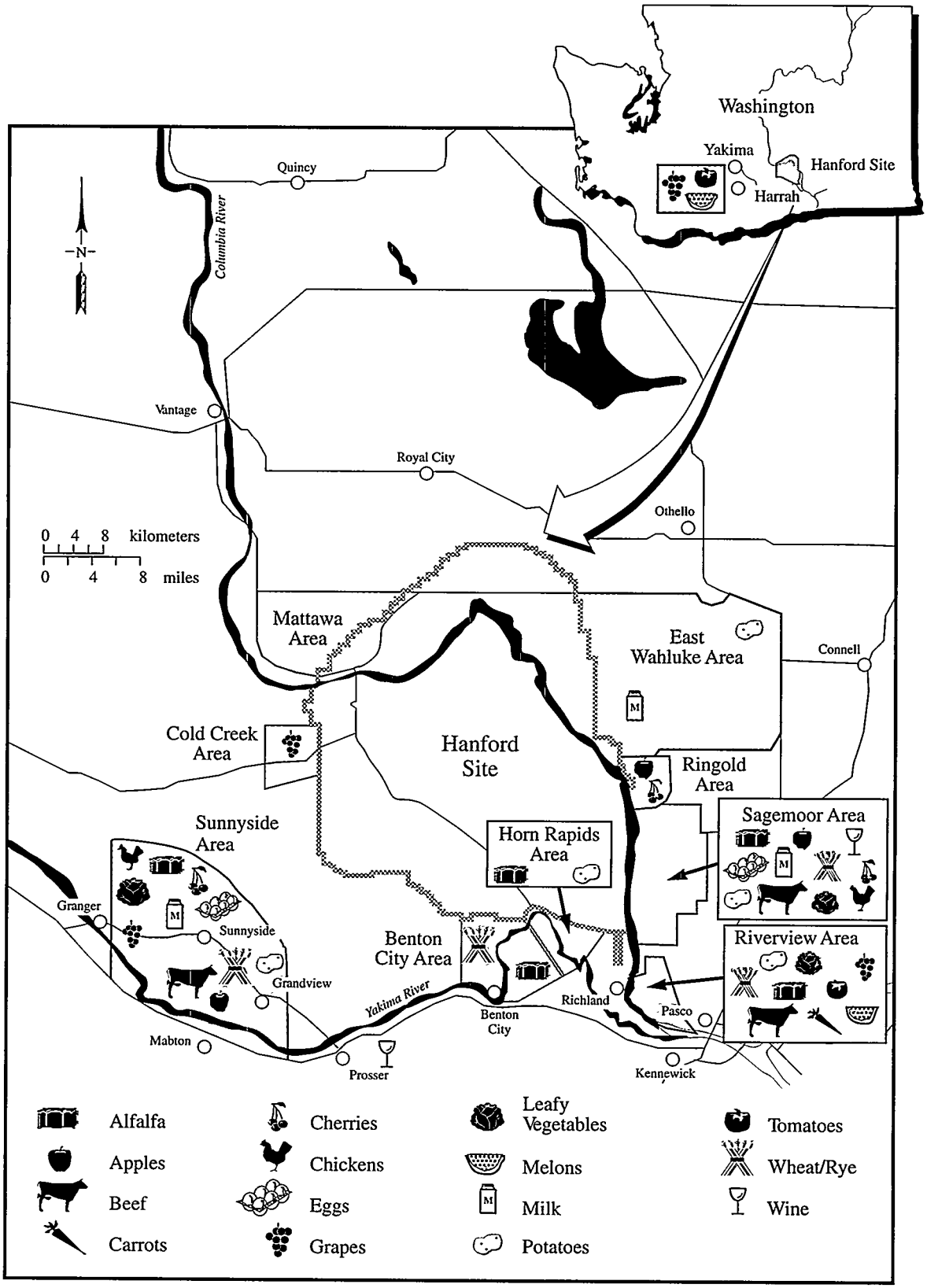


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Figure 4.4.1. Food and Farm Product Sampling Locations, 1995

Table 4.4.1. Numbers of Locations, Sampling Frequencies, and Analyses Performed for Routinely Sampled Food and Farm Products, 1995[a]

Media	Number of Locations		Sampling	Number of Locations Analyzed						
	Upwind	Downwind	Frequency[b]	^{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	A	0	3	3	0	0	0	0
Vegetables	2	4	A	2	6	5	3	1	2	3
Fruit	2	3	A	6	5	6	0	3	0	3
Wheat and alfalfa	1	4	A	0	5	5	0	0	0	1
Wine	1	2	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.

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 chains. Tritium is released into the atmosphere from Site facilities and to the Columbia River via shoreline springs. Strontium-90 is released into the Columbia River through the ground-water springs. Iodine-129 has been released to the air from Hanford operations in the past and is still being released to the Columbia River via the Site ground water. 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 sample, strontium-90 analyses were conducted on each quarterly sample, and iodine-129 analyses were conducted on two semiannual composite samples (Sagemoor, Wahluke, and Sunnyside Areas). Tritium analyses were performed on water distilled from milk; consequently, the true concentration of tritium in bulk milk would be slightly overestimated.

Radiological Results for Milk Samples

Tritium was detected in 3 of the 21 (14%) milk samples analyzed; the maximum concentration was 310 ± 150 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 (see Appendix C, Table C.2).

Strontium-90 was measured in 1 of 14 (7%) milk samples analyzed in 1995, with no apparent differences between upwind and downwind locations. Concentrations of strontium-90 have remained near the nominal detection limit (0.7 pCi/L) and relatively constant over the past 6 years (Figure 4.4.2). The maximum observed concentration of strontium-90 in milk in 1995 was 0.7 ± 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 all seven milk samples tested. In recent years, the levels of iodine-129 in milk collected from generally downwind dairies in the Sagemoor and East Wahluke Areas have persisted at levels two to four times greater than levels measured upwind in the Sunnyside Area (Figure 4.4.3). Iodine-129 concentrations have been declining with the end of nuclear production activities onsite and there appears to be no concentration differences between upwind and downwind locations in 1995. Iodine-129 contributes less than 1% of the dose to the maximally exposed individual through the consumption of dairy products (see Section 5.0, "Potential Radiation Doses from 1995 Hanford Operations"). The maximum observed concentration of iodine-129 in milk in 1995 was 0.0009 ± 0.0001 pCi/L in a sample collected from the Sagemoor Area. While there is no iodine-129 standard for milk, the standard for drinking water is 1 pCi/L.

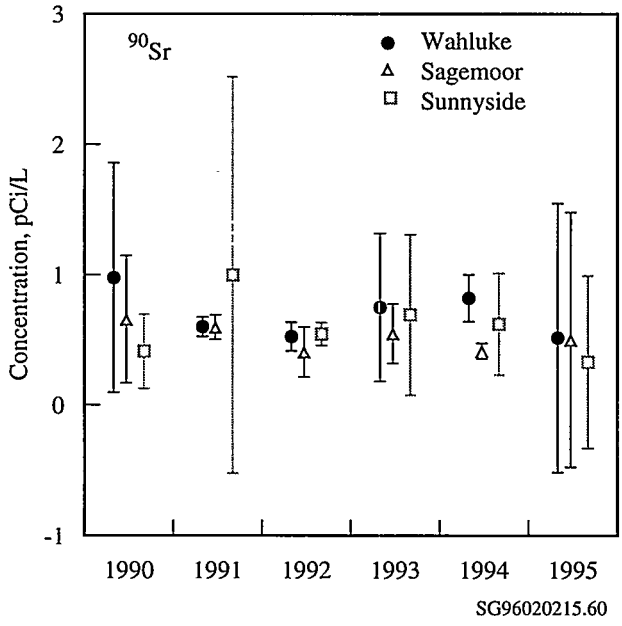

Figure 4.4.2. Mean (±2 standard error of the mean) Strontium-90 Concentrations in Milk, 1990 Through 1995. As a result of figure scale, some uncertainties are concealed by point symbol.

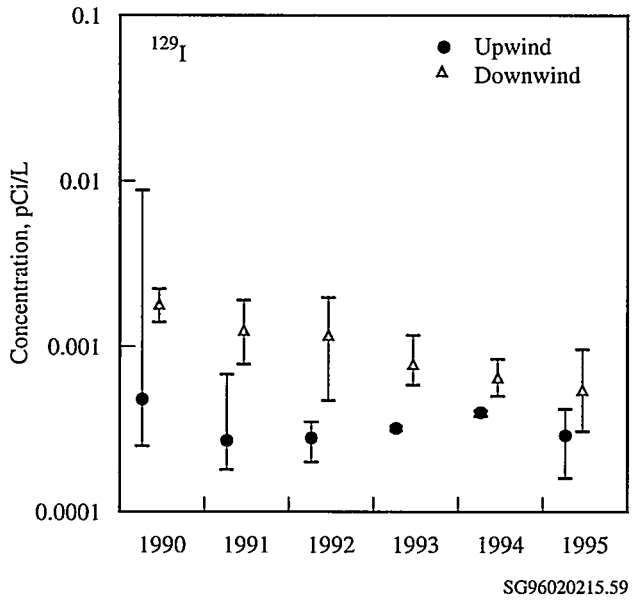

Figure 4.4.3. Mean (±2 standard error of the mean) Iodine-129 Concentrations in Milk, 1990 Through 1995. As a result of figure scale, some uncertainties are concealed by the point symbol.

One of the 21 (5%) milk samples collected and analyzed for cesium-137 in 1995 contained detectable concentrations (>3.3 pCi/L). For all 21 samples, there was no apparent difference between results upwind and downwind of the Site. The maximum observed concentration of cesium-137 in milk in 1995 was 3.3 ± 2.4 pCi/L. While there is no cesium-137 standard for milk, the standard for drinking water is 200 pCi/L. Additionally, no other manmade gamma emitters were detectable in milk (Bisping 1996).

Collection and Analysis of Beef, Chicken, and Chicken Egg Samples

Samples of locally produced poultry and eggs were collected once in 1995 from areas adjacent to the Hanford Site (Sagemoor and Sunnyside Areas, Figure 4.4.1) and analyzed for strontium-90 and gamma emitters such as cesium-137. Beef was collected once in 1995 from the Sagemoor, Riverview, and Sunnyside Areas for analysis of strontium-90 and gamma emitters such as cesium-137. Strontium-90 and cesium-137 are known Hanford Site contaminants that have the potential to move through the food chain to beef, chickens, and eggs.

Radiological Results for Beef, Chicken, and Chicken Egg Samples

In 1995, strontium-90 was measured in eggshells collected from the Sunnyside and Sagemoor Areas. The maximum concentration was 0.21 ± 0.07 pCi/g in a shell sample from the Sagemoor Area. Strontium-90 was not detected in the edible portion of the eggs collected in prior samplings (Dirkes and Hanf 1995). Strontium-90 was not detected in chicken muscle collected in 1995. Cesium-137, however, was measured in chicken muscle collected from the Sagemoor Area (0.04 ± 0.03 pCi/g), but not in eggs collected in 1995 from Sagemoor or Sunnyside.

In 1995, manmade radionuclides were not detected in any samples of locally produced beef.

Collection and Analysis of Vegetable Samples

Samples of leafy vegetables (cabbage, broccoli, beet tops, or turnip greens), tomatoes, carrots, and potatoes were obtained during the summer from gardens and farms located within selected sampling areas (see Figure 4.4.1). In conjunction with the Washington State Department of Health, grapes, melons, and tomatoes 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 the Horn Rapids and Riverview Areas 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. 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 shoreline 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.

Radiological Results for Vegetable Samples

Many of the analytical results for vegetables were below the nominal detection limits for specific radionuclides. For leafy vegetable samples in 1995, the only radionuclide measured above the detection limit was strontium-90. The Sagemoor Area sample (0.006 ± 0.003 pCi/g) exceeded the nominal detection limit of 0.003 pCi/g. There were no concentrations of manmade radionuclides above detection limits in carrot or tomato samples in 1995. The only manmade radionuclide measured in vegetable samples was strontium-90 in the Riverview Area potato sample (0.005 ± 0.004 pCi/g). Measurements of gamma emitters; plutonium-238; plutonium-239,240; technetium-99; and uranium isotopes were all less than their respective detection limits.

Collection and Analysis of Fruit Samples

Samples of apples, cherries, concord grapes, and melons were collected before or during harvest from the areas shown in Figure 4.4.1 (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.

Radiological Results for Fruit Samples

Measurable levels of manmade radioactivity were not detected in apples, cherries, concord grapes, or melons collected in 1995. These results are consistent with fruit measurements over recent years (Bisping and Woodruff 1990, 1991, 1992, 1993, Bisping 1994, 1995b). Nominal levels of detection were 0.02 pCi/g wet weight for cesium-137; 0.04 pCi/g wet weight for iodine-129; 0.0001 pCi/g wet weight for plutonium-239,240; 0.004 pCi/g wet weight for strontium-90; and 200 pCi/L plant distillate for tritium.

Collection and Analysis of Wine Samples

Locally produced red and white wines (1995 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 an upwind location, near Prosser. Three samples each of red and white wines were obtained from each area.

Radiological Results for Wine Samples

Gamma spectroscopy of wine samples did not indicate the presence of cesium-137 in any of the samples. The minimum level of detection for cesium-137 in wine is 5 pCi/L.

The results for tritium in 1995 wine samples indicate no difference between upwind and downwind locations (Figure 4.4.4). Concentrations reported in 1995 showed a wide range of concentrations although within the range observed over the past 6 years. Wine analyses for tritium performed by other laboratories on duplicate samples are consistently lower than the data reported by the Pacific Northwest National Laboratory (Dirkes and Hanf 1995), and the results reported in 1995 are considered to be biased high due to a difference in analytical methods used among laboratories. In 1995, all measured concentrations of tritium in wine were 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.

Collection and Analysis of Wheat and Alfalfa Samples

Samples of grain and mature alfalfa were collected from the areas shown in Figure 4.4.1. Rye was collected in the Riverview Area because wheat was not available.

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.

Radiological Results for Wheat and Alfalfa Samples

Strontium-90 was measured in the rye sample collected from the Riverview Area (0.009 ± 0.006 pCi/g). All other manmade radionuclide concentrations in wheat and rye were below the nominal detection limit (<0.009 pCi/g) and are listed by Bisping (1996).

Alfalfa irrigated with Columbia River water withdrawn downstream from Hanford (the Riverview and Horn Rapids Areas) continued to show slightly higher concentrations of strontium-90 relative to other locations (Figure 4.4.5); however, this difference was not statistically significant in 1995. A single high result for one of the three replicate samples collected at Riverview caused the exceedingly high variability for the 1995 Riverview, Horn Rapids, and Richland group. Samples from the Sagemoor and East Wahluke Areas (locations that use Columbia Basin Irrigation Project water) and Sunnyside and Benton City Areas (locations that use irrigation water from the Yakima River or wells) had strontium-90

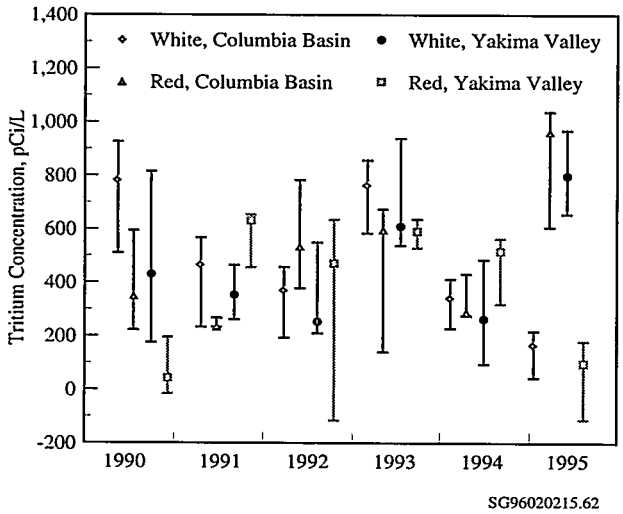

Figure 4.4.4. Maximum, Median, and Minimum Tritium Concentrations in Wine Samples, 1990 Through 1995

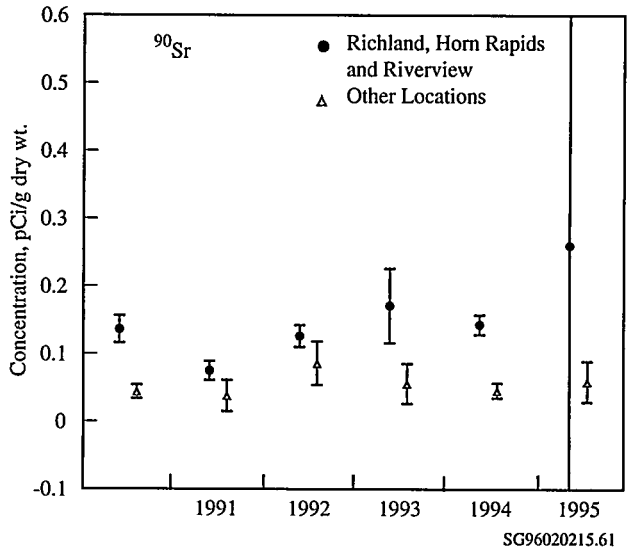

Figure 4.4.5. Mean (±2 standard error of the mean) Strontium-90 Concentrations in Alfalfa Routinely Collected at Riverview, Horn Rapids, Richland, and All Other Sampling Locations, 1990 Through 1995

water from the Yakima River or wells) had strontium-90 concentrations that were lower than those in the Riverview and Horn Rapids Areas in 1995. The actual concentrations at all locations were low and difficult to separate from the influence of fallout (Jaquish 1993).

Cesium-137 was not consistently measured in wheat, rye, or alfalfa during 1995.

4.5 Fish and Wildlife Surveillance

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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 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 to the offsite public. In addition, detection of radionuclides in wildlife may indicate that wildlife are entering contaminated areas (for example, burrowing in waste 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 (Figure 4.5.1). More detailed rationale for selection of specific species sampled in 1995 can be found in DOE (1994).

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 differences. Routine background sampling is conducted roughly every 5 years at locations believed to be unaffected by Hanford releases. Background data also may be collected during special studies or sampling efforts. In 1995, background contaminant concentrations were measured in whitefish from the Wenatchee River, goose eggshells from the Priest Rapids Dam area, and pigeons from Walla Walla and Seattle.

As a result of changing Site operations, fish and wildlife sampling frequencies were modified significantly in 1995. Species that have been collected annually were placed on a rotating schedule so that surveillance of all key species will be accomplished over a three-year period. Contributing factors supporting these changes included the elimination of many radiological source terms onsite and a decrease in environmental concentrations of radionuclides of interest. Several radionuclides that were monitored in the past have not been detected in recent wildlife samples because either they are no longer present in the environment in sufficient amounts to accumulate in wildlife, or surveillance has demonstrated that they do not accumulate in fish or wildlife tissues of interest. Air and water sampling provides additional information on the potential exposure of fish and wildlife. Consequently, the needs of the sitewide fish and wildlife surveillance program can be satisfied by less frequent sampling.

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 the organism (Table 4.5.1). At Hanford, cesium-137 and strontium-90 historically have been the most frequently measured radionuclides in fish and wildlife.

Strontium-90 is chemically similar to calcium; consequently, it accumulates in hard tissues high in calcium such as bone, antlers, and eggshells. 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 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-137 is particularly important because it is chemically similar to potassium and is found in the muscle tissue of fish and wildlife. Cesium-137 has a relatively short biological half-life and is an indicator of more recent exposure to radioactive materials. It 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 E). However, gamma scan results for most radionuclides are not discussed below because concentrations were too low to measure or because measured concentrations were

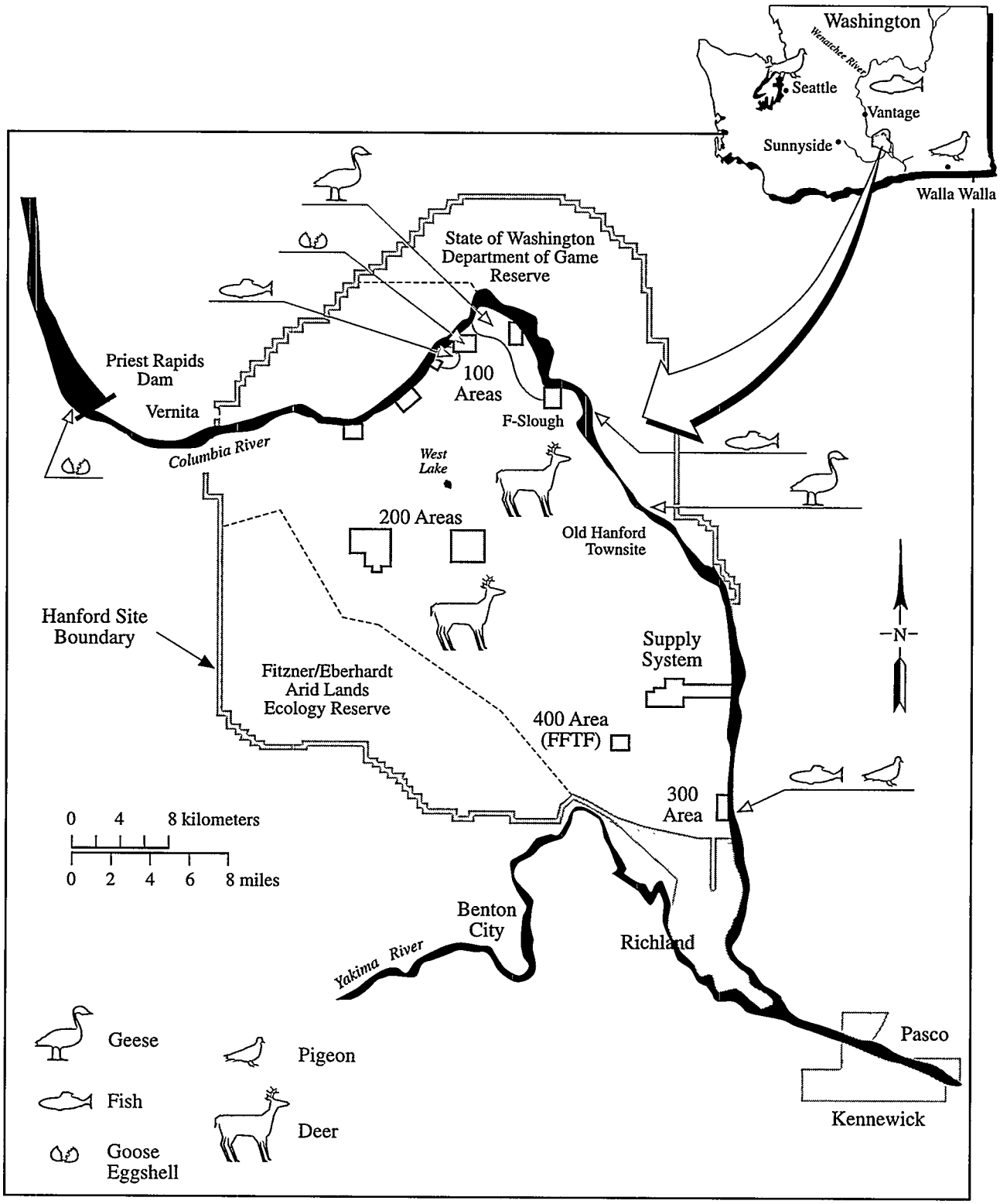

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Figure 4.5.1. Fish and Wildlife Sampling Locations, 1995

Table 4.5.1. Locations, Species, and Contaminants Sampled for Fish and Wildlife, 1995

Media	Number of Species	Offsite Locations	Onsite Locations	Contaminants Sampled/Number of Locations				
				Gamma	^{90}Sr[a]	^{99}Tc	U	Metals
Fish (Sucker, Whitefish)	2	1[b]	2	3	3	1	1	0
Geese	1	0	2	2	2	0	0	0
Pigeons	1	2[c]	1	0	0	0	0	3
Mule deer	1	0	2	5	2	0	0	0

(a) Analyzed in bone and some muscle samples.
(b) Background samples collected from the Wenatchee River.
(c) Background samples collected from Seattle and Walla Walla.

considered artifacts of low background counts. Low background counts occur at random intervals during sample counting and can produce occasional spurious results.

For many radionuclides, concentrations are below levels that can be detected by the analytical laboratory. When this occurs for an entire group of samples, two times the total propagated analytical error is used as an estimate of the nominal detection level for that analyte and particular media. Propagated errors for all results may be found in Bisping (1996).

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 of interest because:

- Technetium-99 is known to enter the Columbia River in shoreline seeps and springs and has a long half-life. Its potential to accumulate in fish is not well-known; however, concentrations of technetium-99 in fish tissues have not been found above the detection limit of 1.0 pCi/g in the past 5 years. In January 1995, three whitefish were sampled for technetium-99 analysis.

- 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 in and near the 300 Area. Prior sampling indicated that uranium is not found in fish muscle; therefore, analysis was shifted to offal samples (identified as carcass samples before 1994) because uranium accumulates in fish bones.

- Isotopes of plutonium accumulate in liver and may also be deposited in bone. In 1995, liver tissue from selected wildlife was analyzed to monitor potential exposure to terrestrial contamination.

In addition to performing routine fish and wildlife surveillance activities, metal concentrations were monitored in muscle, liver, and kidney tissues of pigeons collected from the 300 Area and from two control locations, Seattle and Walla Walla as part of a graduate student study. Metal concentrations were determined by inductively coupled plasma emission-mass spectrometry. This method provides measurements of several trace metals simultaneously: silver (Ag), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), antimony (Sb), thallium (Tl), and zinc (Zn). Pigeons normally are not consumed by hunters; however, elevated metal concentrations in pigeon muscle may indicate the potential for metals to accumulate in other species of gamebirds. Kidney and liver tissues were analyzed because these organs are involved with the metabolism and excretion of trace metals and may provide evidence of environmental exposure to these metals.

Fish Sampling

Whitefish and suckers were the only fish species collected from the Hanford Reach in the summer and winter of 1995. Whitefish were collected because historically they have been the Columbia River sport fish that accumulated the highest radionuclide concentrations. Whitefish routinely are collected from the Columbia River along the shoreline between the 100-N and 100-D Areas and along the 300 Area shoreline. Suckers were collected from the 300 Area in 1995 as a replacement for whitefish because river conditions in the winter were not conducive for the collection of whitefish. However, three whitefish were collected in January 1995. Whitefish and suckers consume the same foods, and prior studies have indicated that suckers generally accumulate similar or slightly higher levels of contaminants than whitefish (Foster 1965, 1966, and 1967). In 1990, whitefish also were collected from the Vernita Bridge to Priest Rapids segment of the Columbia River. Background samples were collected in 1991 from the Kettle River and again in 1995 from the Wenatchee River. Both rivers enter the Columbia River upstream of the Hanford Site.

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 generally are variable. Results for all 1995 samples are listed by Bisping (1996).

Radiological Results for Fish Samples

Muscle. In 1995, strontium-90 was detected in one (0.004 ± 0.003 pCi/g) of 18 whitefish muscle samples (Table 4.5.2). This observation may indicate the presence of some bone in the fillet, but is more likely a spurious result. Strontium-90 was not detected in the muscle of suckers.

Concentrations of cesium-137 in whitefish and sucker muscle were detectable in six of the 24 samples collected from all locations in 1995. Mean concentrations of cesium-137 in whitefish and sucker muscle were at or below the nominal detection limit of 0.02 pCi/g. The background fish collected from the Wenatchee River in 1995 appeared to have slightly higher levels then the background fish collected in 1990 from the Kettle River (Table 4.5.2). There is no demonstrable difference between cesium-137 concentrations in whitefish or suckers collected from the Hanford Reach and concentrations in fish collected from background locations during the past 5 years.

Neither uranium-238 nor technetium-99 was detected in three whitefish samples collected from the 300 Area in 1995. The nominal limits of detection for uranium-238 and technetium-99 are 0.001 pCi/g and 0.4 pCi/g, respectively.

Offal. Strontium-90 was found in all whitefish and sucker offal samples analyzed in 1995. The maximum concentration of 0.46 ± 0.09 pCi/g influenced the relatively high mean strontium-90 concentration for 1995. A comparison of the strontium-90 data from 1990 through 1994 indicates that strontium-90 concentrations in background samples from the Wenatchee and Kettle Rivers were higher than results from the Hanford Reach. Concentrations of strontium-90 in offal were slightly elevated in the 100-N to 100-D Area compared to the 300 Area.

In 1995, uranium isotopes were measured in offal samples from whitefish and suckers (Table 4.5.3). In prior years, edible fillets were analyzed for uranium; however, concentrations were below detection (0.02 pCi/g) and therefore offal was analyzed instead to account for the potential accumulation of uranium in bone tissue.

Wildlife Sampling

Wildlife sampled in 1995 for radioactive constituents included deer and geese. Pigeons were also collected as part of a graduate student project and were analyzed for trace metals. Results from all 1995 samples are summarized by Bisping (1996).

Collection and Analysis of Deer Samples

Samples were taken from two Hanford Site mule deer that were killed by traffic. A third deer (considered an onsite deer) that was tagged by Hanford biologists was provided by a local hunter that shot it in Franklin County. While deer hunting is not allowed onsite, deer do 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. Muscle and bone samples were analyzed for radioactivity. Roadkill samples are used whenever possible to minimize impacts to the Hanford deer population.

Table 4.5.2. Concentrations of Strontium-90 and Cesium-137 in Whitefish and Sucker (300 Area only), 1995 and the Previous 5 Years

Radionuclide	Sampling Location	Mean[a]	Maximum[b]	No. Less Than Detection[c]
		Muscle - 1995		
^{137}Cs	100-N - 100-D Areas	0.01 ± 0.01	0.02 ± 0.03	8 of 8
^{137}Cs	300 Area	0.01 ± 0.00	0.04 ± 0.04	3 of 4
^{137}Cs[d]	300 Area	0.01 ± 0.01	0.04 ± 0.03	4 of 6
^{137}Cs	Wenatchee River	0.00 ± 0.01	0.06 ± 0.03	4 of 7
^{90}Sr	100-N - 100-D Areas	0.001 ± 0.001	0.005 ± 0.014	8 of 8
^{90}Sr	300 Area	-0.013 ± 0.002	0.001 ± 0.003	4 of 4
^{90}Sr[d]	300 Area	0.001 ± 0.000	0.002 ± 0.003	6 of 6
^{90}Sr	Wenatchee River	0.000 ± 0.002	0.004 ± 0.003	5 of 6
		Muscle - 1990-1994		
^{137}Cs	100-N - 100-D Areas	0.02 ± 0.01	0.17 ± 0.04	31 of 50
^{137}Cs	300 Area	0.01 ± 0.00	0.04 ± 0.04	29 of 33
^{137}Cs	Priest Rapids-Vernita[e]	0.01 ± 0.01	0.04 ± 0.04	8 of 10
^{137}Cs	Kettle River	0.00 ± 0.01	0.04 ± 0.03	8 of 9
^{90}Sr	100-N - 100-D Areas	0.004 ± 0.002	0.012 ± 0.005	22 of 30
^{90}Sr	300 Area	0.000 ± 0.002	0.008 ± 0.015	18 of 18
		Offal - 1995		
^{90}Sr	100-N - 100-D Areas	0.094 ± 0.148	0.464 ± 0.088	0 of 8
^{90}Sr	300 Area	0.010 ± 0.006	0.018 ± 0.008	0 of 4
^{90}Sr[d]	300 Area	0.042 ± 0.007	0.053 ± 0.012	0 of 6
^{90}Sr	Wenatchee River	0.049 ± 0.010	0.071 ± 0.018	0 of 6
		Offal - 1990-1994		
^{90}Sr	100-N - 100-D Areas	0.021 ± 0.006	0.099 ± 0.029	1 of 47
^{90}Sr	300 Area	0.013 ± 0.002	0.035 ± 0.032	2 of 33
^{90}Sr	Priest Rapids-Vernita[e]	0.017 ± 0.005	0.032 ± 0.007	0 of 10
^{90}Sr	Kettle River	0.035 ± 0.006	0.048 ± 0.017	0 of 9

(a) Result is pCi/g ±2 standard error of the calculated mean.
(b) Maximum is pCi/g ±2 total propagated analytical uncertainty.
(c) Number of samples with values less than the detection limit out of number of samples analyzed.
(d) Sucker, 300 Area only; results for all other locations are whitefish.
(e) Discontinued in 1990.

Table 4.5.3. Concentrations of Uranium-238 in Whitefish and Sucker Collected in 1995

	Location	Mean[a]	Maximum[b]	No. Less Than Detection[c]
Muscle				
Whitefish	300 Area	0.000 ± 0.001	0.001 ± 0.001	3 of 3
Offal				
Sucker	300 Area	0.023 ± 0.015	0.056 ± 0.008	0 of 6
Whitefish	300 Area	0.001 ± 0.001	0.001 ± 0.001	0 of 4
Whitefish	100-N - 100-D Areas	0.009 ± 0.003	0.017 ± 0.004	0 of 8
Whitefish	Wenatchee River	0.012 ± 0.013	0.050 ± 0.009	0 of 7

(a) Mean is pCi/g ±2 standard error of the calculated mean.
(b) Maximum is pCi/g ±2 total propagated analytical uncertainty.
(c) Number of samples with values less than the detection limit out of number of samples analyzed.

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 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 usually are higher in Stevens County deer than in onsite deer (Poston and Cooper 1994). This relationship was not noted in deer collected from Boardman because the climate and precipitation there are similar to Hanford.

Radiological Results for Deer Samples

Muscle. The concentration of cesium-137 in deer muscle collected near the 200 Area was 0.04 ± 0.01 pCi/g (Table 4.5.4). Cesium-137 was not detected in the two other deer samples collected at Hanford. A low frequency of cesium-137 results above the nominal detection levels (0.01 pCi/g) is consistent with trends observed in deer muscle in recent years (Poston and Cooper 1994). The cesium-137 concentration in Hanford deer muscle was less than background concentrations of cesium-137 measured in deer samples collected in 1992 and 1994 from Stevens County and collected in 1994 from Boardman.

Bone. Strontium-90 was detected in all deer bone samples analyzed in 1995. The maximum concentration was 0.18 ± 0.06 pCi/g in deer sampled from the old Hanford Townsite. Boardman deer bone samples had a maximum concentration of 0.13 ± 0.04 pCi/g strontium-90, which was lower than the Stevens County results but comparable to results for Hanford deer over the past several years (Table 4.5.4). The apparently higher concentrations of strontium-90 in onsite deer bone from 1990 through 1994 may indicate some prior exposure to low-level contamination onsite.

Liver. A single liver sample from a deer collected at the old Hanford Townsite was analyzed for plutonium-238 and plutonium-239,240. Concentrations of plutonium isotopes were below the nominal detection limit of 0.0004 pCi/g.

Collection and Analysis of Waterfowl Samples

Goose muscle was added to the routine surveillance schedule in 1994. In 1995, resident Canada geese were collected from the old Hanford Townsite and from the area between the 100-N and 100-D Areas. Goose eggshells were collected from 100-D Island (100-D Area) and from an island in the pool upstream of Priest Rapids Dam. Muscle tissues were analyzed for gamma emitters and strontium-90; eggshells and bone were analyzed for strontium-90.

Table 4.5.4. Concentrations of Strontium-90 in Deer Bone and Cesium-137 in Deer Muscle (pCi/g wet weight), 1995 Compared to Values from the Previous 5 Years

	1995			1990-1994		
Radionuclide/Location	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
^{90}Sr in Bone						
Onsite	0.18 ± 0.06	0.06 ± 0.12	1 of 3	58 ± 11	6.82 ± 7.8	0 of 15
Stevens County[d]				2.06 ± 0.41	1.08 ± 1.01	0 of 3
Boardman[e]				0.13 ± 0.04	0.11 ± 0.02	0 of 4
^{137}Cs in Muscle						
Onsite	0.04 ± 0.01	0.02 ± 0.02	2 of 3	0.37 ± 0.05	0.01 ± 0.02	20 of 35
Stevens County[d]				0.52 ± 0.06	0.31 ± 0.26	0 of 3
Boardman[e]				0.03 ± 0.03	0.01 ± 0.02	3 of 4

(a) Maximum is pCi/g ±2 total propagated analytical uncertainty.
(b) Result 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 1992 and 1994, Whitetail deer; Mule deer are collected at Hanford. Stevens County is located in the northeast corner of Washington.
(e) Collected in 1994. Boardman is south of the Site in Oregon.

Radiological Results for Waterfowl Samples

Muscle. Cesium-137 was detected only intermittently in goose muscle (Table 4.5.5), concentrations were essentially at the limit of detection of 0.02 pCi/g. Strontium-90 was not detected in goose muscle. Sample collection in 1994 consisted of two geese, and there are no recent data to which 1995 results can be compared; however, the results are similar to background levels in ducks collected from Vantage, Washington in 1990 (Poston and Cooper 1994).

Strontium-90 concentrations in goose eggshells have declined in samples collected from the Hanford Reach (Figure 4.5.2). In 1995, there was essentially no difference between the background samples collected from the Priest Rapids pool (mean concentration of 0.40 ± 0.16 pCi/g) and the samples collected from 100-D Island (0.47 ± 0.13 pCi/g). For comparison, strontium-90 in chicken eggshells collected from the Sagemoor Area ranged from 0.13 ± 0.05 to 0.21 ± 0.05 pCi/g.

Collection and Analysis of Pigeon Samples

Pigeon samples were collected from background locations in Walla Walla and Seattle and were collected twice from the 300 Area, in January and September 1995. Each bird was sampled for kidney, liver, and muscle. Kidneys and livers were sampled because they accumulate trace metals. Muscle tissue was sampled because it may be consumed by humans and because concentrations of metals in pigeon muscle may be similar to concentrations in muscle tissues of upland gamebirds.

Nonradiological Results for Pigeon Samples

Only cadmium, chromium, copper, lead, and zinc were detected in pigeon samples (Table 4.5.6). Generally, metal concentrations were highest in birds collected in Seattle. Metal concentrations in tissues of pigeons collected in Walla Walla were similar to concentrations in

Table 4.5.5. Concentrations of Strontium-90 and Cesium-137 in Canada Goose Tissue, 1995

Location/Tissue	Radionuclide	Mean[a]	Maximum[b]	No. Less Than Detection[c]
100-N - 100-D Areas				
Bone	^{90}Sr	0.313 ± 0.284	0.717 ± 0.164	0 of 5
Muscle	^{90}Sr	0.000 ± 0.001	0.002 ± 0.002	5 of 5
Muscle	^{137}Cs	0.01 ± 0.00	0.01 ± 0.01	5 of 5
Hanford Townsite				
Bone	^{90}Sr	0.220 ± 0.141	0.439 ± 0.112	0 of 5
Muscle	^{90}Sr	0.000 ± 0.001	0.001 ± 0.003	5 of 5
Muscle	^{137}Cs	0.00 ± 0.01	0.01 ± 0.01	5 of 5

(a) Result is pCi/g ±2 standard error of the calculated mean.
(b) Maximum is pCi/g ±2 total propagated analytical uncertainty.
(c) Number of samples with values less than the detection limit out of number of samples analyzed.

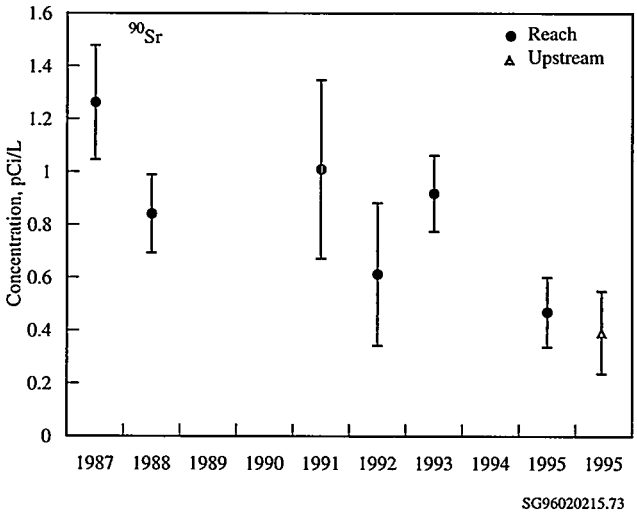

Figure 4.5.2. Mean Strontium-90 Concentrations in Goose Eggshells for Various Years Between 1987 and 1995

samples from the 300 Area. Pigeons collected in August from the 300 Area had higher concentrations of chromium in liver and muscle than birds collected in January. A similar relationship was observed for copper, lead, and zinc in liver tissue. Pigeons collected from Seattle would be expected to have greater concentrations of metals than pigeons collected at Hanford or Walla Walla because Seattle is more industrialized. These results suggest that concentrations of trace metals in 300 Area birds reflect a range of concentrations that likely are nonhazardous to pigeons.

Table 4.5.6. Trace Metal Concentrations in Pigeons, 1995

Tissue/Sampling Location	No. of Samples	Mean[a] (µg/g, dry weight) Cadmium	Chromium	Copper	Lead	Zinc
Kidney						
300 Area (January)	5	5.84 ± 4.6	0.53 ± 0.17	11.8 ± 2.4	0.38 ± 0.19	94.6 ± 5.66
300 Area (August)	5	1.81 ± 2.53	0.59 ± 0.04	17.8 ± 6.6	1.56 ± 1.33	104 ± 22.7
Seattle	8	10.9 ± 5.52	0.52 ± 0.08	20.6 ± 6.98	2.87 ± 2.15	101 ± 18.9
Walla Walla	7	5.27 ± 0.96	0.52 ± 0.06	15.7 ± 2.64	0.37 ± 0.38	115 ± 18.9
Liver						
300 Area (January)	5	0.68 ± 0.22	0.49 ± 0.07	8.45 ± 1.03	0.11 ± 0.02	59.5 ± 10.8
300 Area (August)	5	0.59 ± 0.74	0.81 ± 0.12	17 ± 4.62	0.69 ± 0.53	175 ± 94.9
Seattle	8	4.3 ± 2.4	0.81 ± 0.22	17.6 ± 4.95	1.75 ± 1.19	123 ± 60
Walla Walla	7	1.4 ± 0.38	0.72 ± 0.11	10.8 ± 1.33	0.17 ± 0.12	78.1 ± 19.4
Muscle						
300 Area (January)	5	0.08 ± 0.00	0.25 ± 0.04	18.8 ± 0.68	0.09 ± 0.01	37.4 ± 0.92
300 Area (August)	5	0.08 ± 0.00	0.4 ± 0.04	17.1 ± 0.5	0.13 ± 0.09	43.1 ± 4.62
Seattle	8	0.1 ± 0.02	0.39 ± 0.09	17.2 ± 1.23	0.11 ± 0.03	46.2 ± 4.67
Walla Walla	7	0.08 ± 0.00	0.42 ± 0.06	14.9 ± 0.81	0.08 ± 0.00	36.8 ± 3.94

(a) Result is ±2 standard error of the calculated mean.

4.6 Soil and Vegetation Surveillance

T. M. Poston

Soil surveillance provides information on long-term contamination trends and baseline environmental radionuclide concentrations in undisturbed locations (DOE 1994a). Surveillance of natural vegetation provides information on atmospheric deposition of radioactive materials in uncultivated areas and at onsite locations adjacent to potential sources of manmade radioactivity. Accordingly, concentrations of radionuclides in soil and natural vegetation provide a baseline against which unplanned releases can be compared.

Soil and natural vegetation samples have been collected on and around the Hanford Site for almost 40 years. Consequently, a large database has been established that thoroughly documents onsite and offsite concentrations of manmade radionuclides in soil and natural vegetation at specific locations. Because the current Site mission is environmental restoration and cleanup, and because routine plutonium production operations have ceased, the need for continuous soil and natural vegetation surveillance has diminished. As a result, no soil or natural vegetation samples were collected by Pacific Northwest National Laboratory in 1995. Future sampling of soil and natural vegetation will be conducted on an as-needed basis in support of Site cleanup activities and facility operations.

There are several reasons for the reduced need for soil and natural vegetation sampling. Manmade radionuclides with short half-lives have decayed to stable isotopes and are no longer detected. Moreover, radionuclide releases from Hanford in recent years have been small, and therefore, baseline radionuclide concentrations have not changed appreciably for a number of years. Because only natural radionuclides or manmade radionuclides with relatively long half-lives presently are found in soil and vegetation samples, annual sitewide environmental surveillance sampling of soil and vegetation can be less frequent.

Other soil and vegetation sampling by Westinghouse Hanford Company near active facility release points and waste sites on the Site continued in 1995, and results are discussed in Section 3.2, "Near-Facility Environmental Monitoring."

In 1995, two reports were published that addressed radionuclides in soil and natural vegetation: a trend report of soil and vegetation surveillance data from 1983 through 1993 (Poston et al. 1995) and a special vegetation study of strontium-90 and cesium-137 concentrations in Carey's balsamroot (*Balsamorhiza careyana*) and desert parsley (*Lomatium grayi*) collected onsite in 1994 (Poston 1995). These reports are summarized below.

Radionuclide Concentration Trends in Soil and Vegetation 1983-1993

Concentrations of cobalt-60, strontium-90, cesium-137, uranium isotopes, plutonium isotopes, and americium-241 in soil and natural vegetation were evaluated for 1983 through 1993. Natural vegetation consists of the current year's growth of sagebrush and rabbitbrush. Radionuclide concentrations were evaluated to determine whether there were differences between study areas and whether there were changes over time, i.e., trends. Results from each area should not be construed as a characterization of the area. Characterization of radionuclide distribution in these areas was not the objective of the surveillance sampling design.

The data were grouped into five general locations: the 100 Areas, the 200 Areas, the 300 Area, the undeveloped areas onsite (600 Area), and offsite areas. Sampling locations onsite usually were chosen to monitor a specific facility or operational area and were generally selected to maximize the potential to identify elevated concentrations. Hence, slightly elevated concentrations of manmade radionuclides were expected in these areas. Specific observations on differences between study areas are listed below:

- The 100 Areas (primarily around the 100-N Area) had concentrations of cobalt-60 less than or equal to a nominal detection limit of 0.02 pCi/g; concentrations of cobalt-60 in all other study areas were not detected.

- The 200 Areas had slightly elevated concentrations of strontium-90, cesium-137, plutonium-238, plutonium-239,240, and americium-241 in soil compared to the other study areas. These general observations were also reflected in vegetation samples.

- Uranium concentrations were slightly elevated in soil samples from the 300 Area compared to the other study areas.

Over the 11-year study period, concentrations of cobalt-60, cesium-137, uranium isotopes, plutonium isotopes, and americium-241 in soil and natural vegetation did not change. Concentrations of strontium-90 in soil decreased over the study period in all five areas. The decrease was due to radiological decay and a downward migration of strontium-90 from the 1-in. (2.54-cm) soil sampling horizon. Decreasing strontium-90 concentrations were also noted in vegetation samples collected during the study period. Concentrations of other radionuclides in vegetation were consistently below detection and did not allow for evaluation of trends.

The concentrations of the radionuclides measured in soil and vegetation were well below levels considered hazardous to humans or wildlife. In many instances, onsite measurements were comparable to, or less than, offsite measurements. Offsite measurements exceeded onsite measurements in areas that historically received greater amounts of precipitation and consequently, greater amounts of fallout from weapons testing (Perkins and Thomas 1980).

Special Balsamroot and Desert Parsley Study

Traditionally, big sagebrush and rabbitbrush were routinely collected for surveillance activities. A special vegetation study was conducted in 1994 to determine the existing concentrations of strontium-90 and cesium-137 in Carey's balsamroot and desert parsley. These plants were sampled because they represent taxa that have not been sampled routinely in the past and may be of interest to the Tribes and Site stakeholders. The need for this information was driven by the anticipated transfer of the Fitzner/Eberhardt Arid Lands Ecology Reserve to another caretaker. Plant samples were collected on Rattlesnake Mountain on the Arid Lands Ecology Reserve and from land around the 100 and 200 Areas (Figure 4.6.1). Balsamroot leaves and roots were both sampled, but only leaves were collected from desert parsley. Results were compared to concentrations of radionuclides measured in composite samples of sagebrush and rabbitbrush foliage routinely collected in 1994. These data were sorted into onsite and offsite groups.

Radiological Results

Cesium-137 was found only in balsamroot, and almost exclusively in the roots, from all areas sampled (Figure 4.6.2). The concentrations of cesium-137 in balsamroot roots collected from the 200 Areas were greater than concentrations observed in samples collected on the Fitzner/Eberhardt Arid Lands Ecology Reserve. This observation is consistent with observations reported in prior years. Two of fourteen balsamroot leaf samples contained cesium-137 at concentrations slightly above the nominal detection limit (~0.05 pCi/g). The maximum and median onsite concentrations of cesium-137 in balsamroot leaves collected from the 200 Areas were 0.05 (±0.02) and 0.02 pCi/g, respectively. The maximum and median onsite concentrations (sampled outside of nuclear facility boundaries) of cesium-137 in routinely monitored vegetation sampled in 1994 were 0.03 (±0.02) pCi/g and 0.02 pCi/g, respectively. These results show that cesium-137 in the species collected are not elevated relative to cesium-137 concentrations in other desert vegetation that have been monitored historically.

Strontium-90 concentrations in these vegetation samples were highest in samples collected from the Fitzner/Eberhardt Arid Lands Ecology Reserve (Figure 4.6.3). The median concentration of strontium-90 was higher in balsamroot root tissue (0.34 pCi/g) compared to leafy portions of balsamroot (0.08 pCi/g) collected from the Fitzner/Eberhardt Arid Lands Ecology Reserve. Foliage concentrations of strontium-90 were similar to concentrations of strontium-90 associated with composite samples of sagebrush and rabbitbrush routinely collected at offsite locations. For comparison, the maximum concentration of strontium-90 in 1994 vegetation samples was 0.17 (±0.04) pCi/g from the 200 Areas. The median concentration was 0.04 pCi/g. The maximum and median concentrations of strontium-90 collected at offsite locations were 0.07 (±0.02) pCi/g and 0.04 pCi/g, respectively.

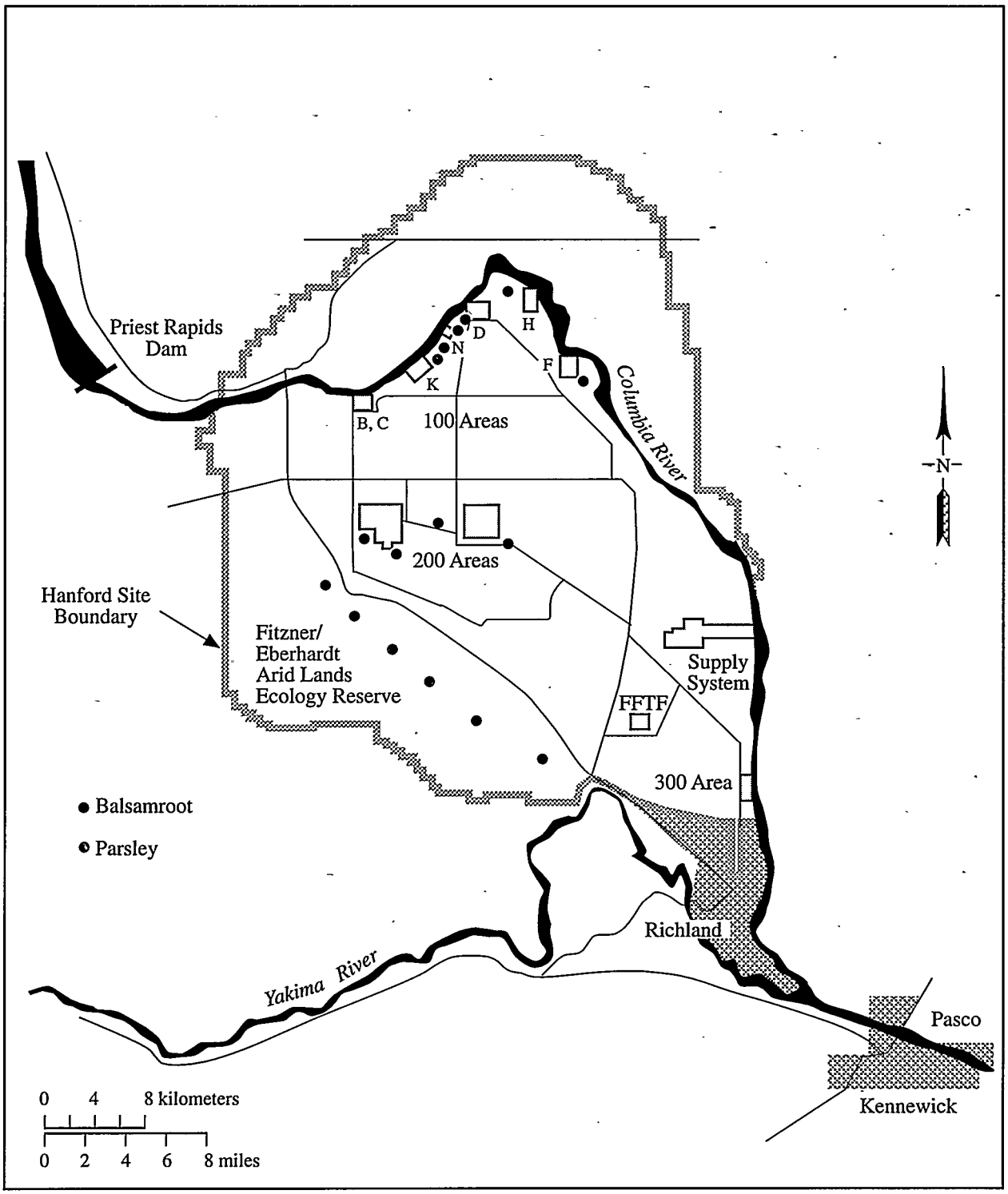

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Figure 4.6.1. Desert Parsley and Balsamroot Sampling Locations

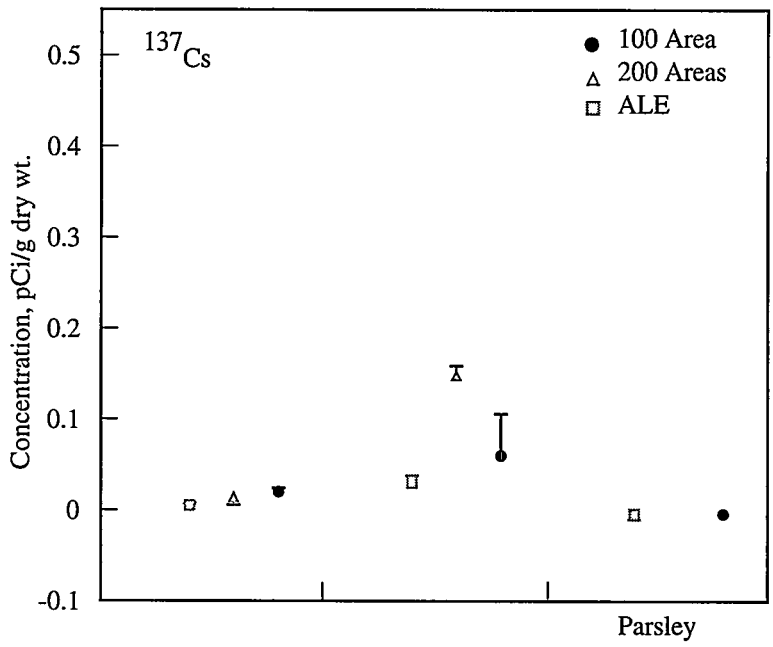

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Figure 4.6.2. Cesium-137 Concentrations (maximum, median, and minimum) in Balsamroot and Desert Parsley Collected on the Hanford Site in 1994. As a result of figure scale, some minimum and maximum values are concealed by the point symbol.

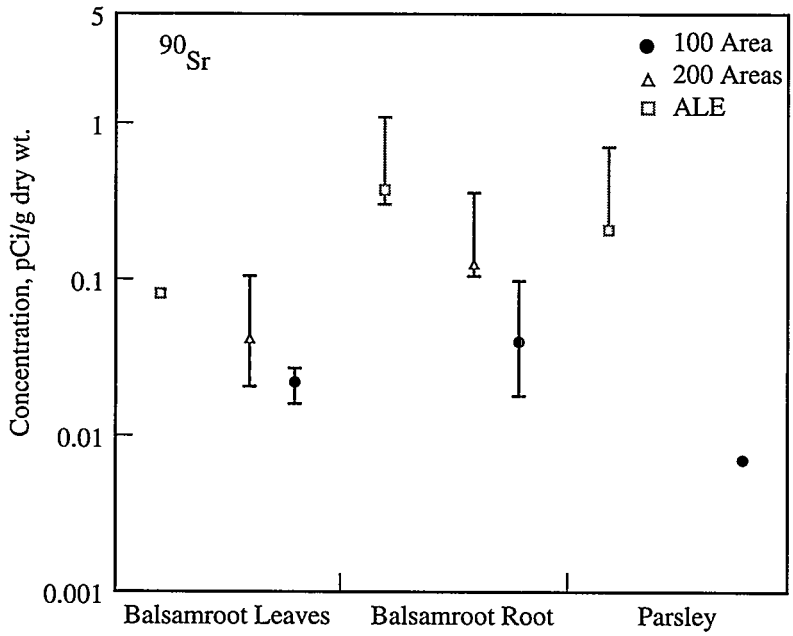

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Figure 4.6.3. Strontium-90 Concentrations (maximum, median, and minimum) in Balsamroot and Desert Parsley Collected on the Hanford Site in 1994. As a result of figure scale, some minimum and maximum values are concealed by the point symbol.

4.7 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. During any year, external radiation levels can vary from 15% to 25% at any location because of changes in soil moisture and snow cover (NCRP 1987).

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. For ease of comparison, one Gy is equivalent to 100 rad.

Thermoluminescence, or light output exhibited by thermoluminescent dosimeters, 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.

$$D\ (\text{rad}) \approx X\ (R) * 1.0$$

$$H\ (\text{rem}) \approx D * N * Q$$

To convert to SI units of Gy and Sv, divide rad and rem by 100, respectively.

External radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters. 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

In January 1995, a new Harshaw 8800 series system replaced the old Hanford standard environmental dosimeter system. The Harshaw dosimeter consists of two TLD-700 and two TLD-200 chips. This dosimeter provides both shallow- and deep-dose measurement capabilities. Thermoluminescent dosimeters are positioned one meter (3.3 ft) above the ground at various locations onsite (Figure 4.7.1), around the Site perimeter, in nearby and distant communities, (Figure 4.7.2), and along the Hanford Reach of the Columbia River (Figure 4.7.3). The thermoluminescent dosimeters are collected and read quarterly. The two 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 thermoluminescent dosimeter was in the field. The two TLD-200 chips are included to determine doses in the event of a radiological emergency.

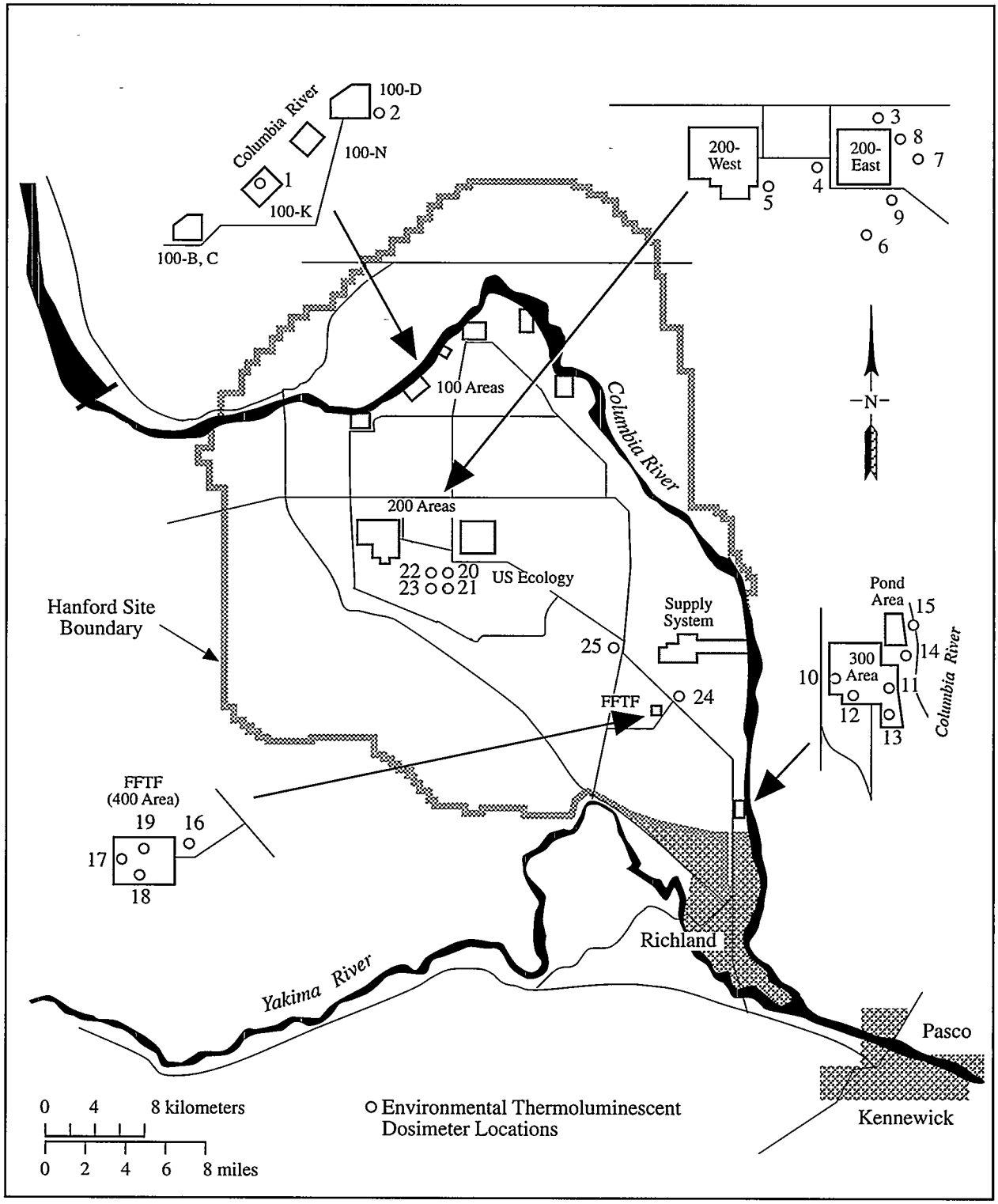

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Figure 4.7.1. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 1995

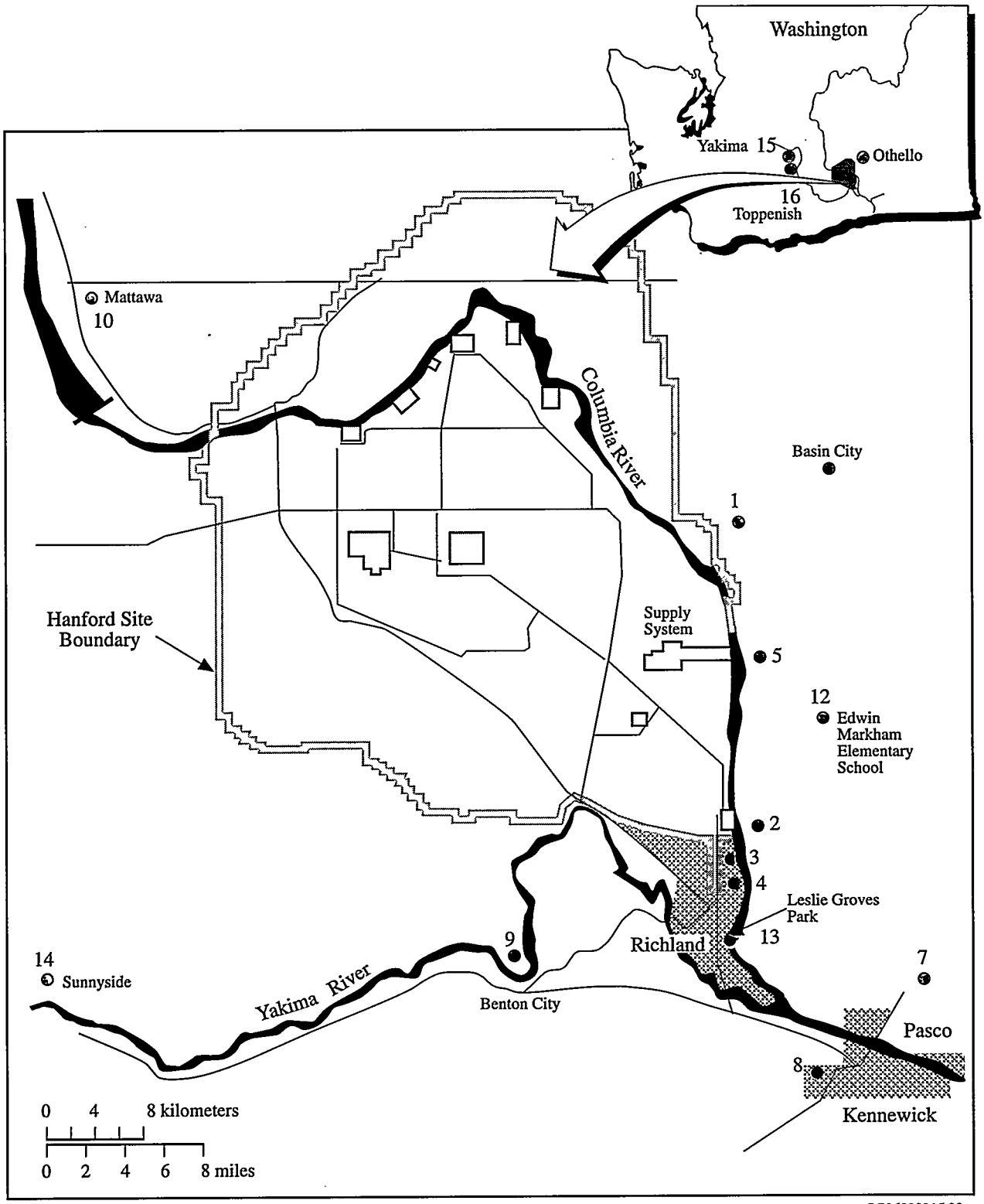

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Figure 4.7.2. Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 1995

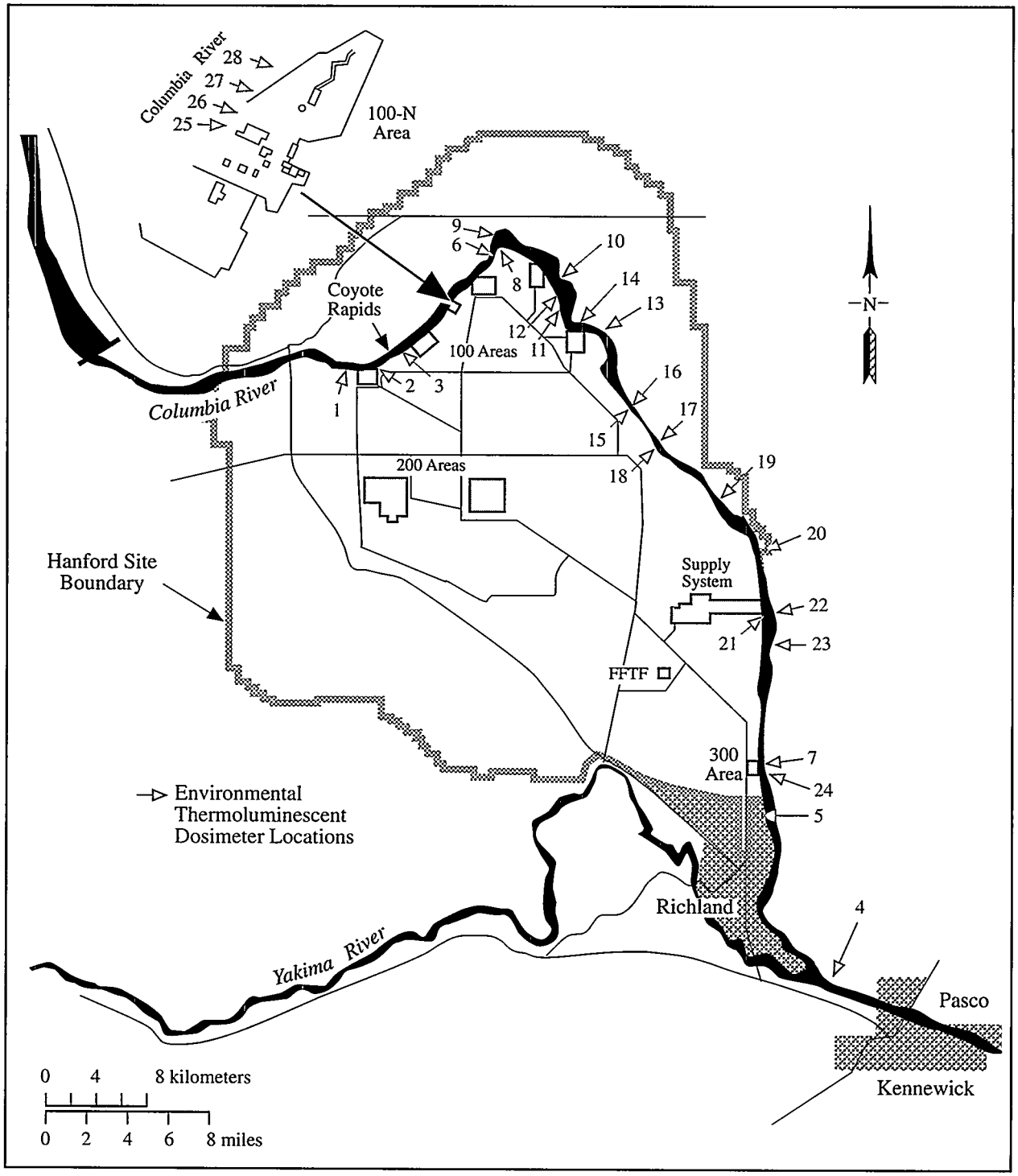

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Figure 4.7.3. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Reach of the Columbia River, 1995

All community, and most of the onsite and perimeter locations, are collocated with air monitoring stations, including the eight community-operated environmental surveillance stations identified in Section 4.1, "Air Surveillance." 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.

Twenty-eight thermoluminescent dosimeter locations have been established on the Columbia River shoreline, from upstream of the 100-B Area to just downstream of Bateman Island at the mouth of the Yakima River. The 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 thermoluminescent dosimeters. Thermoluminescent dosimeter exposures have been converted to dose equivalent rates by the process described above. Table 4.7.1 shows maximum and average dose rates for perimeter and offsite locations measured in 1995 and the previous 5 years. Quarterly dose equivalent rates (mrem/day) at each location were converted to annual dose equivalent rates (mrem/yr) by averaging the quarterly dose rates and multiplying by 365 days/yr. External dose rates reported in Tables 4.7.1 through 4.7.3 include the maximum annual average dose rate (±2 standard error of the mean) for all locations within a given area, and the mean dose rate (±2 standard error of the mean) for each area. The mean dose rates were computed by averaging annual means for each location within an area.

In 1995, the average perimeter external radiation dose rate was 86 ± 8 mrem/yr, while in 1994, the average was 110 ± 9.2 mrem/yr (Table 4.7.1). This 23% reduction in the exposure rate for the year may be attributed to the new Harshaw environmental dosimeter used in 1995. The new dosimeters are packaged in a holder that has an O-ring seal and is more opaque than the previous system. The newer packaging provides protection from light, moisture, and dirt and may improve the low-dose performance of the new system. Variations in natural background radiation can also 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 the annual dose rates reported here may include variations in the sensitivity of individual thermoluminescent dosimeter zero-dose readings, fading, random errors in the readout equipment, procedural errors (Rathbun 1989), and changes in thermoluminescent dosimeter station locations.

Table 4.7.1. Average and Maximum External Dose Rates Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations, 1995 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1995		1990-1994		
Sampling Area	Map Locations[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Perimeter	1 - 5	93 ± 2	86 ± 8	40	120 ± 17	94 ± 4
Nearby communities	6 - 13	88 ± 4	76 ± 4	41	106 ± 16	88 ± 3
Distant communities	14 - 16	78 ± 2	72 ± 8	16	100 ± 11	86 ± 4

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 4.7.2.
(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.

Table 4.7.2. Average and Maximum External Dose Rates Measured Along the Hanford Reach of the Columbia River, 1995 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1995		1990-1994		
Sampling Area	Map Locations[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Typical shoreline	1 - 24	114 ± 4	90 ± 3	116	167 ± 5	104 ± 4
100-N Shoreline[e]	25 - 28	187 ± 7	175 ± 12	20	356 ± 143	225 ± 27
All shoreline		187 ± 7	103 ± 12	136	356 ± 143	122 ± 3

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 4.7.3.
(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 4.7.3. Average and Maximum External Dose Rates for Thermoluminescent Dosimeter Locations on the Hanford Site, 1995 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1995		1990-1994		
Sampling Area	Map Locations[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
100 Areas	1 - 2	86 ± 2	79 ± 14	15	120 ± 35	94 ± 6
200 Areas	3 - 9	93 ± 3	88 ± 3	42	121 ± 10	97 ± 3
300 Areas	10 - 15	88 ± 4	84 ± 3	30	110 ± 18	94 ± 3
400 Areas	16 - 19	87 ± 3	84 ± 3	22	111 ± 18	94 ± 4
600 Areas	20 - 25	135 ± 9	102 ± 16	31	183 ± 16	110 ± 10
Combined Onsite		135 ± 9	86 ± 4	140	183 ± 16	98 ± 3

(a) Quarterly integrated readings in mrem were converted to annual dose equivalent rates.
(b) Locations are identified in Figure 4.7.1.
(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.

The average background external radiation dose rate (in distant communities) in 1995 was 72 ± 8 mrem/yr as compared to the perimeter average of 86 ± 8 mrem/yr. This 15% difference in exposure rate may be partially 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]), to variations resulting from human activity, or to use of the new dosimetry system for the reasons stated above. Human activities affecting the average dose rates may include landscape modifications such as buildings and other construction, which may shield a portion of the terrestrial component. Figure 4.7.4 graphically displays a comparison between, and trends of, onsite, perimeter,

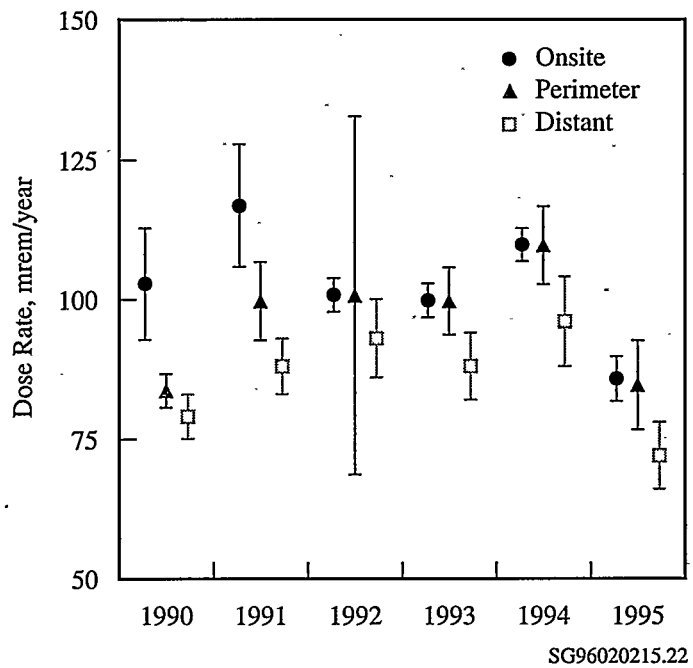

Figure 4.7.4. Annual Average Dose Rates (±2 standard error of the mean), 1990 Through 1995

and distant thermoluminescent dosimeter locations during 1990 through 1995. Year-to-year variability is possible for the reasons outlined above, and 10% annual variability is possible (NCRP 1987).

Figure 4.7.3 shows locations of thermoluminescent dosimeters positioned along the Columbia River shoreline, and Table 4.7.2 shows the maximum and average measured dose rates for shoreline locations. Dose rates were highest near the 100-N Area shoreline and two to three times higher than typical shoreline dose rates. The high rates measured in the 100-N Area historically have been attributed to past waste management practices in that area. In 1995, however, third quarter thermoluminescent dosimeter readings showed a marked increase in the 100-N shoreline exposures. The increase was due to work that took place in August. This work involved removing reactor core fuel spacers from a storage vault (silo), transferring them to rail cars, and shipping them to another location. These spacers were radioactively "hot" and were the cause of elevated thermoluminescent dosimeter readings at shoreline sites near the 105-N building. The maximum quarterly reading from the 100-N Area shoreline was 405 mrem/yr for the third quarter thermoluminescent dosimeter at the station below the 100-N stack. 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 5.0, "Potential Radiation Doses from 1995 Hanford Operations."

Table 4.7.3 summarizes the results of 1995 measurements, which are grouped by operational area. The average dose rates in all operational areas were higher than average 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 1995, hand-held survey instruments were used to perform radiation surveys at selected Columbia River shoreline thermoluminescent dosimeter 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 3 to 20 µrem/h. Survey information is not included in the 1995 data volume (Bisping 1996), but is maintained in the Surface Environmental Surveillance Project files at Pacific Northwest National Laboratory and can be obtained by written request.

Gamma Radiation Measurements

During 1995, gamma radiation levels in air were continuously monitored at three community-operated air monitoring stations. These stations were located in Leslie Groves Park in Richland, at Edwin Markham Elementary School in north Franklin County, and at Basin City Elementary School (see Figure 4.1.1). Measurements were collected to determine ambient gamma radiation levels near and downwind of the Hanford Site, to display real-time exposure rate information to the public living near the station, and to be an educational aid for the teachers who manage the stations (see Section 6.4, "Community-Operated Environmental Surveillance Program").

Measurements at Basin City and Edwin Markham schools were obtained using Reuter-Stokes Model S-1001-EM19 pressurized ion chambers connected to Reuter-Stokes RSS-112 Radiation Monitoring Stations. Data were collected every 5 seconds, and an average reading was recorded on an electronic data card every 30 minutes. Data cards were exchanged monthly. Readings at Leslie Groves Park were collected every 10 seconds with a Reuter-Stokes Model RSS-121 pressurized ion chamber, and an average reading was recorded every hour by a flat panel computer system manufactured by Computer Dynamics. Data were obtained from the computer monthly via modem. Data were not collected at every station every month because of problems with instrument batteries and equipment failures that were caused by high ambient air temperatures. The computer at Leslie Groves Park was inoperable for several months when the hard drive failed and had to be replaced.

Table 4.7.4. Average Exposure Rates Measured with Pressurized Ion Chambers at Three Offsite Locations

	Average Exposure Rate (μR/h)[a](number of readings)[b]		
Sampling Locations[c]	Leslie Groves Park[d]	Basin City[e]	Edwin Markham[e]
Month			
January	8.9 ± 0.7 (743)	ND[f]	8.9 ± 0.6 (1,493)
February	8.6 ± 0.6 (473)	8.3 ± 0.5 (1,342)	ND
March	ND	8.4 ± 0.4 (1,555)	8.7 ± 0.5 (1,358)
April	8.6 ± 0.3 (261)	8.4 ± 0.4 (1,356)	ND
May	8.5 ± 0.3 (162)	ND	ND
June	ND	8.3 ± 1.3 (819)	ND
July	ND	ND	8.5 ± 0.3 (1,443)
August	ND	ND	ND
September	ND	8.3 ± 0.5 (1,081)	8.6 ± 0.4 (1,662)
October	8.7 ± 0.5 (290)	8.3 ± 0.5 (982)	8.7 ± 0.4 (1,263)
November	8.6 ± 0.6 (721)	8.4 ± 0.4 (1,445)	8.8 ± 0.4 (1,444)
December	8.7 ± 0.6 (745)	8.4 ± 0.5 (1,480)	8.8 ± 0.5 (1,567)

(a) Averages are ±2 times the standard error of the mean.
(b) Number of 30- or 60-minute averages used to compute monthly average.
(c) Sampling locations are illustrated in Figure 4.1.1.
(d) Readings are stored every 60 minutes. Each 60-minute reading is an average of 360 individual measurements.
(e) Readings are stored every 30 minutes. Each 30-minute reading is an average of 360 individual measurements.
(f) Equipment problems, no data collected.

The measurements recorded at all three locations during the year were similar and unremarkable. Thirty- and 60-minute averages ranged from 11.7 microroentgen per hour (μR/h) at Edwin Markham School for January and September to 7.2 μR/h in Leslie Groves Park in November. Average monthly readings at all stations were consistently between 8.3 and 8.9 μR/h (Table 4.7.4). These dose rates are consistent with the dose rates measured by the thermoluminescent dosimeters located at these stations and are comparable to the dose rates measured with thermoluminescent dosimeters at distant (background) stations.

4.8 Ground-Water Protection and Monitoring Program

P. E. Dresel, W. D. Webber, P. D. Thorne, and S. P. Luttrell

The strategy for protecting ground water at the Hanford Site is presented in the *Hanford Site Ground Water Protection Management Plan* (DOE 1995d). 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 the Hanford Site monitor and document ground-water quality to effectively meet the needs of these elements. The monitoring programs are designed to document the distribution and movement of ground-water contamination and to assess the movement of contamination into previously uncontaminated areas. Monitoring provides the historical baseline for evaluating current and future risk from exposure to ground-water 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.

The effort to protect ground-water quality at the Hanford Site 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 the Tri-Party Agreement, which 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."

The DOE has prepared a *Plan and Schedule to Discontinue Disposal of Liquids Into the Soil Column at the Hanford Site* (DOE 1987), which presents a plan for providing alternative treatment and disposal of contaminated effluent discharged to the soil. Of the 33 major waste streams identified, the Phase I (higher priority) streams have either been eliminated or are being treated before diverting them to a treated effluent disposal facility, which is located east of the 200-East Area. In addition, process condensate from the 242-A Evaporator is discharged to a state-approved facility (C-018H) north of the 200-West Area after treatment at the 200 Area Effluent Treatment Facility. These facilities are discussed in detail in Section 2.3, "Current Issues and Actions." Significant reductions in disposal of liquids to soil have occurred recently. For example, in 1987 over 23 billion L (6 billion gal) of liquid effluents were discharged to the soil column. Less than 11 billion L (3 billion gal) were discharged annually as of 1993. This was reduced to approximately 4.9 billion L (1.3 billion gal) in 1995. The rate was approximately 25 L/s (400 gal/min) by late 1995 (DOE 1995d), which equates to an annual volume of approximately 790 million L (210 million gal). The locations and status of Phase I streams are shown in Figure 4.8.1. Ground water is pumped for drinking water and other uses at a few locations on the Hanford Site. Drinking water supplies are monitored at the point of use by ICF Kaiser Hanford Company and Pacific Northwest National Laboratory. Results of the radiological monitoring conducted by Pacific Northwest National Laboratory are summarized in Section 4.3, "Hanford Site Drinking Water Surveillance." Water samples are collected directly from water supply wells by the Ground-Water Surveillance Project. The locations of wells completed in the unconfined aquifer that are used for water supplies are shown in Figure 4.8.2.

Hydrogeology

The Hanford Site lies within the Pasco Basin, one of several 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 4.8.3).

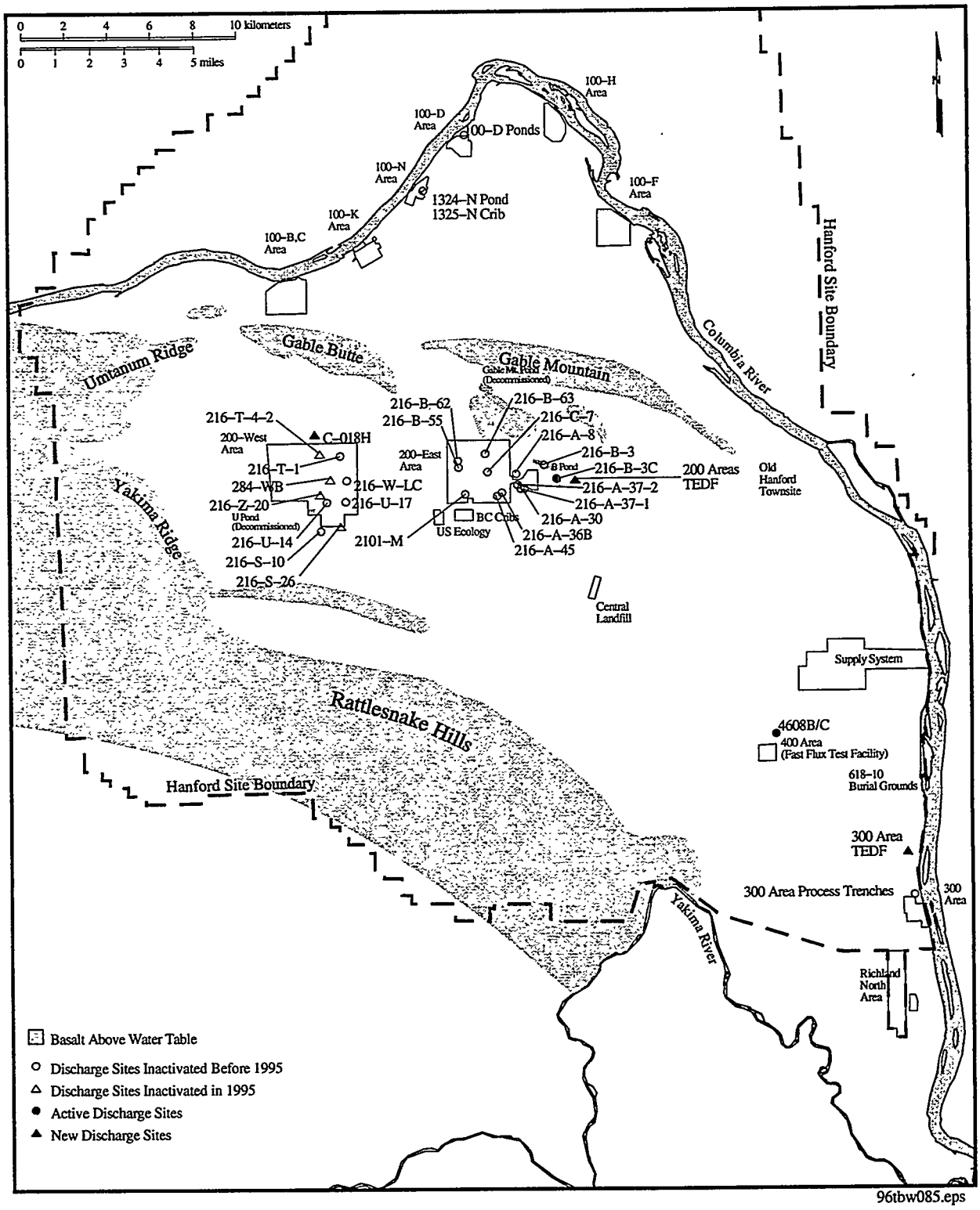

Figure 4.8.1. Disposal Facilities for the Major Liquid Waste Streams at the Hanford Site

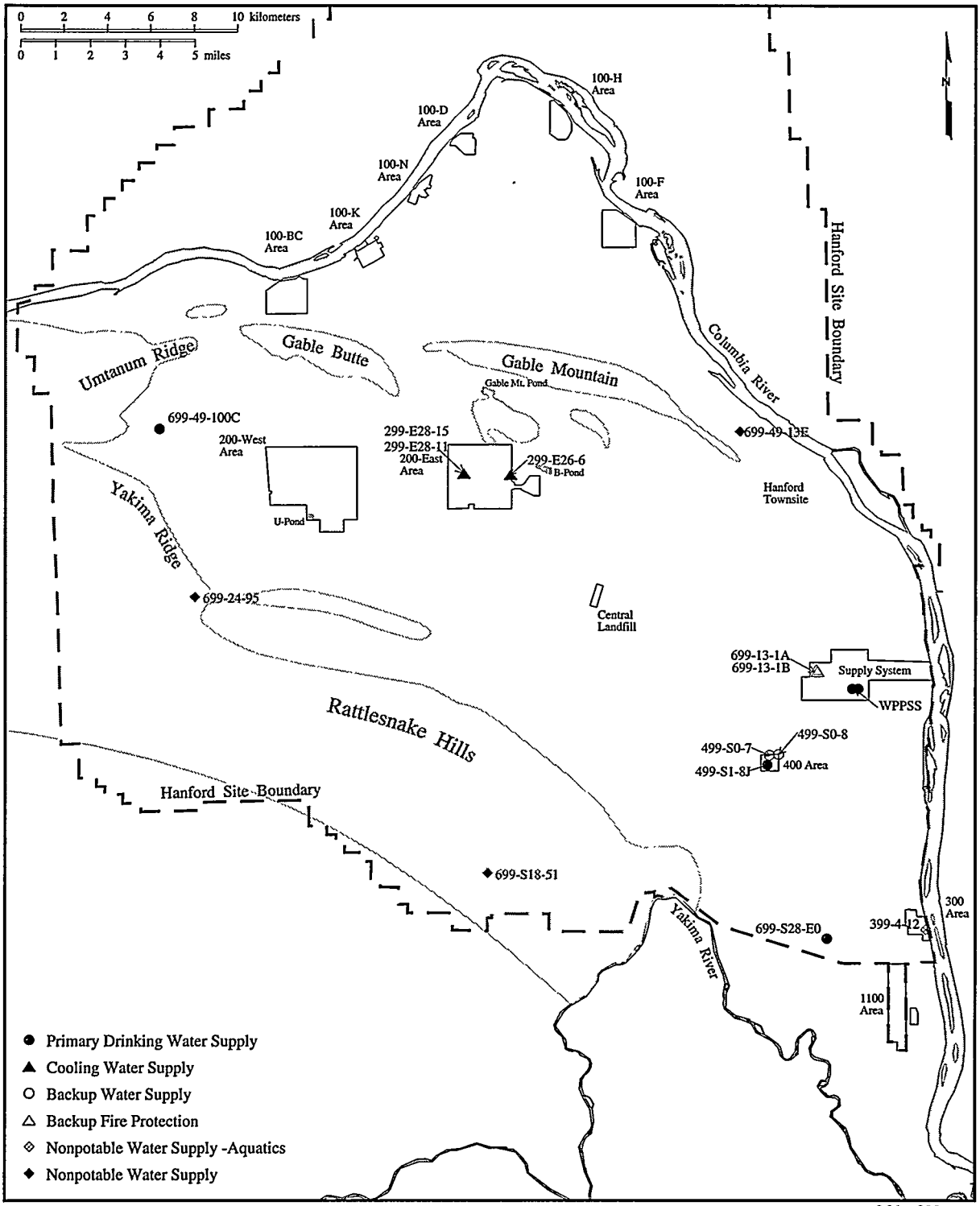

Figure 4.8.2. Water Supply Wells in the Unconfined Aquifer at the Hanford Site

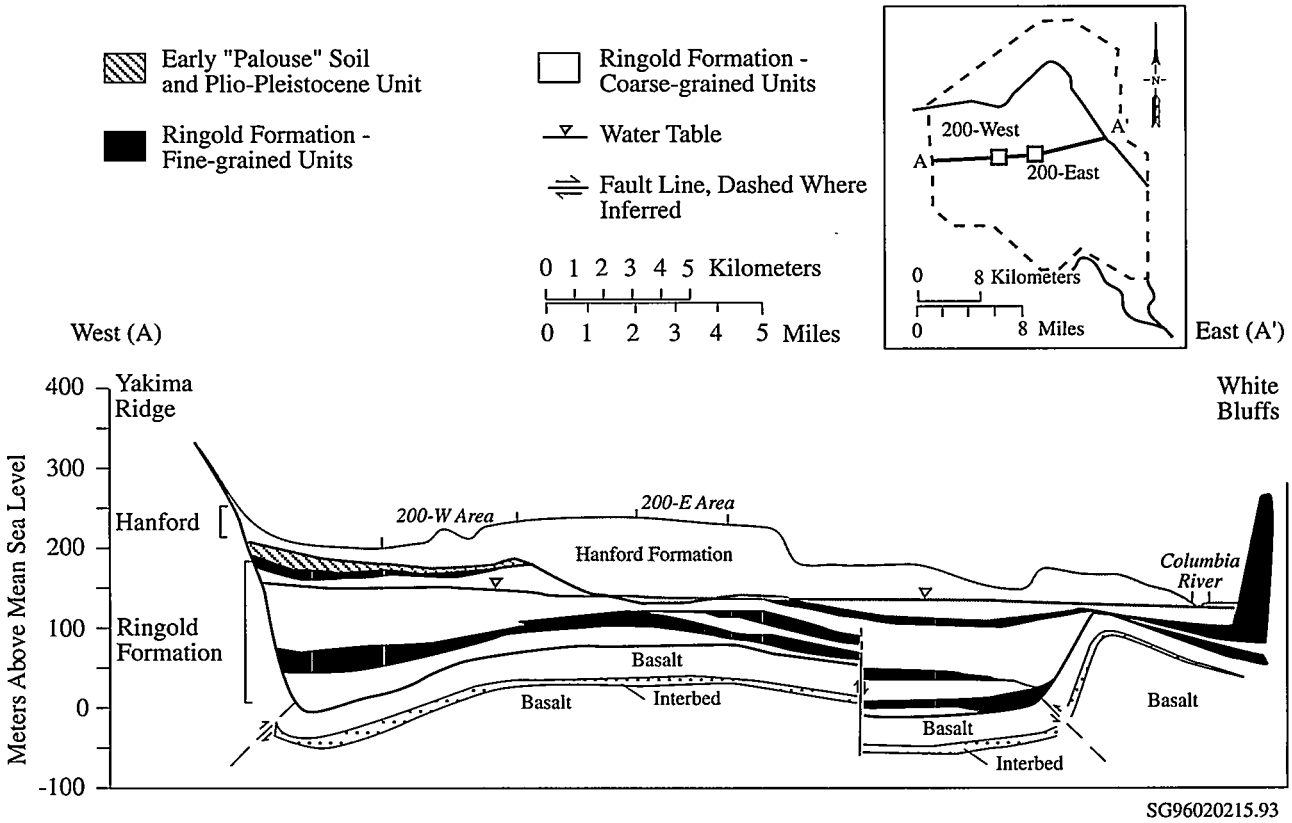

Figure 4.8.3. Geologic Cross Section of the Hanford Site

The Columbia River basalts were formed from lava that periodically erupted from volcanic fissures starting about 17 million years ago and continuing until about 8.5 million years ago. The regional river system eroded the basalt and deposited sediments across the basalt surfaces between eruptions. Zones between the basalt flows and the sediments deposited as interbeds between basalt eruptions are frequently water-bearing zones that are used as water sources in areas around the Hanford Site.

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. After the last major basalt eruption, the Ringold Formation was deposited by the ancestral Columbia River as it meandered back and forth across the relatively flat basalt surface depositing sand and gravel in the central portion of the Pasco Basin. Two major interruptions that occurred when the Columbia River was blocked downstream caused a lake to develop in the Pasco Basin. Relatively thick mud layers accumulated in the lake each time. About 3.4 million years ago, the Columbia River began to erode, rather than deposit, sediments in the Pasco Basin. The uppermost mud layer was eroded from much of the Pasco Basin and a caliche layer, part of the Plio-Pleistocene unit, developed in places on the eroded surface of the Ringold Formation.

The Hanford formation sediments were deposited by catastrophic ice age floods during the past 700,000 years. Fine sands and silts were deposited in slack-water areas at the margins of the basin. However, primarily sand and gravel were deposited on the Hanford Site. 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 at the Hanford Site 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 clay and silt layers above.

Unconfined aquifers, or water-table aquifers, are overlain by unsaturated sediments. In general, the unconfined aquifer at Hanford is located in the Ringold Formation and the Hanford formation. In some areas, the water table (the upper surface of the unconfined aquifer) is below the bottom of the Hanford formation and the unconfined aquifer is entirely within the Ringold Formation. The Hanford formation sands and gravels are unconsolidated and are generally much more permeable than the compacted and silty Ringold Formation gravels. Clay and silt units form low-permeability zones in the Ringold Formation.

The unconfined aquifer forms the uppermost ground-water zone and has been directly impacted by waste-water disposal at the Hanford Site. For this reason, it is the most thoroughly monitored aquifer beneath the Site. The Rattlesnake Ridge Interbed is the uppermost, widespread basalt-confined aquifer within the Pasco Basin and the Hanford Site. This aquifer and other basalt-confined aquifers are generally isolated from the unconfined aquifer by dense rock that forms the interior of the basalt flows. However, interflow between the unconfined aquifer and the basalt-confined aquifer system is known to occur at 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). Additional information on the basalt-confined aquifer system can be found in Spane and Webber (1995) and Spane and Vermeul (1994).

The thickness of saturated sediments above the basalt bedrock is greater than 200 m (656 ft) in some areas of the Hanford Site and thins out along the flanks of the basalt ridges (Figure 4.8.4). 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 within the Ringold Formation. The water table defines the upper boundary of the unconfined aquifer. Laterally, the unconfined aquifer is bounded by basalt ridges 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 east and north of the Columbia River is shown in Figure 4.8.5.

The water-table elevation contours shown in Figure 4.8.5 indicate the direction of ground-water flow and the magnitude of the 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, because sediments with low permeabilities inhibit ground-water flow and produce steeper gradients, a 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 bottom of the Hanford formation. Figure 4.8.6 shows the generalized distribution of transmissivity as determined from ground-water flow model calibration.

Recharge of water within the unconfined aquifer comes 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 the Hanford Site. The unconfined aquifer is also recharged by the Yakima River where it flows along the southern boundary of the Hanford Site. The Columbia River is the primary discharge area for the unconfined aquifer. However, the Columbia River also recharges the unconfined aquifer for short periods during high river stage when river water is transferred into the aquifer along the riverbank. Ground water discharges to the surface north of the 200-East Area forming West Lake. West Lake is a small saline water body formed in a closed depression. The size of West Lake fluctuates in response to changes

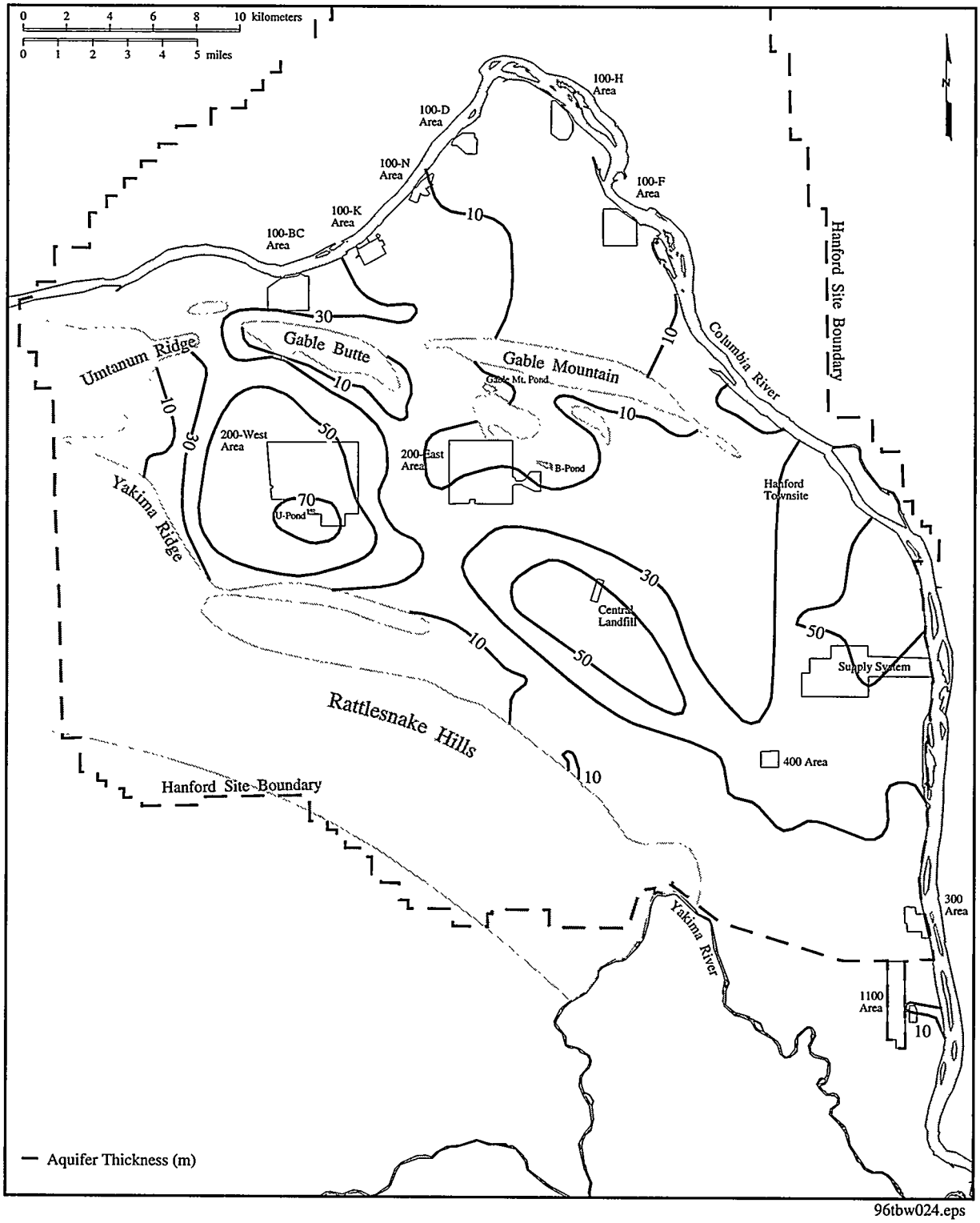

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Figure 4.8.4. Saturated Thickness of the Unconfined Aquifer at the Hanford Site

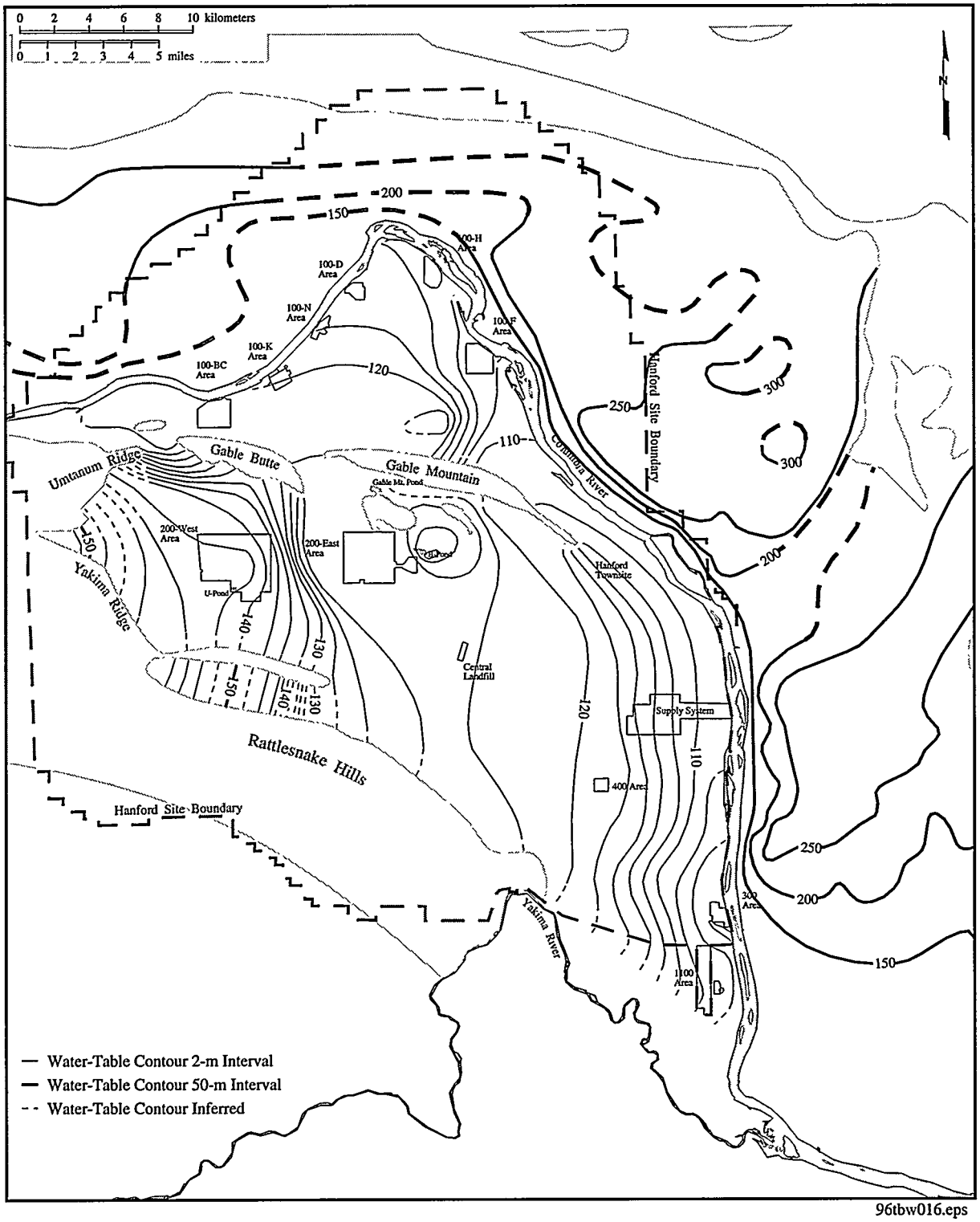

Figure 4.8.5. Water-Table Elevations for the Unconfined Aquifer at Hanford and in Adjacent Areas East and North of the Columbia River, June 1995

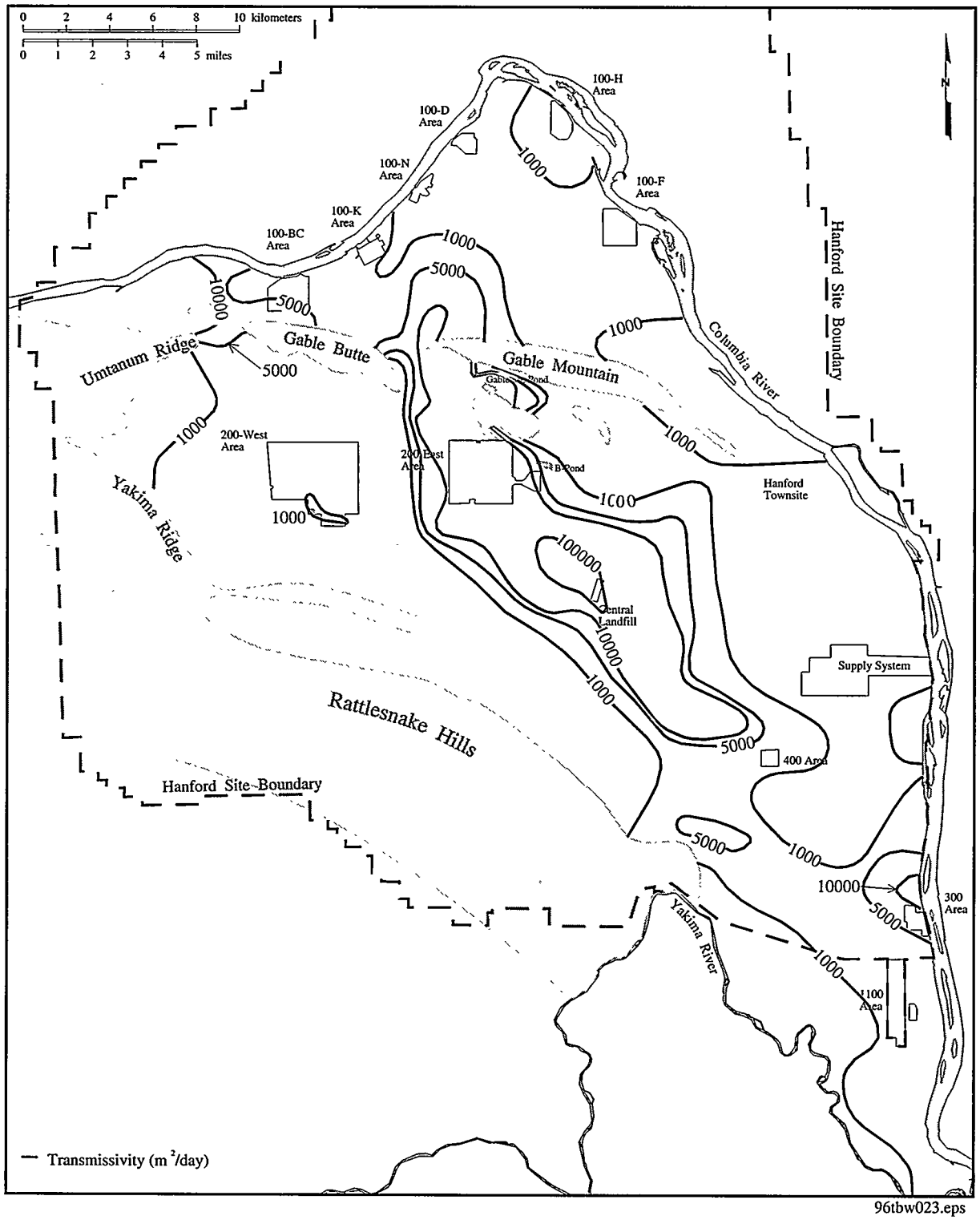

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Figure 4.8.6. Distribution of Transmissivity of the Unconfined Aquifer at the Hanford Site

in the water table (Posten et al. 1991). Site discharge has influenced the size of West Lake. Sampling of West Lake is discussed in Section 4.2, "Surface Water and Sediment Surveillance." Recharge from infiltration of precipitation is highly variable on the Hanford Site and depends on soil texture, vegetation, and climate (Gee et al. 1992, Fayer and Walters 1995). 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. Discharge of waste water has caused the water table to rise over most of the Hanford Site. Local areas with elevated water tables are called ground-water mounds. Figure 4.8.7 shows the change in water table elevations between 1948 and 1979, when the water table had stabilized over most of the Site. During the past 10 years, water-table elevations have declined in response to a decrease in liquid-waste discharges from Hanford operations. The change in water table elevations from 1979 to 1995 is shown in Figure 4.8.8. Irrigation in the Cold Creek Valley has increased water levels in this area west of the Hanford Site. Recharge from the Cold Creek Valley irrigation enters the Hanford Site as ground-water flow across the western boundary. Recharge from irrigation and canal leakage in agricultural areas across the Columbia River from the Hanford Site has caused larger water table increases than those on the Hanford Site. As indicated in Figure 4.8.5, the water-table elevation to the east of the Columbia River is currently from 50 to 150 m (328 to 492 ft) higher than the water-table elevation on the Hanford Site.

Two major ground-water mounds formed in the 200 Areas in response to waste-water discharges. The first of these mounds was created by disposal at U Pond in the 200-West Area. This mound is slowly dissipating because the pond was decommissioned in 1984. The second major mound was created by discharge to B Pond, east of the 200-East Area. The water-table elevation near B Pond increased to a maximum of about 9 m (29 ft) above pre-operational conditions 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 continually changed as a result 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 and high permeability.

In the 100 and 300 Areas, and other locations near the river, ground-water levels are influenced by river stage. Water levels in the Columbia River fluctuate on annual and 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 flows from the river into the aquifer when the river stage is high and flows in the opposite direction when the river stage is low. This produces some dilution of contaminants near the river. However, the pressure effects of river stage variation are observed much farther inland (up to 1.6 km [1 mi] in places) than the river water actually travels.

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 of the ground-water contamination onsite resulted from discharge of waste water from Site processes. Table 4.8.1 lists major contaminants found in each area and the type of operation that generated the contaminants. 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. In the 200 Areas, large quantities of contaminated water from fuel processing were discharged. 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 the discharge of large amounts of chemicals in a liquid organic chemical form. In particular, carbon tetrachloride was discharged in the 200-West Area in a liquid organic chemical form. This liquid, once in contact with ground water, slowly dissolves

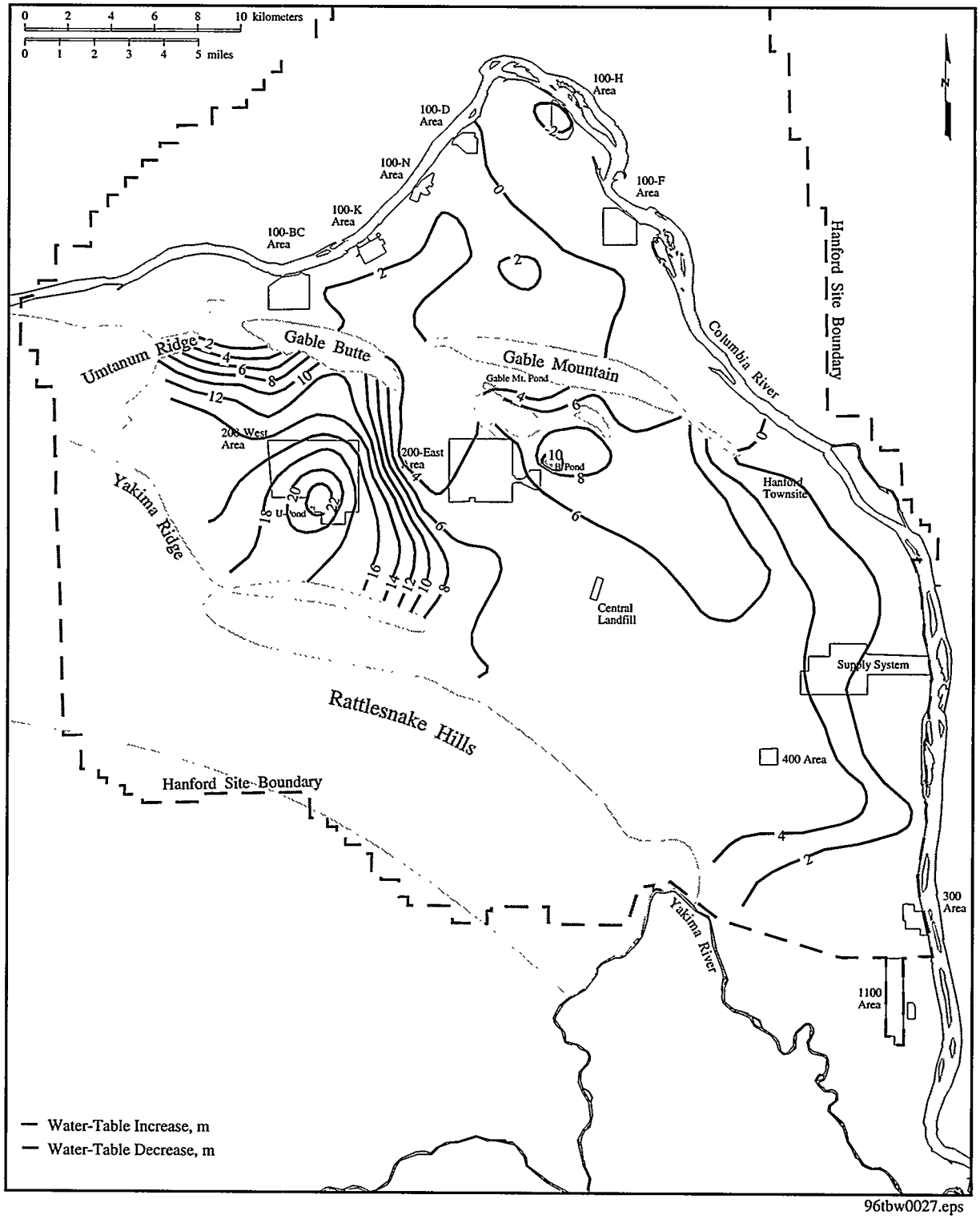

Figure 4.8.7. Change in Water-Table Elevations Between 1944 and 1979

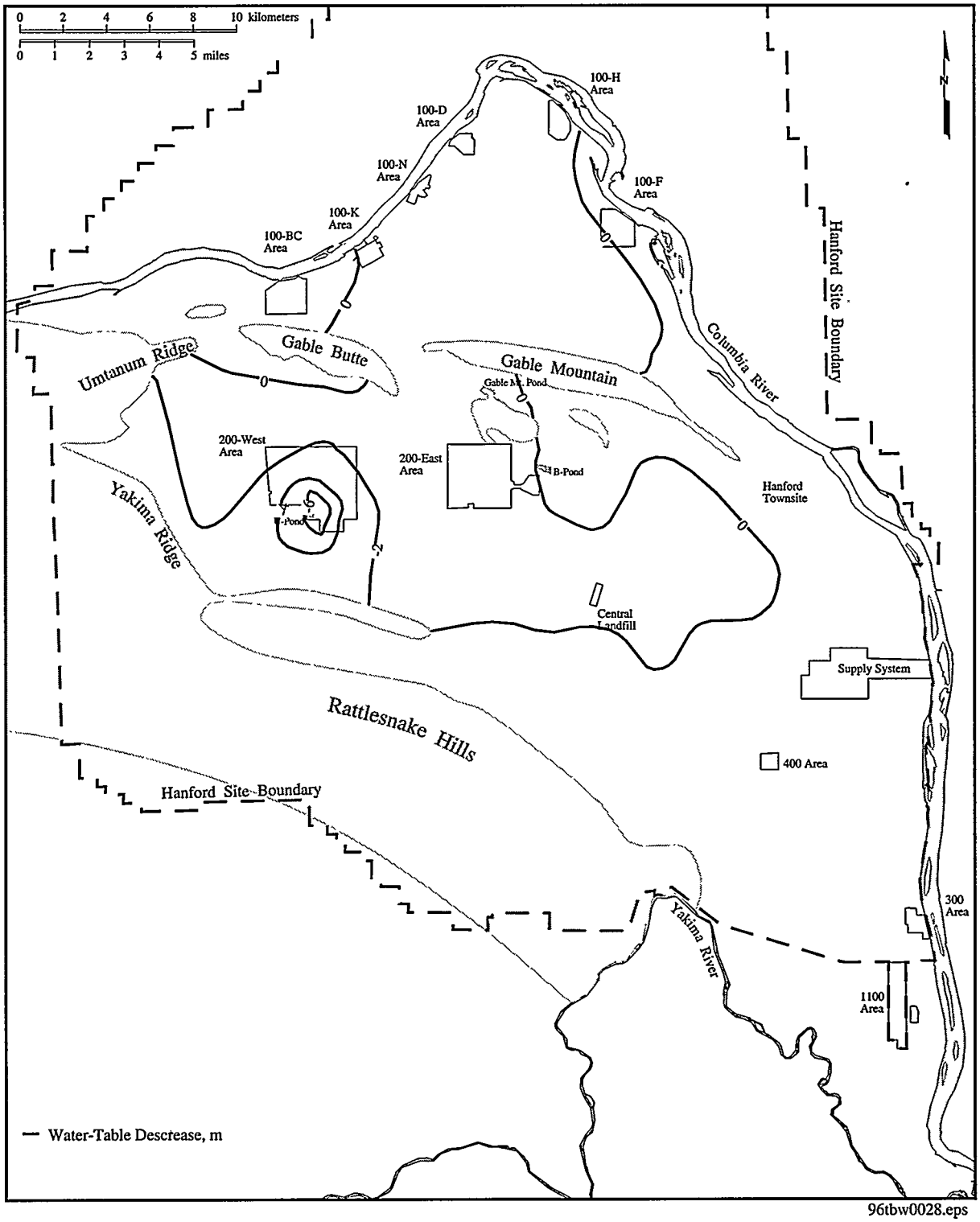

Figure 4.8.8. Change in Water-Table Elevations Between 1979 and 1995

Table 4.8.1. 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^{+6}, F^-, NO_3^-
Plutonium purification	200	Pu, ^{241}Am, carbon tetrachloride, chloroform, NO_3^-
Fuel fabrication	300	^{99}Tc, U, Cr^{+6}, Cu, trichloroethylene

and produces ground-water contaminant plumes. The presence of non-aqueous phase liquid has a major impact on the Site's ground-water remediation strategy because the organic liquid in the subsurface represents a continuing source of ground-water contamination but is very difficult to clean up. Ground-water contamination in the 300 Area was mainly from discharge of wastes from fuel fabrication. Historically, the discharge water during Site operations had a major impact on ground-water flow beneath Hanford and thus affected the rate and direction of contamination spread. The effects of discharge have been dissipating since production operations ceased.

Liquid effluents discharged to the ground at Hanford facilities percolated downward through the unsaturated zone toward 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 to saturate the soil column to the surface.

Not all contaminants move 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, and 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 reduced further 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 just below 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 Monitoring

Ground-water monitoring at the Hanford Site is an integral part of the *Hanford Site Ground-Water Protection Management Plan* (DOE 1995d). The plan integrates monitoring at active waste disposal facilities to comply with the Resource Conservation and Recovery Act, operational monitoring in and adjacent to reactor and chemical processing facilities, and environmental surveillance. Monitoring is also carried out during cleanup investigations under the Comprehensive Environmental Response, Compensation, and Liability Act programs (DOE 1992d). The Resource Conservation and Recovery Act and operational monitoring programs are managed by the Site operating contractor. The Comprehensive Environmental Response, Compensation, and Liability Act investigations are managed by the Environmental Restoration Contractor. Additional details on Resource Conservation and Recovery Act-compliant monitoring are presented in Section 2.0, "Environmental Compliance Summary."

The Hanford Ground-Water Surveillance Project 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 project integrates information on contaminant distribution and transport into a sitewide evaluation of ground-water quality.

Collection and Analysis of Ground-Water Samples

Ground-water samples were collected as part of the Hanford Ground-Water Surveillance Project and other monitoring programs. The Hanford Ground-Water Surveillance Project uses data from other programs to provide a more complete interpretation. Monitoring data from past years supplement the current analyses and allow for the evaluation of trends through time. Wells monitored by the various programs are shown in Figures 4.8.9 and 4.8.10. These figures indicate only well names that are specifically discussed in the text. Due to the high concentration of unconfined aquifer wells in the operational areas, only 600-Area unconfined aquifer wells are shown. Other unconfined aquifer wells called-out in the text are shown on detailed maps for those areas in the following sections. Ground-water monitoring was conducted at the facilities shown in Figure 4.8.11 to comply with the Resource Conservation and Recovery Act (Hartman 1996).

Ground-water samples were collected from approximately 800 wells for all monitoring programs during 1995. The Ground-Water Surveillance Project sampled 499 wells. 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, approximately 270 were sampled once, 280 were sampled twice, 100 were sampled three times, 90 were sampled four times and 60 were sampled more frequently during the year. Wells at the Hanford Site generally follow a naming system in which the well name indicates the approximate location of the well. The prefix of the well name indicates the area of the Site, as shown in Table 4.8.2. The well names for 600-Area wells follow a local coordinate system in which the numbers indicate the distance relative to an arbitrary datum location in the south-central part of the Site.

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 1.4 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, with the open interval 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 basalt 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 Resource Conservation and Recovery Act monitoring projects and Comprehensive Environmental Response, Compensation, and Liability Act characterizations have been constructed with stainless-steel casing and screens. 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 1986a). Analytical techniques used are listed in Dresel et al. (1995), the *Environmental Monitoring Plan* (DOE 1994a), and Comprehensive Environmental Response, Compensation, and Liability Act work plans. The radionuclides and chemicals analyzed are listed in Table 4.8.3. Several of the parameters listed in Table 4.8.3 were not measured during 1995 because sufficient characterization has been obtained by past analyses.

Most ground-water samples collected onsite in 1995 were analyzed for tritium. Selected samples were analyzed for other radionuclides. Sample results for radionuclides are generally presented in picocuries per liter. However, the results for total uranium, which is usually measured by laser fluorescence, are given in micrograms per liter. The results for analysis of individual uranium isotopes are reported in picocuries per liter.

Nitrate analyses were performed on many samples collected during 1995 because of the extensive areas with elevated nitrate concentrations originating from onsite and offsite sources. However, the elevated nitrate concentrations were below the Drinking Water Standard for most of the affected area. Selected monitoring wells were used for additional chemical surveillance. Chemical sampling wells were chosen by considering the results of

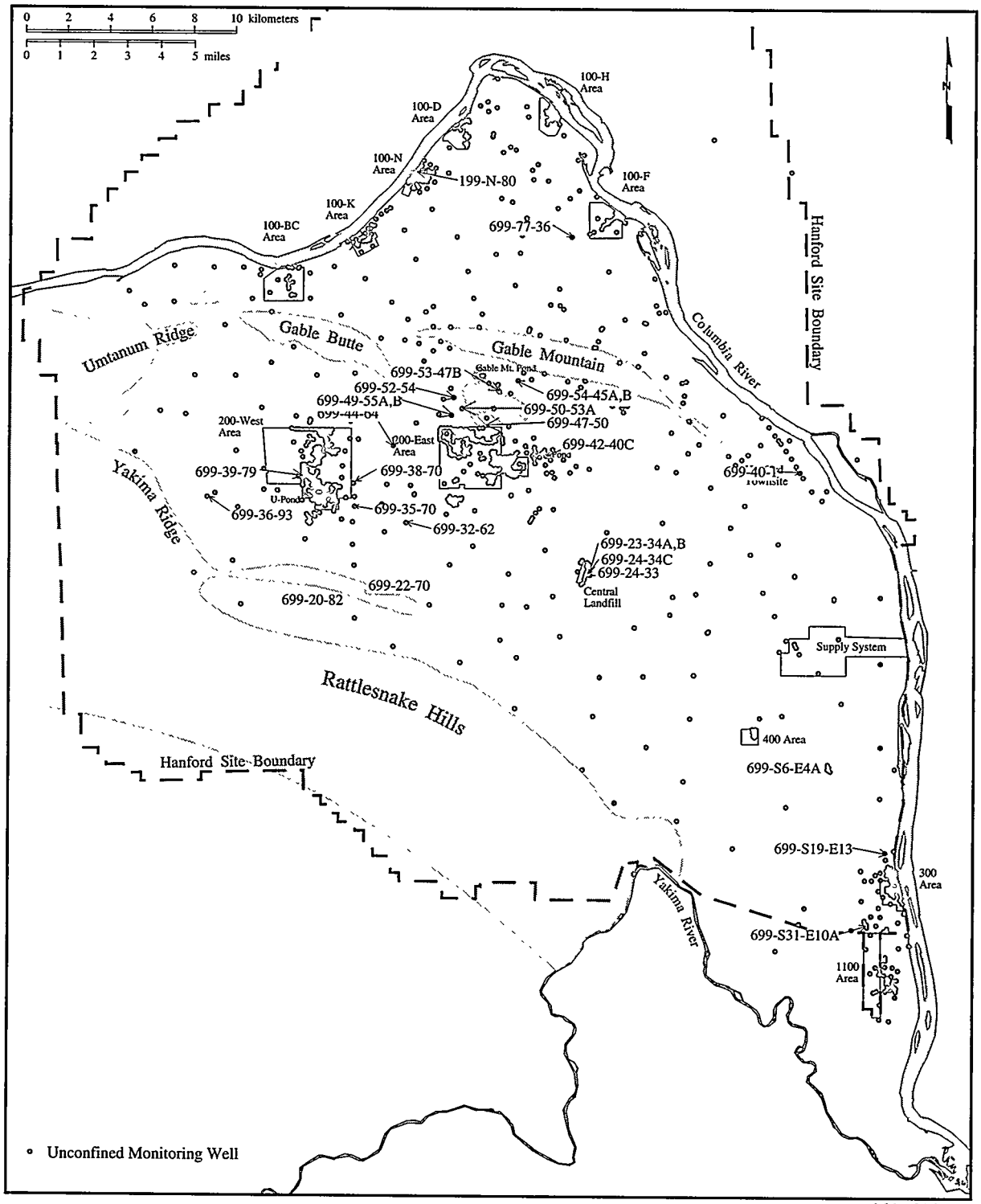

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Figure 4.8.9. Hanford Site Unconfined Aquifer Monitoring Well Locations, 1995

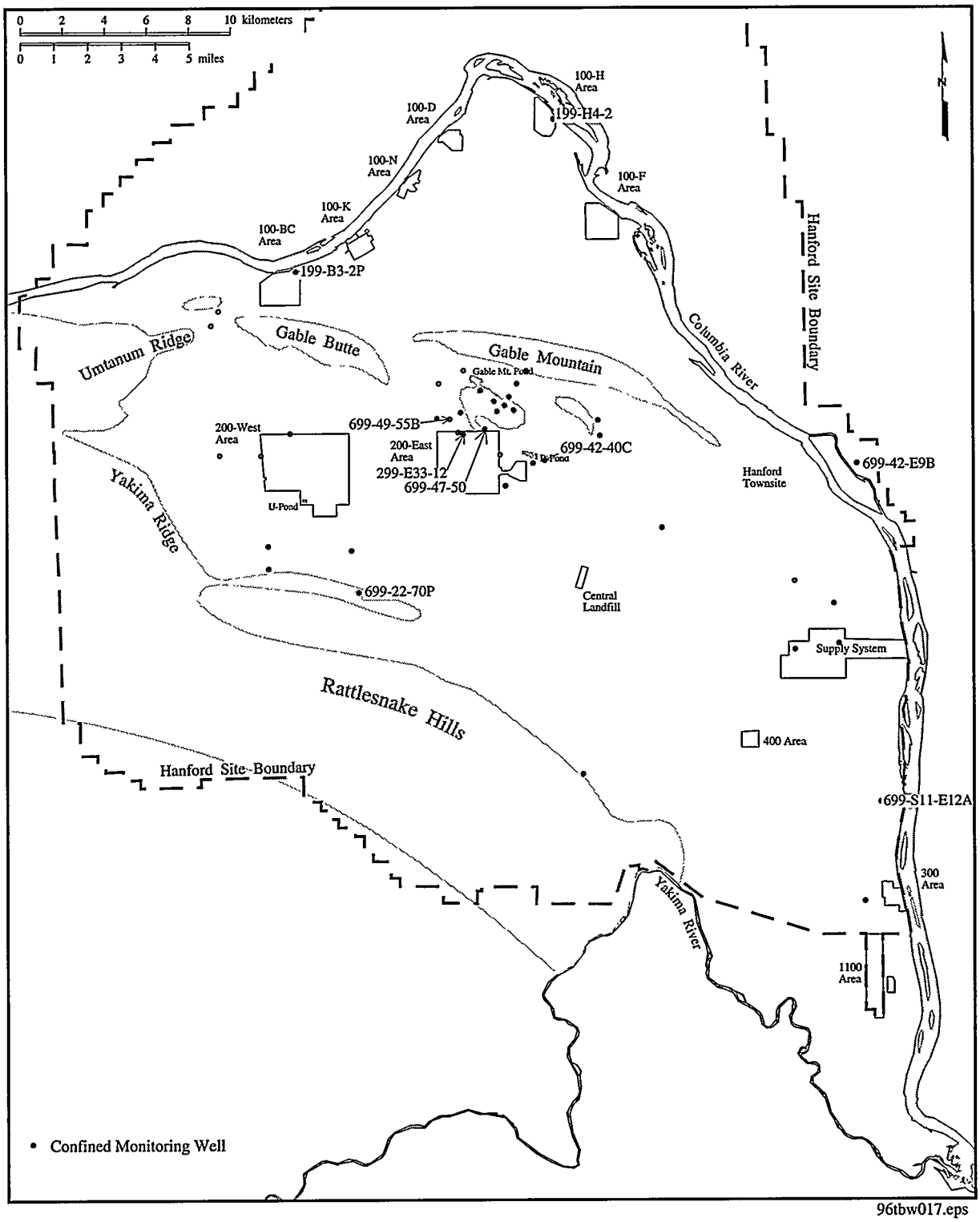

Figure 4.8.10. Hanford Site Confined Aquifer Monitoring Well Locations, 1995

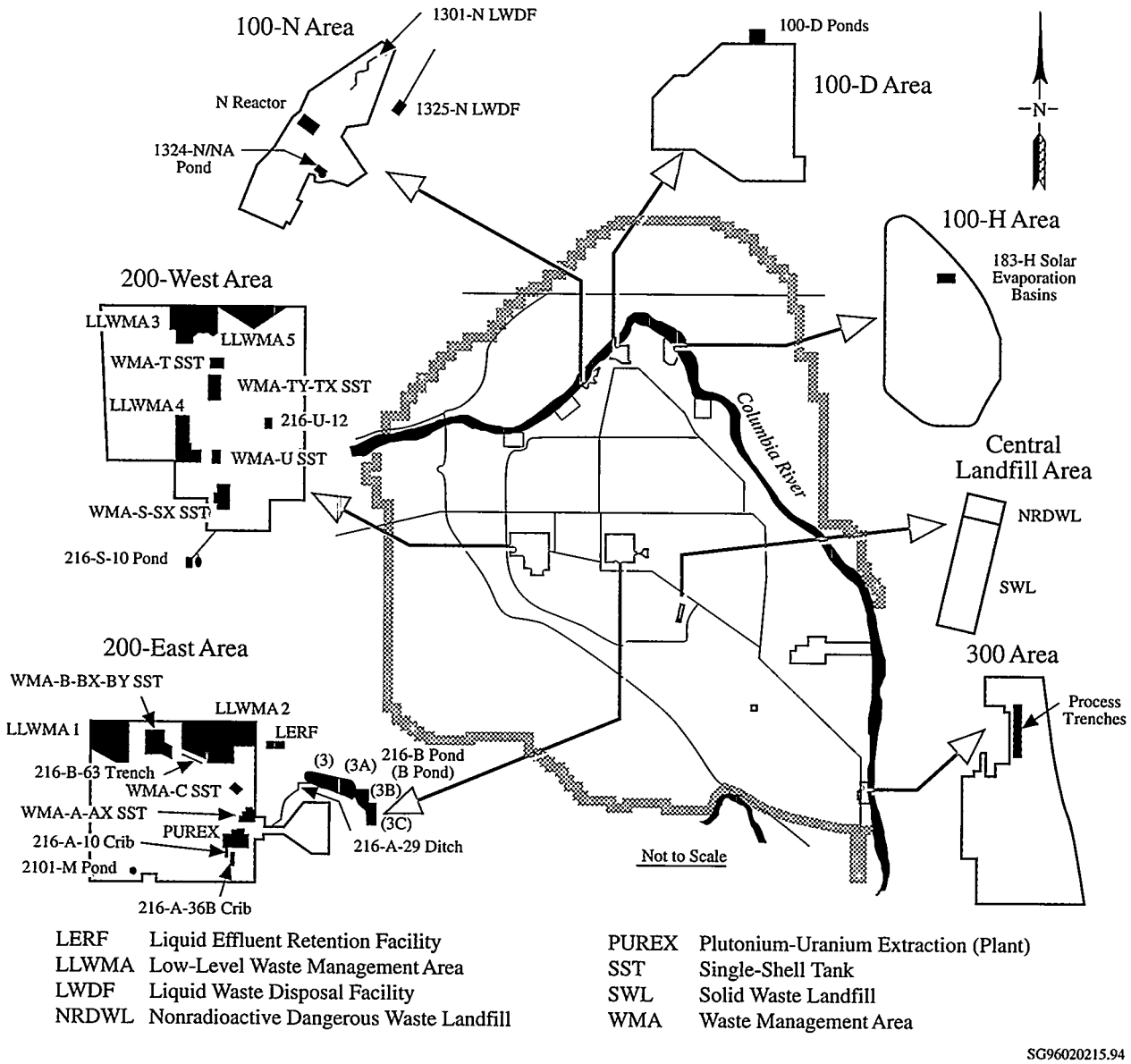

Figure 4.8.11. Locations of Resource Conservation and Recovery Act Ground-Water Monitoring Projects on the Hanford Site

previous chemical analyses and the proximity to known active and inactive chemical disposal sites.

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 to interpret the sample results are also discussed.

Ground-water sampling techniques are designed to collect a sample that is 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

Table 4.8.2. Explanation of the Hanford Site Well Naming System

Example Well Name	Area
199-	**100 Area**
199-B3-47	100-BC Area
199-D5-12	100-D Area
199-F8-3	100-F Area
199-H4-3	100-H Area
199-K-30	100-K Area
199-N-67	100-N Area
299-	**200 Area**
299-W19-3	200-West Area
299-E28-4	200-East Area
399-	**300 Area**
399-1-17A	300 Area
499-	**400 Area**
499-S1-8J	400 Area
699-	**600 Area**
699-50-53A	600 Area north and west of datum
699-42-E9A	600 Area north and east of datum
699-S19-11	600 Area south and west of datum
699-S19-E13	600 Area south and east of datum

Note: Letters at end of well names distinguish either multiple wells located close together or multiple intervals within a single well-bore.

results. Duplicate samples and field blanks are used to assess the sampling procedure.

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 (see Helpful Information Section for more details).

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 Project and other programs participate in interlaboratory comparisons in which many laboratories analyze blind samples prepared by the EPA (see Section 7.0, "Quality Assurance").

In 1995, double-blind samples for specific constituents were analyzed as part of the Ground-Water Surveillance Project (see Section 7.0, "Quality Assurance," for further discussion of double-blind results). Several wells were also co-sampled with the Washington State Department of Health for intercomparison. Results of the intercomparison sampling are available from the Washington State Department of Health.

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 helps 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

Table 4.8.3. 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	Polychlorinated biphenyls
Uranium isotopes	Dioxins/furans
Uranium (total)	Pesticides/herbicides
	Biological oxygen demand/chemical oxygen demand
	Dissolved oxygen

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 illustrate Site ground-water chemistry. Although analytical data are available only 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 are factored into map preparation.

Ground-Water Monitoring Results

The following sections of the report summarize the most significant results of ground-water monitoring for the year. Further information on the interpretations are presented in the Ground-Water Surveillance Project's annual report (Dresel et al. 1995). The ground-water report also includes 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 and C.5). Specific Drinking Water Standards have been proposed for only a few radiological constituents. 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 DOE Derived Concentration Guides because the Drinking Water Standards are based on an annual dose to the affected organ of 4 mrem/yr, and the DOE Derived Concentration Guides for drinking water are based on an effective dose equivalent of 100 mrem/yr (see Appendix C, Tables C.2 and C.5). In addition, the EPA Drinking Water Standards use older factors for calculating the concentrations that would produce a 4 mrem/yr dose than are used in calculating DOE Derived Concentration Guides. Thus, the values used below for Drinking Water Standards are not always in agreement with the DOE Derived Concentration Guides. The DOE 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 4.8.3. 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 Plutonium-Uranium Extraction 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 tritium, iodine-129, strontium-90, technetium-99, uranium, cobalt-60, cesium-137, plutonium, and antimony-125 will be discussed in the following sections. The locations and types of operations resulting in the release of these radionuclides to ground water are listed in Table 4.8.1.

Tritium

Tritium was present in many waste streams discharged to the subsurface and is the most mobile radionuclide onsite. As a result, the extent of contamination in the ground water from Site operations is generally reflected by the tritium distribution. Tritium is the radionuclide most frequently monitored at the Hanford Site for this reason. 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 4.8.12 shows the 1995 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-B, 100-D, 100-F, 100-K, and 100-N Areas. One sample from the 100-B Area, from well 199-B5-2, contained 27,000 pCi/L of tritium, slightly above the Drinking Water Standard. Although this well appears to show an increasing trend in tritium concentration, wells upgradient show lower tritium levels. Tritium concentrations greater than the Drinking Water Standard were detected in two wells in the 100-D Area. The maximum tritium level reported was 44,000 pCi/L in monitoring well 199-D5-12.

Only one well in the 100-F Area (199-F8-3) contained tritium at concentrations greater than the Drinking Water Standard (a maximum of 111,000 pCi/L). This well is located near the 118-F-1 Burial Ground. The source and downgradient extent of this contamination has not been determined.

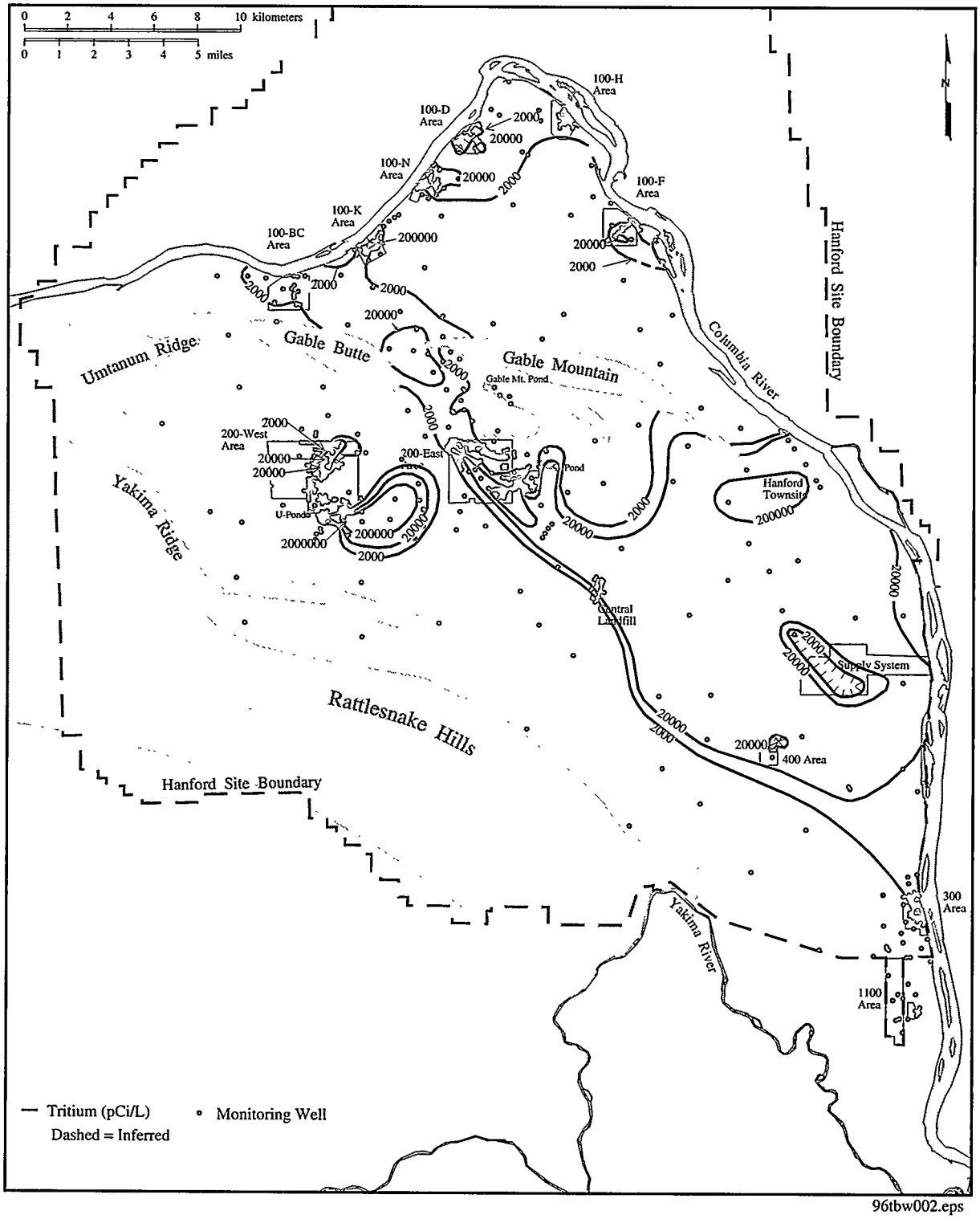

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Figure 4.8.12. Distribution of Tritium in the Unconfined Aquifer, 1995

Well 199-K-30, located in the 100-K Area, continued to contain the highest tritium concentration within the 100 Areas, with a maximum concentration of 1,560,000 pCi/L reported in 1995. Previously, in April and May 1993, this well contained tritium in excess of the DOE Derived Concentration Guide (2,000,000 pCi/L). The tritium trend for well 199-K-30 is shown in Figure 4.8.13. The source of tritium contamination found in well 199-K-30 is subject to some question. 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 primary 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, located just north of the K-East reactor building. Tritium concentrations in monitoring well 199-K-27 continue to decline but remained well above the drinking water standard (maximum of 234,000 pCi/L) in 1995. Well 199-K-106A was installed in 1994 adjacent to a French drain near the K-West reactor building. Samples from this well revealed another high concentration tritium plume. The maximum concentration of tritium detected in well 199-K-106A in 1995 was 711,000 pCi/L.

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 1995 was 70,200 pCi/L in well 199-N-75, located between the 1301-N Liquid Waste Disposal Facility and the Columbia River. This value is comparable to results ranging from 58,600 to 72,000 pCi/L from 1992 through 1994.

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 Plutonium-Uranium Extraction Plant. Concentrations greater than the 2,000,000-pCi/L DOE Derived Concentration Guide were detected in only one well in 1995 in the 200-East Area, 299-E17-9. The tritium level detected in this well monitoring the 216-A-36B Crib was 3,470,000 pCi/L, which was the highest concentration detected in any well onsite. The tritium concentration in this well is generally declining slowly, as shown in Figure 4.8.14. Concentrations in monitoring wells downgradient of the 216-A-10 Crib decreased to less than the DOE Derived Concentration Guide in 1993 and remained below the DOE Derived Concentration Guide in 1995. Although

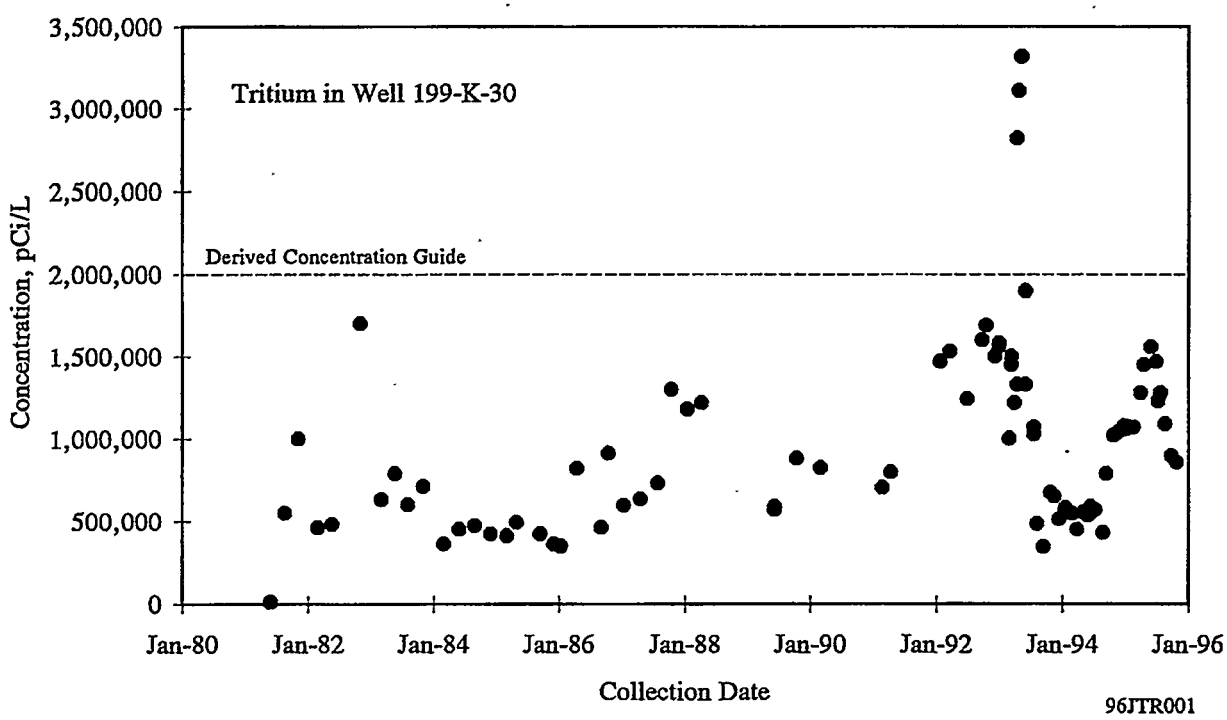

Figure 4.8.13. Tritium Concentrations in Well 199-K-30, 1981 Through 1995

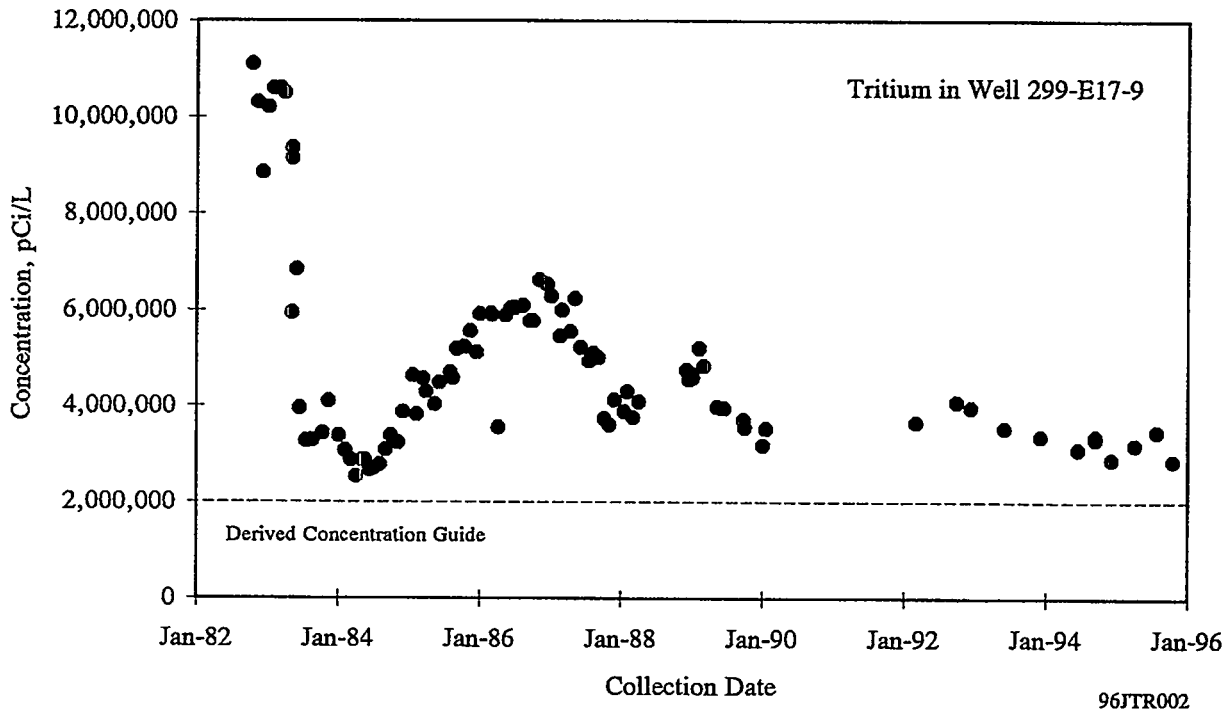

Figure 4.8.14. Tritium Concentrations in Well 299-E17-9, 1982 Through 1995

tritium concentrations are generally decreasing in wells near the Plutonium-Uranium Extraction Plant cribs, tritium concentrations exceeding the Drinking Water Standard continued to occur in many wells affected by Plutonium-Uranium Extraction Plant discharge.

The movement of the widespread tritium plume (see Figure 4.8.12) extending from the southeastern portion of the 200-East Area to the Columbia River was consistent with patterns noted in past monitoring reports (Dirkes and Hanf 1995, Dresel et al. 1995). Separate tritium pulses associated with the two episodes of Plutonium-Uranium Extraction Plant 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 during the operation of the Plutonium-Uranium Extraction Plant from 1956 to 1972. Following an 11-year shutdown, plant operation began again in 1983 and ceased in December 1988. This resulted in elevated tritium concentrations measured in several wells downgradient from the 200-East Area. Movement of the leading edge of this plume is clearly observable in well 699-24-33, Figure 4.8.15, which shows arrival of the plume in early 1987 following the passage of the plume from the earlier operation of the Plutonium-Uranium Extraction Plant. Tritium concentrations from the first plume were much higher than from the second. Concentrations of tritium detected in 1995 in this plume were generally lower than in previous years due to dissipation and radioactive decay. Thus, the area of contaminated ground water downgradient of the Plutonium-Uranium Extraction Plant with tritium concentrations above 200,000 pCi/L in 1995 was considerably smaller than in previous years. The effects of the second operational period have not been seen near the Columbia River. A trend plot of the tritium concentrations in well 699-40-1 (Figure 4.8.16), located near the shore of the Columbia River, 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, attributable to the first operational period of the Plutonium-Uranium Extraction Plant (see Figure 4.8.12), continues to shrink from approximately 42 km^2 (16 mi^2) in 1988 (Evans et al. 1989) to approximately 7 km^2 (3 mi^2) in 1995. However, the overall extent of contamination from the Plutonium-Uranium Extraction Plant at levels greater than the 20,000 pCi/L Drinking Water Standard remained nearly the same as in previous years.

The tritium plume resulting from Site activities has been monitored for much of the time the Site has been in

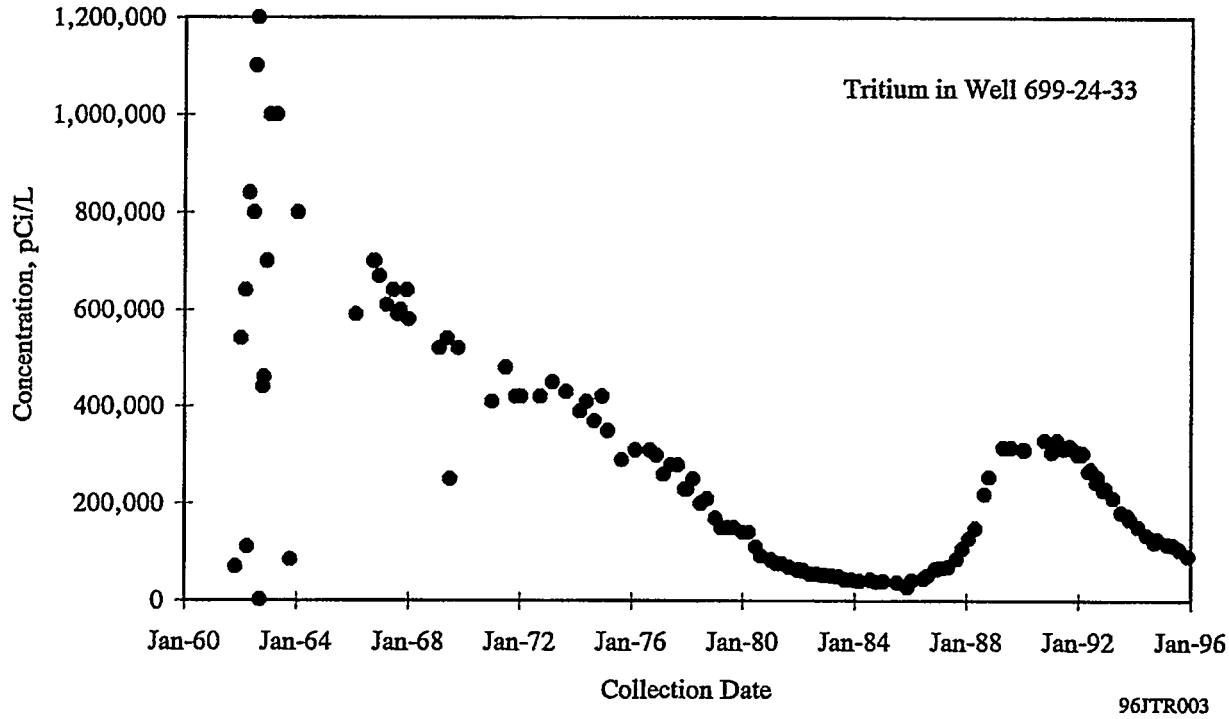

Figure 4.8.15. Tritium Concentrations in Well 699-24-33, 1961 Through 1995

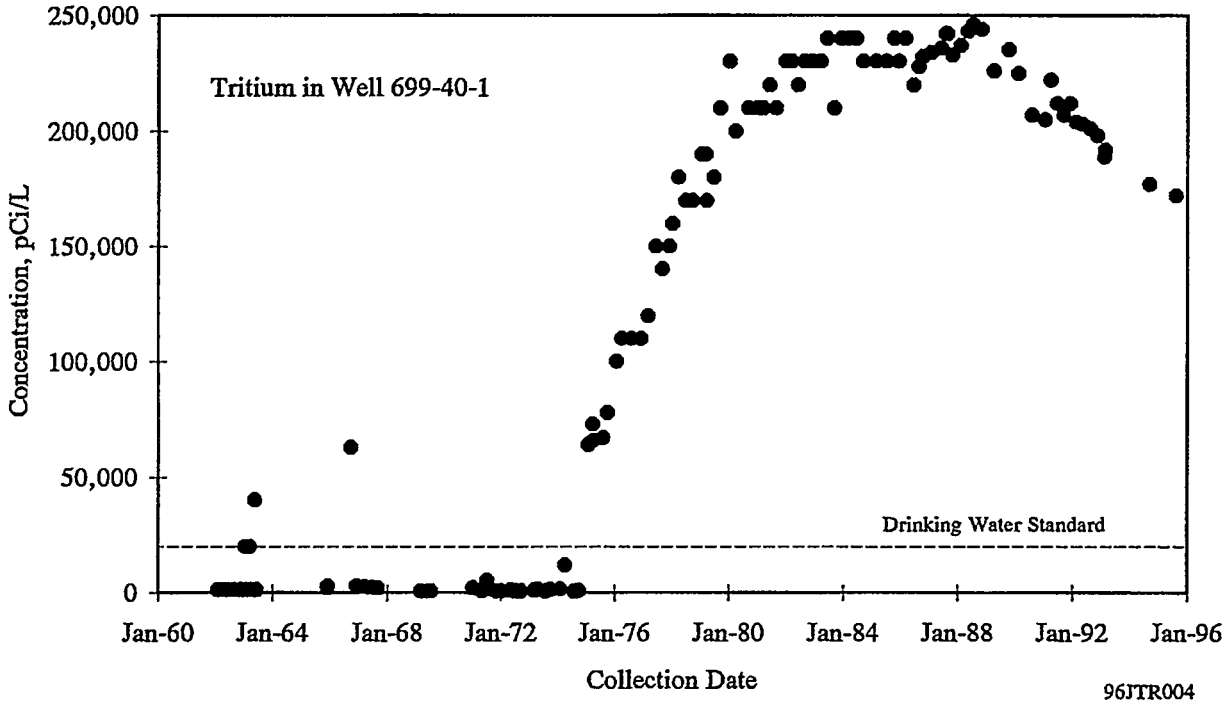

Figure 4.8.16. Tritium Concentrations in Well 699-40-1, 1962 Through 1995

operation, providing information on the change in extent of contamination over time. Figure 4.8.17 shows the extent of tritium in selected years from 1964 through 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 4.8.17 shows that tritium at concentrations greater than the Drinking Water Standard reached the Columbia River in approximately the mid-1970s. Variations in the extent of tritium mapped in the 100 Areas appear to result from differences in the monitoring network and different interpretations 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 4.8.18 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 1995, the same as the 1994 maximum value. The tritium plume extends into the 300 Area, where concentrations in some wells (e.g., well 399-2-2) are greater than half the Drinking Water Standard (Figure 4.8.19). The tritium plume is not expected to impact the North Richland Wellfield because of the influence on ground-water flow from the Yakima River and recharge from infiltration ponds at the North Richland Wellfield (Figure 4.8.20). The Yakima River is at a higher elevation and recharges the ground water in this area (Newcomer et al. 1991). As a result, ground water flows from west to east (Figure 4.8.20), minimizing 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. Ongoing monitoring is being performed by the Ground-Water Surveillance Program in order to confirm this interpretation.

The configuration of the western portion of the tritium plume shown in Figure 4.8.12 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 controlled by a zone of highly permeable 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 4.8.17. The mound under B Pond is expected to dissipate 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 Plant forms the most extensive and highest concentration plume in the 200-West Area. This plume extends into the 600 Area east of the 200-West Area. The Reduction-Oxidation Plant is located in the southeastern part of the 200-West Area and operated from 1951 through 1967. No wells in the 200-West Area showed tritium levels in excess of the DOE Derived Concentration Guide during 1995. Samples from the well in the 200-West Area with the highest tritium concentrations, well 299-W22-9, contained a maximum of 1,050,000 pCi/L of tritium. The declining concentrations in this well are shown in Figure 4.8.21. 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 4.8.11) and disposal facilities, which received liquid waste from T-Plant operations. This plume extends northeast past the boundary of the 200-West Area. Although a number of the single-shell waste tanks in this area are known or assumed to have leaked, it has not

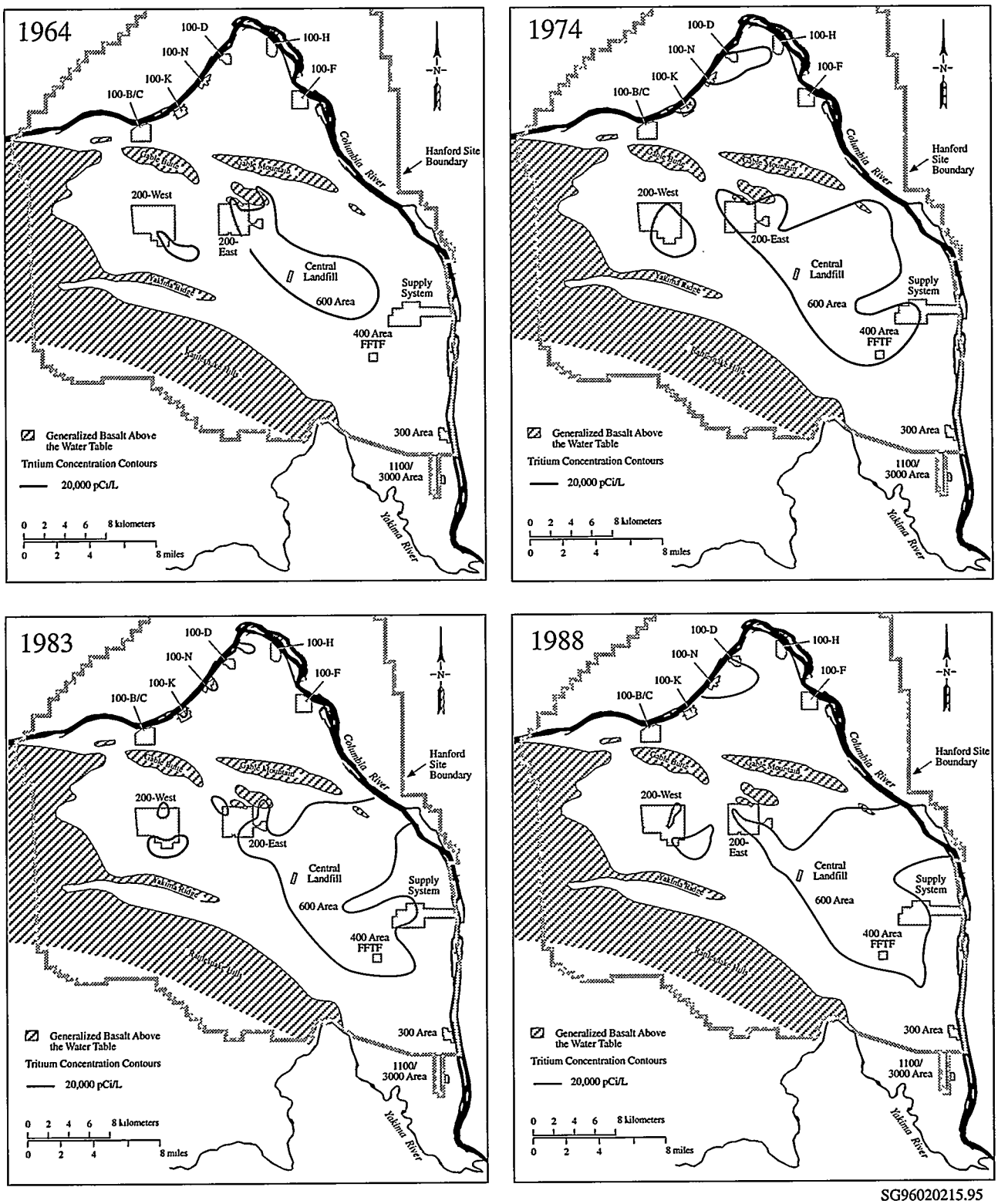

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Figure 4.8.17. Historical Tritium Concentrations on the Hanford Site

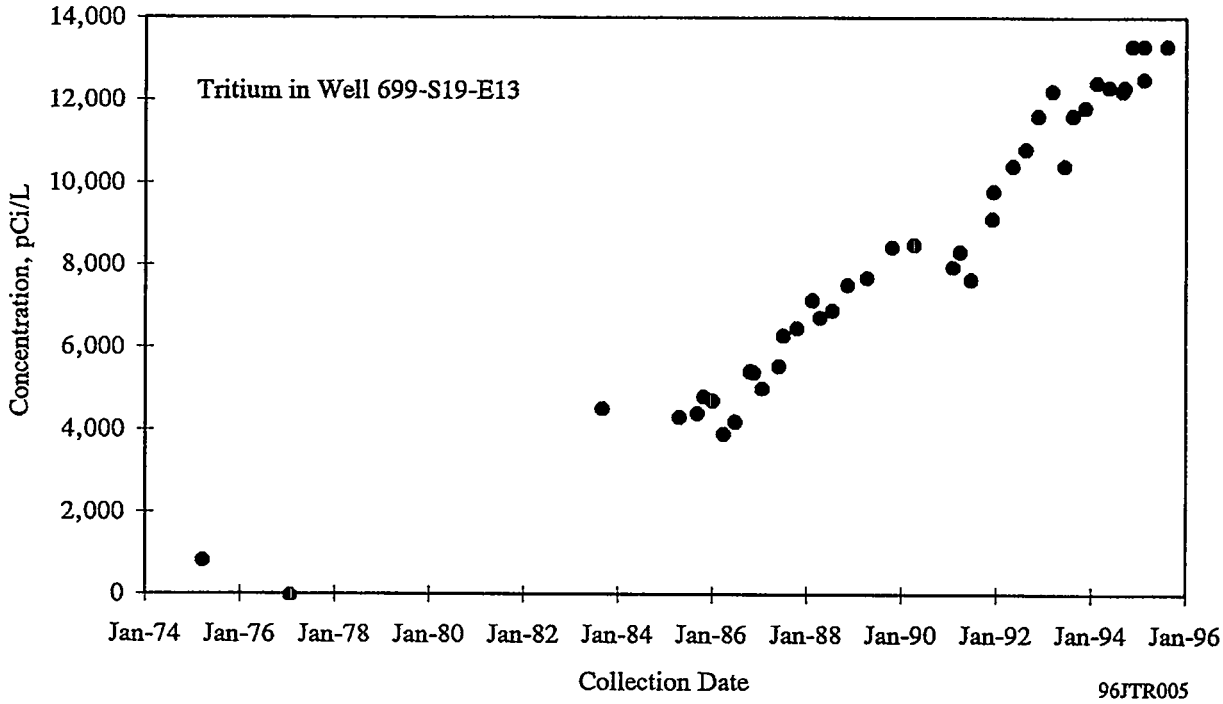

Figure 4.8.18. Tritium Concentrations in Well 699-S19-E13, 1975 Through 1995

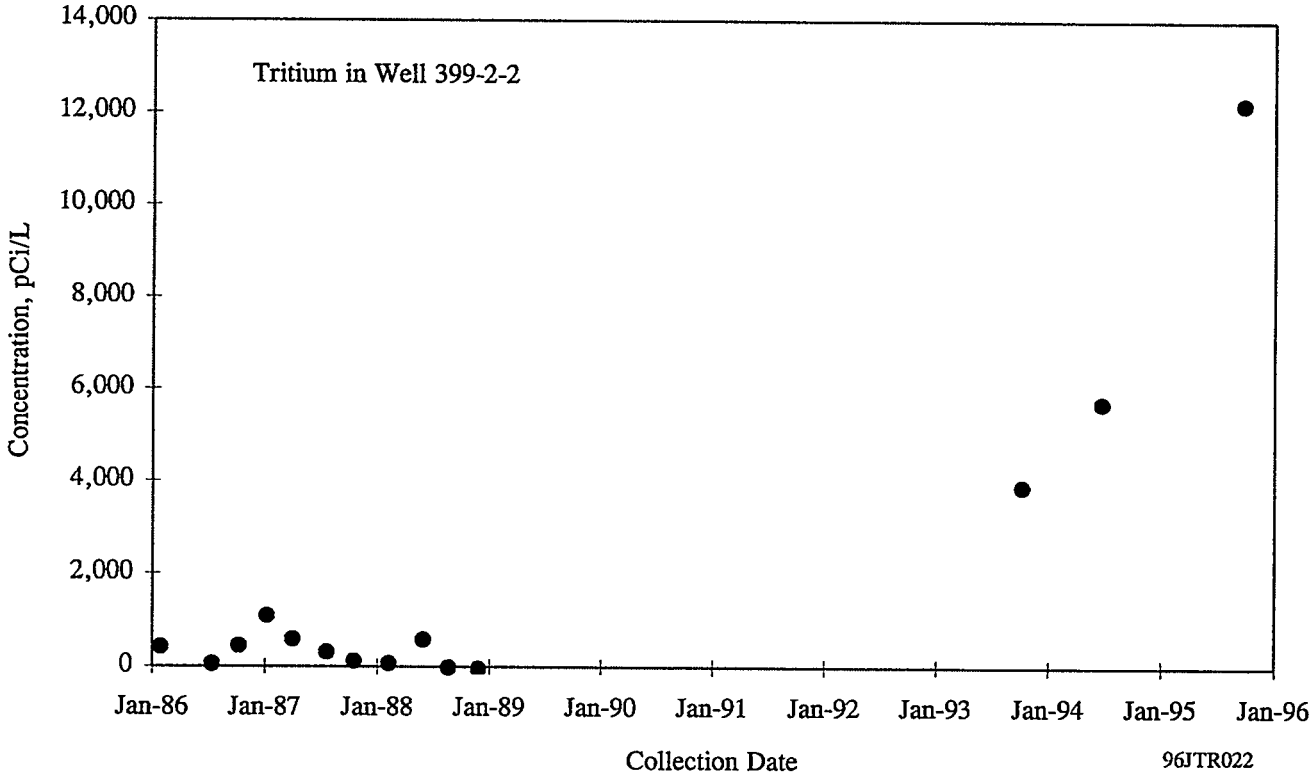

Figure 4.8.19. Tritium Concentrations in Well 399-2-2, 1986 Through 1995

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Figure 4.8.20. Tritium Distribution and Ground-Water Flow Near the 300 Area, 1995

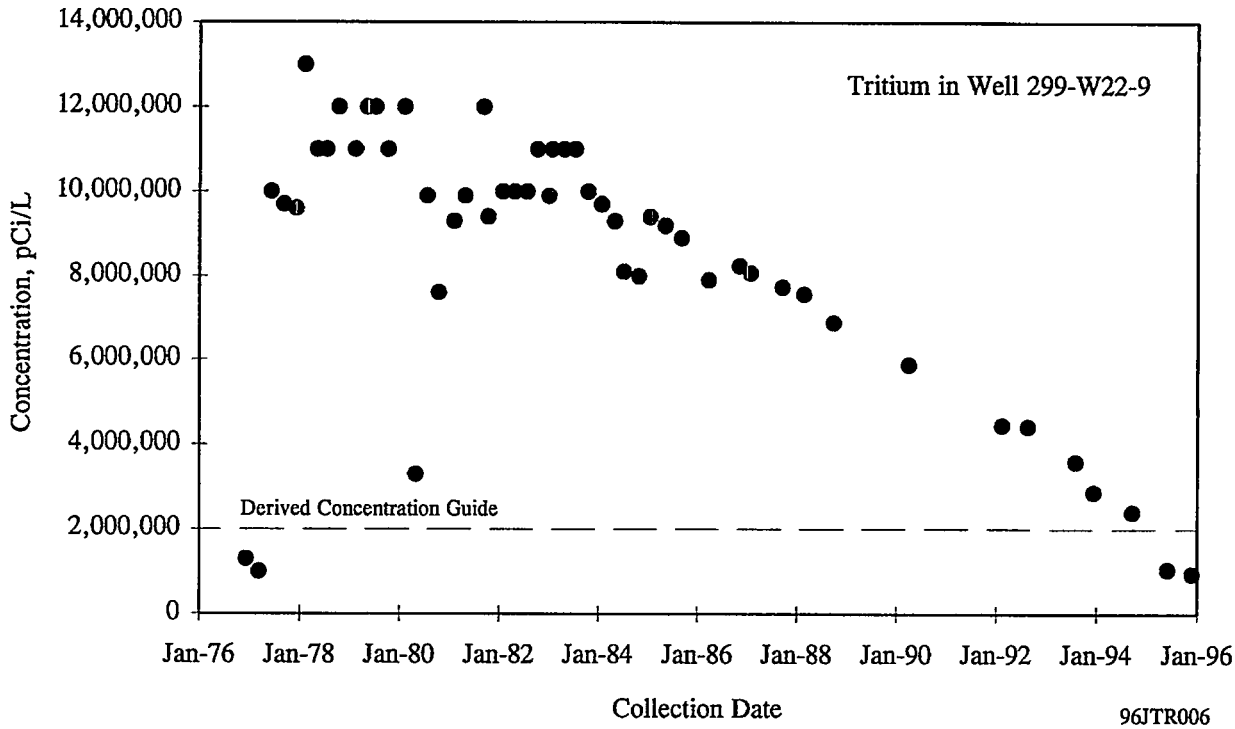

Figure 4.8.21. Tritium Concentrations in Well 299-W22-9, 1976 Through 1995

been determined if the leaks have impacted ground water or if the nearby cribs and other liquid waste disposal facilities are the only sources of contaminants, including tritium, in this area.

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 the Hanford Site, the main contributor of iodine-129 to ground water has been liquid discharges to cribs in the 200 Areas. Iodine-129 has essentially the same high mobility in ground water as tritium and nitrate. The highest concentrations observed onsite are downgradient from the Reduction-Oxidation Plant in the 200-West Area and the Plutonium-Uranium Extraction Plant in the 200-East Area. Iodine-129 contamination extends into the 600 Area as shown in Figure 4.8.22. No iodine-129 samples were above the DOE Derived Concentration Guide of 500 pCi/L in 1995.

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 Plutonium-Uranium Extraction Plant. The maximum concentration of iodine-129 detected in 1995 in the 200-East Area was 13.2 pCi/L in well 299-E24-17. This well is located south of the Plutonium-Uranium Extraction Plant near the 216-A-10 Crib. The iodine-129 plume from the Plutonium-Uranium Extraction Plant area extends southeast into the 600 Area and appears coincident with the nitrate and tritium plumes. The iodine-129 plume appears smaller than the tritium plume because of the lower initial concentration of iodine-129. Iodine-129 can be detected as far as the Columbia River, but at levels below the Drinking Water Standard. Current data indicate that iodine-129 at levels above the Drinking Water Standard is approaching the Columbia River (Figure 4.8.22). The iodine-129 plume likely had the same sources as the nitrate and tritium plumes. 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

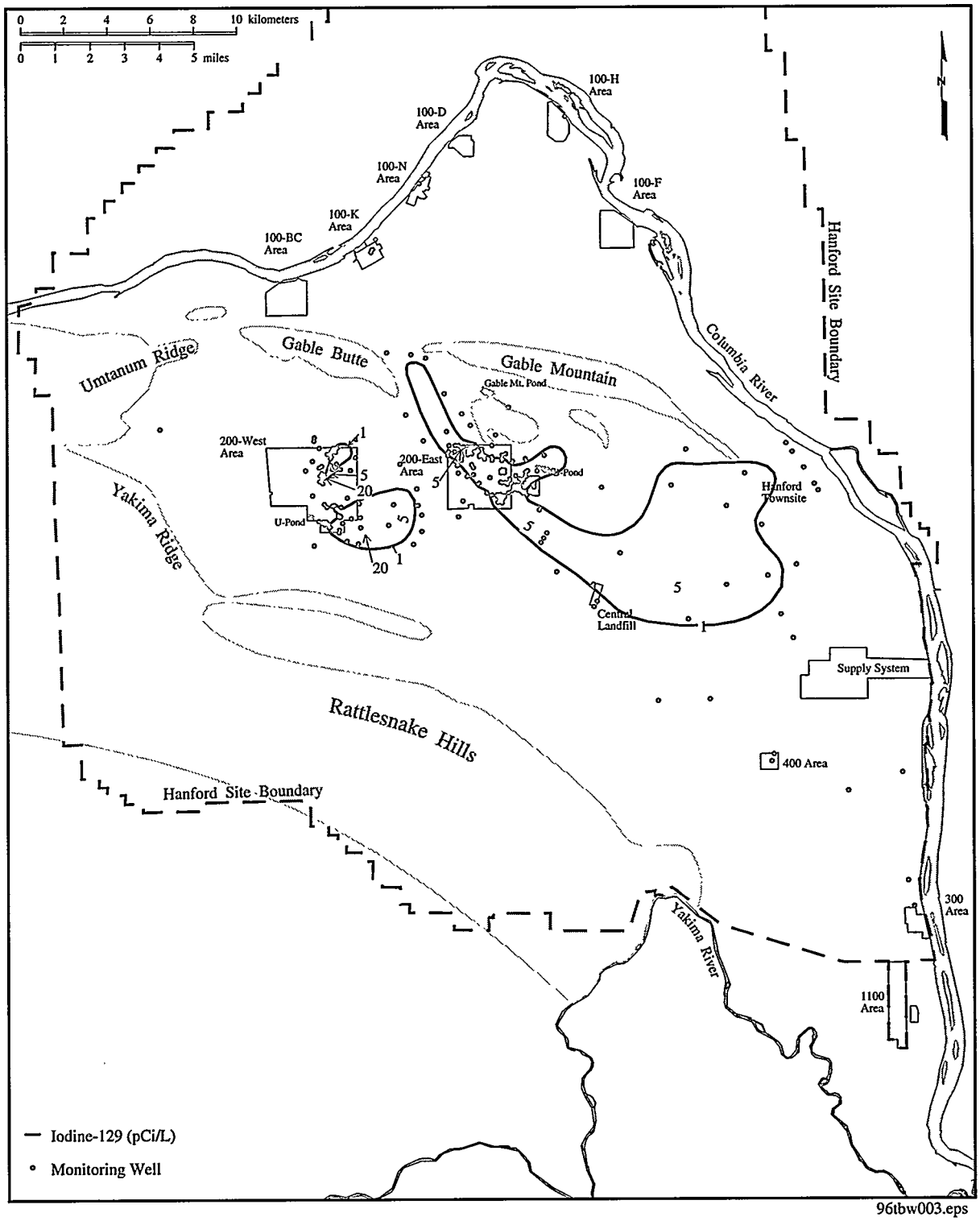

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Figure 4.8.22. Distribution of Iodine-129 in the Unconfined Aquifer, 1995

tanks. This plume extends northwest into the gap between Gable Mountain and Gable Butte.

The highest iodine-129 concentration observed in 1995 in Hanford ground water was 74.2 pCi/L in well 299-W22-9, in the southern part of the 200-West Area near the Reduction-Oxidation 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 single-shell 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 was produced as a high-yield fission product and was present in waste streams associated with fuel processing. Reactor operations also may have resulted 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. Because of sorption, a significant portion of the strontium-90 in the subsurface is not in solution. If ground-water concentrations of strontium-90 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 DOE Derived Concentration Guide in the 100-K, 100-N and 200-East Areas. This is the first year on record in which strontium-90 values above the DOE Derived Concentration Guide were detected in the 100-K Area.

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 1995 was 48.4 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 4.8.23. 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 1993a). 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, located near the D reactor building. The maximum concentration in 1995 was 38.7 pCi/L, similar to that in 1994. 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 1995 was 136 pCi/L in monitoring well 199-F5-3. The 100-F Area strontium-90 plume is shown in Figure 4.8.24.

The extent of strontium-90 contamination at levels greater than the Drinking Water Standard in the 100-H Area is shown in Figure 4.8.25. The maximum concentration detected in the 100-H Area in 1995 was 27.7 pCi/L in monitoring well 199-H4-13. This is similar to the level detected in 1994.

The extent of strontium-90 at levels greater than the Drinking Water Standard in the 100-K Area is shown in Figure 4.8.26. The maximum concentration detected in 1995 was in well 199-K-109A, where the concentration reached 2,810 pCi/L, which is over twice the DOE Derived Concentration Guide. A trend plot of strontium-90 in well 199-K-109A is shown in Figure 4.8.26. Strontium-90 concentrations in 3 other samples from this well were below the DOE Derived Concentration Guide. This strontium-90 plume was identified for the first time when this well was installed in 1994. Strontium-90 is also found near the K-West reactor building, and an extensive plume continues to be found near the liquid waste trench.

Strontium-90 was detected in concentrations greater than the 1,000 pCi/L DOE Derived Concentration Guide in the 100-N Area in 1995. The maximum level detected was 9,180 pCi/L in well 199-N-67. This well is located between the 1301-N Liquid Waste Disposal Facility and the Columbia River. Concentrations of strontium-90 in this well generally declined from 1989 through 1994 but increased in 1995 to over one third of the 1989 level (Figure 4.8.26). The distribution of strontium-90 in the 100-N Area is shown in Figure 4.8.26. Strontium-90 discharges to the Columbia River in the 100-N Area through springs along the shoreline. Springs are sampled as part of the surface water surveillance and near-facility

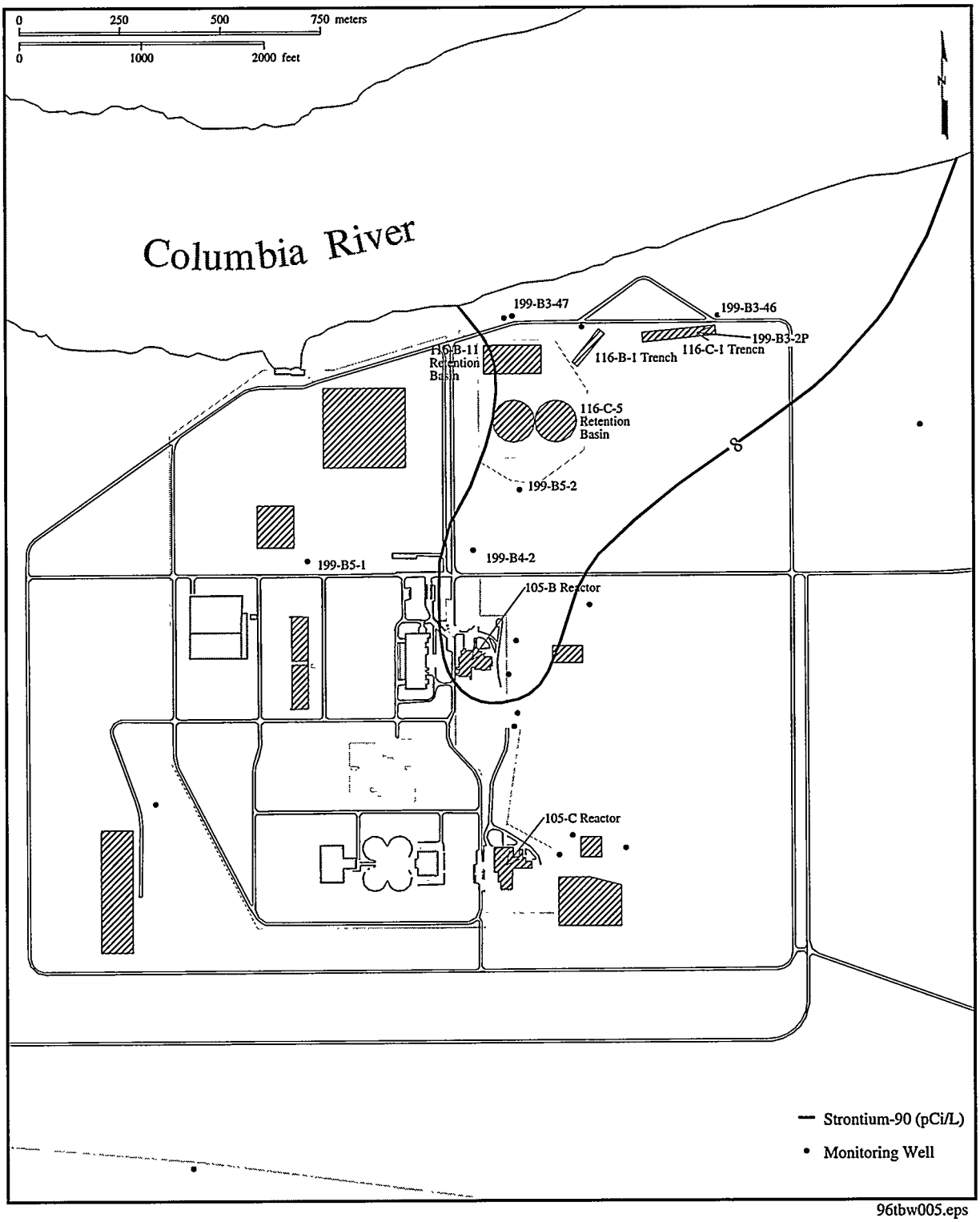

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Figure 4.8.23. Concentrations of Strontium-90 in the Unconfined Aquifer in the 100-B Area, 1995

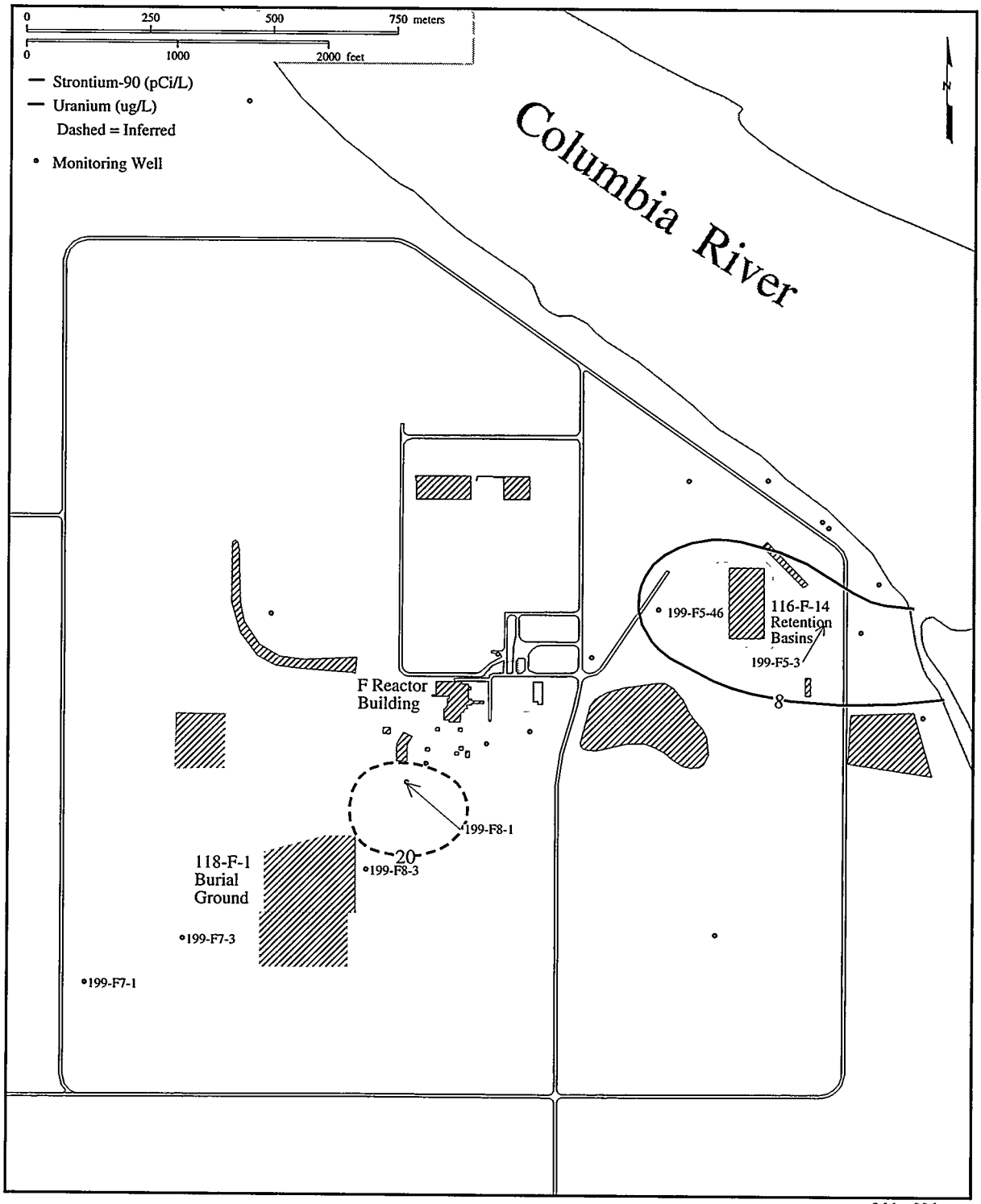

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Figure 4.8.24. Concentrations of Strontium-90 and Uranium in the Unconfined Aquifer in the 100-F Area, 1995

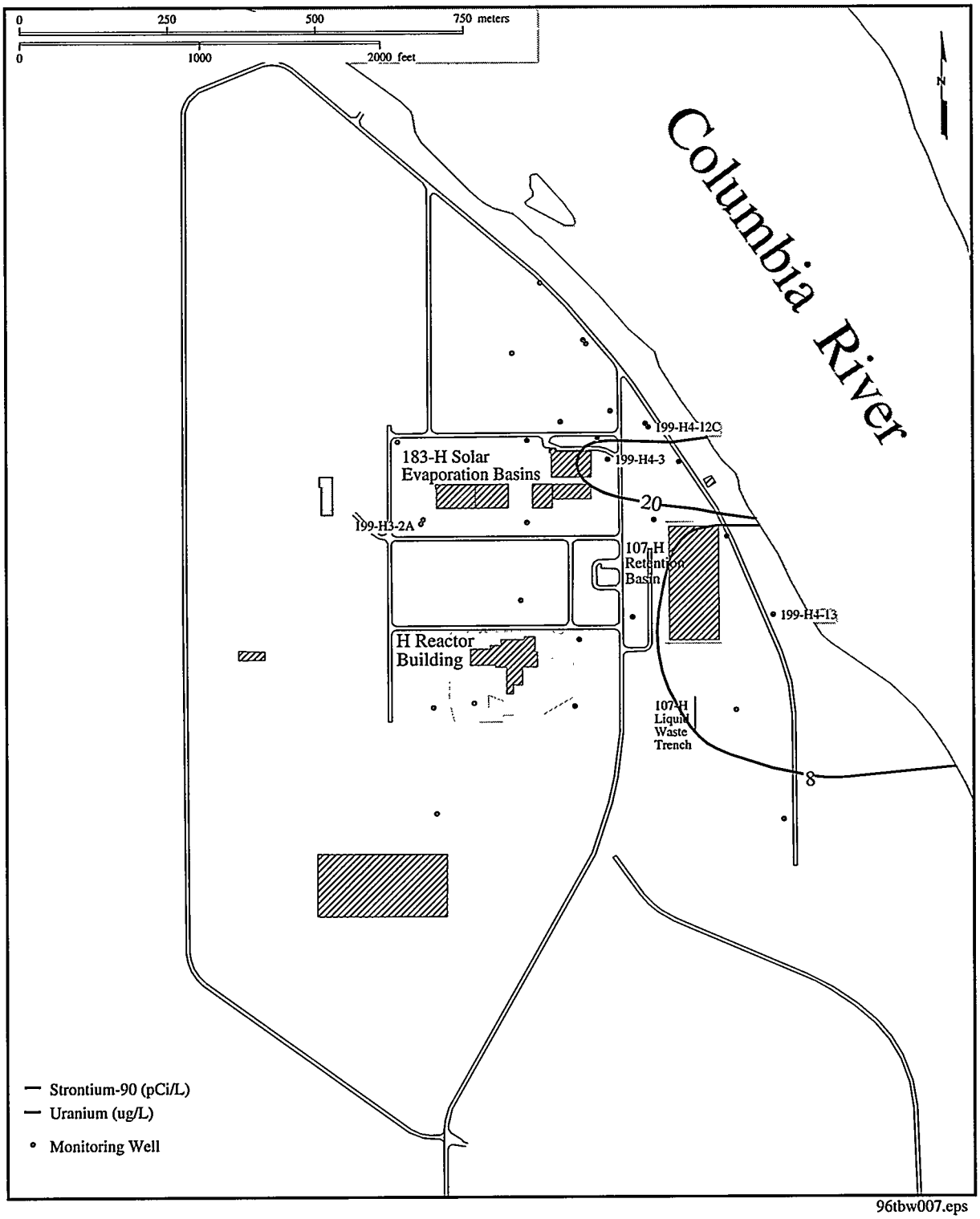

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Figure 4.8.25. Concentrations of Strontium-90 and Uranium in the Unconfined Aquifer in the 100-H Area, 1995

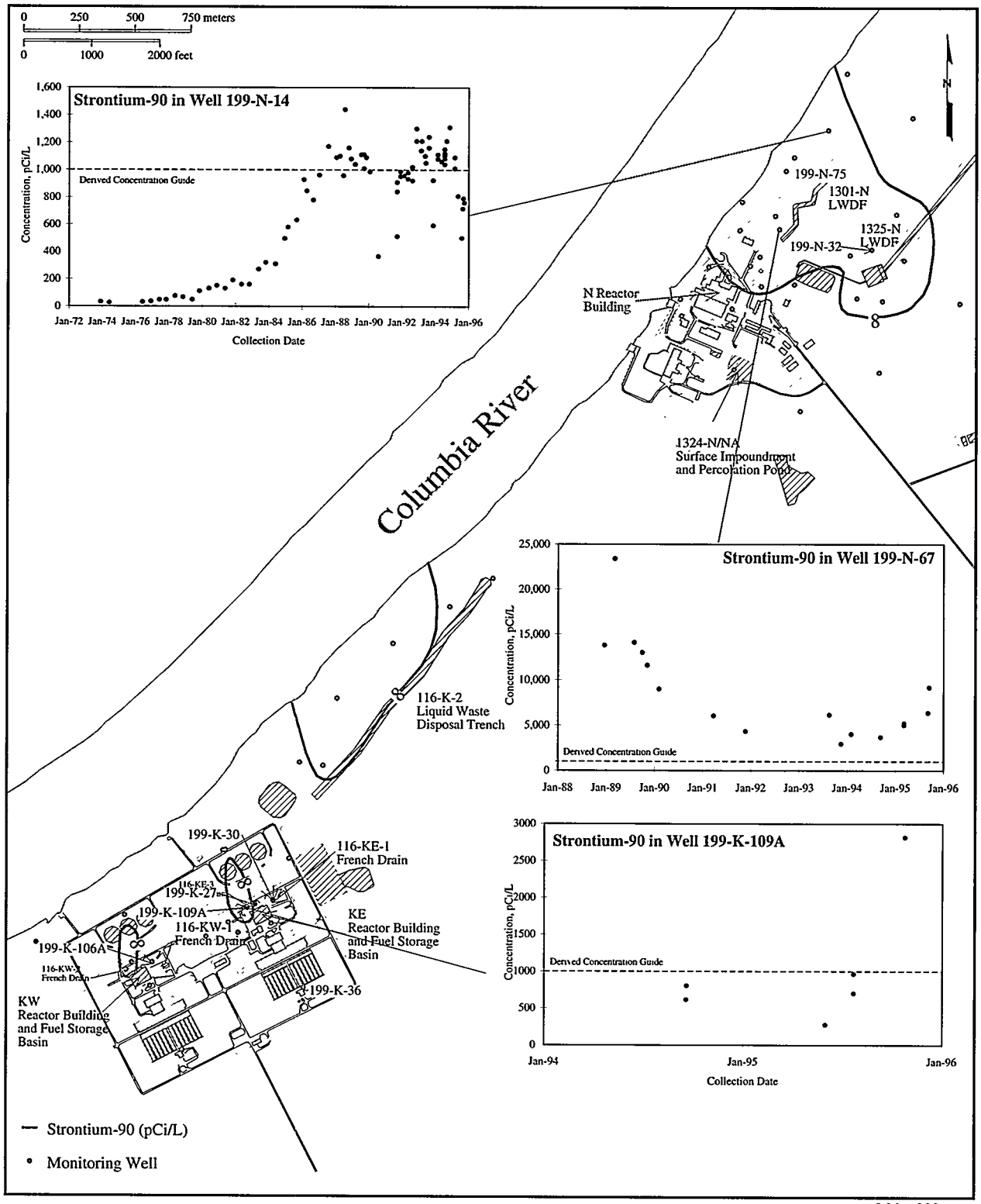

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Figure 4.8.26. Concentrations of Strontium-90 in the Unconfined Aquifer in the 100-K and 100-N Areas, 1995, and Concentration Trends in Selected Wells

environmental monitoring programs (see Section 4.2, "Surface Water and Sediment Surveillance"). The movement of the strontium-90 plume northward in the 1980s is illustrated by the trend data from well 199-N-14 (Figure 4.8.26). The strontium-90 concentrations in this well have remained approximately level, or have declined slightly since 1989. Wells farther northeast do not show detectable strontium-90. The steady levels indicate the plume is not spreading north at this time. Remediation of strontium-90 in the 100-N Area by pump-and-treat method began in 1995.

Strontium-90 in the 200 Areas. Concentrations of strontium-90 in the 200-East Area ranged up to 4,710 pCi/L in well 299-E28-23 near the 216-B-5 Reverse Injection Well. Strontium-90 was also found at 71.9 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 4.8.27. Strontium-90 was detected in 1995 at levels above the Drinking Water Standard in two wells, 299-E17-14 and 299-E17-8, near the Plutonium-Uranium Extraction Plant cribs. The maximum concentration of strontium-90 detected in 1995 in this vicinity was 14.9 pCi/L in well 299-E17-14.

Strontium-90 is detected occasionally in the 200-West Area. In 1995, samples from two wells exceeded the Drinking Water Standard, with the maximum concentration detected at 71.3 pCi/L in well 299-W22-1, located in the southern part of the 200-West Area.

Strontium-90 in the 600 Area. Concentrations of strontium-90 greater than the Drinking Water Standard but less than the DOE Derived Concentration Guide of 1,000 pCi/L were detected in several wells in the former Gable Mountain Pond area (Figure 4.8.27). Strontium-90 contamination in this area resulted from the discharge of radioactive waste to the 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 730 pCi/L in well 699-53-47B.

Technetium-99

Technetium-99 is produced as a fission by-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 solution as anions that sorb poorly to sediments so technetium is very mobile in Hanford Site ground water.

Technetium-99 was found at concentrations greater than the 900-pCi/L Drinking Water Standard in several areas of the Hanford Site. One location is downgradient of the 183-H solar evaporation basins in the 100-H Area. These basins were used for storage of waste primarily from fuel fabrication in the 300 Area. Some of the waste leaked into the subsurface, contaminating the ground water. The maximum concentration of technetium-99 detected in this area in 1995 was in well 199-H4-3, where the highest sample contained 4,980 pCi/L. This is the only well where technetium-99 was detected above the Drinking Water Standard; thus, this plume appears to be very narrow and restricted to a small area between the basins and the Columbia River.

Ground water from 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, contains technetium-99 at concentrations above the Drinking Water Standard (Figure 4.8.27). The source of this technetium was apparently the BY Cribs (Dresel et al. 1995). The technetium-99 plume is associated with cobalt-60, cyanide, and tritium contamination. The maximum technetium-99 concentration detected in this plume in 1995 was 9.910 pCi/L in well 699-50-53A. This well had been used as an extraction well for testing pump-and-treat technology for ground-water remediation. The technetium-99 trend for well 699-52-54 shows the progress of this plume as it migrates north (Figure 4.8.28). The concentration in well 699-52-54 in 1995 was similar to the concentration in 1994.

Technetium-99 is also detected at levels greater than the Drinking Water Standard in the 200-West Area and the adjacent 600 Area (Figure 4.8.29). 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 1995 was in well 299-W19-30, which

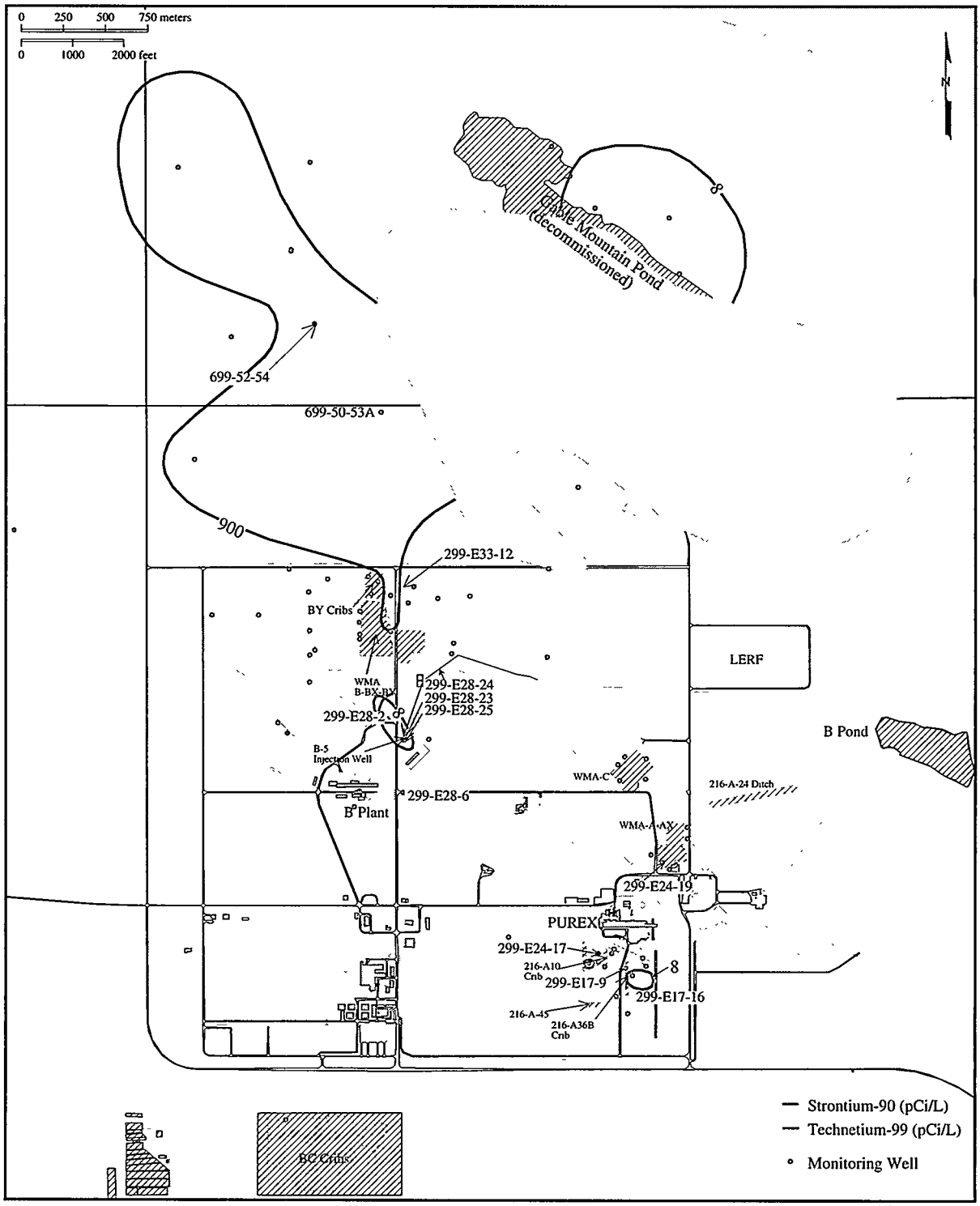

Figure 4.8.27. Concentrations of Strontium-90 and Technetium-99 in the Unconfined Aquifer Near the 200-East Area, 1995

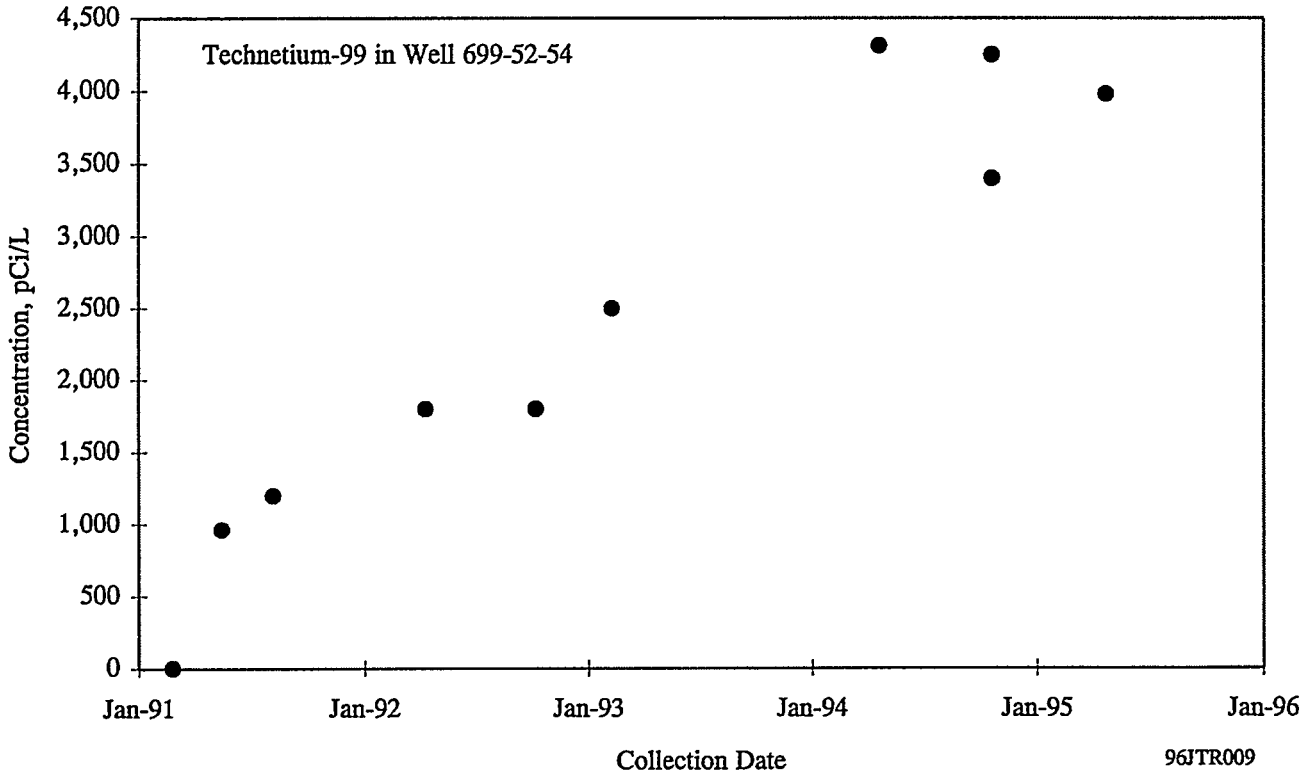

Figure 4.8.28. Technetium-99 Concentrations in Well 699-52-54, 1991 Through 1995

had a technetium-99 concentration of 12,700 pCi/L. This plume extends well into the 600 Area towards the 200-East Area. The highest concentration part of this plume is currently undergoing remediation by the pump-and-treat method.

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 in the vicinity of the WMA-TY-TX single-shell, high-level waste tanks and nearby disposal facilities. Only one well in this plume contained technetium-99 at levels above the Drinking Water Standard.

The southernmost plume in the 200-West Area originates near the WMA-S-SX high-level waste, single-shell tank farm and nearby disposal facilities. In 1994, samples from two wells in this area were above the Drinking Water Standard for technetium-99 (Dirkes and Hanf 1995) but in 1995, all samples were below the Drinking Water Standard. The source of the technetium-99 in this vicinity has not been identified. Although many of the high-level waste tanks are assumed to have leaked, similar wastes but at lower concentrations were discharged to nearby cribs. In addition, transfer pipelines in the tank farm had leaked during tank farm operations and are potentially an additional source of contamination.

Uranium

There are numerous possible sources of uranium released to the ground water at the Hanford Site 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-99 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 picocuries per liter. The reason for the different units relates to evidence that uranium ingestion may cause kidney damage,

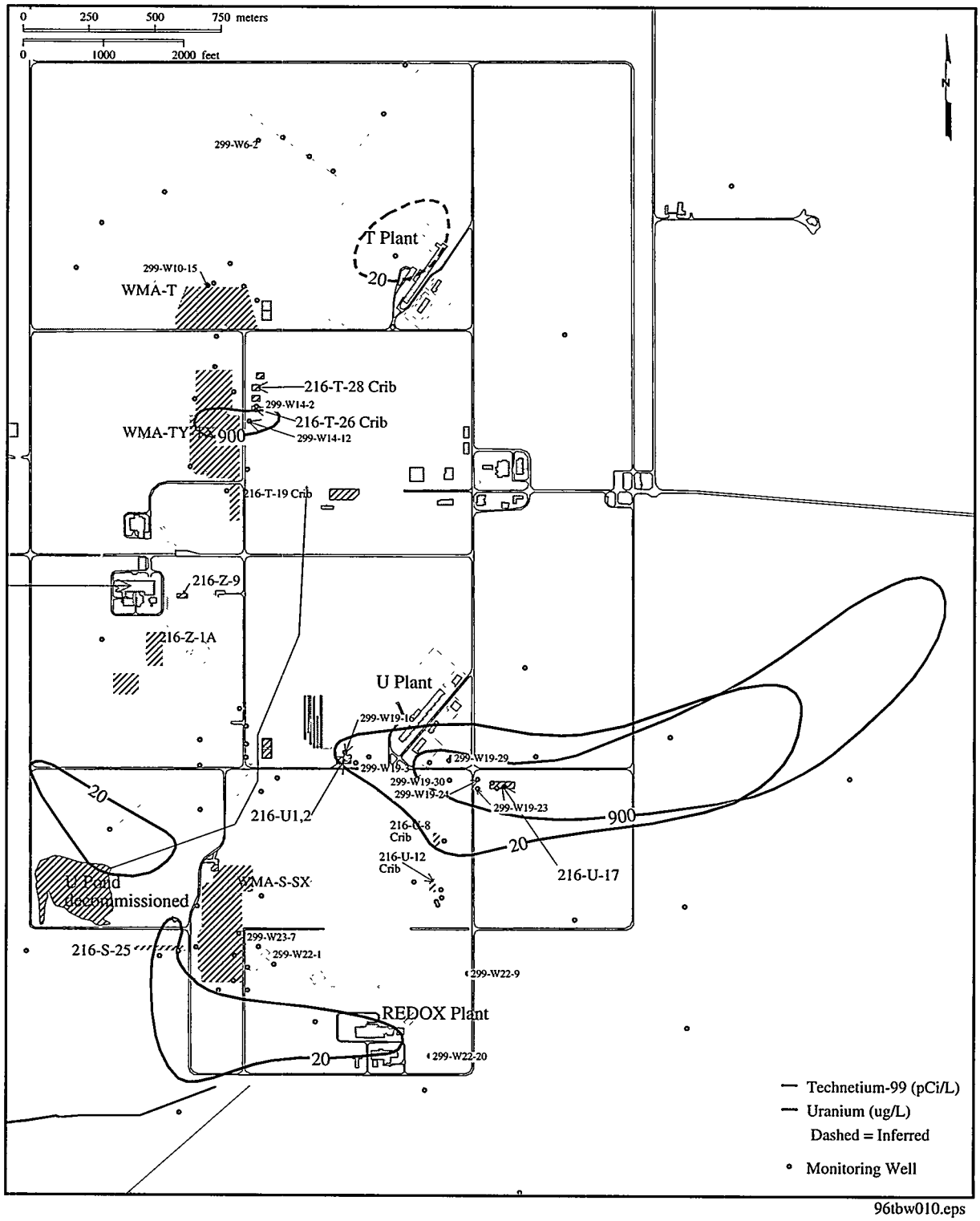

Figure 4.8.29. Concentrations of Technetium-99 and Uranium in the Unconfined Aquifer in the 200-West Area, 1995

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 micrograms per liter and those expressed in picocuries per liter. The conversion factor depends on the proportions of uranium-234, -235, and -238 in the ground water. The EPA considers the proposed 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 (40 CFR 141 and 142). 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 picocuries per liter should be multiplied by 1.49 to convert to the concentration in micrograms per liter. This means that the proposed Drinking Water Standard is equivalent to 13.4 pCi/L.

Uranium has been detected at concentrations greater than the proposed Drinking Water Standard in the 100-F, 100-H, 200-East, 200-West, 300, and 600 Areas. The highest concentrations detected onsite in 1995 were in the 200-West Area, near the U Plant.

Uranium in the 100 Areas. In 1995, uranium was detected at concentrations greater than the proposed Drinking Water Standard near the reactor building in the 100-F Area (Figure 4.8.24). The maximum concentration detected was 257 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 4.8.25). The maximum concentration detected in 1995 was 273 µg/L in well 199-H4-3. Uranium concentrations in this well fluctuate widely; the lowest concentration detected in this well in 1995 was 64.7 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 50.8 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 4.8.29). 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 4.8.30. 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 16,400 µg/L in a sample from well 299-W19-24. This value is considerably higher than values detected in previous years. Samples from two other nearby wells were analyzed in the same batch and were also anomalously high. These values may represent gross errors in the analysis. These wells are located in the area being remediated by pump-and-treat methods. Except for the above samples, the maximum uranium detected in this area in 1995 was 2,540 µg/L in well 299-W19-29. Results from that well have been erratic since 1991. However, the maximum concentration detected in well 299-W19-29 represents isotopic values greater than the DOE Derived Concentration Guides of 500 pCi/L for uranium-234 and 600 pCi/L for uranium-238. This uranium plume extends east into the 600 Area along with the technetium-99 discussed above. The uranium, at levels above the proposed Drinking Water Standard, does not extend as far east as the technetium-99 in this plume. Other areas within the 200-West Area with uranium contamination are also shown in Figure 4.8.29, including fairly widespread areas west and northwest of the Reduction-Oxidation Plant. Uranium concentrations in those areas are considerably lower than the concentrations detected near U 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 inactive Liquid Waste Disposal Facilities to the Columbia River (Figure 4.8.31). In recent years, uranium concentrations have fallen in the northern part of the plume, risen in the central part, and remained fairly constant in the southern part, as shown in the trend plots in Figure 4.8.31. The maximum concentration of uranium detected in the 300 Area in 1995 was 247 µg/L in well 399-1-17A, located adjacent to the 300 Area Process Trenches. 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 discharge to the trenches was much lower than before the expedited

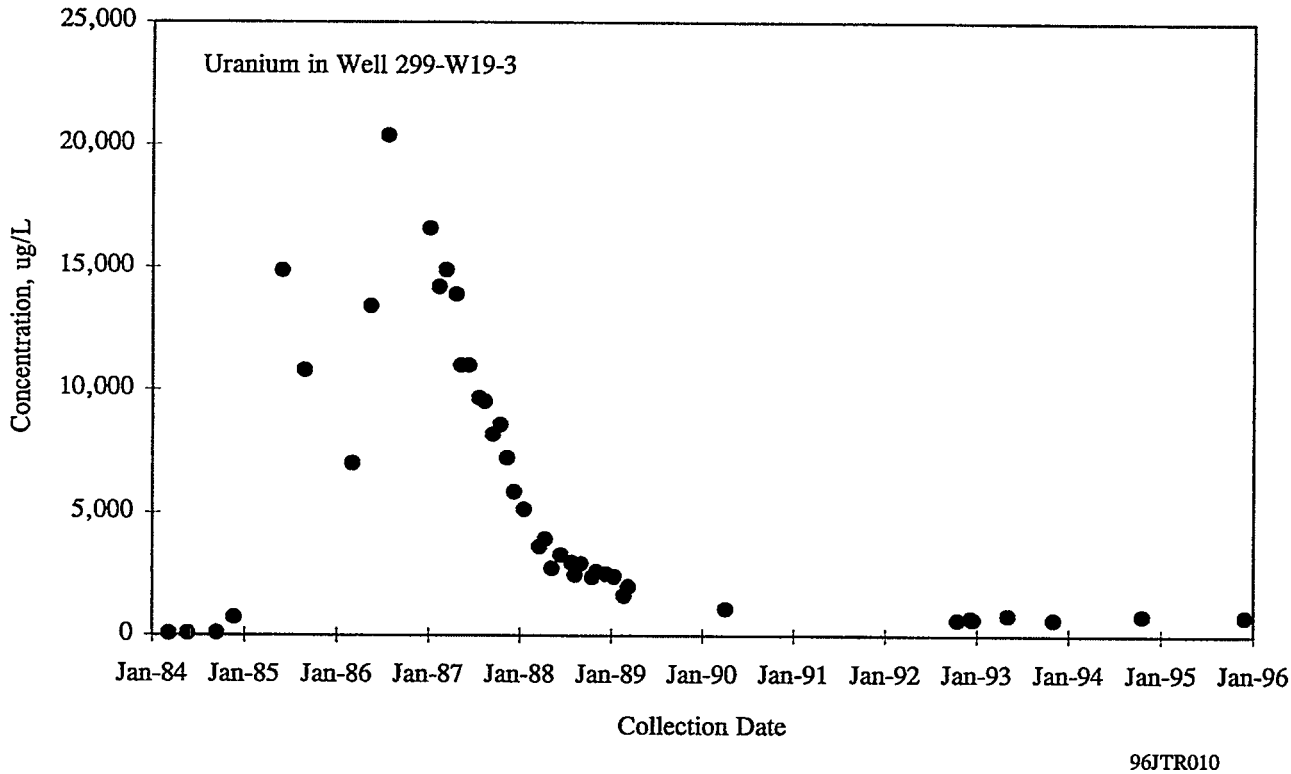

Figure 4.8.30. Uranium Concentrations in Well 299-W19-3, 1984 Through 1995

response and ceased completely in 1995. Uranium levels in well 399-1-17A, located near the trenches, were lower following that remedial action. However, levels increased sharply in late 1994 and 1995. This increase is probably related to the cessation of discharge of water to the trenches. Recent discharges have been low in uranium because fuel fabrication activities have ceased. The sudden increase after discharges were terminated is most likely related to redistribution of contamination in the aquifer or reequilibration of the water with the sediments. A trend plot showing the uranium concentrations in well 399-1-17A is shown in Figure 4.8.32.

High levels of uranium (768 µg/L) were detected in 1995 in well 699-S6-E4A, which is located near the 618-10 burial grounds. This well was not designed as a monitoring well but was sampled as part of Comprehensive Environmental Response, Compensation, and Liability Act investigations. The well will be renovated and resampled in 1996. The well is open to the unconfined aquifer at depths well below the water table. The uranium level measured in well 699-S6-E4A equates to a potential drinking water dose of 97 mrem/yr, which is just below the DOE 100 mrem standard, assuming natural isotopic abundance.

Cobalt-60

Cobalt-60 is a neutron activation product typically associated with wastes generated by processing 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.

Low levels of cobalt-60 were detected in 100-N Area wells. The maximum concentration detected was 15.1 pCi/L in well 199-N-32.

Cobalt-60 was detected at levels above the Drinking Water Standard of 100 pCi/L in the 600 Area north of the 200-East Area. The maximum concentration of cobalt-60 detected was 166 pCi/L in well 699-50-53A. The cobalt-60 plume is found in the same area as the technetium-99 contamination associated with the BY cribs. Several 200-East Area wells near the BY Cribs had low levels of cobalt-60, with the highest reported value of 31 pCi/L from well 299-E33-12, which is completed in the upper basalt confined aquifer system. The cobalt in the plume from the BY Cribs is apparently mobilized by reaction with cyanide or ferrocyanide, forming a dissolved cobalt species.

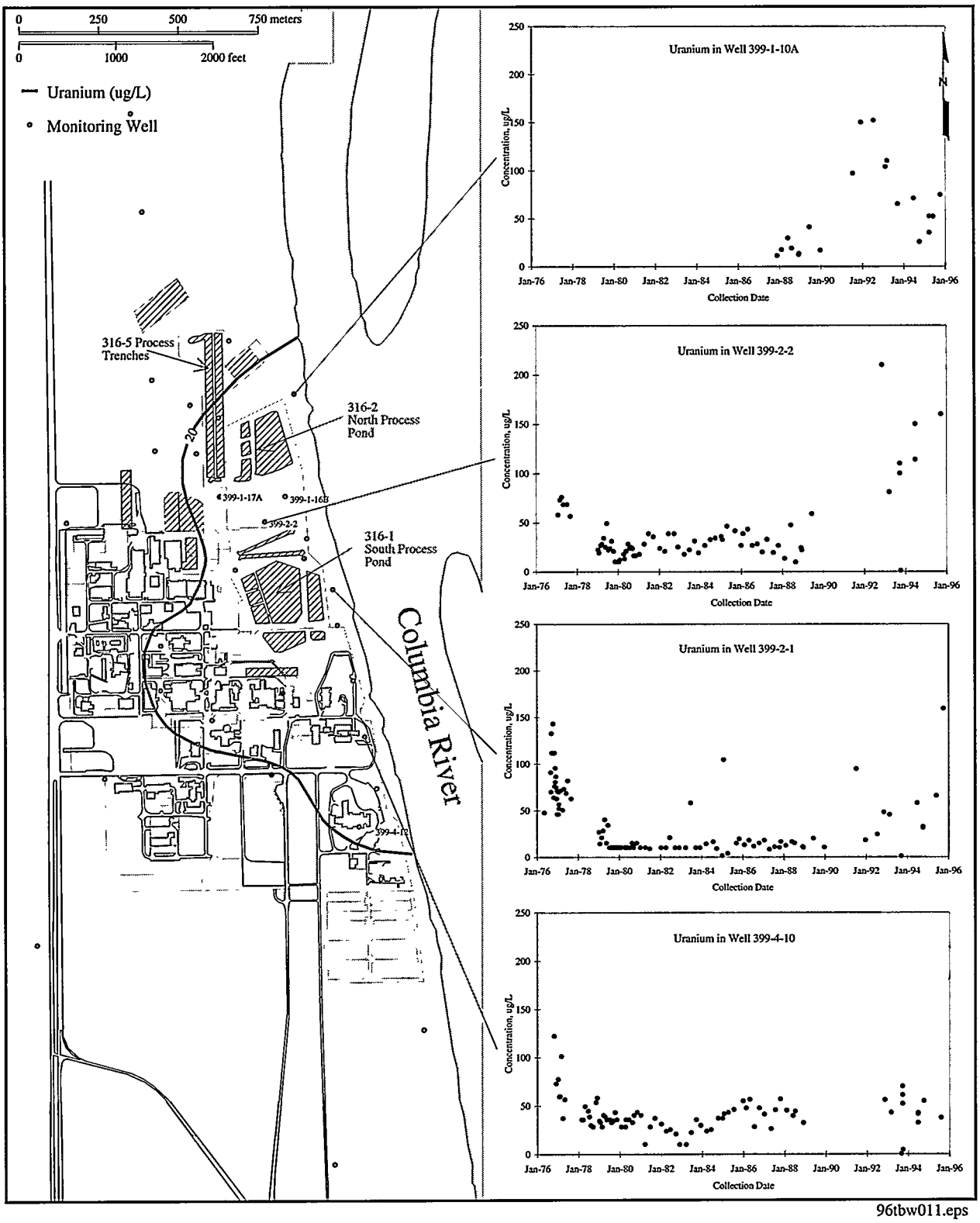

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Figure 4.8.31. Uranium Concentrations in the Unconfined Aquifer in the 300 Area, 1995, and Concentration Trends for Selected Wells

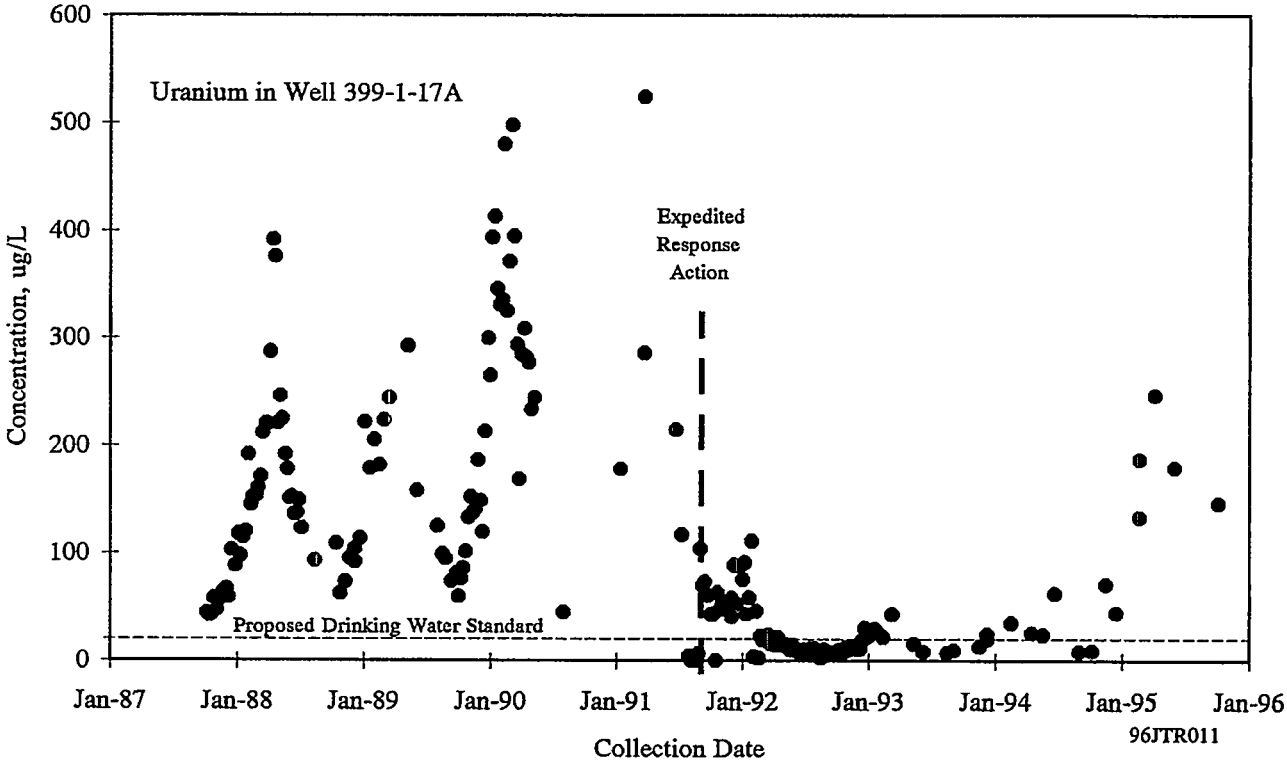

Figure 4.8.32. Uranium Concentrations in Well 399-1-17A, 1987 Through 1995

Cobalt-60 was detected near the Plutonium-Uranium Extraction 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. However, samples from this well were not analyzed for cobalt-60 in 1995 due to changes in the Resource Conservation and Recovery Act monitoring and Operational Monitoring programs.

Cobalt-60 was occasionally detected at low levels in a few 200-West Area wells. Well 299-W14-12 continued to contain detectable cobalt-60 in 1995 samples. The highest value reported in this well was 17.2 pCi/L. This well is located to the east of the WMA-TY-TX single-shell tank farms. It is not known if the presence of cobalt-60 in the ground water results from tank leaks, other tank farm releases, or discharge to nearby cribs. The levels of cobalt-60 are well below regulatory standards and contribute little to the overall dose estimates for drinking water in this area. The concentrations and extent of the plume appear stable with time.

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. The Drinking Water Standard for cesium-137 is 200 pCi/L, and the DOE Derived Concentration Guide is 3,000 pCi/L.

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 1995 concentration of cesium-137 in well 299-E28-23 was 1,470 pCi/L, and the maximum concentration in well 299-E-28-25 was 90.1 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 cesium-137 sample from 200-West Area, well 299-W23-7, contained 21.8 pCi/L of cesium-137 in 1994. This well was not sampled in 1995. Well 299-W23-7 is located in the WMA-SX single-shell tank farm. This well was sampled in early 1996 in order to confirm the presence of cesium-137 in ground water at this location. In March 1996, 18 pCi/L of cesium-137 was detected in this well.

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 sorb strongly to sediments and thus has limited mobility in the aquifer. The DOE 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 total alpha Drinking Water Standard of 15 pCi/L would be applicable at a minimum. Alternately, if the DOE 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.

Ground water sampled at 200-East Area wells located near the 216-B-5 Injection Well ranged up to 53.3 pCi/L of plutonium-239,240 in well 299-E28-24 in 1995. This value is above the DOE Derived Concentration Guide, but is much lower than the 1994 maximum result of 2,670 pCi/L and generally agrees with results for 1994 and previous years. Plutonium-238 was also detected but at considerably lower levels, up to 0.228 pCi/L, in the same sample from well 299-E28-24. 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 (0.178 pCi/L) 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).

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). The Drinking Water Standard for antimony-125 is 300 pCi/L.

Antimony-125 was detected at levels below the drinking water standard in 100-B Area well 199-B4-2 (27.1 pCi/L). It was also detected in several 100-K Area wells. The maximum concentration detected in the 100-K Area was 44.8 pCi/L in well 199-K-109A. Antimony-125 was also detected at a concentration of 21.1 pCi/L in well 699-35-70, which is located to the east of the 200-West Area Reduction-Oxidation Plant.

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. Other chemicals and parameters listed in Table 4.8.3 are indicators of the natural chemical composition of ground water and, in general, are not contaminants from operations at the Hanford Site. 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 1995 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 although 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 south, west, and southwest. The distribution of nitrate on the Hanford Site is shown in Figure 4.8.33; 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 smaller.

Most nitrate analyses performed onsite in recent years have been performed using an ion chromatography method. However, a colorometric method also has been used. The colorometric results appear prone to erratic errors. These results are currently being investigated. Several results for colorometric nitrate analyses have been excluded from the discussion below because they are off trend from other analyses and are considered suspect.

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 1995 was 184 mg/L in well 199-D8-3, located in the northern part of the Area near the Columbia River.

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 1995 was 117 mg/L in well 199-F7-3, located in the southwest part of the Area.

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 1995 was 1100 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 1995 was 131 mg/L in a sample from 199-K-30.

Minor nitrate contamination is found in parts of the 100-N Area. The maximum detected in a 1995 sample was 161 mg/L in well 199-N-67, located in the central 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 Plutonium-Uranium Extraction Plant 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 130 mg/L in well 299-E17-9 adjacent to the 216-A-10 Crib. The nitrate plume related to Plutonium-Uranium Extraction Plant operations is coincident with the tritium plume shown in Figure 4.8.12. However, as shown in Figure 4.8.33, nitrate is only found at levels above the Drinking Water Standard in a few restricted areas. 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 699-50-53A at 350 mg/L in 1995. Nitrate is also found in a few wells near the former Gable Mountain Pond, north of the 200-East Area.

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 1995 was 1,400 mg/L in well 299-W19-30. 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 (2,200,000 lb) 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.

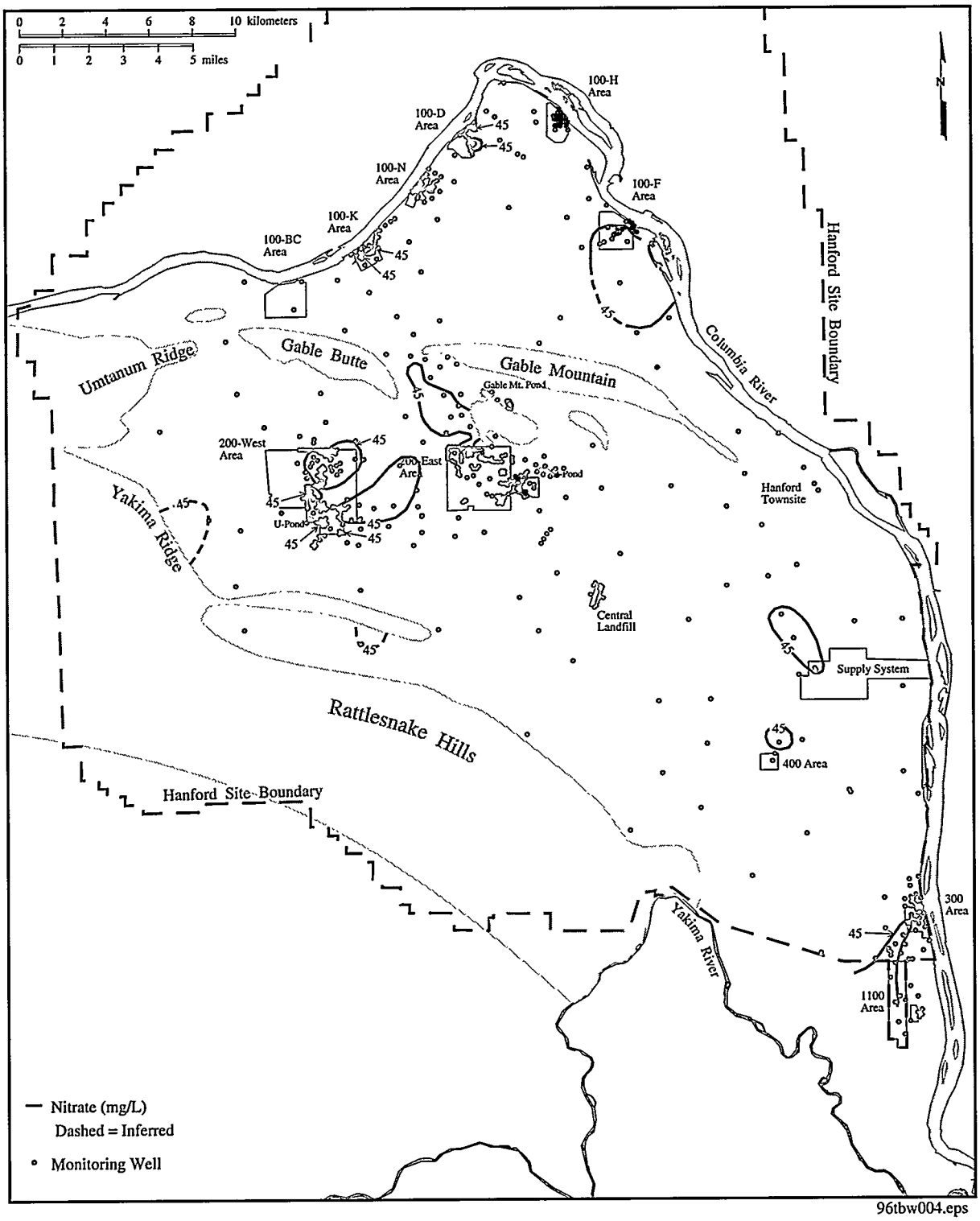

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Figure 4.8.33. Distribution of Nitrate in the Unconfined Aquifer, 1995

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 1995 ranged up to 940 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 the Hanford Site. There is no known source of nitrate in that area associated with Site operations, 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 with nitrate concentrations greater than the Drinking Water Standard extends from offsite to the 300 Area.

High nitrate concentrations have been reported offsite in parts of Grant, Adams, and Franklin counties to the east and north of Hanford. Ryker and Jones (1995) report that 28% of the wells sampled in this area had nitrate concentrations above the Drinking Water Standard. The nitrate is related, in general, to fertilizer and water usage and has been increasing since the 1950s. This nitrate may impact surface water quality (see Section 4.2, "Surface Water and Sediment Surveillance") and ground water in the north slope part of the Site.

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. A chemical speciation study performed in 1988 indicated that approximately one-third of the cyanide in ground water is present as free cyanide, and the rest may be present as ferrocyanide (Evans et al. 1989a and b). The Drinking Water Standard for cyanide is 200 µg/L.

Cyanide was detected in samples collected from wells in the northwestern part of the 200-East Area and in the 600 Area north of the 200-East Area. Only one sample collected in 1995 contained cyanide at levels above the Drinking Water Standard. That sample was from well 699-50-53A and contained 490 µg/L of cyanide. 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.

Low-level cyanide contamination is often found in limited locations in the 200-West Area. Cyanide has been detected in past years near the 216-T-26 Crib, which received a total estimated inventory of 6,000 kg (13,000 lb) of ferrocyanide from 1955 to 1956 (Stenner et al. 1988). Low levels of cyanide are also occasionally detected near the U Plant and into the 600 Area between the 200-West and 200-East Areas. In particular, well 699-44-64, which is relatively distant from potential source areas, consistently contains detectable cyanide (30 µg/L in 1995).

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 1995.

A few wells in the 200-West Area near T Plant had fluoride concentrations greater than the primary or secondary standards in 1995. Well 299-W11-7 showed a maximum fluoride concentration of 9.7 mg/L in 1995. This value is anomalously high compared to other values from this well and is considered suspect. Aluminum fluoride nitrate used in the 200-West Area processes is the probable source of the fluoride contamination.

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 used for decontamination in the 100, 200, and 300 Areas and also was used for oxidation state control in the Reduction-Oxidation Plant process. In the hexavalent form, chromium is present in an anionic state. Hexavalent chromium is thus freely mobile in the ground water. The federal Drinking Water Standard for chromium is 100 µg/L, and the Washington State Standard is 50 µg/L.

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. In general, filtered samples provide the best indication of ground-water contamination levels for chromium since unfiltered samples are subject to greater variability introduced by the sampling process. Chromium concentrations in filtered samples will be used to describe the level of contamination in the discussion below.

Chromium in the 100 Areas. Chromium has been detected in ground water from wells in each of the 100 Areas. Chromium concentrations in filtered samples collected from the 100-B/C Area in 1995 were above the Washington State Drinking Water Standard in only two wells. The maximum concentration detected was 86.6 µg/L in well 199-B5-1.

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 ground water. The maximum chromium concentration from filtered samples in the 100-D Area in 1995 was 1,760 µg/L in well 199-D5-14. The chromium distribution in the 100-D Area is shown in Figure 4.8.34.

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 1995 in filtered samples from the 100-F Area was 196 µg/L in well 199-F5-46. This is the only well that was above the Drinking Water Standards.

Many samples from the 100-H Area contained chromium at levels greater than the Drinking Water Standard (Figure 4.8.34). Chromium was often present at similar levels in both filtered and unfiltered samples. The maximum chromium concentration from 100-H Area filtered samples collected from the shallow parts of the unconfined aquifer in 1995 was 190 µg/L in well 199-H3-2A. 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 in 1995. Potential chromium sources in the 100-H Area include disposal of sodium dichromate near the reactor building, disposal 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 Standards (Figure 4.8.35). The maximum concentration in 1995 was 914 µg/L in well 199-K-36, near the K-East reactor filter plant. Chromium is also found at levels above the Drinking Water Standard near the 100-K Area Liquid Waste Disposal Trench and the K-West reactor building.

At the 100-N Area, only two wells sampled in 1995 contained filtered chromium at concentrations greater than

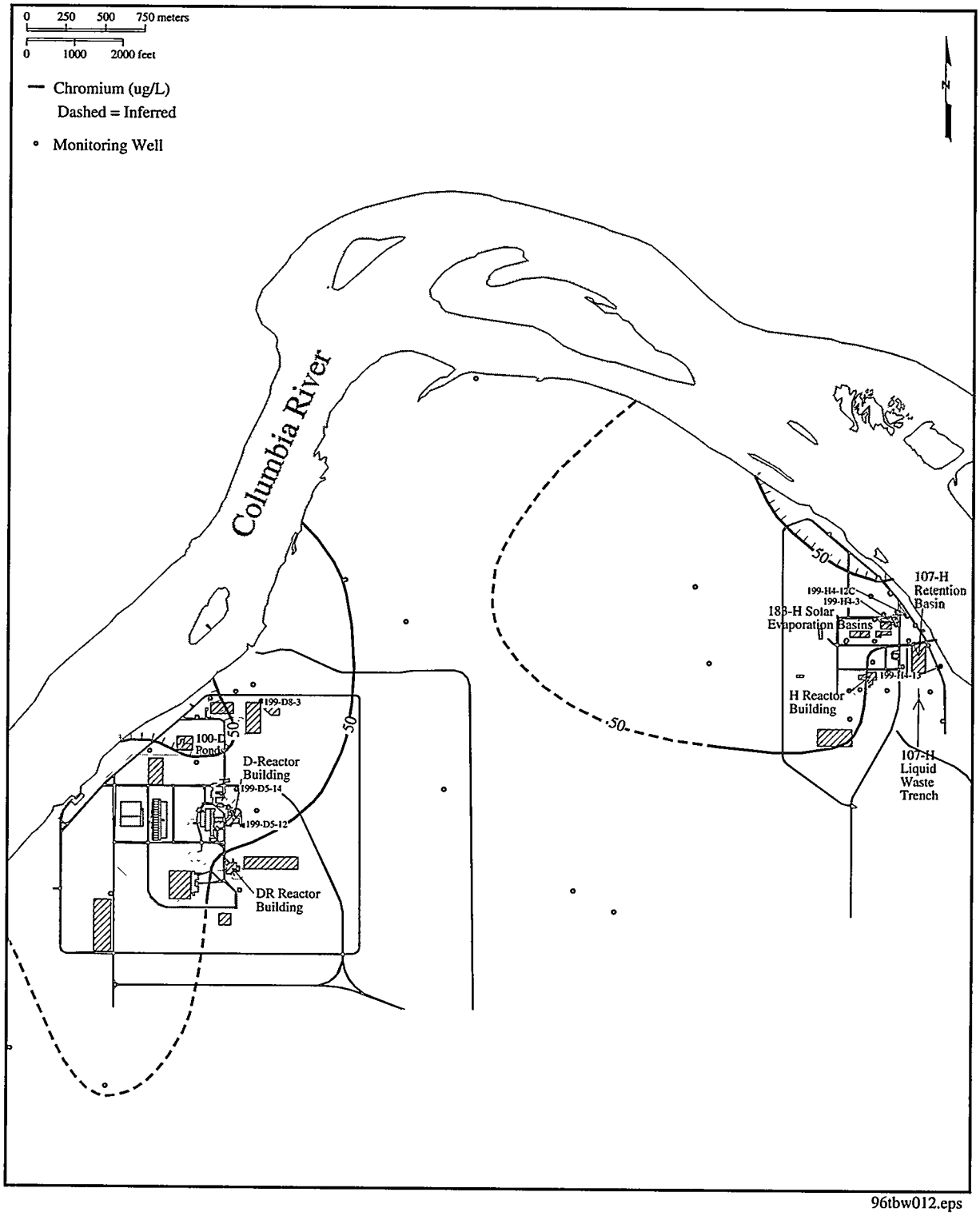

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Figure 4.8.34. Distribution of Filtered Chromium in the 100-D and 100-H Areas, 1995

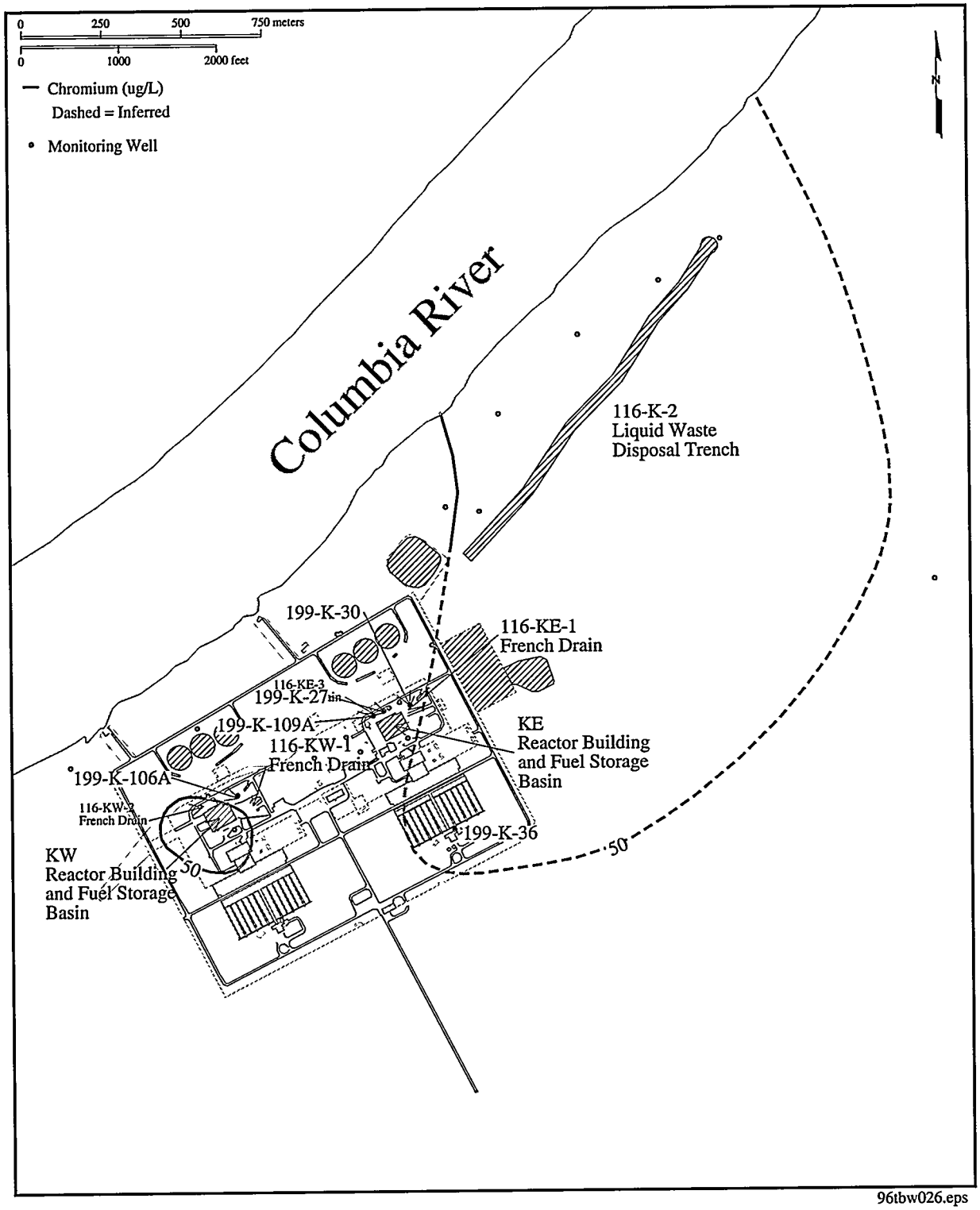

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Figure 4.8.35. Distribution of Filtered Chromium in the 100-K Area, 1995

the Drinking Water Standards. The maximum concentration detected was in well 199-N-80, which 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 filtered samples from this well was 234 µg/L.

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 maximum concentration detected in a filtered sample collected in 1995 was 410 µg/L. This well is located on the southern boundary of the WMA-A-AX single-shell high-level waste tank farms. Chromium concentrations in this well have decreased since a sharp peak in concentration, which occurred in late 1992 (Figure 4.8.36). Chromium is a component of stainless steel, and its presence in groundwater samples at the Hanford Site is often attributed to corrosion of stainless-steel well components. Nickel, which is another stainless-steel component, also showed elevated concentrations. However, the chromium present in samples from this well does not follow the pattern usually attributed to corrosion of the stainless steel well casing and well screen. Other stainless steel wells tend to show elevated chromium values in only the unfiltered samples, and the trends tend to be erratic due to variable amounts of particulate matter being entrained in the sample.

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 1995 was 930 µg/L in one sample from well 299-W10-15, which is located to the north of the WMA-T single-shell tank farm, and in an area near facilities that received liquid discharge from T Plant operations.

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. Filtered samples from several wells south of the 200-East Area contain chromium at levels above the Drinking Water Standards. The maximum concentration detected in filtered samples in this area was 220 µg/L in well 699-32-62. These wells are located generally downgradient of the southern part of the 200-West Area. The extent of chromium contamination in this area is poorly defined, and the source has not been determined. The wells in this area are widely spaced so the extent of the contamination is potentially large.

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 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 [68°F]). 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. The Drinking Water Standard for carbon tetrachloride is 5 µg/L.

The maximum concentration of carbon tetrachloride detected in the 200-West Area in 1995 was 4,900 µg/L in well 299-W18-1. The carbon tetrachloride distribution in the 200-West Area ground water (Figure 4.8.37) has changed slowly since the presence of the contaminant plume was first noted in 1987. Figure 4.8.37 shows the trends in carbon tetrachloride concentrations through time for wells located at the east, west, north, and south parts of the plume. The greatest increases in concentration are found to the north and south of the Plutonium Finishing Plant. Carbon tetrachloride concentrations in the central part of the carbon tetrachloride plume have declined in recent years. The trend plot for well 299-W15-16 illustrates this decline from concentrations over 8,000 µg/L in the late 1980s to values ranging from 3,800 to 4,200 µg/L in 1995 (Figure 4.8.38).

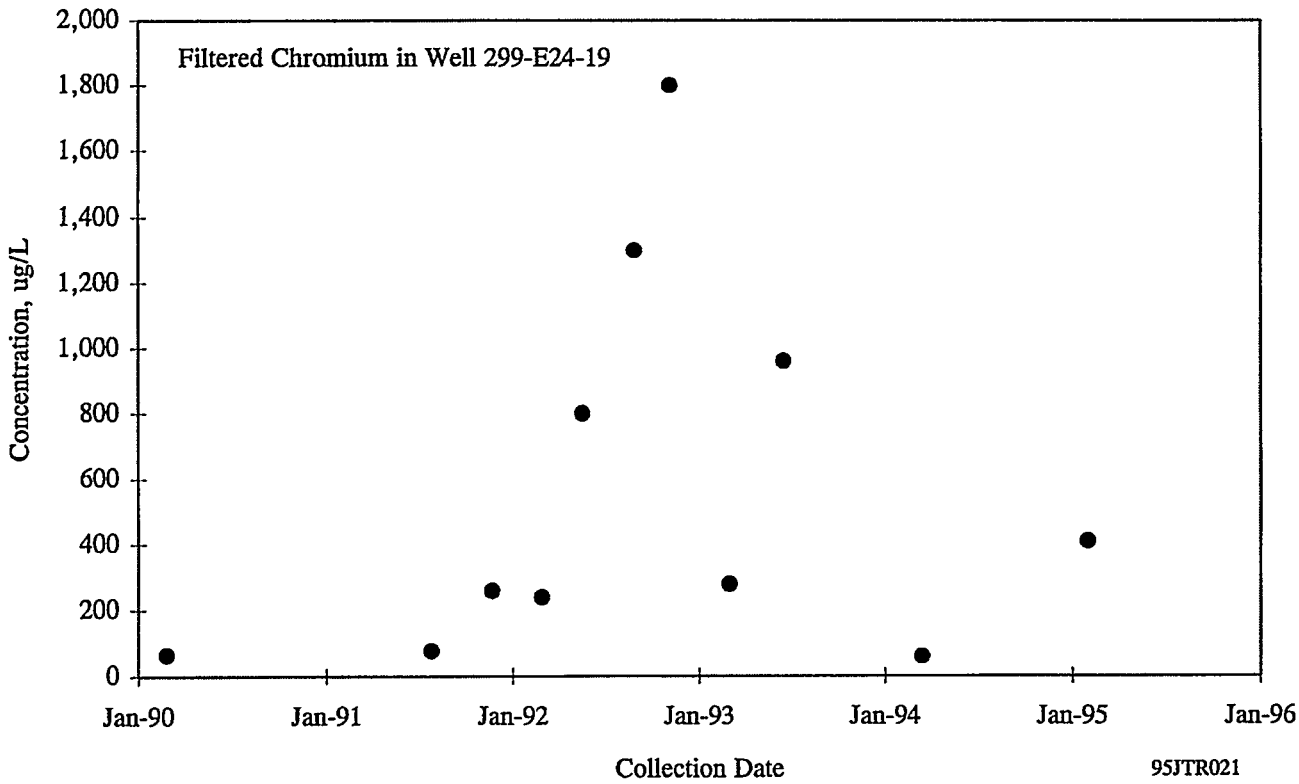

Figure 4.8.36. Filtered Chromium Concentrations in Well 299-E24-19, 1990 Through 1995

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 east. In addition, there is 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 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, lateral expansion of the carbon tetrachloride plume is expected to continue.

In addition to carbon tetrachloride, significant amounts of other chlorinated hydrocarbon solvents were found in 200-West Area ground water, including chloroform. The Drinking Water Standard for chloroform is 100 µg/L (total trihalomethanes), which is 20 times higher than that for carbon tetrachloride. The highest chloroform level recorded in 1995 was 1,100 µg/L in well 299-W15-30, located near the Plutonium Finishing Plant. The chloroform plume appears to be associated with, but not exactly coincident with, the carbon tetrachloride plume. 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 1995, 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 1995 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 some 100-F Area wells. The maximum concentration detected in the 100-F Area in 1995 was 22 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 two wells sampled in 1995 in the 100-K Area contained trichloroethylene at levels above the Drinking

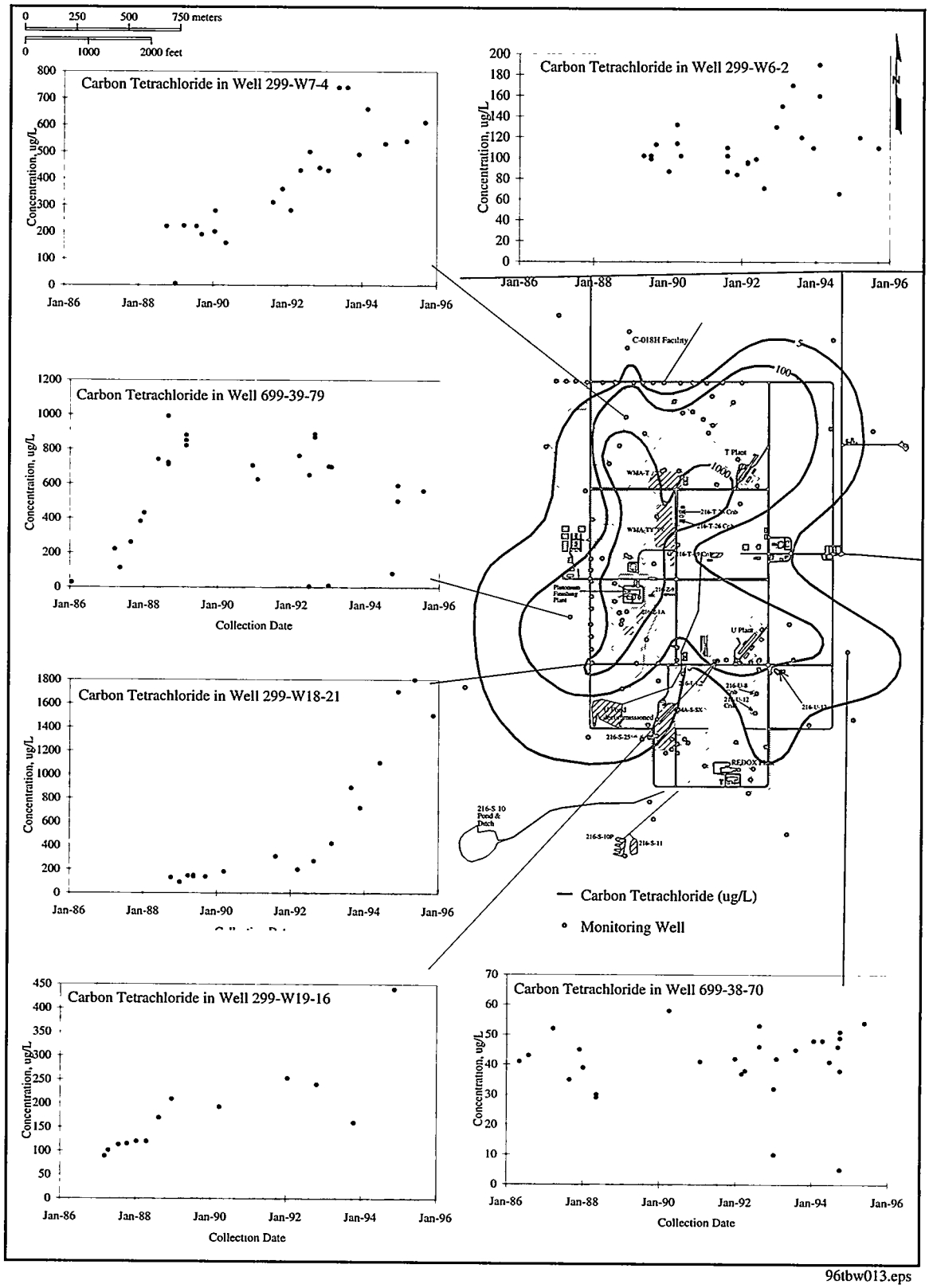

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Figure 4.8.37. Distribution of Carbon Tetrachloride in the Unconfined Aquifer in the 200-West Area, 1995, and Concentrations Trends for Several Wells Within the 200-West Area

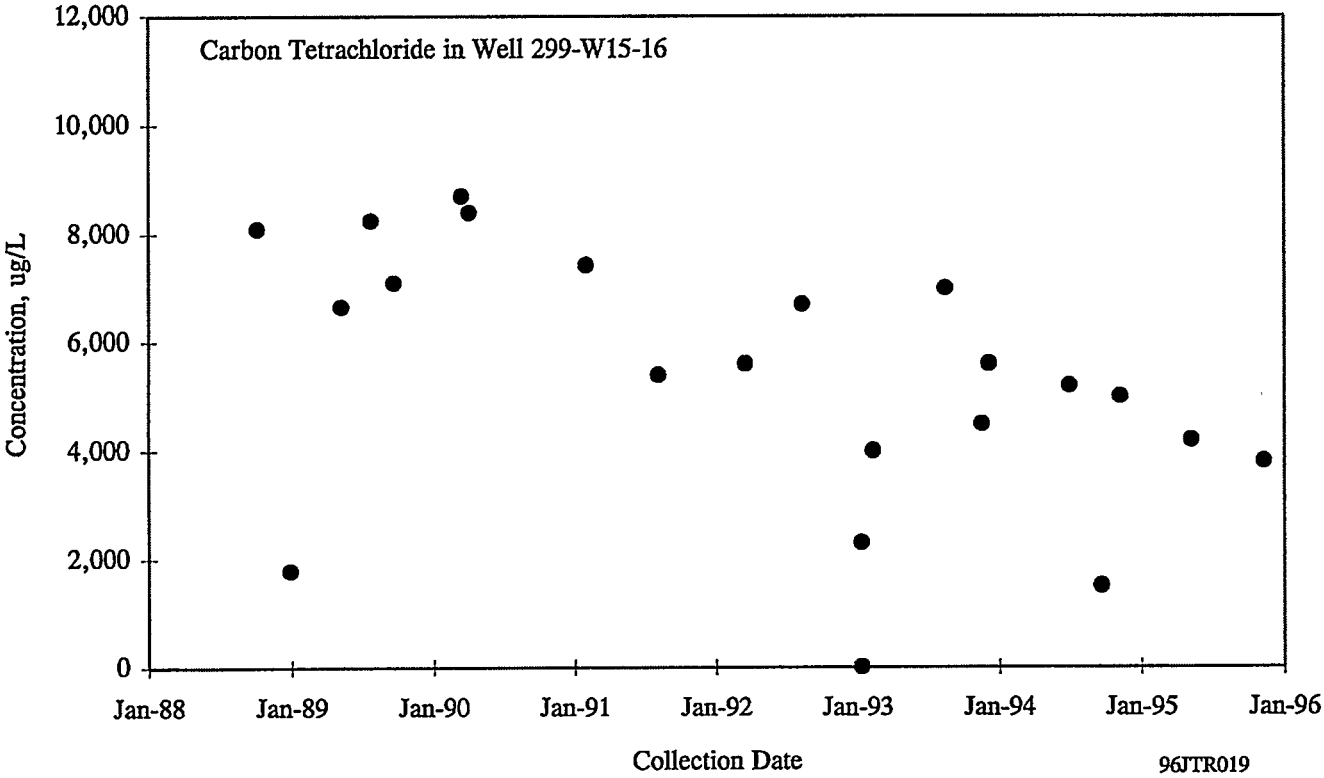

Figure 4.8.38. Carbon Tetrachloride Concentrations in Well 299-W15-16, 1988 Through 1995

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 1995 was 35 µg/L in monitoring well 199-K-106A which is located near the K-West reactor building.

Trichloroethylene in the 200 Areas. Trichloroethylene was detected in 1995 at levels greater than the Drinking Water Standard in the 200-West Area in several areas (Figure 4.8.39). The first area extends from the Plutonium Finishing Plant to the west of T Plant, past the northern boundary of the 200-West Area. Concentrations up to 19 µg/L were detected in 1995 in this plume. 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 was also measured at 25 µg/L in a sample from well 299-W22-20 near the Reduction-Oxidation 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 in 1995 was 6.0 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 one well, 399-4-12 in the southern half of the 300 Area, where the concentration reported in 1995 was 5.0 µg/L. This well is used as a non-potable water supply for aquatics research (Figure 4.8.2).

Trichloroethylene in the 600 Area. Several wells at the Solid Waste Landfill (part of the central landfill) contained trichloroethylene levels that are less than the Drinking Water Standard (maximum of 2.8 µg/L in well 699-23-34A). Solid Waste Landfill wells had shown trichloroethylene concentrations greater than the Drinking Water Standard before 1994. 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 but was not sampled for trichloroethylene in 1995.

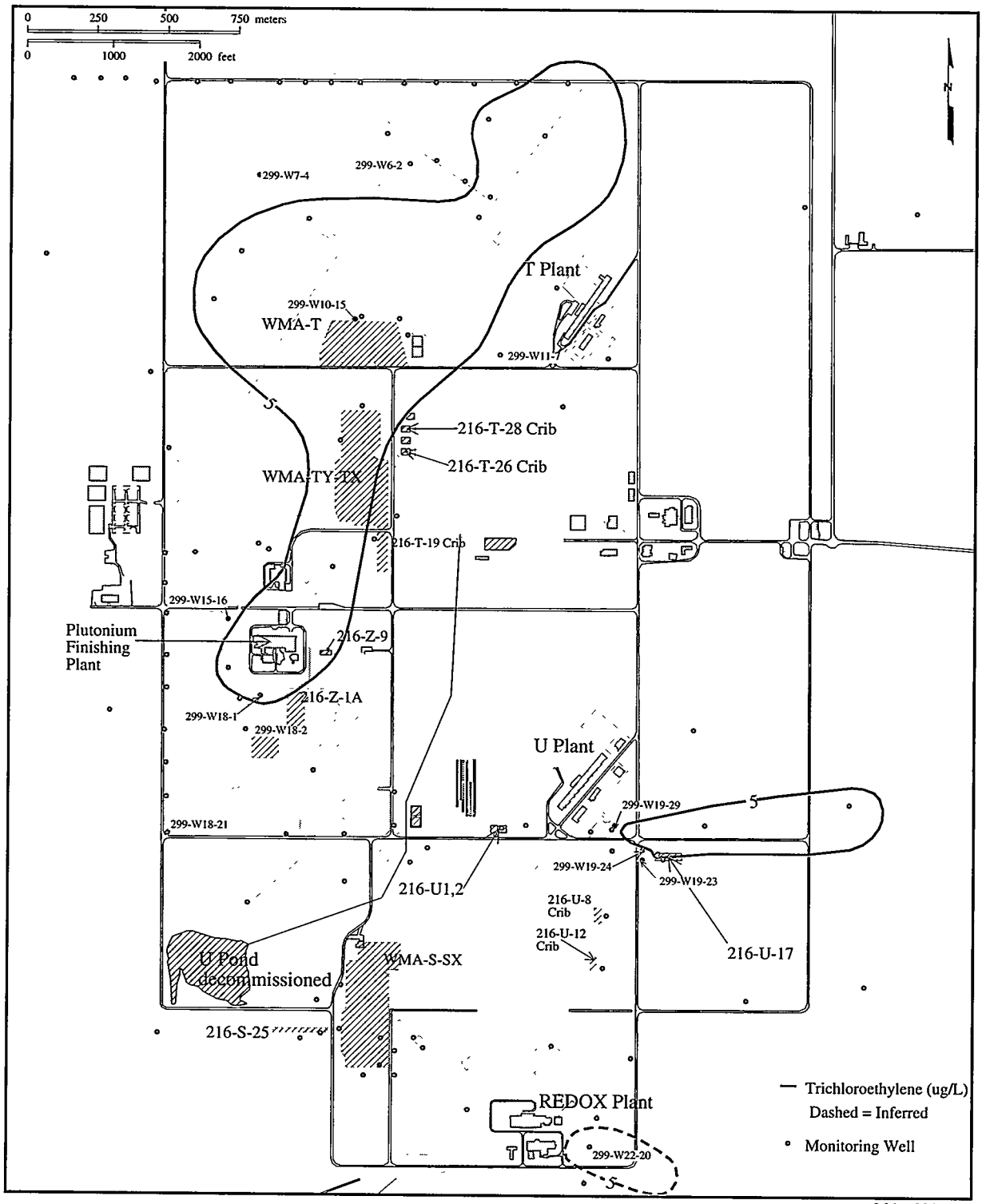

Figure 4.8.39. Distribution of Trichloroethylene in the Unconfined Aquifer in the 200-West Area, 1995

Trichloroethylene is found at levels above the Drinking Water Standard in a number of wells in the vicinity of the Horn Rapids Landfill in the southern part of the Site (Richland North Area). This contamination forms a plume leading towards the 300 Area but appears to have an origin off the Hanford Site (Figure 4.8.40). The trend plots shown on Figure 4.8.40 provide an indication of the migration of the trichloroethylene plume toward the northeast in this vicinity. The maximum trichloroethylene contamination detected in this plume in 1995 was 30 µg/L in well 699-S31-E10C. DOE monitors this plume under the 1100-EM-1 Record of Decision and through the Ground-Water Surveillance Project.

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 concentrations of tetrachloroethylene below the Drinking Water Standard. In 1995, 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 4.1 µg/L in well 699-24-34B in 1995. Tetrachloroethylene exceeded the Drinking Water Standard in wells near the Solid Waste Landfill before 1994. Tetrachloroethylene is commonly used as a degreasing solvent.

Radiological and Chemical Monitoring Results for the Confined Aquifer

The confined aquifers below the unconfined aquifer show much less impact from Site contamination than the unconfined aquifer. The minor contamination found in the confined aquifer may be attributed to several factors including areas where the confining layers of basalt have been eroded away, areas where disposal of large amounts of water resulted in downward gradients, and areas where wells penetrating to the confined aquifers provided pathways for contaminant migration. These factors produced intercommunication between the aquifers, meaning they permitted the flow of ground water from the unconfined aquifer to the underlying confined aquifer, thereby increasing the potential to spread contamination. Because fewer wells are available to evaluate contamination in the confined aquifer, it is important to consider contamination in the confined aquifer even where the levels are well below Drinking Water Standards. The extent of tritium and other detected contaminants in the uppermost confined aquifer are shown in Figure 4.8.41.

Intercommunication between the unconfined and the underlying confined aquifers in the vicinity of the northern part of the 200-East Area has been identified previously by Gephart et al. (1979) and Graham et al. (1984). Spane and Webber (1995) evaluated the hydrochemical and hydrogeologic conditions within the upper basalt confined aquifer system and evaluated the potential for offsite migration of contaminants through confined aquifer pathways. The upper basalt confined aquifer was monitored to determine the extent of ground-water contamination resulting from interaction between the unconfined and confined aquifers. Ground-water samples from selected confined aquifer wells have been analyzed for a variety of radionuclides and hazardous chemicals. Spane and Webber (1995) identified several confined aquifer wells north and east of the 200-East Area that show evidence of intercommunication with the overlying unconfined aquifer. Intercommunication between the unconfined and confined aquifers in the area north and east of the 200-East Area has been attributed to erosion of the upper Saddle Mountains Basalt and downward vertical gradients resulting from ground-water mounding associated with waste disposal. Ground-water chemical data from most confined aquifer wells in other areas of the Hanford Site do not exhibit evidence of contamination, with the exception of wells that were previously open to both the unconfined and confined aquifers, thus providing conduits for the downward transport of contamination.

Samples collected in 1995 from well 199-B3-2P in the 100-B Area contained up to 469 pCi/L of tritium and 3.93 pCi/L of strontium-90. Even though the value for strontium-90 observed in 1995 was below the Drinking Water Standard, values observed in the past were above the Drinking Water Standard. This well is currently completed in the confined aquifer but was open to both the unconfined and confined aquifers between 1953 and 1970. It is likely that the well provided a conduit for downward migration of contamination from the unconfined aquifer. The current extent of contamination in the confined aquifer near well 199-B3-2P is unknown.

Contamination has been identified in the confined aquifer in the northern part of the 200-East Area and adjacent parts of the 600 Area. The highest levels of contamination detected in the confined aquifer in this vicinity were in well 299-E33-12. Contamination in this well is attributed to migration of high-salt waste down the borehole during construction when it was open to both the

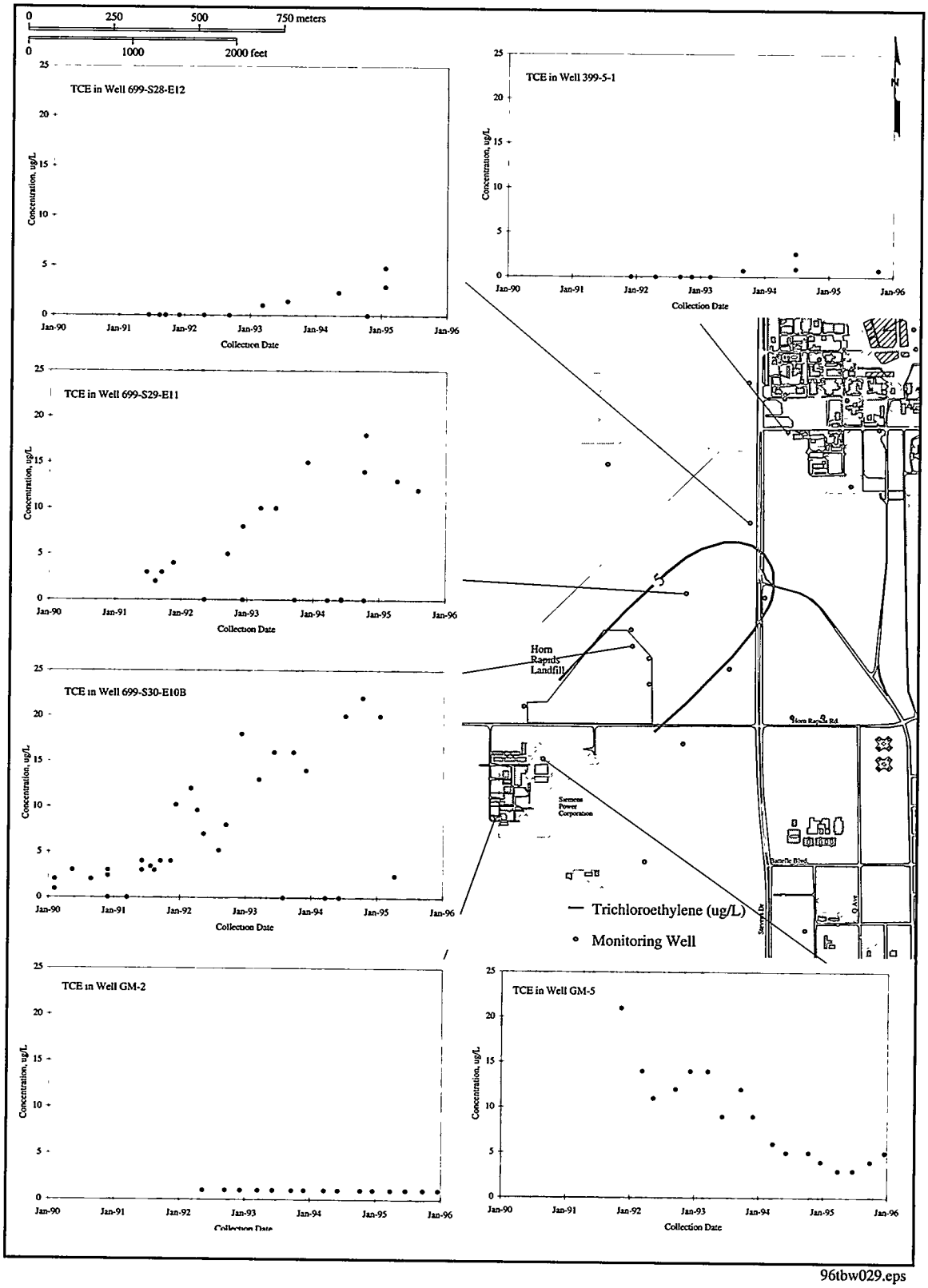

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Figure 4.8.40. Distribution of Trichloroethylene in the Vicinity of the Horn Rapids Landfill and Richland North Area, 1995, and Concentration Trends for Selected Wells

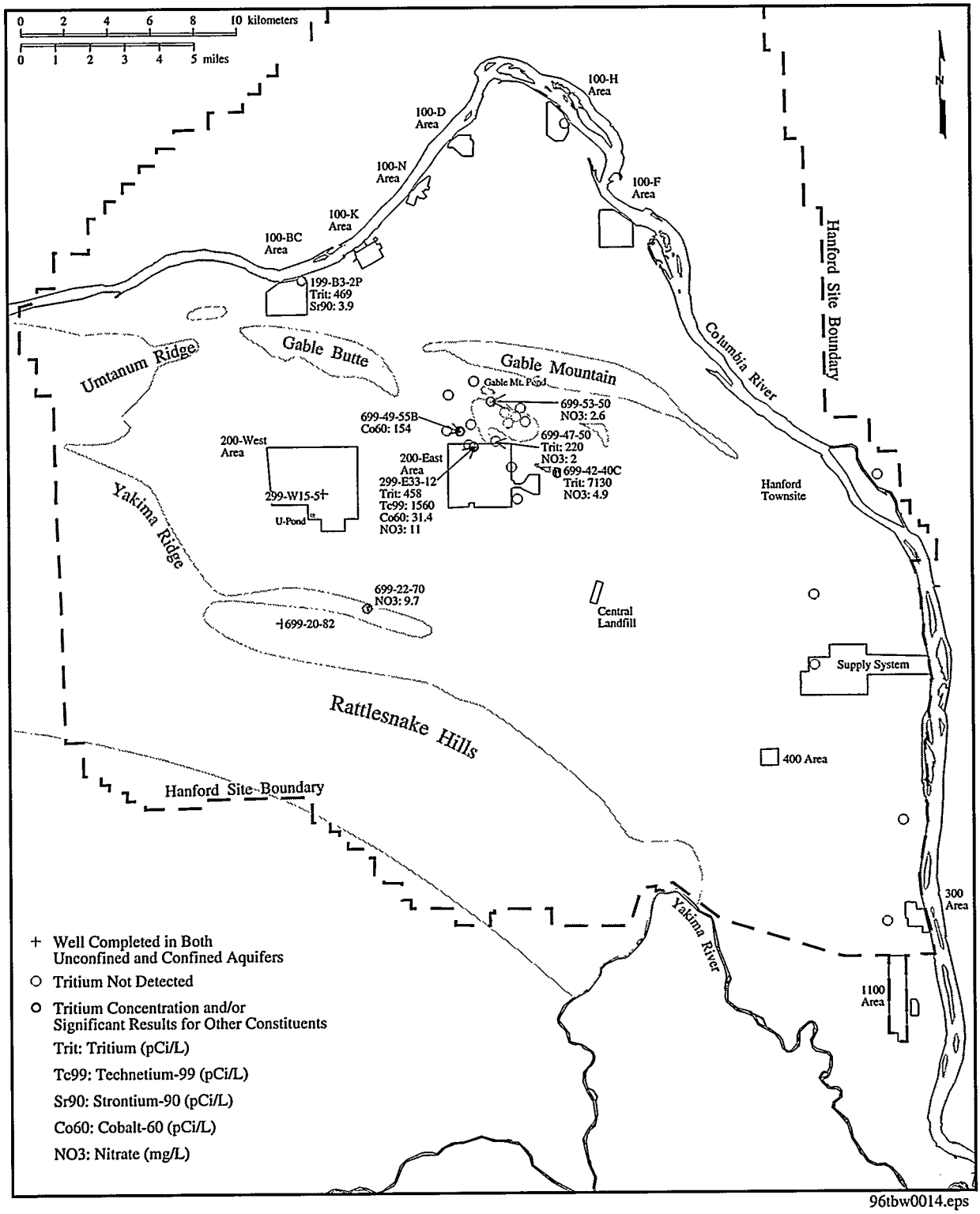


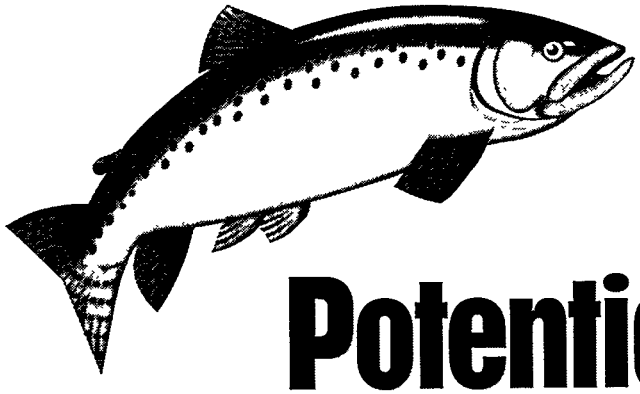
Figure 4.8.41. Tritium and Other Contaminants Detected in Confined Aquifer Wells, 1995

unconfined and confined aquifers (Graham et al. 1984). The 1995 samples from well 299-E33-12 contained technetium-99 at levels above the Drinking Water Standard (maximum of 1,560 pCi/L). The 1995 tritium levels (up to 458 pCi/L) in this well were similar to levels detected since 1982, when the well was modified to isolate the unconfined and confined aquifers. The 1995 samples from this well also contain cobalt-60 at levels up to 31.4 pCi/L, nitrate at levels up to 11 mg/L, and cyanide at levels up to 20.7 µg/L. Cobalt-60 was detected at levels up to 154 pCi/L in well 699-49-55B, located north of the 200-East Area. In the past, cobalt-60 concentrations in samples from this well have been below detection. Currently, the cause and extent of cobalt-60 contamination in the confined aquifer near well 699-49-55B is unknown. However, it should be noted that ground-water flow at this location was perturbed by the use of well 699-49-55A, completed in the unconfined aquifer, for injection of water from a pump-and-treat treatability test for ground-water remediation in 1994.

The 1995 samples from well 699-42-40C, located adjacent to B Pond, contained up to 7,130 pCi/L of tritium, and 4.9 mg/L of nitrate, which are significantly below the Drinking Water Standards. Well 699-47-50 is located near the edge of the ground-water mound beneath B Pond where vertical gradients are upward. The 1995 samples from well 699-47-50 contained only 2 mg/L of nitrate and did not contain tritium above the detection limit (300 pCi/L). However, 1993 samples from well 699-47-50, which were analyzed using more sensitive methods for tritium, indicated elevated tritium (220 pCi/L) at levels similar to process-cooling waters discharged to B Pond. These low levels of contamination indicate that some intercommunication has occurred between the aquifers.

Well 299-W15-5 in the 200-West Area is completed in both the unconfined and confined aquifers, where ground-water mounding associated with the decommissioned U Pond has increased the downward vertical gradient and may be a conduit for downward migration of contamination from the unconfined aquifer. Past data for this well indicate that tritium concentrations were as high as 7,000 pCi/L in 1982. The current extent of contamination in the confined aquifer near well 299-W15-5 is unknown.

Wells 699-20-82 and 699-22-70 are completed in the basalt near the base of the Rattlesnake Hills in an area where pervasive downward flow from the unconfined aquifer recharges the upper portion of the confined aquifer (Spane and Webber 1995). Samples for well 699-22-70 contained up to 9.7 mg/L of nitrate in 1995, well below the Drinking Water Standard. Samples from well 699-20-82 in past years contained as much as 23.9 mg/L of nitrate. Nitrate in the overlying unconfined aquifer in the Dry Creek Valley area, and in wells 699-20-82 and 699-22-70, may result from agricultural sources to the south and west but is not believed to originate from sources on the Hanford Site.



Potential Radiation Doses from 1995 Hanford Operations

5.0 Potential Radiation Doses from 1995 Hanford Operations

E. J. Antonio and K. Rhoads

During 1995, radionuclides reached the environment in gaseous and liquid effluents from Hanford operations. Gaseous effluents were released from operating stacks and ventilation exhausts. Liquid effluents were released from operating waste-water treatment facilities and from contaminated ground water seeping into the Columbia River.

Potential radiological doses to the public from these releases were evaluated in detail to determine compliance with pertinent regulations and limits. The radiological impacts of 1995 Hanford operations were assessed in terms of the following:

- dose to a hypothetical maximally exposed individual 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 Hanford operating areas
- absorbed dose rate (rad/d) received by animals caused by radionuclide releases to the Columbia River.

It is generally accepted that radiological 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 1995 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, 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, radiological doses from the water pathway were calculated based on the differences in radionuclide concentrations between upstream and downstream sampling points. During 1995, tritium, strontium-90, technetium-99, and isotopes of uranium were found in the Columbia River downstream of Hanford at greater concentrations than predicted based on direct discharge from the 100 Areas. Riverbank spring water containing these radionuclides is known to enter the river along the portion of shoreline extending from the old Hanford Townsite to downstream of the 300 Area (see Section 4.2, "Surface Water and Sediment Surveillance"). No direct discharges from the 300 Area to the Columbia River were reported in 1995.

The radiological doses[a] to the public from Hanford operations in 1995 were calculated for a hypothetical maximally exposed individual and for the collective population 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 the GENII computer code Version 1.485 (Napier et al. 1988a, 1988b, 1988c) and Hanford Site-specific parameters listed in Appendix D and in Bisping (1996).

The dose to the maximally exposed individual from Hanford operations in 1995 was potentially 0.02 mrem (2×10^{-4} mSv), compared to 0.04 mrem (4×10^{-4} mSv) reported for 1994. The dose to the local population of

(a) Unless stated otherwise, the term "dose" in this section is the "total effective dose equivalent" (see Appendix B, "Glossary").

380,000 (Beck et al. 1991) from 1995 operations was 0.3 person-rem (0.003 person-Sv), compared to 0.6 person-rem (0.006 person-Sv) reported for 1994. The 1995 average dose to the population was about 0.0009 mrem (9 x 10^{-6} mSv) per person. The current DOE radiation dose limit for an individual member of the public is 100 mrem/yr (1 mSv/yr) from all pathways and 10 mrem/y (0.1 mSv/y) from airborne radionuclide emissions. The national average dose from natural sources is 300 mrem/yr (3 mSv/yr). Thus, 1995 Hanford emissions potentially contributed to the maximally exposed individual a dose equivalent to only 0.02% of the DOE dose limit, or 0.01% of the average dose received from natural radioactivity in the environment. For the average member of the local population, these contributions were 0.001% and 0.0003%, respectively.

The uncertainty associated with the radiological dose calculations on which this report is based has not been quantified. However, when 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 hypothetical maximum estimates of doses resulting from Hanford operations.

Maximally Exposed Individual Dose

The maximally exposed individual 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 diet, dwelling place, and other factors were chosen to maximize the combined doses from all reasonable environmental pathways of exposure to radionuclides in Hanford effluents. In reality, such a combination of maximized parameters is unlikely to apply to any one individual.

The location of the maximally exposed individual 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 used to assess the dose to the maximally exposed individual: 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 5.0.1). The Ringold location is closer than Riverview to Hanford facilities that were the major contributors of airborne effluents in the past. At Riverview, the maximally exposed individual has the highest exposure to radionuclides in the Columbia River. Since 1993, a third location has been considered because of the shift in Site operations from strategic materials production to the current mission of research and environmental restoration. This change has resulted in decreased significance in the air emissions from the 200-Area production facilities relative to the activity in the 300 Area, i.e., the shift in the location of the maximally exposed individual is mainly due to the reduction in releases at the 100 and 200 Areas and increased activity in the 300 Area. Therefore, a receptor directly across the river from the 300 Area, at Sagemoor, would be maximally exposed to airborne radionuclides from those facilities. The applicable exposure pathways for each of these locations are described in the following.

The Ringold location is situated to maximize the air pathway exposures from emissions at the 200 Area facilities, including direct exposure to the plume, inhalation, external exposure to radionuclides that deposit on the ground, and ingestion of locally grown food products. In addition, it is assumed that individuals at the Ringold location irrigate their crops with water taken from the Columbia River downstream of where ground water enters the river from the 100 Areas and 200-East Area (Figure 4.8.17). This results in additional exposures from ingestion of irrigated food products and external irradiation from radionuclides deposited on the ground by irrigation. Recreational use of the Columbia River is also considered for this individual, resulting in direct exposure from water and radionuclides deposited on the shoreline and internal dose from ingestion of locally caught fish.

The Riverview receptor is assumed to be exposed via the same pathways as the individual at Ringold, except that irrigation water from the Columbia River may contain radionuclides that enter the river at the 300 Area, in addition to those from upstream release points. This individual is also assumed to obtain domestic water from the river via a local water treatment system. Exposure to this individual from the air pathways is typically lower than exposure at Ringold because of the greater distance from the major onsite emission sources.

The individual at Sagemoor (assumed to be located 1.5 km [1 mi] directly across the Columbia River from

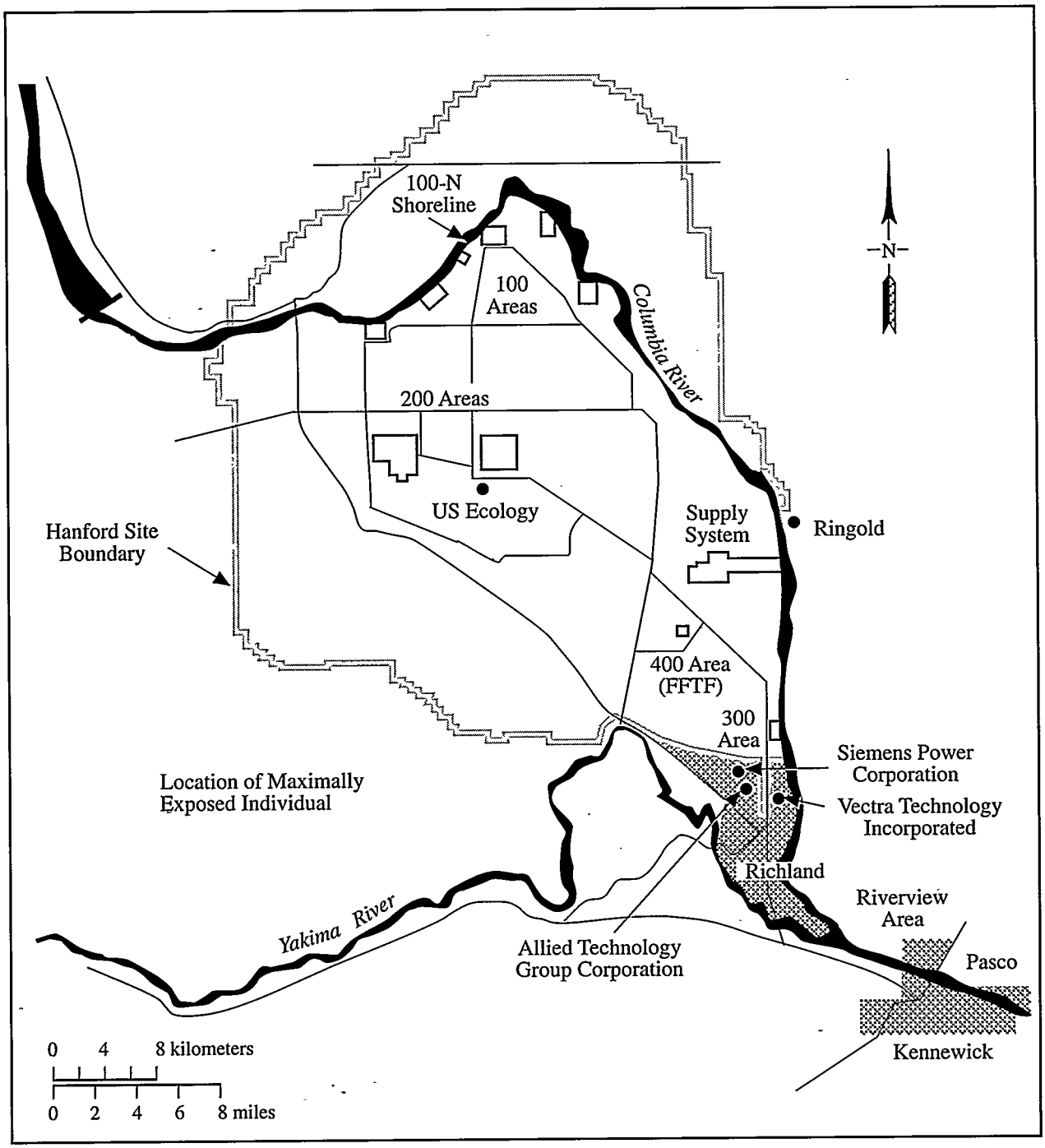


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Figure 5.0.1. Locations Important to Dose Calculations

the 300 Area) receives maximum exposure to airborne effluents from the 300 Area, including the same pathways as the individual at Ringold. Domestic water at this location comes from a well rather than from the river, and wells in this region are not contaminated by radionuclides of Hanford origin (DOH 1988). Although the farms located across from the 300 Area obtain irrigation water from upstream of the Hanford Site, the conservative assumption was made that the diet of the maximally exposed individual 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 radionuclides in the Riverview irrigation water maximizes the calculated dose from all air and water pathways combined.

During 1995, the hypothetical maximally exposed individual at Sagemoor was calculated to have received a slightly higher dose than a maximally exposed individual located at either Ringold or Riverview. Radiation doses to the maximally exposed individual were calculated using the effluent data in Section 3.1, Tables 3.1.1, and 3.1.4. Quantities of radionuclides assumed to be present in the Columbia River from riverbank springs were also calculated for input to the GENII code. The estimated releases to the river from these sources were derived from the difference between the upstream and downstream concentrations. These radionuclides were assumed to enter the river through ground-water seeps between the old Hanford Townsite and the 300 Area. The calculated doses for the maximally exposed individual are summarized in Table 5.0.1. These values include the doses received from exposure to liquid and airborne effluents during 1995, as well as the future, or committed dose from radionuclides that were inhaled or ingested during 1995. 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"). The estimated dose from diffuse sources was similar to the dose reported in Table 5.0.1 for measured emissions. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix D.

The total radiation dose to the hypothetical maximally exposed individual in 1995 was calculated to be 0.02 mrem (2×10^{-4} mSv) compared to 0.04 mrem (4×10^{-4} mSv) calculated for 1994. The primary pathways contributing to this dose (and the percentage of all pathways) were:

- consumption of food irrigated with Columbia River water containing radionuclides (38%), principally tritium and uranium

Table 5.0.1. Dose to the Hypothetically Maximally Exposed Individual Residing 1.5 km East of the 300 Area in 1995

		Operating Area Contribution Doses, mrem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	1.0×10^{-4}	2.0×10^{-6}	5.2×10^{-5}	2.2×10^{-8}	1.5×10^{-4}
	Inhalation	4.0×10^{-5}	2.1×10^{-4}	5.2×10^{-3}	1.4×10^{-5}	5.5×10^{-3}
	Foods	1.1×10^{-6}	8.3×10^{-4}	5.9×10^{-5}	2.4×10^{-7}	8.9×10^{-4}
	Subtotal air	1.4×10^{-4}	1.0×10^{-3}	5.3×10^{-3}	1.4×10^{-5}	6.5×10^{-3}
Water	Recreation	3.5×10^{-6}	7.0×10^{-5}	0.0	0.0	7.3×10^{-5}
	Foods	6.4×10^{-4}	8.2×10^{-3}	0.0	0.0	8.8×10^{-3}
	Fish	6.1×10^{-4}	6.5×10^{-3}	0.0	0.0	7.1×10^{-3}
	Subtotal water	1.3×10^{-3}	1.5×10^{-2}	0.0	0.0	1.6×10^{-2}
Combined total		1.4×10^{-3}	1.6×10^{-2}	5.3×10^{-3}	1.4×10^{-5}	2.3×10^{-2}

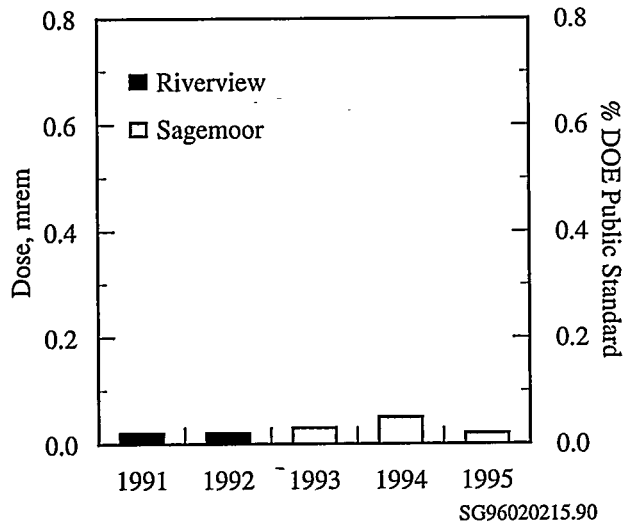


Figure 5.0.2. Calculated Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual, 1991 Through 1995

- consumption of Columbia River fish containing radionuclides (31%), principally isotopes of uranium
- inhalation of airborne radionuclides (24%), principally lead-212 released from the 300 Area.

The DOE radiological 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 maximally exposed individual for 1995 was 0.02% of the DOE limit.

The doses from Hanford operations for the maximally exposed individual for 1991 through 1995 are illustrated in Figure 5.0.2. During each year, the doses were estimated using methods and computer codes that were state-of-the-art at the time. From 1991 to 1992, the maximally exposed individual was located at either Ringold or Riverview, whichever location represented the maximum hypothetical dose. For 1993 through 1995, the hypothetical maximally exposed individual was located across the Columbia River from the 300 Area.

Special Case Exposure Scenarios

Exposure parameters used to calculate the dose to the maximally exposed individual are selected to define a high-exposure scenario that is unlikely to occur. Such a scenario does not necessarily result in the highest conceivable radiological dose. Low-probability exposure scenarios exist that could result in somewhat higher doses. Two scenarios that could lead to larger doses include an individual who could spend time at the Site boundary location with the maximum external radiation dose rate and a sportsman who might consume contaminated wildlife that migrated from the Site. These special cases are discussed below, as is the dose from consumption of drinking water at the Fast Flux Test Facility.

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 thermoluminescent dosimeters 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 (Fast Flux Test Facility) Areas are described in Section 4.7, "External Radiation Surveillance." The 200 Areas results were not used because these locations are not accessible to the public. Radiation measurements made at the 100-N Area shoreline (Figure 5.0.1) 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 1995 was 0.02 mrem/h (2×10^{-4} mSv/h), or about twice 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 1995, the external radiation dose received from Hanford operations would be about 0.01 mrem (1×10^{-4} mSv) above the natural background dose. If an individual spent 2 hours at this location they would receive a dose similar to the annual dose calculated for the hypothetical maximally exposed individual at Sagemoor. The public can approach the shore-

line by boat, but they are legally restricted from stepping onto the shoreline. Therefore, an individual is unlikely to remain on or near the shoreline for an extended period of time.

Sportsman Dose

Wildlife have access to areas of the Site that contain radioactive materials, and some do become contaminated. Sometimes contaminated wildlife travel offsite. Sampling is conducted onsite to estimate maximum contamination levels that might possibly exist in animals hunted offsite. Since this scenario has a relatively low probability of occurring, these doses are not included in the maximally exposed individual calculation.

Listed below are estimates of the radiation doses that could have resulted if wildlife containing the maximum concentrations measured in onsite wildlife in 1995 migrated offsite, were hunted, and were eaten.

- The dose from eating 1 kg (2.2 lb) of deer meat containing the maximum concentration of cesium-137 (0.037 pCi/g) measured in a deer collected onsite is estimated to be 2×10^{-3} mrem (2×10^{-5} mSv).

- The dose from eating 1 kg (2.2 lb) of whitefish or sucker meat containing the maximum concentrations of cesium-137 (0.04 pCi/g) measured in whitefish or suckers collected from the Hanford Reach of the Columbia River is estimated to be 2×10^{-3} mrem (2×10^{-5} mSv).

- The dose from eating 1 kg (2.2 lb) of goose meat containing the maximum concentration of cesium-137 (0.007 pCi/g) measured in a Canada goose collected onsite is estimated to be 4×10^{-4} mrem (4×10^{-6} mSv).

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 (Eberhardt et al. 1982) and the inaccessibility of onsite wildlife to hunters. The methodology for calculating doses from consumption of wildlife, was to multiply the maximum concentration measured in edible tissue by a dose conversion factor for ingestion of that tissue and, are addressed in more detail in Soldat et al. (1990).

Fast Flux Test Facility Drinking Water

The Fast Flux Test Facility Visitors Center, located southeast of the Fast Flux Test Facility Reactor building (Figure 5.0.1), was not open to the public during 1995. Ground water was therefore not used as a public drinking water source, and no calculation of potential dose to the public was performed for this facility.

During 1995, ground water was used as drinking water by workers at the Fast Flux Test Facility. Therefore, this water was sampled and analyzed throughout the year in accordance with applicable drinking water regulations. All annual average radionuclide concentrations measured during 1995 were well below applicable drinking water standards, but concentrations of tritium were detected at levels greater than typical background values (see Section 4.3, "Hanford Site Drinking Water Surveillance"). Based on the measured concentrations, the potential dose to Fast Flux Test Facility workers (an estimate derived by assuming a consumption of 1 L/d for 240 working days), the worker would receive a dose of 0.2 mrem (0.002 mSv). Of this total, drinking water obtained from the emergency back-up ground-water well 499-S0-7 during June and July 1995 accounted for 0.05 mrem (see Appendix D, Table D.10).

Comparison with Clean Air Act Standards

Limits for radiation dose to the public for airborne emissions from 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 1995 air emissions report (Gleckler et al. 1996).

The 1995 air emissions from monitored Hanford facilities, including radon-220 and radon-222 releases from the 327 building in the 300 Area, resulted in a potential dose to a maximally exposed individual across from the 300 Area of 0.006 mrem (6×10^{-5} mSv), which is 0.06% of the limit. Of this total, radon emissions from the 327 building contributed 0.0035 mrem, and non-radon emissions from all stack sources contributed 0.0029 mrem. Therefore, the estimated annual dose from monitored stack releases at the Hanford Site during 1995 was well

below the Clean Air Act standard. The Clean Air Act requires the use of CAP88-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 CAP88-PC for air emissions from Hanford facilities agrees well with that calculated using the GENII code (0.006 mrem or 6×10^{-5} mSv).

The December 1989 revisions 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 all potential sources of airborne radionuclides. DOE and EPA have interpreted the regulation to include diffuse and unmonitored sources as well as 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 1995, the estimated dose from diffuse sources to the maximally exposed individual across the river from the 300 Area was 0.02 mrem (2×10^{-4} mSv), which was greater than the estimated dose at that location from stack emissions (0.006 mrem or 6×10^{-5} mSv). Doses at other locations around the Hanford Site perimeter ranged from 0.02 to 0.03 mrem (2×10^{-4} to 3×10^{-4} mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1995 was much less than the EPA standard.

Collective Dose to the Population Within 80 km (50 mi)

Exposure pathways for the general public from releases of radionuclides to the atmosphere include inhalation, air submersion, and consumption of contaminated food. Pathways of exposure for radionuclides present in the Columbia River include consumption of drinking water, fish, and irrigated foods, and external exposure during aquatic recreation. The regional collective dose from 1995 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 5.0.2. Food pathway, dietary, residency, and recreational activity assumptions for these calculations are given in Appendix D.

Table 5.0.2. Dose to the Population from 1995 Hanford Operations

		Operating Area Contribution Doses, person-rem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	7.8×10^{-6}	1.3×10^{-4}	5.8×10^{-4}	7.1×10^{-7}	7.2×10^{-4}
	Inhalation	2.4×10^{-3}	2.1×10^{-2}	3.8×10^{-2}	6.7×10^{-4}	6.2×10^{-2}
	Foods	8.3×10^{-5}	9.9×10^{-2}	2.6×10^{-3}	2.3×10^{-5}	1.0×10^{-1}
	Subtotal air	2.5×10^{-3}	1.2×10^{-1}	4.1×10^{-2}	6.9×10^{-4}	1.6×10^{-1}
Water	Recreation	1.9×10^{-5}	4.0×10^{-4}	0.0	0.0	4.2×10^{-4}
	Foods	6.7×10^{-4}	8.6×10^{-3}	0.0	0.0	9.3×10^{-3}
	Fish	2.3×10^{-4}	2.4×10^{-3}	0.0	0.0	2.6×10^{-3}
	Drinking water	1.7×10^{-3}	1.5×10^{-1}	0.0	0.0	1.5×10^{-1}
	Subtotal water	2.6×10^{-3}	1.6×10^{-1}	0.0	0.0	1.6×10^{-1}
Combined total		5.1×10^{-3}	2.8×10^{-1}	4.1×10^{-2}	6.9×10^{-4}	3.3×10^{-1}

The collective dose calculated for the population was 0.3 person-rem (0.003 person-Sv) in 1995, compared to 0.6 person-rem (0.006 person-Sv) in 1994. The 80-km (50-mi) collective doses attributed to Hanford operations from 1991 through 1995 are compared in Figure 5.0.3.

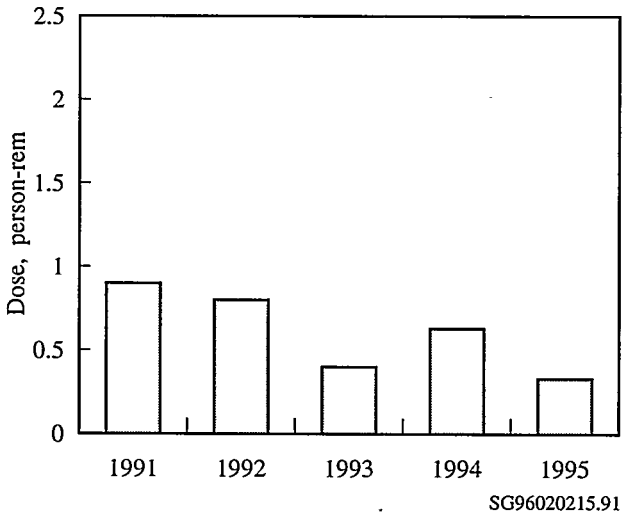


Figure 5.0.3. Calculated Effective Dose Equivalent to the Population Within 80 km (50 mi) of the Hanford Site, 1991 Through 1995

Primary pathways contributing to the 1995 dose to the population were

- consumption of drinking water (46%) contaminated with radionuclides released to the Columbia River at Hanford, principally tritium and uranium
- consumption of foodstuffs (30%) contaminated with radionuclides released in gaseous effluents, primarily iodine-129 from the Plutonium-Uranium Extraction Plant stack
- inhalation of radionuclides (19%) that were released to the air, principally iodine-129 from the Plutonium-Uranium Extraction Plant stack.

The average per capita dose from 1995 Hanford operations, based on a population of 380,000 within 80 km (50 mi), was 0.0009 mrem (9×10^{-6} mSv). To place this dose from Hanford activities into perspective, the 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 5.0.4. The estimated average per capita dose to members of the public from Hanford sources is only approximately 0.0003% of the annual per capita dose (300 mrem) from natural background sources.

The doses from Hanford effluents to the maximally exposed individual and to the population within 80 km (50 mi) are compared to appropriate standards and natural background radiation in Table 5.0.3. This table shows that the calculated radiological doses from Hanford operations in 1995 are a small percentage of the standards and of natural background.

Doses from Other Than DOE Sources

Various non-DOE industrial sources of public radiation exposure exist at or near the Hanford Site. 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 5.0.1). DOE maintains an awareness of other manmade sources of radiation which, if combined with the DOE sources, might have the potential to cause a dose exceeding 10 mrem (0.1 mSv) to any member of the public. With information gathered from these companies, it was conservatively estimated that the total 1995 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 1995 was well below any regulatory dose limit.

Hanford Public Radiation Dose in Perspective

This section provides information to put the potential health risks of radionuclide emissions from the Hanford

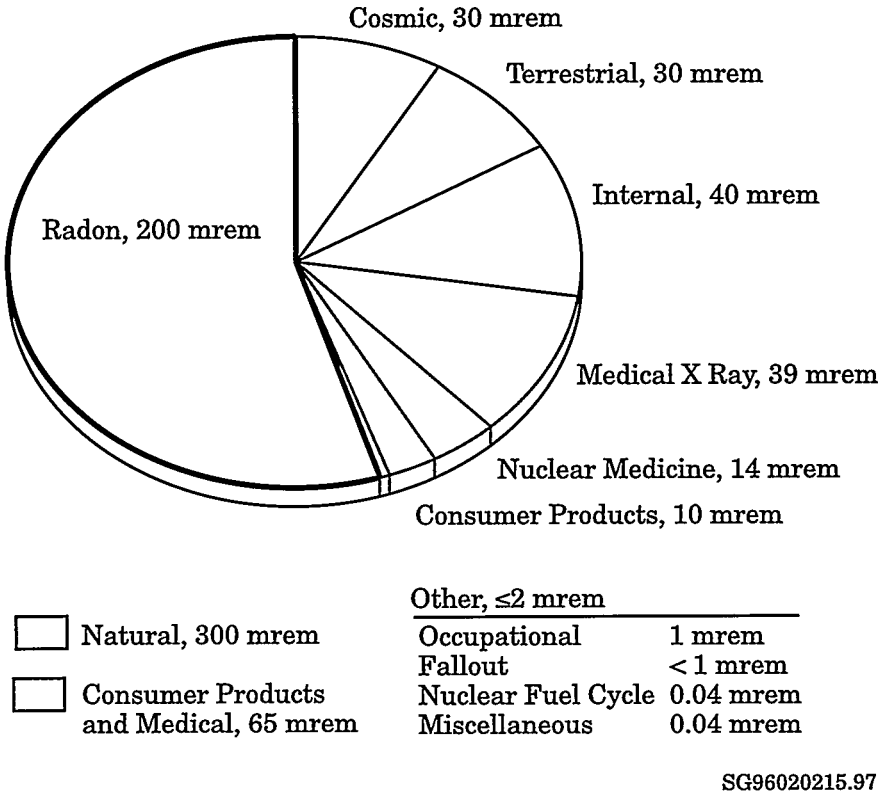


Figure 5.0.4. National Annual Average Radiation Doses from Various Sources (mrem) (NCRP 1987)

Table 5.0.3. Summary of Doses to the Public in the Vicinity of Hanford from Various Sources, 1995

Source	Maximum Individual, mrem[a]	80-km Population, person-rem[a]
All Hanford effluents[b]	0.02	0.3
DOE limit	100	--
Percent of DOE limit	0.02%	--
Background radiation	300	110,000
Hanford doses percent of background	<0.01%	3×10^{-4} %
Doses from gaseous effluents[c]	0.006	--
EPA air standard	10	--
Percent of EPA standard	0.06%	--

(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 CAP88-PC code.

Site into perspective. Several scientific studies (NRC 1980, 1990; UNSCEAR 1988) have been performed to estimate the possible risk of 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 scientists accept the hypothesis that low-level doses might increase the probability of certain types of effects, such as cancer. 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 per unit dose of these same health effects observed historically at much higher doses (in atomic bomb victims, radium dial painters, etc.). Under these assumptions, even natural background radiation (which is hundreds of times greater than radiation from current Hanford releases) increases each person's probability or chance of developing a detrimental health effect.

Not all scientists agree on 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 indicated that low radiation doses may cause beneficial effects (HPS 1987). Because cancer and hereditary diseases in the general population may be caused by many sources (e.g., genetic defects, sunlight, chemicals, and background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be conclusively proved. In developing Clean Air Act regulations, EPA uses 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) (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 needed benefits from industry.

One perspective on risks from industrial activities is to compare them to risks involved in other typical activities. For instance, two risks that an individual receives from flying on an airline are the risks of added radiation dose (from a stronger cosmic radiation field that exists at higher altitudes) and the possibility of being in an aircraft accident. Table 5.0.4 compares the estimated risks from various radiation doses to the risks of some activities encountered in everyday life.

The risk of detrimental health effects from Hanford radioactive releases are illustrated in Table 5.0.5. Listed are some activities considered approximately equal in risk to the risk from the dose received by the maximally exposed individual from monitored Hanford effluents in 1995 (excluding diffuse or unmonitored sources).

Dose Rates to Animals

Conservative (upper) estimates have been made of radiological dose to "native aquatic organisms," in accordance with a DOE Order 5400.5 interim requirement for management and control of liquid discharges. Possible radiological dose rates during 1995 were calculated for several 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 river and onsite. Because the water 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 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 of 10 to 1 by the river. Radiological doses were calculated for several different types of aquatic animals, using these highly conservative assumptions and the computer code CRITR2 (Baker and Soldat 1992). The animal receiving the highest potential dose was a duck consuming aquatic plants. However, even if a duck spent 100% of its time in the one-tenth diluted spring water and consumed only plants growing there, it would receive a radiation dose rate of 4×10^{-5} rad/d. This dose rate is 0.004% of the limit of

Table 5.0.4. 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)	$3{,}600 \times 10^{-6}$
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 1995 (0.02 mrem, 2×10^{-4} mSv)	0 to 0.01×10^{-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).

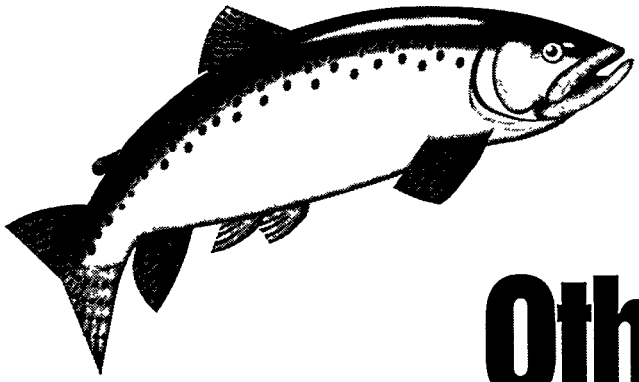
(b) Real actuarial values. Other values are predicted from statistical models. For radiation dose, the values are reported in a possible range from the least conservative (0) to the currently accepted most conservative value.

Table 5.0.5. Activities Comparable in Risk to That from the 0.02-mrem Dose Calculated for the 1995 Maximally Exposed Individual

Driving or riding in a car 3 km (1.8 mi)
Smoking 3/100 of a cigarette
Flying 8 km (5 mi) on a commercial airline
Eating 2.4 tablespoons of peanut butter
Eating one 0.5-kg (1.1-lb) charcoal-broiled steak
Drinking about 2.9 L (3 quarts) of chlorinated tap water
Being exposed to natural background radiation for about 56 minutes in a typical terrestrial location
Drinking about one-half of a can of beer or one-half of a glass of wine

1 rad/d for native aquatic animal organisms established by DOE Order 5400.5 and is not expected to cause detrimental effects to animal populations.

Doses were also estimated for clams, fish, and waterfowl living in the Columbia River. The highest potential dose from all the radionuclides reaching the Columbia River from Hanford sources during 1995 was 5×10^{-3} rad/d for a duck that consumed contaminated vegetation. Dose estimates based on the maximum concentrations of cesium-137 measured in muscle of animals collected onsite and from the Columbia River ranged from 2×10^{-7} rad/d for a Canada goose to 1×10^{-6} rad/d for a mule deer.



Other Hanford Site Environmental Programs

6.0 Other Hanford Site Environmental Programs

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 activities conducted in 1995 to monitor the meteorology and climatology of the Site, assess the status of wildlife and cultural resources, monitor Hanford Cultural Resources, and actively involve the public in Site surveillance activities.

6.1 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 winter and summer. During spring and fall, the frequency of southwesterly winds increases, with a corresponding decrease in the northwesterly flow. Monthly average wind speeds are lowest during winter months, averaging 10 to 11 km/h (6 to 7 mph), and highest during 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, 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 1945 through 1994 have been reported by Hoitink et al. (1995). From 1945 through 1994, the record maximum temperature was 45°C (113°F) recorded in August 1961, and the record minimum temperature was -30.6°C (-23°F) in February 1950. Normal monthly temperatures ranged from a low of -0.4°C (31.3°F) in January to a high of 24.6°C (76.2°F) in July. During winter, the highest monthly average temperature at the Hanford Meteorology Station was 6.9°C (44.5°F) in February 1991, and the record lowest was -11.1°C (12.1°F) in January 1950. During summer, the record maximum monthly average temperature was 27.9°C (82.2°F) in July 1985, and the record minimum was 17.2°C (63.0°F) in June 1953. The annual average relative humidity at the Hanford Meteorology Station was 54%. Humidity was highest during winter, averaging about 76%, and lowest during summer, averaging about 36%. Average annual precipitation at the Hanford Meteorology Station was 16 cm (6.26 in.). The wettest year on record, 1995, received 31 cm (12.30 in.) of precipitation, while the driest, 1976, received 8 cm (2.99 in.). Most precipitation occurred during winter, with more than half of the annual amount occurring from November through February.

Atmospheric dispersion is a function of wind speed, wind duration and direction, atmospheric stability, and mixing depth. Dispersion conditions are generally good if winds are moderate to strong, the atmosphere is of neutral or unstable stratification, and there is a deep mixing layer. Good conditions associated with neutral and unstable stratification exist about 57% of the time during summer. Less favorable conditions may occur when wind speed is light and the mixing layer is shallow. These conditions are most common during winter, when moderately to extremely stable stratification exists about 66% of the time. Occasionally, there are extended periods of poor dispersion conditions, primarily during winter, which are associated with stagnant air in stationary high-pressure systems.

Results of 1995 Monitoring

1995 was warmer than normal and the wettest year on record. The average temperature for 1995 was 12.6°C (54.7°F), which was 0.7°C (1.2°F) above normal (11.8°C [53.3°F]). Eight months during 1995 were warmer than

normal, and four months were cooler than normal. February had the highest positive departure, 2.8°C (5.1°F), while August, at 1.7°C (3.1°F) below normal, had the largest negative departure.

Precipitation for 1995 totaled 31.3 cm (12.30 in.), 196% of normal (15.9 cm [6.3 in.]), with 19.6 cm (7.7 in.) of snow (compared to an annual normal snowfall of 35.1 cm [13.8 in.]). The previous wettest year on record was 1950, with 29.1 cm (11.45 in.) of precipitation.

The average wind speed for 1995 was 12.6 km/h (7.8 mph), which was 0.2 km/h (0.1 mph) above normal, and the peak gust for the year was 98 km/h (61 mph) on December 12. Figure 6.1.1 shows the 1995 wind roses (diagrams showing direction and frequencies of wind) at 10 m for meteorological monitoring stations on and around the Hanford Site.

Table 6.1.1 provides monthly climatological data from the Hanford Meteorology Station for 1995.

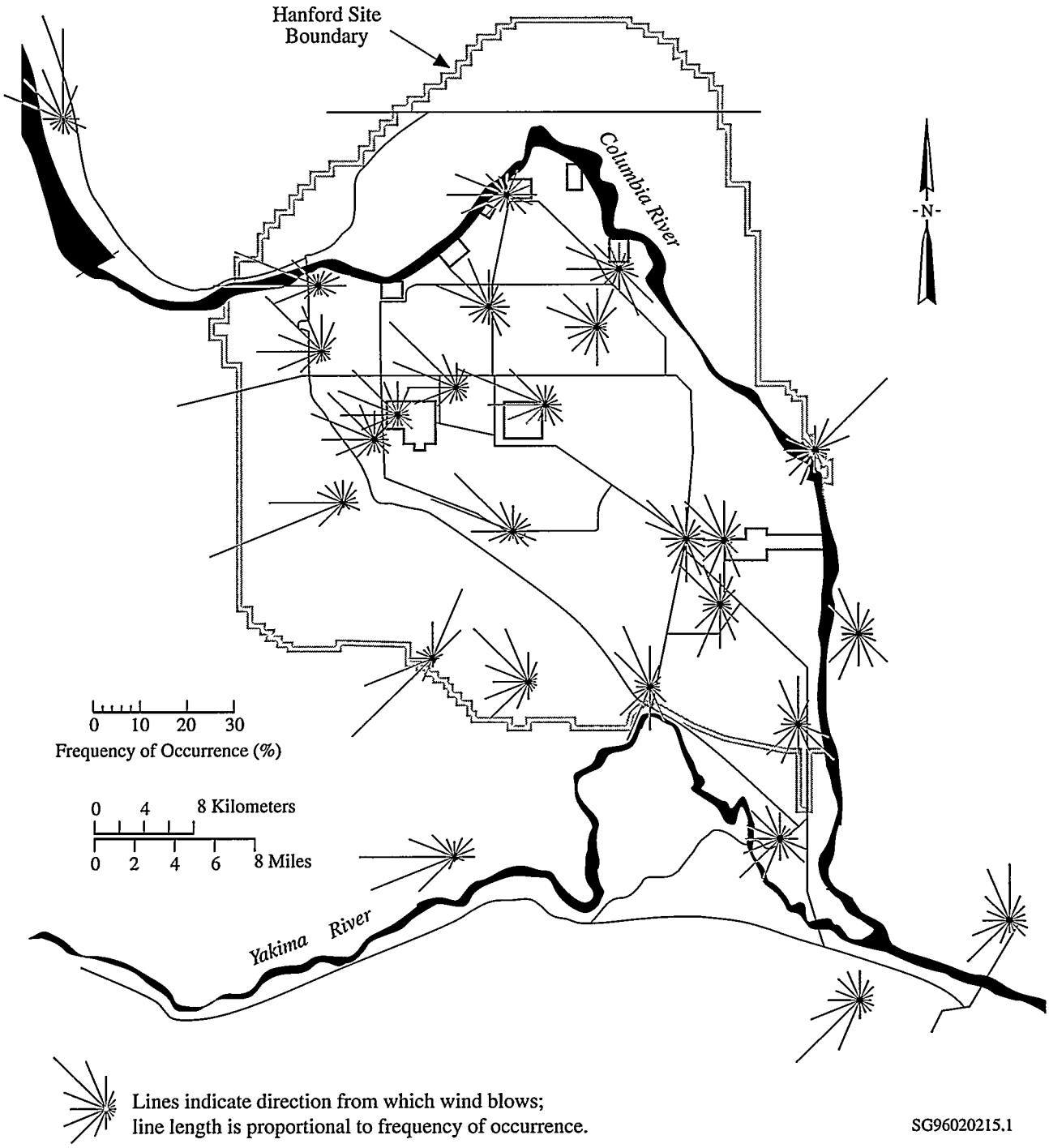


Figure 6.1.1. Hanford Meteorological Monitoring Network Wind Roses (at 10 m), 1995. Individual lines indicate direction from which wind blows. Length of line is proportional to frequency of occurrences from a particular direction.

Table 6.1.1. Monthly Climatological Data from the Hanford Meteorology Station, 1995

Hanford Meteorology Station, 40 km N.W. of Richland, Washington
Latitude 46° 34'N, Longitude 119° 35'W, Elevation 223 m (733 ft)

Month	Temperatures, °C								Precipitation (cm)				Relative Humidity (%)		15-m Wind[a]				
	Averages				Extremes						Snowfall						Peak Gusts		
	Daily Maximum	Daily Minimum	Monthly	Departure[b]	Highest	Date	Lowest	Date	Total	Departure[b]	Total	Departure[b]	Average	Departure[b]	Average Speed, km/h	Departure[b]	Speed, km/h	Direction	Date
J	4.9	-2.4	1.2	+1.6	19.4	31	-13.3	4+[c]	5.4	+3.4	6.9	-3.0	85.1	+8.7	10.9	+0.5	63	WSW	31
F	11.7	0.6	6.2	+2.8	20.0	21+[c]	-13.3	14	1.8	+0.2	T[d]	-5.1	66.7	-3.6	13.4	+1.8	71	SSW	17
M	14.4	1.3	7.8	+0.3	20.6	30	-6.1	6	2.4	+1.2	0	-0.8	56.8	+0.9	13.5	+0.2	79	SW	9
A	18.4	4.4	11.4	-0.1	26.7	24	-2.2	15	3.9	+2.9	T[d]	0	53.6	+6.4	13.8	-0.6	63	SW	4
M	25.8	10.3	18.1	+1.8	35.0	29	3.9	12	2.0	+0.7	--[e]	--	45.2	+2.5	14.3	-0.3	87	E	25
J	27.4	12.8	20.1	-0.8	36.7	30	8.3	12	2.0	+1.0	--	--	44.9	+6.1	14.0	-0.8	68	NW	5
J	33.4	16.8	25.1	+0.5	40.6	19	11.1	31	0.9	+0.4	--	--	37.8	+4.3	15.1	+1.0	84	WSW	6
A	30.7	13.7	22.2	-1.7	38.9	4	7.2	14	0.2	-0.5	--	--	39.0	+3.2	13.7	+1.0	64	NW	23
S	29.4	12.7	21.1	+2.4	38.3	2	5.6	23	2.0	+1.2	--	--	45.4	+2.7	11.1	-0.8	63	WSW	30
O	17.9	4.4	11.2	-0.4	23.3	15	-8.9	31	2.2	+1.2	0	-0.2	61.0	+5.8	11.3	+0.8	77	WNW	3
N	12.2	1.4	6.8	+2.2	20.6	8	-8.3	3+[c]	2.6	+0.3	2.5	-2.0	76.2	+2.8	10.9	+0.6	90	SSW	29
D	3.6	-2.9	0.3	+0.7	13.9	1	-8.9	7	5.9	+3.3	10.2	-4.3	82.3	+2.0	9.0	-0.5	98	SSW	12
Y[f]	19.2	6.1	12.6	+0.7	40.6	Jul 19	-13.3	Feb 14+[c]	31.3	+15.4	19.6	-15.4	57.8	+3.5	12.6	+0.2	98	SSW	Dec 12

(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 snow fall during these months.
(f) Yearly averages, extremes, and totals.

6.2 Wildlife

L. L. Cadwell, M. A. Simmons, and B. L. Tiller

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 1995). 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 1995). 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 Fitzner/Eberhardt Arid Lands Ecology Reserve in the Rattlesnake Hills. These include Rattlesnake Springs, Dry Creek, Snively Springs, and West Lake, a small, natural pond near the 200 Areas.

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 currently are candidates for formal listing under the Endangered Species Act. Appendix F lists special-status species that could occur on the Hanford Site.

Results for Wildlife Resource Monitoring, 1995

Wildlife populations inhabiting the Hanford Site are monitored to measure the status and condition of the populations and to assess effects of Hanford operations. Particular attention is paid to species that are rare, threatened, or endangered nationally or statewide and 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 6.2.1). Following the passage of the Endangered Species Act in 1973, the 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

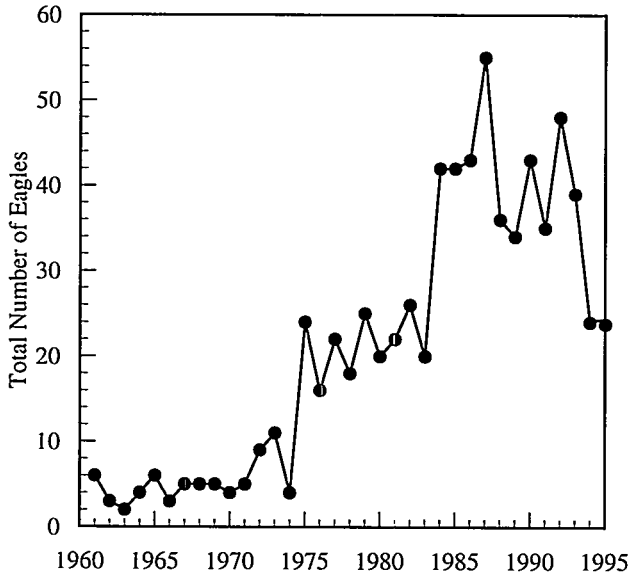


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Figure 6.2.1. Bald Eagles Observed Along the Hanford Reach, Fall and Winter Months, 1961 Through 1995

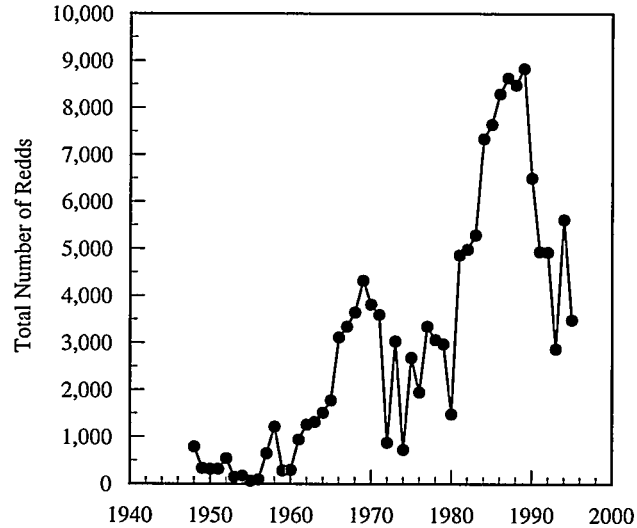

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Figure 6.2.2. Chinook Salmon Spawning Redds in the Hanford Reach, 1948 Through 1995

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 nesting attempts has been successful.

Chinook Salmon

Chinook salmon are an important resource in the Pacific Northwest. Salmon are caught commercially and for recreation. The commercial and recreational catch is managed carefully 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 6.2.2). 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 also have 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. In 1994, low daytime discharges from Priest Rapids Dam also contributed to generally low water as far downstream as Ringold. In 1995, river flow reached 130,000 ft^3/s when the final redd counts were being conducted. The high river flow caused reduced visibility and interfered with redd counting during the time when counts are normally highest. This resulted in a low overall redd count for 1995 relative to 1994. Because of the high river flows, the lower redd counts may not mean that adult numbers or spawning were reduced in 1995. The Hanford Reach under existing management practices continues to provide valuable salmon spawning habitat.

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 6.2.3). 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 total nest count increased in 1995 compared to 1994. In 1995 fewer surveys were conducted, which affected the count primarily because gulls used the abandoned goose nests making it difficult to relocate the nests and determine if hatching occurred. Coyote predation again eliminated or severely affected nesting on some islands. In 1995, the Canada goose nesting surveys were conducted biannually.

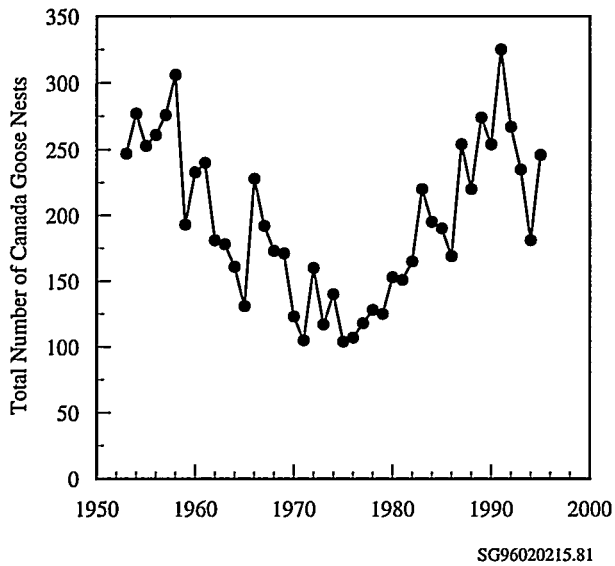

Figure 6.2.3. Canada Goose Nests on Islands in the Hanford Reach, 1952 Through 1995

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 6.2.4). The Site continues to provide hawk nesting habitats that are administratively protected from human intrusion, and also provides suitable foraging areas. The sharp declines in red-tailed and Swainson's hawk nests in the late 1980s probably are not a result of Hanford Site activities because the number of nests for the very sensitive ferruginous hawk did not decline (Figure 6.2.4). 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. A limited number of hawk surveys were conducted in 1993 and 1994; however, because survey methods differed from those used in previous years, the nest counts are not included in Figure 6.2.4. No surveys were conducted in 1995.

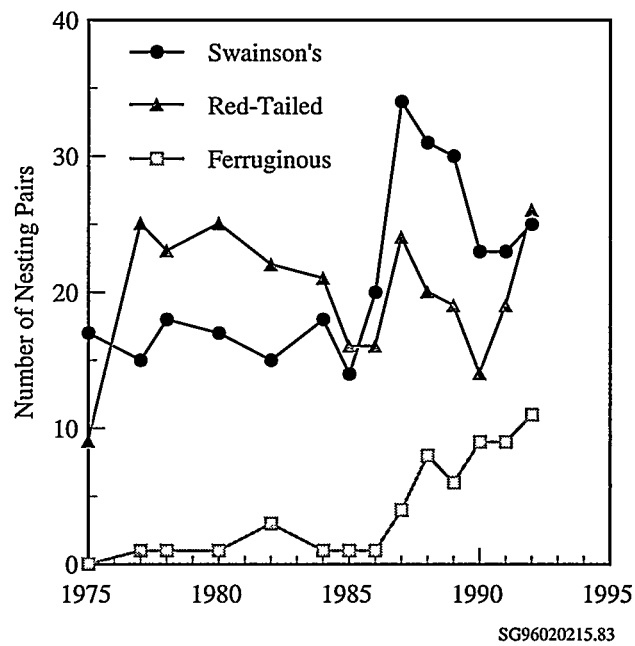

Figure 6.2.4. Red-Tailed, Swainson's, and Ferruginous Hawks on the Hanford Site, 1975 Through 1992

Rocky Mountain Elk

Rocky Mountain elk did not inhabit the Hanford Site when it was established in 1943. Elk appeared on the Fitzner/Eberhardt Arid Lands Ecology Reserve in the winter of 1972. A few animals stayed and reproduced. Over 300 elk were recorded in 1995 before the offsite hunting season began (Figure 6.2.5). During the 1995 hunting season, 20 elk (17 bulls and 3 cows) were known to have been harvested from the adjacent private lands.

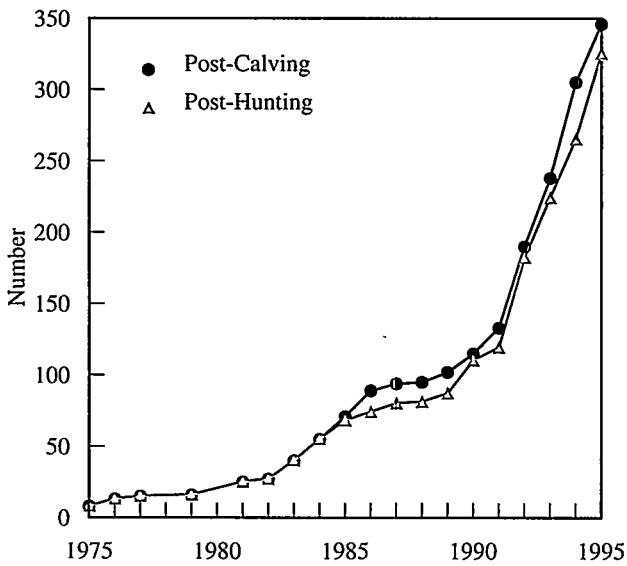

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Figure 6.2.5. Elk on the Hanford Site Counted by Aerial Surveillance During the Post-Calving Period, August Through September, and the Post-Hunting Period, December Through January, 1975 Through 1995

A significant change in cow/calf ratios was observed from the 1980s to more recent times. An average of 79 calves per 100 cows was observed consistently through 1987. Since then, calf recruitment has been down, averaging 52 calves per 100 cows. A check on the status of 19 cow elk found that all but one were pregnant, indicating that the reduced calving rates may result from neonatal mortality or increased predation on newborn calves rather than from low fecundity.

Accurate demographic information on the Hanford Site herd is becoming more difficult to obtain as the elk population increases; however, cooperation with Washington State Department of Fish and Wildlife officials and private land owners adjacent to the Site provides valuable information on the number of animals harvested each year.

Elk are successful on the Fitzner/Eberhardt Arid Lands Ecology Reserve because of 1) available forage without competition from domestic livestock; 2) unrestricted access to drinking water at springs located on the Fitzner/Eberhardt Arid Lands Ecology 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 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 4.5, "Fish and 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.

In the early 1990s, the deer population onsite was estimated by marking several Hanford deer and counting the ratio of marked to unmarked animals along the Columbia River. In addition, relative deer densities were determined throughout the remainder of the Hanford Site by comparing the frequency of fecal pellet groups found within each region. Over 300 deer were estimated to reside in the region of the Hanford Site bordering the Columbia River. The Fitzner/Eberhardt Arid Lands Ecology Reserve contains approximately half the number of deer found near the Columbia River, and less than 100 deer are estimated to reside within the central portion of the Hanford Site.

Offsite movement of deer was monitored by radiocollaring 53 animals (15 bucks and 38 does). Some deer frequently moved across the Columbia River or onto islands, particularly during the breeding (October-December) and fawning (May-July) seasons. Twenty-four of the 53 radiocollared animals were located at least once either across the river or on the islands. The most frequently visited offsite locations were the riparian areas along the Columbia River. Additional movement data collected in 1995 confirm these findings.

A total of 38 deer antlers were 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 in the 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 more than 4 years old; 10 were between 8 and 12 years old. The unaffected animals were between 1 and 6 years old. Blood tests revealed no parasitic cause for the testicular atrophy, and radiation was ruled out because there were no effects found in other tissues. The condition has been reported in mule deer from other areas in the United States including Arizona, California, Texas, and Colorado. Analysis of the radiocollared normal and affected animals' movement on the Site suggests that the two groups readily intermix; however, affected animals are common only along the Columbia River portions of the Site. Seasonal foraging patterns suggest that woody plants (principally bitterbrush and riverine shrubs such as mulberry, willow, and Russian olive) comprise a large portion of their diets, providing a direct pathway for ground-water contaminants to the deer. Several plants known to produce estrogen-like compounds also were found in deer diets during the summer and may influence their reproductive performance. To date, no single agent has been linked directly to the testicular atrophy observed in the Hanford Site deer.

Monitoring Northern Oriole Populations

During the 1980s, scientists noted declines in the number of North American migratory songbirds. 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 that 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 songbirds 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. Fifty nests were located in seven tree groups (Figure 6.2.6) in 1995 compared to 40 nests located in 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 any land use changes at the old Hanford Townsite if the land is used for other purposes in the future.

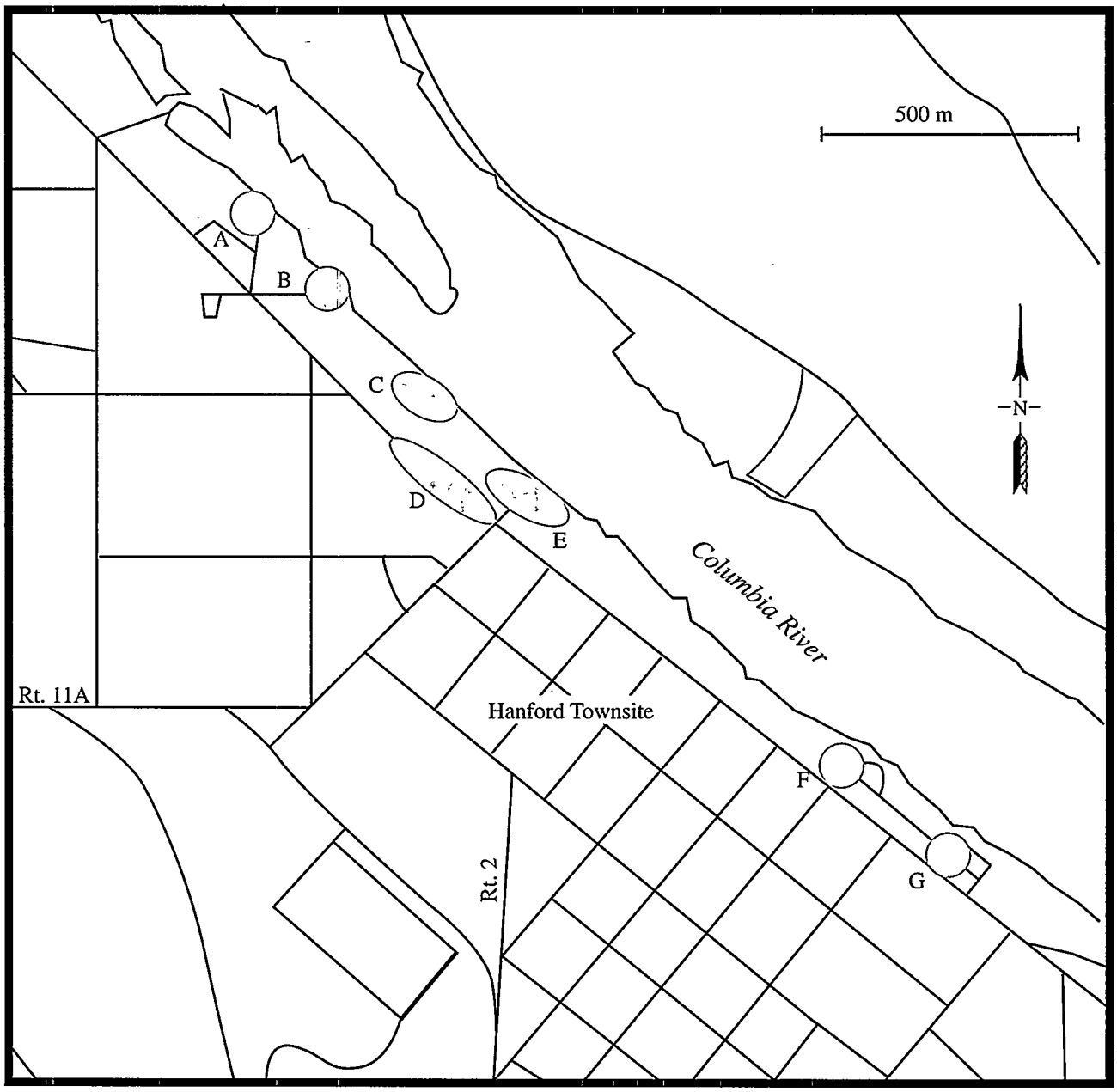

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Figure 6.2.6. Oriole Nesting Sites at the Old Hanford Townsite, 1995

6.3 Hanford Cultural Resources Laboratory

M. K. Wright

The Hanford Cultural Resources Laboratory was established by the Richland Operations Office in 1987 as part of Pacific Northwest National Laboratory. The Hanford Cultural Resources Laboratory 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 calendar year 1995, Hanford contractors requested 290 such reviews, 10 of which required archaeological surveys. The surveys covered a total of 2.4 km^2 (0.9 mi^2) and resulted in the discovery of 5 archaeological sites and 2 isolated finds. Three hundred thirty-three buildings and/or structures were also inventoried and added to the Hanford Cultural Resources Laboratory database. 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 and completion of a Native American Graves Protection and Repatriation Act inventory report.

Section 110 of the National Historic Preservation Act requires that federal agencies undertake a program to identify, evaluate, and nominate historic properties, and consider the use and re-use of historic properties. Agencies are also required to maintain and manage historic properties in a way that considers preservation of their values and ensures that preservation-related activities are completed in consultation with other agencies, Indian tribes, and the private sector. Two survey projects, the 100 Area Block Survey and the 300 Area Survey, were conducted as a result of Section 110 requirements. These surveys covered a total of 83.1 km^2 (33.2 mi^2) and resulted in the discovery of 220 archaeological sites and 73 isolated finds. The sites recorded were predominately historic in nature and contained information ranging from lifeways of early settlers in the Hanford area to military installations of the 1950s. An Historic American Engineering Record documentation process was completed for a multibuilding complex and one additional building. Twenty-seven individual buildings were determined eligible and 28 buildings were determined not eligible for the National Register of Historic Places during 1995.

Historic properties that are listed or are eligible for listing on the National Register of Historic Places are provided management protection. To assist with the evaluation of historic properties, four historic contexts were drafted as part of the National Register Multiple Property Documentation process. These contexts will be used to determine National Register eligibility for sites and buildings on the Hanford Site associated with the prehistoric period, the contact period between early explorers and native peoples, the pre-1943 Euroamerican settlement period, and the Manhattan Project/Cold War periods.

Educational activities associated with the cultural resources program included presenting lectures to groups ranging from primary school rock hounds to civic groups and professional societies. The Hanford Cultural Resources Laboratory participated in the Associated Western Universities, Inc., Northwest Division and the Student Research Apprenticeship Programs by hosting two student interns who were involved in field and laboratory work with Hanford Cultural Resources Laboratory staff.

Research activities were continued as part of compliance work. Research in the field of archaeology and history focused on several general areas of interest: archaeological site preservation and protection, the pre-1943 settlement of the Hanford Site, and the manmade environment of the Manhattan Project and the Cold War periods.

6.4 Community-Operated Environmental Surveillance Program

R. W. Hanf

Since 1991, citizens living near the Hanford Site have been actively participating in Hanford Site environmental surveillance activities. Local teachers are managing and operating eight radiological sampling stations positioned at selected locations around the perimeter of the Hanford Site. Each station consists of equipment for collecting air samples and for monitoring ambient radiation levels. Four of the eight stations also include large, lighted, and covered informational displays that provide real-time meteorological and radiological information as well as general information on station equipment, sample types, and analyses (Figure 6.4.1). The station managers' names and phone numbers are provided on the four displays for anyone desiring additional information about the purpose of the station, station equipment, or analytical results.

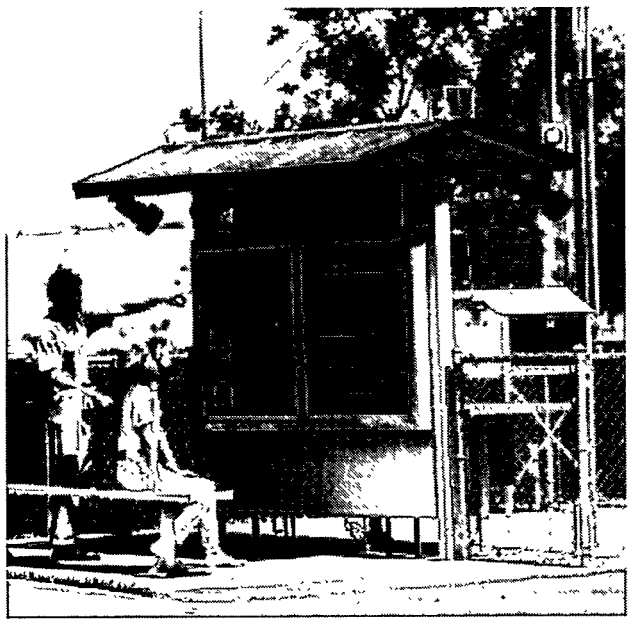


Figure 6.4.1. Community Members Can See Environmental Surveillance in Action at Four of Eight Local Community-Operated Environmental Surveillance Stations

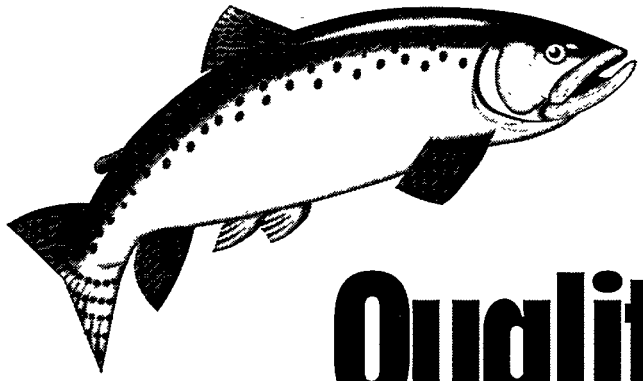
On three of the four display panels, brochure boxes have been installed containing a variety of free pamphlets and brochures about Hanford environmental programs.

Two teachers from schools located near the stations have been selected to operate each station. Each pair of teachers is 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 are points-of-contact for local citizens. Pacific Northwest National Laboratory staff work closely with the teachers to provide training, maintain station equipment and displays, and coordinate sampling and analytical efforts with other Hanford environmental surveillance activities. Analytical results for samples collected at these stations in 1995 are discussed in Section 4.1, "Air Surveillance." Results of gamma radiation measurements are discussed briefly in Section 4.7, "External Radiation Surveillance."

In 1995, the Community-Operated Environmental Surveillance Program expanded from five to eight stations. In addition to the five stations operating in 1994 in Basin City, Richland, Pasco, Kennewick, and north Franklin County, Washington, the program now includes stations in Othello, Mattawa, and Toppenish, Washington (see Figure 4.1.1 in Section 4.1, "Air Surveillance"). The station in Toppenish is new and located on the campus of Heritage College, a small, regional, 4-year college. This station is similar in design to the three original public information stations established in 1991; however, additional soil and meteorological monitoring equipment has been installed for the benefit of the college's science programs. The other two stations added to the program in 1995 are established air monitoring stations that are part of DOE's routine sitewide radiological air monitoring

network. These two stations have not been enhanced to attract the attention of the public, although the Othello station was relocated to its present site for convenience. The station was formerly located at Berg Ranch, a rural location just south of town.

The long-range goal for the expansion of the Community-Operated Environmental Surveillance Program is to involve the public to a significant extent in radiological monitoring activities conducted around the Hanford Site. Environmental sampling on and around the Hanford Site has been conducted by Site personnel for 50 years, so this represents a major change in DOE's approach to accomplishing its sitewide monitoring objectives. It is anticipated that this program will help bolster public acceptance of the surveillance data and increase public understanding of the reported results.



Quality Asssurance

7.0 Quality Assurance

B. M. Gillespie and B. P. Gleckler

Quality assurance and quality control 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 quality control, participation in interlaboratory cross-checks, replicate sampling and analysis, submittal of blind standard samples and blanks, and splitting samples with other laboratories.

Quality assurance/quality control for ground-water environmental surveillance also includes procedures and protocols for 1) documenting instrument calibrations, 2) conducting program-specific activities in the field, 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 quality assurance programs, including various quality control practices, are maintained to ensure the quality of data collected through the surveillance programs. Quality assurance 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 quality assurance 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 thermoluminescent dosimeters and performing dose calculations, are subject to an overall quality assurance 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 quality assurance manual (PNL 1992), which provides guidance for implementation by addressing the following 18 quality assurance 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 quality assurance plans that describe the specific quality assurance elements that apply to each project. These plans are approved by a quality assurance organization that conducts surveillances and audits to verify compliance with the plans. Work performed through contracts, such as sample analysis, must meet the same quality assurance 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 (PNNL 1996). 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 4.0, "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 1986b) 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 1995 ground-water field quality control 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 quality control program that meets the requirements of EPA SW-846 (EPA 1986a), which is audited and reviewed. Pacific Northwest National Laboratory submits additional quality control double-blind spiked samples for analysis.

Routine radiochemical analyses for environmental and ground-water surveillance samples are performed by Quanterra Incorporated's Richland Laboratory, Quanterra Environmental Services. The laboratory participates in DOE's Quality Assessment Program and EPA's Laboratory Intercomparison Studies. An additional quality control blind spiked sample program is conducted for each project. Quanterra Environmental Services also maintains an internal quality control program, which is audited and reviewed. Additional information on these quality control efforts is provided in the following subsections.

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 times the standard error of the mean).

The DOE Quality Assessment program and EPA's Intercomparison Studies Program provided standard samples of environmental media (water, air filters, soil, and vegetation) containing specific amounts of one or more radionuclides that were 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 1995 results for the programs are provided in Tables 7.0.4 and 7.0.5. Approximately 92.5% of the results during the year were within the typically used "3-sigma control limits" (±3 times the standard error of the mean).

Pacific Northwest National Laboratory Evaluations

In addition to DOE and EPA interlaboratory quality control programs, a quality control program is maintained by Pacific Northwest National Laboratory 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 quality control samples and blanks were prepared and submitted to check the accuracy and precision of analyses at DataChem Laboratories and Quanterra Environmental Services. In 1995, blind spiked samples were submitted for air filters, vegetation, soil, tissue, water,

Table 7.0.1. Summary of Ground-Water Surveillance Full Trip Blank Samples, 1995

Constituents	Number of Results Reported	Number Within Control Limits[a]
Radionuclides		
Total alpha	2	2
Total beta	3	3
^{3}H	11	9
^{60}Co	3	2
^{90}Sr	3	3
^{99}Tc	3	2
^{129}I	2	2
^{106}Ru	1	1
^{125}Sb	1	1
^{134}Cs	2	2
^{137}Cs	3	3
^{154}Eu	2	2
^{155}Eu	2	2
U total	10	10
^{234}U	6	6
^{235}U	6	6
^{238}U	6	5
Alkalinity	1	1
ICP metals	8	
Al, Sb, Ba, Cd, Co, Ni, Ag, Sn		8
Be, Ca, K, V		7
Cu, Mg, Mn		6
Cr, Zn		5
Fe		4
Na		2
Anions	9	
Bromide, nitrite, phosphate, sulfate		9
Fluoride		8
Nitrate		7
Chloride		6
Volatile organics	129	124

(a) Control limit is less than detection level (method detection level for hazardous constituents and below total propograted analytical uncertainty for radioactive constituents).

and ground water. Overall, 83% of the DataChem Laboratories blind spiked determinations were within control limits and 85% of Quanterra Environmental Services' blind spiked determinations were within control limits (Table 7.0.6 and 7.0.7). This indicates, overall, acceptable results.

Pacific Northwest National Laboratory also participates in a Quality Assurance Task Force, a program conducted by the Washington Department of Health. Organizations, both public and private, from Idaho, Oregon, and Washington participate in analyzing the intercomparison samples. No samples were designated by the Quality Assurance Task Force for analysis in 1995.

Table 7.0.2. Summary of Ground-Water Surveillance Field Duplicate Samples, 1995

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)	4	1	1
Uranium isotopic (^{234}U, ^{235}U, and ^{238}U)	4	4	4
^{129}I	5	2	2
^{3}H	12	8	8
^{90}Sr	5	3	2
^{99}Tc	4	4	4
Total alpha	3	3	3
Total beta	3	3	3
U total	5	5	4
ICP metals			
Al, Fe, Mg, Mn, Ni, K, Ag, Na, Sn, Sb, Ba, Be, Co, Cu, V, Zn, Ca, Cd, Cr	171	73	66
Ions			
Bromide, chloride, fluoride, nitrate, nitrite, phosphate, sulfate	74	50	49
Volatile organic constituents	76	4	4

(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 the detection level, the Relative Percent Difference was not calculated.

Table 7.0.3. Summary of DataChem Laboratory's EPA Water Pollution and Water Supply Performance Evaluation Studies, 1995

Analytes	Number of Results Reported	Number Within Control Limits[a]
Metals		
Ag, Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mo, Mn, Ni, Pb, Sb, Se, Sr, Tl, Ti, V, Zn	78	78
Other inorganic tests		
pH, conductivity, total dissolved solids, total hardness, calcium, potassium, sodium, alkalinity, chloride, fluoride, sulfate, ammonia, nitrate, nitrite, chemical oxygen demand, etc.	72	69
Organic tests		
Total organic carbon, PCBs, pesticides, herbicides, volatile organic constituents	157	150

(a) Control limits from EPA (1982).

Table 7.0.4. Summary of Quanterra Environmental Services' Performance on DOE Quality Assessment Program Samples, 1995

Media	Radionuclides	Number of Results Reported	Number Within Acceptable Control Limits[a]
Air filters	^{54}Mn, ^{57}Co, ^{60}Co, ^{125}Sb, ^{137}Cs, ^{144}Ce, ^{238}Pu, ^{239}Pu, ^{134}Cs, total alpha, total beta	2	2
	^{241}Am	2	1
	^{90}Sr	2	0
	^{106}Ru, U total	1	1
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{241}Am, ^{238}Pu, ^{239}Pu	2	2
	U total	1	1
Vegetation	^{40}K, ^{60}Co, ^{137}Cs, ^{241}Am, ^{239}Pu	2	2
	^{238}Pu, ^{90}Sr	1	1
Water	^{3}H, ^{137}Cs, ^{241}Am, ^{239}Pu, ^{90}Sr, total alpha, total beta	2	2
	^{60}Co, ^{54}Mn	2	1
	^{238}Pu, ^{244}Cm, ^{134}Cs, U total	1	1

(a) Control limits are from Sanderson et al. (1995).

Table 7.0.5. Summary of Quanterra Environmental Services' Performance on EPA Intercomparison Program Samples, 1995

Media	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Air filters	Total alpha, total beta, ^{90}Sr, ^{137}Cs	1	1
Milk	^{89}Sr, ^{90}Sr, ^{137}Cs	1	1
	^{131}I	1	0
Water	^{239}Pu, ^{131}I	1	1
	^{133}Ba, ^{3}H, ^{65}Zn	2	2
	^{60}Co, ^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs	3	3
	Total alpha, total beta, U total, ^{226}Ra, ^{228}Ra	4	4

(a) Control limits are from Jarvis and Siu (1981).

Table 7.0.6. Summary of Ground-Water Surveillance Project Quarterly Blind Spiked Determinations, 1995

Constituents	Number of Results Reported[a]	Number Within ±30% RPD[b]
^{3}H	12	12
^{60}Co	12	12
^{90}Sr	12	11
^{99}Tc	12	10
^{129}I	12	8
^{137}Cs	12	12
^{239}Pu	12	9
U total	12	12
Chloroform	12	9
Carbon tetrachloride	12	7
Trichloroethylene	12	9
Chromium	12	12
Cyanide	12	12
Fluoride	12	9
Nitrate	12	12

(a) Blind samples were submitted in triplicate each quarter and compared to actual spike value.
(b) RPD = Relative Percent Difference.

Laboratory Internal Quality Assurance Programs

DataChem Laboratories and Quanterra Environmental Services are required to maintain an internal quality control program. Periodically, the laboratories are internally audited for compliance to the quality control programs. At the DataChem Laboratories, the quality control program meets the quality control criteria of EPA SW-846 (EPA 1986b). This program also requires the laboratory to maintain a system for reviewing and analyzing the results of the quality control samples to detect problems that may arise from contamination, inadequate calibrations, calculation errors, or improper procedure performance. Method Detection Levels are determined annually for each analytical method.

Quanterra Environmental Services' internal quality control program involves routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation check sources and background

Table 7.0.7. Summary of Surface Environmental Surveillance Project Blind Spiked Determinations, 1995

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, ^{238}Pu, ^{239}Pu	21	20
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}U, ^{238}Pu, ^{239}Pu	17	10
Water	^{3}H, ^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{234}U, ^{238}U, ^{239}Pu	27	25
Vegetation	^{40}K, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu	15	12
Animal tissue	^{40}K, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}U	5	4

(a) Control limit of ± 30%.

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 National Institute of Standards and Technology were used for radiochemical calibrations. Minimum detectable concentration verification is conducted (when requested) for radionuclide-media combination analyses. Calculation of minimum detectable concentrations 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 (EPA 1980a).

Periodically, inspections of services are performed, which document conformance with contractual requirements of the analytical facility and provide the framework for identifying and resolving potential performance problems. Responses to audit and inspection findings are documented by written communication, and corrective actions are verified by follow-up audits and inspections. There were no scheduled inspections of services performed in 1995; however, the laboratories were frequently contacted regarding questions on results, clarification of methodology, status of scheduled improvements, etc.

Internal laboratory quality control program data are summarized by the laboratories in quarterly reports. The results of the quality control sample summary reports and the observations noted by each laboratory indicated an acceptably functioning internal quality control program.

Media Audits and Comparisons

Additional audits and comparisons are conducted on several specific types of samples. The Washington State Department of Health routinely co-sampled various environmental media and measured external radiation levels at multiple locations during 1995. Media that were co-sampled with the Washington State Department of Health included: 26 ground-water wells; 3 Columbia River sites; 2 riverbank springs; 1 onsite pond; 2 onsite drinking water systems; 3 offsite water systems; 8 Columbia River sediment sites; 4 air monitoring stations; 15 thermoluminescent dosimeter sites; and 1 rabbit. Also co-sampled were upwind and downwind samples of alfalfa, tomatoes, leafy vegetables, whitefish, melons, potatoes, chicken, concord grapes, and wine. Results will be available in the Washington State Department of Health 1995 annual report. The National Food and Drug Administration also co-sampled vegetables, fruit, and wheat. The data are presented in Table 7.0.8.

Quality Control for environmental thermoluminescent dosimeters includes the audit exposure of three environmental thermoluminescent dosimeters per quarter to known values of radiation (between 17 and 28 mR). A summary of 1995 results is shown in Table 7.0.9. On average, the thermoluminescent dosimeter measurements were biased 0.76% higher than the known values.

Effluent Monitoring and Near-Facility Environmental Monitoring

The Site effluent monitoring and near-facility environmental monitoring programs are subject to the quality assurance programs defined in the Westinghouse Hanford Company *Quality Assurance Manual* (WHC 1989), and Pacific Northwest National Laboratory *Quality Assurance Manual* (PNL 1992). These quality assurance 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 1980a) and *Data Quality Objectives for Remedial Response Activities* (EPA 1987).

The facility effluent monitoring and near-facility environmental monitoring programs each have a quality assurance project plan describing applicable quality assurance elements. These plans are approved by contractor quality assurance 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 contract selection is made for equipment and services that may significantly impact the quality of a project.

Sample Collection Quality Assurance

Effluent monitoring and near-facility environmental monitoring samples are collected by staff who are trained for the task in accordance with approved procedures. Established sample locations are accurately identified and documented to ensure continuity of data for those sites. Effluent and environmental sample locations, for the Hanford Site, are described in the *Environmental Monitoring Plan* (DOE 1994a).

Table 7.0.8. Comparison of Food and Drug Administration (FDA) Co-Sampling, 1995

Media	Area	Organization	^{131}I (pCi/kg)	^{106}Ru (pCi/kg)	^{137}Cs (pCi/kg)[a,b]	^{40}K (pCi/kg)[a]	^{90}Sr (pCi/kg)[a,b]	Tritium (pCi/kg)[a]
Alfalfa	Benton City Area	FDA	ND[c]	ND	ND	18.6 ± 4.0	NV[d]	NA[e]
		PNNL	ND	ND	<0.016	29.8 ± 3.08	0.0493 ± 0.0116	NA
	Horn Rapids Area	FDA	ND	ND	ND	22.2 ± 4.6	NV	NA
		PNNL	ND	ND	<0.0115	25.5 ± 2.69	0.0175 ± 0.00611	NA
	Sunnyside Area	FDA	ND	ND	ND	16.4 ± 2.4	NV	NA
		PNNL	ND	ND	<0.00936	22.5 ± 2.34	0.0177 ± 0.00643	NA
	Riverview Area	FDA	ND	ND	ND	21.3 ± 4.6	NV	NA
		PNNL	ND	ND	<0.0104	18.4 ± 1.94	0.0967 ± 0.027	NA
	Sagemoor Area	FDA	ND	ND	ND	15.7 ± 2.6	NV	NA
		PNNL	ND	ND	0.0103 ± 0.00878	21.0 ± 2.17	0.0947 ± 0.0246	NA
Leafy vegetables	Riverview Area	FDA	ND	ND	ND	3.3 ± 0.8	NA	ND
		PNNL	ND	ND	<0.0103	4.47 ± 0.598	<0.00309	NA
	Sunnyside Area	FDA	ND	ND	ND	2.9 ± 0.9	3.0 ± 1.4	ND
		PNNL	ND	ND	<0.00983	1.82 ± 0.418	<0.00296	NA
Potatoes	Sagemoor Area	FDA	ND	ND	ND	4.0 ± 0.9	NA	ND
		PNNL	ND	ND	<0.00941	3.62 ± 0.600	<0.00296	NA
	Sunnyside Area	FDA	ND	ND	ND	4.6 ± 0.9	ND	ND
		PNNL	ND	ND	<0.0118	4.47 ± 0.705	<0.00292	NA
	Riverview Area	FDA	ND	ND	ND	4.6 ± 0.9	ND	ND
		PNNL	ND	ND	<0.0113	4.05 ± 0.605	<0.00280	NA
Apples	Riverview Area	FDA	ND	ND	ND	1.1 ± 0.8	ND	ND
		PNNL	ND	ND	<0.00927	0.647 ± 0.284	<0.00191	<141[f]
	Sagemoor Area	FDA	ND	ND	ND	1.0 ± 0.7	NA	ND
		PNNL	ND	ND	<0.0099	0.839 ± 0.326	<0.00251	<138[f]

(a) ±2 sigma total propagated analytical uncertainty.
(b) < values are 2 sigma total propagated analytical uncertainties.
(c) ND = not detected.
(d) NV = not available at this time.
(e) NA = not analyzed.
(f) Reported in pCi/L of water extract.

Table 7.0.9. Comparison of Thermoluminescent Dosimeter Results with Known Exposure, 1995

Quarter	Known Exposure, mR	Determined, mR (±2 SD)	% of Exposure
First	17 ± 0.63	16.59 ± 0.58	97.61
	23 ± 0.85	22.61 ± 0.21	98.32
	27 ± 1.00	27.03 ± 1.38	100.10
Second	19 ± 0.70	19.02 ± 0.18	100.11
	22 ± 0.81	21.65 ± 1.48	98.41
	28 ± 1.04	27.48 ± 0.38	98.14
Third	18 ± 0.67	17.51 ± 0.29	97.28
	24 ± 0.89	25.08 ± 0.11	104.50
	26 ± 0.96	27.62 ± 0.45	106.23
Fourth	17 ± 0.63	17.76 ± 0.49	104.47
	20 ± 0.74	20.31 ± 0.02	101.55
	25 ± 0.93	25.59 ± 0.16	102.36

Analytical Results Quality Assurance

Effluent monitoring and near-facility environmental monitoring samples are analyzed by four different analytical laboratories. The use of these laboratories is dependent on the Hanford contractor collecting the samples and contract(s) established between the contractor and the analytical laboratory(s) used. Table 7.0.10 provides a summary of Hanford's analytical laboratory use for effluent monitoring and near-facility monitoring samples, which are grouped by contractor and sample media.

The quality of the analytical data is assured by several means. Counting room instruments are kept within calibration limits through daily checks, the results of which are stored in computer databases. Radiochemical standards used in analyses are measured regularly and the results are 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.

Table 7.0.10. Laboratories Utilized in 1995 by Contractor and Sample Type

	Laboratories Utilized for Effluent Monitoring Samples					Laboratories Utilized for Near-Facility Environmental Monitoring Samples		
	WHC[a]		PNNL[b]	BHI[c]		WHC		
Laboratory	Air Samples	Water Samples	Air Samples	Air Samples	Water Samples	Air Samples	Water Samples	Other
Waste Sampling and Characterization Facility	X	X		X		X	X	X
222-S Analytical Laboratory							X	X
Quanterra Environmental Services (Richland)	X		X	X	X	X		
PNNL Analytical Chemistry Laboratory	X	X	X					

(a) Westinghouse Hanford Company.
(b) Pacific Northwest National Laboratory.
(c) Bechtel Hanford Inc.

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 7.0.11 through 7.0.16 for the Waste Sampling and Characterization Facility, the 222-S Analytical Laboratory, and the Pacific Northwest National Laboratory Analytical Chemistry Laboratory.

Table 7.0.11. Waste Sampling and Characterization Facility Performance on DOE Quality Assessment Program Samples, 1995

Sample Media	Analysis	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Air filters	Total alpha, total beta, ^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{238}Pu, ^{239}Pu, ^{241}Am, U total	27	27	0
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am	8	5	3[a]
Vegetation	^{40}K, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{239}Pu, ^{241}Am	9	8	1[b]
Water	Total alpha, total beta, ^{3}H, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, U total	21	21	0

(a) One ^{90}Sr analysis, one ^{238}Pu analysis, and one ^{239}Pu analysis were not within control limits.
(b) One ^{239}Pu analysis was not within control limits.

Table 7.0.12. 222-S Analytical Laboratory Performance on DOE Quality Assessment Program Samples, 1995

Sample Media	Analysis	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Soil	^{40}K, ^{137}Cs, ^{238}Pu, ^{239}Pu	6	6	0
Vegetation	^{40}K, ^{90}Sr, ^{137}Cs, ^{239}Pu	5	4	1[a]
Water	^{3}H, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, U total	16	15	1[b]

(a) One ^{90}Sr analysis was not within control limits.
(b) One ^{241}Am analysis was not within control limits.

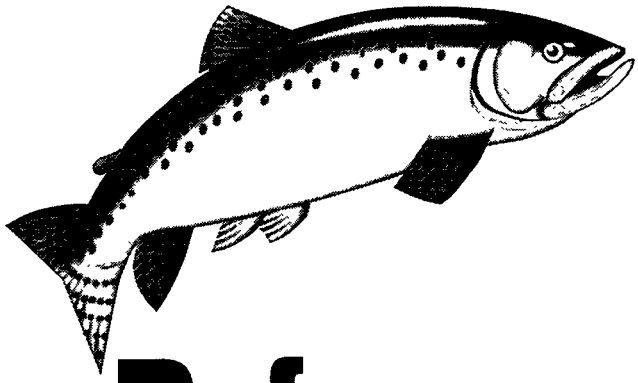
Table 7.0.13. Pacific Northwest National Laboratory Analytical Chemistry Laboratory Performance on DOE Quality Assessment Program Samples, 1995

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, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{238}Pu, ^{239}Pu, ^{241}Am	12	12	0
Water	^{3}H, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, U total	9	9	0

Table 7.0.14. Waste Sampling and Characterization Facility Performance on EPA Intercomparison Program Samples, 1995

Sample Category	Analysis	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Air filters	Total alpha, total beta, ^{90}Sr, ^{137}Cs	8	8	0
Total alpha-beta in water	Total alpha, total beta	6	4	2[a]
Gamma in water	^{60}Co, ^{65}Zn, ^{106}Ru, ^{134}Cs, ^{137}Cs, ^{133}Ba,	20	17	3[b]
Strontium in water	^{89}Sr, ^{90}Sr	4	4	0
Uranium-radium in water	U total, ^{226}Ra, ^{228}Ra	9	7	2[c]
Plutonium in water	^{239}Pu	1	1	0
Tritium in water	^{3}H	3	1	2[d]
Blind A[e]	Total alpha, U total, ^{226}Ra, ^{228}Ra	8	8	0
Blind B[f]	Total beta, ^{60}Co, ^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs	12	10	2[g]

(a) Two total alpha analyses were not within control limits.
(b) Three ^{134}Cs analyses were not within control limits. EPA has indicated that laboratories calibrating with a mixed gamma standard are having difficulty with this analysis.
(c) Two uranium analyses were not within control limits.
(d) Two tritium analyses were not within control limits.
(e) Blind A samples are liquid samples with unknown quantities of alpha emitters, which are analyzed for total alpha and each radionuclide component.
(f) Blind B samples are liquid samples with unknown quantities of beta emitters, which are analyzed for total beta and each radionuclide component.
(g) One total beta analysis and one ^{89}Sr analysis were not within control limits.



References

8.0 References

10 CFR 1021, U.S. Department of Energy, "Compliance with the National Environmental Policy Act." *Code of Federal Regulations.*

29 CFR 1910, U.S. Department of Labor, "Occupational Safety and Health Administration." *Code of Federal Regulations.*

40 CFR 61, U.S. Environmental Protection Agency, "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations.*

40 CFR 82, U.S. Environmental Protection Agency, "Protection of Stratospheric Ozone." *Code of Federal Regulations.*

40 CFR 141 and 142, U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations; Radionuclides; Proposed Rule." *Code of Federal Regulations.*

40 CFR 264, U.S. Environmental Protection Agency, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities." *Code of Federal Regulations.*

40 CFR 265, U.S. Environmental Protection Agency, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities." *Code of Federal Regulations.*

40 CFR 761, U.S. Environmental Protection Agency, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." *Code of Federal Regulations.*

40 CFR 1500-1508, Council on Environmental Quality, "Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act." *Code of Federal Regulations.*

55 FR 42633, U.S. Department of Energy, "Intent to Prepare a Programmatic Environmental Impact Statement on the Department of Energy's Proposed Integrated Environmental Restoration and Waste Management Program, and to Conduct Public Scoping Meetings." *Federal Register.*

58 FR 39528, U.S. Department of Energy, "Revised Notice of Intent to Prepare a Programmatic Environmental Impact Statement for Reconfiguration of the Nuclear Weapons Complex." *Federal Register.*

58 FR 48509, U.S. Department of Energy, "Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington." *Federal Register.*

59 FR 4052, U.S. Department of Energy, "Intent to Prepare Hanford Tank Waste Remediation System Environmental Impact Statement, Richland, Washington." *Federal Register.*

60 FR 30926, U.S. Environmental Protection Agency, "Reportable Quantity Adjustments." *Code of Federal Regulations.*

American Society of Mechanical Engineers (ASME). 1989. *Quality Assurance Program for Nuclear Facilities, ASME NQA-1-1989 Edition.* American Society of Mechanical Engineers, New York.

Ames, B. N., R. Magaw, and L. S. Gold. 1987. "Ranking Possible Carcinogenic Hazards." *Science* 236:271-280.

Anderson, J. D., and D. O. Hagel. 1996 (in press). *Summary of Radioactive Solid Waste Received in the 200 Areas During Calendar Year 1995.* Westinghouse Hanford Company, Richland, Washington.

Ashby, E. C., A. Annis, E. K. Barefield, D. Boatright, F. Doctorovich, C. L. Liotta, H. M. Neuman, A. Konda, C. F. Yao, K. Zhang, and N. G. McDuffie. 1994. *Synthetic Waste Chemical Mechanisms Studies.* WHC-EP-0823, Westinghouse Hanford Company, Richland, Washington.

Atallah, S. 1980. "Assessing and Managing Industrial Risk." *Chemical Engineering* 9/8/80:94-103.

Backman, G. E. 1962. *Dispersion of 300 Area Liquid Effluent in the Columbia River.* HW-73672, Hanford Atomic Products Operation, General Electric Company, Richland, Washington.

Baker, D. A., and J. K. Soldat. 1992. *Methods for Estimating Doses to Organisms from Radioactive Materials Released into the Aquatic Environment.* PNL-8150, Pacific Northwest Laboratory, Richland, Washington.

Barney, G. S. 1994. *The Solubilities of Significant Organic Compounds in HLW Tank Supernatant Solutions.* WHC-SA-2565-FP, Westinghouse Hanford Company, Richland, Washington.

Beasley, T. M., L. A. Ball, and J. E. Andrews III. 1981. "Hanford-Derived Plutonium in Columbia River Sediments." *Science* 214(20):913-915.

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.

Betsch, M. D. 1995. *Pollution Prevention Accomplishments Book.* WHC-SA-2963, Westinghouse Hanford Company, Richland, Washington.

Bisping, L. E. 1996. *1995 Surface Environmental Surveillance Data.* PNNL-11140, Pacific Northwest National Laboratory, Richland, Washington.

Bisping, L. E. 1995a. *Environmental Surveillance Master Sampling Schedule.* PNL-9215, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E. 1995b. *Hanford Site Environmental Data for Calendar Year 1994-Surface and Columbia River.* PNL-10575, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E. 1994. *Hanford Site Environmental Data 1993 - Surface and Columbia River.* PNL-9824, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E. 1993. *Environmental Surveillance Master Sampling Schedule.* PNL-8532. Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E. 1992. *Environmental Surveillance Master Sampling Schedule.* PNL-7964. Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E. 1991. *Environmental Surveillance Master Sampling Schedule.* PNL-7619. Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E., and R. K. Woodruff. 1993. *Hanford Site Environmental Data for Calendar Year 1992—Surface and Columbia River.* PNL-8693, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E., and R. K. Woodruff. 1992. *Hanford Site Environmental Data for Calendar Year 1991—Surface and Columbia River.* PNL-8149, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E., and R. K. Woodruff. 1991. *Hanford Site Environmental Data for Calendar Year 1990—Surface and Columbia River.* PNL-7929, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E., and R. K. Woodruff. 1990. *Hanford Site Environmental Data for Calendar Year 1989—Surface and Columbia River.* PNL-7360, Pacific Northwest Laboratory, Richland, Washington.

Blanton, M. L., A. T. Cooper, and K. J. Castleton. 1995a. *Nonradiological Chemical Pathway Analysis and Identification of Chemicals of Concern for Environmental Monitoring at the Hanford Site.* PNL-10714, Pacific Northwest National Laboratory, Richland, Washington.

Blanton, M. L., W. W. Gardiner, and R. L. Dirkes. 1995b. *Environmental Monitoring of Columbia River Sediments: Grain-Size Distribution and Containment Association.* PNL-10535, Pacific Northwest Laboratory, Richland, Washington.

Borghese, J. V. 1994. "300 Area Process Trench." In *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993.* DOE/RL-93-88, Geosciences Group, Westinghouse Hanford Company, editors. U.S. Department of Energy, Richland, Washington.

Braun, D. J., and S. A. Szendre. 1994. *High-Level Waste Tank Subcriticality Safety Assessment.* WHC-SD-WM-SARR-003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Campbell, M. D., W. J. McMahon, and K. R. Simpson. 1993. *Water Level Measurements for Modeling Hydraulic Properties in the 300-FF-5 and 100 Aggregate Area Operable Units.* PNL-8580, Pacific Northwest Laboratory, Richland, Washington.

Connelly, M. P., B. H. Ford, J. W. Lindberg, S. J. Trent, and C. D. Delaney. 1992a. *Hydrogeologic Model for the 200 East Groundwater Aggregate Area.* WHC-SD-EN-TI-019, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Connelly, M. P., B. H. Ford, and J. V. Borghese. 1992b. *Hydrogeologic Model for the 200 West Groundwater Aggregate Area.* WHC-SD-EN-TI-014, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Cushing, C. E., (ed.). 1994. *Hanford Site National Environmental Policy Act (NEPA) Characterization.* PNL-6415, Rev. 5, Pacific Northwest Laboratory, Richland, Washington.

Cushing, C. E., (ed.). 1995. *Hanford Site National Environmental Policy Act (NEPA) Characterization.* PNL-6415, Rev. 7, Pacific Northwest Laboratory, Richland, Washington.

Diediker, L. P., and D. J. Rokkan. 1993. *Environmental Releases for Calendar Year 1992.* WHC-EP-0527-2, Westinghouse Hanford Company, Richland, Washington.

Dinman, B. D. 1980. "The Reality and Acceptance of Risk." *Journal of the American Medical Association (JAMA)* (11):1226-1228.

Dirkes, R. L. 1990. *1988 Hanford Riverbank Springs Characterization Report.* PNL-7500, Pacific Northwest Laboratory, Richland, Washington.

Dirkes, R. L. 1993. *Columbia River Monitoring: Distribution of Tritium in Columbia River Water at the Richland Pumphouse.* PNL-8531, Pacific Northwest Laboratory, Richland, Washington.

Dirkes, R. L., G. W. Patton, and B. L. Tiller. 1993. *Columbia River Monitoring: Summary of Chemical Monitoring Along Cross Sections at Vernita Bridge and Richland.* PNL-8654, Pacific Northwest Laboratory, Richland, Washington.

Dirkes, R. L., and R. W. Hanf. 1995. *Hanford Site Environmental Report for Calendar Year 1994.* PNL-10574, Pacific Northwest Laboratory, Richland, Washington.

DOE - See U.S. Department of Energy.

Dresel, P. E., S. P. Luttrell, J. C. Evans, W. D. Webber, P. D. Thorne, M. A. Chamness, B. M. Gillespie, B. E. Opitz, J. T. Rieger, J. K. Merz. 1994. *Hanford Site Ground-Water Monitoring for 1993.* PNL-10082, Pacific Northwest Laboratory, Richland, Washington.

Dresel, P. E., P. D. Thorne, S. P. Luttrell, B. M. Gillespie, W. D. Webber, J. K. Merz, J. T. Rieger, M. A. Chamness, S. K. Wurstner, and B. E. Opitz. 1995. *Hanford Site Ground-Water Monitoring for 1994.* PNL-10698, Pacific Northwest Laboratory, Richland, Washington.

Drummond, M., and Future Site Uses Working Group. 1992. *The Future of Hanford: Uses and Cleanup.* U.S. Department of Energy, Richland, Washington.

Eberhardt, L. E., E. E. Hanson, and L. L. Cadwell. 1982. *Analysis of Radionuclide Concentrations and Movement Patterns of Hanford Site Mule Deer.* PNL-4420, Pacific Northwest Laboratory, Richland, Washington.

Eberhardt, L. E., R. G. Anthony, and W. H. Rickard. 1989. "Survival of Juvenile Canada Geese During the Rearing Period." *Journal of Wildlife Management* 53:372-377.

Ecology - See Washington State Department of Ecology.

Eisenbud, M. 1987. *Environmental Radioactivity from Natural, Industrial, and Military Sources.* Third Edition, Chapter 5, Academic Press Inc., New York.

EPA - See U.S. Environmental Protection Agency.

Evans, J. C., R. W. Bryce, and D. R. Sherwood. 1989a. *Hanford Site Ground-Water Monitoring for January Through June 1988.* PNL-6886, Pacific Northwest Laboratory, Richland, Washington.

Evans, J. C., R. W. Bryce, D. R. Sherwood, M. L. Kemmer, and D. R. Newcomer. 1989b. *Hanford Site Ground-Water Monitoring for July Through December 1988.* PNL-7120, Pacific Northwest Laboratory, Richland, Washington.

Evans, J. C., R. W. Bryce, and D. J. Bates. 1992. *Hanford Site Ground-Water Monitoring for 1990.* PNL-8073, Pacific Northwest Laboratory, Richland, Washington.

Fauske, H. K., M. Epstein, D. R. Dickinson, R. J. Cash, D. A. Turner, and J. E. Meacham. 1995. *The Contact-Temperature Ignition (CTI) Criteria for Propagating Chemical Reactions Including the Effect of Moisture and Application to Hanford Waste.* WHC-SD-WM-ER-496, Rev. O, Westinghouse Hanford Company, Richland, Washington.

Fayer, M. J., and T. B. Walters. 1995. *Estimated Recharge Rates at the Hanford Site.* PNL-10285, Pacific Northwest Laboratory, Richland, Washington.

Freshley, M. D., and M. J. Graham. 1988. *Estimation of Ground-Water Travel Time at the Hanford Site: Description, Past Work, and Future Needs.* PNL-6328, Pacific Northwest Laboratory, Richland, Washington.

Gee. G. W., M. J. Fayer, M. L. Rockhold, and M. D. Campbell. 1992. "Variations in Recharge at the Hanford Site." *Northwest Science* 66(4): 237.

Gephart, R. E., P. A. Eddy, R. C. Arnett, and G. A. Robinson. 1976. *Geohydrologic Study of the West Lake Basin.* ARH-CD-775, Atlantic Richfield Hanford Company, Richland, Washington.

Gephart, R. E., R. C. Arnett, R. G. Baca, L. S. Leonhart, F. A. Spane, Jr., D. A. Palumbo, and S. R. Strait. 1979. *Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge.* RHO-BWI-ST-5, Rockwell Hanford Operations, Richland, Washington.

Gerber, M. S. 1992. *Past Practices Technical Characterization Study - 300 Area - Hanford Site.* WHC-MR-0388, Westinghouse Hanford Company, Richland, Washington.

Gerber, M. S. 1993. *Summary of 100-B/C Reactor Operations and Resultant Wastes, Hanford Site.* WHC-SD-EN-RPT-004, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Gibbs, R. J. 1973. "Mechanisms of Trace Metal Transport in Rivers." *Science* 180:71-73.

Gilmore, T. J., D. R. Newcomer, S. K. Wurstner, F. A. Spane. 1992. *Calculation of Groundwater Discharge to the Columbia River in the 100 Area.* PNL-8057, Pacific Northwest Laboratory, Richland, Washington.

Gleckler, B. P., L. P. Diediker, K. Rhoads, E. G. Damberg, and S. J. Jette. 1996. *Radionuclide Air Emissions Report for the Hanford Site Calendar Year 1995.* DOE/RL-96-37, U.S. Department of Energy, Richland, Washington.

Graham, M. J., M. D. Hall, S. R. Strait, and W. R. Brown. 1981. *Hydrology of the Separations Area.* RHO-ST-42, Rockwell Hanford Operations, Richland, Washington.

Graham, M. J., G. V. Last, and K. R. Fecht. 1984. *An Assessment of Aquifer Intercommunication in the B Pond - Gable Mountain Pond Area of the Hanford Site.* RHO-RE-ST-12P, Rockwell Hanford Operations, Richland, Washington.

Hanford Site Radiological Control Manual (HSRCM). 1994. *Hanford Site Radiological Control Manual.* HSRCM-1, Revision 2, HSRCM Project, Richland, Washington.

Hanlon, B. M. 1994. *Waste Tank Summary for Month Ending October 31, 1994.* WHC-EP-0182-79, Westinghouse Hanford Company, Richland, Washington.

Hanlon, B. M. 1996. *Waste Tank Summary for Month Ending December 31, 1995.* WHC-EP-0182-93, Westinghouse Hanford Company, Richland, Washington.

Hartman, M. J. 1996. "Introduction." In *Annual Report for RCRA Groundwater Monitoring Projects at the Hanford Site Facilities for 1995.* DOE/RL-96-01, Rev. 0, U.S. Department of Energy, Richland, Washington.

Hartman, M. J., and K. A. Lindsey. 1993. *Hydrogeology of the 100-N Area, Hanford Site, Washington.* WHC-SD-EN-EV-027, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Health Physics Society (HPS). 1987. *Health Physics Society Official Journal: Special Issue on Radiation Hormesis* 52(5).

Hoitink, D. J., and K. W. Burk. 1995. *Climatological Data Summary 1994, With Historical Data.* PNL-10553, Pacific Northwest Laboratory, Richland, Washington.

Huckaby, J. L. 1994. *Vapor Sampling System (VSS) and In Situ Sampling (ISS) Method Comparison.* WHC-SD-WM-RPT-101, Revision 0, Westinghouse Hanford Company, Richland, Washington.

Huckaby, J. L., and H. Babad. 1994. *Progress Toward Resolution of Vapor Release Problems Associated with Tank 241-C-103.* WHC-SA-2102-FP, Westinghouse Hanford Company, Richland, Washington.

Jacobson, E. A., and M. D. Freshley. 1990. *An Initial Inverse Calibration of the Ground-Water Flow Model for the Hanford Unconfined Aquifer.* PNL-7144, Pacific Northwest Laboratory, Richland, Washington.

Jaquish, R. E. 1993. *Contribution of Hanford Liquid Effluents to Strontium-90 Levels in Offsite Soils.* PNL-8817, Pacific Northwest Laboratory, Richland, Washington.

Jaquish, R. E., and R. W. Bryce. 1989. *Hanford Site Environmental Report for Calendar Year 1988.* PNL-6825, Pacific Northwest Laboratory, Richland, Washington.

Jarvis, A. B., and L. Siu. 1981. *Environmental Radioactivity Laboratory Intercomparison Studies Program: Fiscal Year 1980-81.* EPA-600/4-81-004, U.S. Environmental Protection Agency, Las Vegas, Nevada.

Jenkins, O. P. 1922. *Underground Water Supply of the Region About White Bluffs and Hanford.* State of Washington, Department of Conservation and Development, Olympia, Washington.

Johnson, A. R., R. M. Mitchell, and C. A. Rowley. 1996. *Preoperational Environmental Survey Report: 200 Areas Cross-Site Transfer Line Replacement (W-058).* WHC-SD-W058-RPT-001, Westinghouse Hanford Company, Richland, Washington.

Johnson, A. R., R. M. Mitchell, S. J. Guzek, and M. A. Juguilon. 1995. *Preoperational Environmental Survey Report: 200 Areas Effluent Treatment Facility, State Approved Land Disposal Site, and Liquid Effluent Retention Facility (C-018H).* WHC-SD-C018H-RPT-004, Westinghouse Hanford Company, Richland, Washington.

Johnson, A. R., B. M. Markes, J. W. Schmidt, A. N. Shah, S. G. Weiss, and K. J. Wilson. 1994. *Historical Records of Radioactive Contamination in Biota at the 200 Areas of the Hanford Site.* WHC-MR-0418, Westinghouse Hanford Company, Richland, Washington.

Johnson, V. G. 1993. *Westinghouse Hanford Company Operational Groundwater Status Report,* 1980-1992. WHC-EP-0595, Westinghouse Hanford Company, Richland, Washington.

Karickhoff, W. S., S. D. Brown, and A. T. Scott. 1978. "Sorption of Hydrophobic Pollutants on Natural Sediment." *Water Resources Bulletin* 13:231-248.

Lambert, S. M. 1967. "Functional Relationship Between Sorption in Soil and Chemical Structure." *J. Agric. Fd. Chem.* 15(4):572-576.

Landeen, D. S., A. R. Johnson, R. M. Mitchell, and M. R. Sackchewsky. 1994. *Comparison of Radionuclide Levels in Soil, Sagebrush, Plant Litter, Cryptograms, and Small Mammals.* WHC-EP-0771, Westinghouse Hanford Company, Richland, Washington.

Lilga, M. A., E. V. Alderson, R. T. Hallen, M. O. Hogan, T. L. Hubler, G. L. Jones, D. J. Kowalski, M. R. Lumetta, G. F. Schiefelbein, and M. R. Telander. 1995. *Ferrocyanide Safety Project Ferrocyanide Aging Studies FY 1995 Annual Report.* PNL-10713, Pacific Northwest Laboratory, Richland, Washington.

Lilga, M. A., E. V. Alderson, M. R. Lumetta, and G. F. Schiefelbein. 1994. *Ferrocyanide Safety Project, Task 3: Ferrocyanide Aging Studies - FY 1994 Annual Report.* PNL-10126, Pacific Northwest Laboratory, Richland, Washington.

Lindberg, J. W. 1993a. *Geology of the 100-B/B Area, Hanford Site, South-Central Washington.* WHC-SD-EN-TI-133, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Lindberg, J. W. 1993b. *Geology of the 100-K Area, Hanford Site, South-Central Washington.* WHC-SD-EN-TI-155, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K. A., and G. K. Jaeger. 1993. *Geologic Setting of the 100-HR-3 Operable Unit, Hanford Site, South-Central Washington.* WHC-SD-EN-TI-132, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

McCormack, W. D., and J. M. V. Carlile. 1984. *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River.* PNL-5289, Pacific Northwest Laboratory, Richland, Washington.

Mudroch, A. 1983. "Distribution of Major Elements and Metals in Sediment Cores from the Western Basin of Lake Ontario." *J. Great Lakes Res.* 9(2):125-133.

Napier, B. A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell. 1988a. *Conceptual Representation. Volume 1 of GENII - The Hanford Environmental Radiation Dosimetry Software System.* PNL-6584, Vol. 1, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell. 1988b. *User's Manual. Volume 2 of GENII - The Hanford Environmental Radiation Dosimetry Software System.* PNL-6584, Vol. 2, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell. 1988c. *Code Maintenance Manual. Volume 3 of GENII - The Hanford Environmental Radiation Dosimetry Software System.* PNL-6584, Vol. 3, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., N. C. Batishko, D. A. Heise-Craff, M. F. Jarvis, and S. F. Snyder. 1995. *Identification of Contaminants of Concern, Columbia River Comprehensive Impact Assessment--Draft.* PNL-10400, Pacific Northwest Laboratory, Richland, Washington.

National Council on Radiation Protection and Measurements (NCRP). 1987. *Ionizing Radiation Exposure of the Population of the United States.* NCRP Report No. 93, Bethesda, Maryland.

National Park Service (NPS). 1994. *Hanford Reach of the Columbia River: Comprehensive River Conservation Study and Final Environmental Impact Statement,* Volume 1.

National Research Council (NRC), Committee on the Biological Effects of Ionizing Radiation. 1980. *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation.* National Academy Press, Washington, D.C.

National Research Council (NRC), Committee on the Biological Effects of Ionizing Radiation. 1990. *Health Effects of Exposure to Low Levels of Ionizing Radiation.* National Academy Press, Washington, D.C.

Nelson, J. L., R. W. Perkins, J. M. Nielsen, and W. L. Haushild. 1966. "Reactions of Radionuclides from the Hanford Reactors with Columbia River Sediments." In *Disposal of Radioactive Wastes into Seas, Oceans, and Surface Waters,* pp. 139-161. International Atomic Energy Agency, Vienna, Austria.

Newcomb, R.C., J.R. Strand, and F.J. Frank. 1972. *Geology and Ground-Water Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington.* Geological Survey Professional Paper 717, U.S. Atomic Energy Commission, Washington, D.C.

Newcomer, D.R. 1990. *Evaluation of Hanford Site Water-Table Changes* -- 1980-1990. PNL-7498, Pacific Northwest Laboratory, Richland, Washington.

Newcomer, D. R., K. D. Pohlod, and J. P. McDonald. 1991. *Water-Table Elevations on the Hanford Site, 1990.* PNL-7693, Pacific Northwest Laboratory, Richland, Washington.

Osborne, J. W. 1994. *Program Plan for the Resolution of Vapor Issues.* WHC-EP-0562, Revision 1, Westinghouse Hanford Company, Richland, Washington.

Pacific Northwest Laboratory (PNL). 1992. *Quality Assurance Manual.* PNL-MA-70. PNL-7000, Pacific Northwest Laboratory, Richland, Washington.

Pacific Northwest Laboratory (PNL). 1993. *Procedures for Ground-Water Investigations.* PNL-6894, Rev. 1, Pacific Northwest Laboratory, Richland, Washington.

Patton, G. W., A. T. Cooper, and M. L. Blanton. 1994. *Measurement and Estimated Health Risks of Volatile Organic Compounds and Polychlorinated Biphenyls in Air at the Hanford Site.* PNL-10168, Pacific Northwest Laboratory, Richland, Washington.

Patton, G. W., A. T. Cooper, and M. R. Tinker. 1995. *Evaluation of an Ambient Air Sampling System for Tritium (as Tritiated Water Vapor) Using Silica Gel Adsorbent Columns.* PNL-10690, Pacific Northwest Laboratory, Richland, Washington.

Perkins, R. W., and C. W. Thomas. 1980. "Worldwide Fallout." In W. C. Hanson, (Ed.), *Transuranic Elements in the Environment.* DOE/TIC-22880, U.S. Department of Energy, Springfield, Virginia.

Peterson, R. E. 1992. *Hydrologic and Geologic Data Available for the Region North of Gable Mountain, Hanford Site, Washington.* WHC-SD-EN-TI-006, Westinghouse Hanford Company, Richland, Washington.

Peterson, R. E., and M. P. Connelly. 1992. *Characterization of a Chromium Plume in Groundwater Along the Columbia River Shoreline, Hanford Site, Washington.* WHC-SA-1674-VA, Westinghouse Hanford Company, Richland, Washington.

Postma, A. K., D. B. Bechtold, G. L. Borsheim, J. M. Grigsby, R. L. Guthrie, M. Kummerer, M. G. Plys, and D. A. Turner. 1994a. *Safety Analysis of Exothermic Reaction Hazards Associated with the Organic Liquid Layer in Tank 241-C-103.* WHC-SD-WM-SARR-001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Postma, A. K., J. E. Meacham, G. S. Barney, G. L. Borsheim, R. J. Cash, M. D. Crippen, D. R. Dickinson, J. M. Grigsby, D. W. Jeppson, M. Kummerer, J. M. McLaren, C. S. Simmons, and B. C. Simpson. 1994b. *Ferrocyanide Safety Program: Safety Criteria for Ferrocyanide Watch List Tanks.* WHC-EP-0691, Westinghouse Hanford Company, Richland, Washington.

Poston, T. M. 1995. *Concentrations of Radionuclides in Terrestrial Vegetation on the Hanford Site of Potential Interest to Native Americans.* PNL-10397, Pacific Northwest Laboratory, Richland, Washington.

Poston, T. M., E. J. Antonio, and A. T. Cooper. 1995. *Radionuclide Concentrations in Terrestrial Vegetation and Soil on and Around the Hanford Site, 1983 Through 1993.* PNL-10728, Pacific Northwest Laboratory, Richland, Washington.

Poston, T. M., and A. T. Cooper. 1994. *A Qualitative Evaluation of Radionuclide Concentrations in Hanford Site Wildlife, 1983 through 1992.* PNL-10174, Pacific Northwest Laboratory, Richland, Washington.

Poston, T. M., K. R. Price, and D. R. Newcomer. 1991. *An Evaluation of the Chemical, Radiological, and Ecological Conditions of West Lake on the Hanford Site.* PNL-7662, Pacific Northwest Laboratory, Richland, Washington.

Prater, L. S., J. T. Rieger, C. S. Cline, E. J. Jensen, T. L. Liikala, K. R. Oster, and P. A. Eddy. 1984. *Ground-Water Surveillance at the Hanford Site for CY 1993.* PNL-5041, Pacific Northwest Laboratory, Richland, Washington.

Public Law 101-510, Section 3137, "Safety Measures for Waste Tanks at Hanford Nuclear Reservation," November 5, 1990. (Note: This is section 3137 of the National Defense Authorization Act for Fiscal Year 1991. This does not have a USC number.)

Rathbun, L. A. 1989. *The Determination of the Penetrating Radiation Dose at Hanford.* PNL-7124, Pacific Northwest Laboratory, Richland, Washington.

Raymond, J. R., D. A. Myers, J. J. Fix, V. L. McGhan, and P. M. Schrotke. 1976. *Environmental Monitoring Report on Radiological Status of the Ground Water Beneath the Hanford Site January-December 1974.* BNWL-1970, Pacific Northwest Laboratory, Richland, Washington.

Reidel, S. P., K. A. Lindsey, and K. R. Frecht. 1992. *Field Trip Guide to the Hanford Site.* WHC-MR-0391, Westinghouse Hanford Company, Richland, Washington.

Revised Code of Washington (RCW) 17.21, "Washington Pesticide Application Act 1961," as amended.

Richardson, E. M., and E. Epstein. 1971. "Retention of Three Insecticides on Different Size Soil Particles Suspended in Water." *Soil Sci. Soc. Am. Proc.* 35:884-887.

Robertson, D. E., and J. J. Fix. 1977. *Association of Hanford Origin Radionuclides with Columbia River Sediment.* BNWL-2305, Pacific Northwest Laboratory, Richland, Washington.

Sackschewsky, M. R., D. S. Landeen, G. I. Baird, W. H. Rickard, and J. L. Downs. 1992. *Vascular Plants of the Hanford Site.* WHC-EP-0054, Westinghouse Hanford Company, Richland, Washington.

Sanderson, C. G., V. Pan, and P. Greenlaw. 1995. *Semi-Annual Report of the Department of Energy, Office of Environmental Management, Quality Assessment Program.* EML-565, Environmental Measurements Laboratory, U.S. Department of Energy, New York.

Schmidt, J. W., B. M. Markes, and S. M. McKinney. 1994. *Routine Environmental Monitoring Schedule, Calendar Year 1995.* WHC-SP-0098-6, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Schmidt, J. W., J. W. Fasset, A. R. Johnson, V. G. Johnson, B. M. Markes, S. M. McKinney, K. J. Moss, C. J. Perkins, and L. R. Richterich. 1995. *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1994.* WHC-EP-0573-3, Westinghouse Hanford Company, Richland, Washington.

Schmidt, J. W., J. W. Fassett, R. G. Gant, A. R. Johnson, V. G. Johnson, R. M. Mitchell, B. M. Markes, S. M. McKinney, K. J. Moss, and C. J. Perkins. 1996. *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1995.* WHC-EP-0573-4, Westinghouse Hanford Company, Richland, Washington.

Shleien, B. 1992. *The Health Physics and Radiological Health Handbook.* Revised Edition, Scinta, Inc., Silver Spring, Maryland.

Sinex, S. A., and G. R. Helz. 1981. "Regional Geochemistry of Hampton Roads Harbor and Lower Chesapeake Bay Sediments." *Environ. Geol.* 3:315-323.

Skoog, D. A., and D. M. West. 1980. *Analytical Chemistry.* Third Edition, Saunders Golden Sunburst Series, Philadelphia, Pennsylvania.

Soldat, J. K. 1976. "Radiation Doses from Iodine-129 in the Environment." *Health Physics* 30:61-70.

Soldat, J. K., K. R. Price, and W. H. Rickard. 1990. *Methodology Used to Compute Maximum Potential Doses from Ingestion of Edible Plants and Wildlife Found on the Hanford Site.* PNL-7539, Pacific Northwest Laboratory, Richland, Washington.

Spane, F. A., Jr., and V. R. Vermeul. 1994. *Summary and Evaluation of Hydraulic Property Data Available for the Hanford Site Upper Basalt Confined Aquifer System.* PNL-10158, Pacific Northwest Laboratory, Richland, Washington.

Spane, F. A., Jr., and W. D. Webber. 1995. *Hydrochemistry and Hydrogeologic Conditions Within the Hanford Site Upper Basalt Confined Aquifer System.* PNL-10817, Pacific Northwest Laboratory, Richland, Washington.

Speer, D. R., J. J. Fix, and P. J. Blumer. 1976. *Environmental Surveillance at Hanford for CY-1975.* BNWL-1979, Pacific Northwest Laboratory, Richland, Washington.

Stenner, R. D., K. H. Cramer, K. A. Higley, S. J. Jette, D. A. Lamar, T. J. McLaughlin, D. R. Sherwood, and N. C. Van Houten. 1988. *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford.* PNL-6456, Pacific Northwest Laboratory, Richland, Washington.

Sula, M. J. 1980. *Radiological Survey of Exposed Shorelines and Islands of the Columbia River Between Vernita and the Snake River Confluence.* PNL-3127, Pacific Northwest Laboratory, Richland, Washington.

Suzuki, M., T. Yamada, and T. Miyazaki. 1979. "Sorption and Accumulation of Cadmium in the Sediment of the Tama River." *Water Res.* 13:57-63.

Swanson, L. C. 1992. *Phase 1 Hydrogeologic Summary of the 300-FF-5 Operable Unit, 300 Area.* WHC-SD-EN-TI-052, Westinghouse Hanford Company, Richland, Washington.

Tada, F., and S. Suzuki. 1982. "Adsorption and Desorption of Heavy Metals in Bottom Mud of Urban Rivers." *Water Res.* 16:1489-1494.

Thurman, P. A. 1995. *Hanford Sanitary Water Quality Surveillance for Calendar Year 1994.* HEF-96, Hanford Environmental Health Foundation Industrial Hygiene Laboratory, Richland, Washington.

Thurman, P. A. 1994. *Hanford Sanitary Water Quarterly Surveillance, CY 1993.* HEHF-95, Hanford Environmental Health Foundation, Environmental Health Sciences, Richland, Washington.

Travis, C. C., and S. T. Hester. 1990. "Background Exposure to Chemicals: What Is the Risk?" *Risk Analysis* 10(4).

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 1988. *Sources, Effects and Risks of Ionizing Radiation.* Report E.88.1X.7, United Nations, New York.

U.S. Bureau of Census. 1994. *County and City Data Book.* U.S. Government Printing Office, Library of Congress, No. 52-4576, Washington, D.C.

U.S. Department of Energy (DOE). 1986. *Environmental Assessment, Reference Repository Location, Hanford Site, Washington.* DOE/RW-0070, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1987. *Plan and Schedule to Discontinue Disposal of Liquids Into the Soil Column at the Hanford Site.* U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1988. *Consultation Draft, Site Characterization Plan, Reference Repository Location, Hanford Site, Washington.* DOE/RW-0164, Vol. 1 and 2, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1991. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance.* DOE/EH-0173T, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1992a. *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington.* Final Environmental Impact Statement, DOE/EIS-0119F, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1992b. *Final Remedial Investigation/Feasibility Study - Environmental Assessment Report for the 1100-EM-1 Operative Unit, Hanford.* DOE/RL-92-67, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1992c. *Hanford Federal Facility Agreement and Consent Order, Volume 1.* DOE 89-10, Rev 2, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1992d. *Hanford Site Environmental Restoration and Waste Management Five-Year Plan, Fiscal Years 1992-1996.* DOE/S-0078P, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1992e. *Sampling and Analysis of 100 Area Springs.* DOE/RL-92-12, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1993a. *Limited Field Investigation Report for the 100-BC-5 Operable Unit.* DOE/RL-93-37 Draft A, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1993b. *Limited Field Investigation Report for the 100-KR-4 Operable Unit.* DOE/RL-93-79, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1994a. *Environmental Monitoring Plan United States Department of Energy Richland Operations Office.* DOE/RL 91-50, Revision 1, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1994b. *Hanford Site Environmental Restoration Project 1995 Fiscal Year Work Plan - Volumes 1 Through 4.* DOE/RL-94-103, Rev 0, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1994c. *Plan and Schedule for Disposition and Regulatory Compliance for Miscellaneous Streams.* DOE/RL-93-94, Revision 1, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1994d. *The Waste Minimization/Pollution Prevention Cross Cut Plan 1994.* DOE/FM-0145, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1994e. *United States Department of Energy Richland Operations Office Environmental Protection Implementation Plan, November 9, 1994, to November 9, 1995.* DOE/RL-94-127, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1995a. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement.* DOE/EIS-0203-F, U.S. Department of Energy, Office of Environmental Management, Idaho Operations Office.

U.S. Department of Energy (DOE). 1995b. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Record of Decision.* U.S. Department of Energy, Office of Environmental Management, Idaho Operations Office.

U.S. Department of Energy (DOE). 1995c. *Final Environmental Impact Statement: Safe Interim Storage of Hanford Tank Wastes.* DOE/EIS-0212, Washington State Department of Ecology, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1995d. *Hanford Site Ground-Water Protection Management Plan.* DOE-RL-89-12, Revision 2. U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1996a. *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1995.* DOE/RL-96-01, Rev. 0, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1996b. *Hanford Site Annual Dangerous Waste Report Calendar Year 1995.* DOE/RL-96-13, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1996c. *Hanford Tier Two Emergency and Hazardous Chemical Inventory Emergency Planning and Community Right-To-Know Act Section 312.* DOE/RL-96-18, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1996d. *Management of Spent Nuclear Fuel from the K Basins at the Hanford Site, Richland, Washington, Addendum (Final Environmental Impact Statement).* DOE/EIS-0245F, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1996e. *Radionuclide Air Emissions Report for the Hanford Site Calendar Year 1995.* DOE/RL-96-37, U.S. Department of Energy, Richland, Washington.

U.S. Department of Health, Education and Welfare (USDHEW). 1970. *Radiological Health Handbook, Revised Edition.* U.S. Department of Health, Education, and Welfare, Rockville, Maryland.

U.S. Environmental Protection Agency (EPA). 1980a. *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans.* EPA/005/80, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1980b. *Upgrading Environmental Radiation Data: Health Physics Society Committee Report HPSR-1 (1980).* EPA 520/1-80-012, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1986a. *Ground-Water Monitoring Technical Enforcement Guidance Document.* OWSER 9950-1, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1986b. *Test Methods for Evaluating Solid Waste: Physical/ Chemical Methods.* 3rd ed, SW-846, Office of Solid Waste and Emergency Response, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1987. *Data Quality Objectives for Remedial Response Activities.* EPA/540/G-87/003, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1988. *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air.* EPA/600/4-89/ 017, Atmospheric Research and Exposure Assessment Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (EPA). 1989. *Risk Assessment Methodology: Draft Environmental Impact Statement for Proposed NESHAPS for Radionuclides, Vol. 1, Background Information Document.* EPA 520/1-89-005, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1994. *Briefing Report to the EPA Science Advisory Board on the Equilibrium Partitioning Approach to Predicting Metal Bioavailability in Sediments and the Derivation of Sediment Quality Criteria for Metals.* EPA 822-D-94-002, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Geological Survey (USGS). 1995. *Nitrate Concentrations in Ground Water of the Central Columbia Plateau.* Open File Report 95-445, U.S. Geological Survey, Tacoma, Washington.

Washington Administrative Code (WAC) 16-228, *Pesticide Regulations*, Washington State Department of Agriculture.

Washington Administrative Code (WAC) 173-201A-040. 1992. *Water Quality Standards for Surface Waters of the State of Washington*, Washington State Department of Ecology.

Washington Administrative Code (WAC) 173-216, *State Waste Discharge Permit Program*, Washington State Department of Ecology.

Washington Administrative Code (WAC) 173-218, *Underground Injection Control Program*, Washington State Department of Ecology, Olympia, Washington.

Washington Administrative Code (WAC) 173-240-130, *Submission of Plans and Reports for Construction of Wastewater Facilities, Engineering Report*, Washington State Department of Health.

Washington Administrative Code (WAC) 173-303, *Dangerous Waste Regulations*, Washington State Department of Ecology.

Washington Administrative Code (WAC) 173-360, *Underground Storage Tank Regulations*, Washington State Department of Health.

Washington Administrative Code (WAC) 246-247, *Radiation Protection--Air Emissions*, Washington State Department of Health.

Washington Agricultural Statistics Service. 1994. *Washington Agricultural Statistics 1993-94*. Washington Agricultural Statistics Service, Washington State Department of Agriculture, Olympia, Washington.

Washington Department of Health (DOH). 1988. *Environmental Radiation Program 26th Annual Report January Through December 1987*. EPS-87-367A, Olympia, Washington.

Washington State Department of Ecology (Ecology). 1992. *Water Quality Standards for Waters of the State of Washington*. Washington Administrative Code, Chapter 173-201a, Olympia, Washington.

Washington State Department of Social and Health Services (WDSHS). 1988. *Investigation Report: Radiological Evaluation of Well Water in Franklin County*. EPS-87-367A, Environmental Protection Section, Olympia, Washington.

Webb, A. B., D. M. Camaioni, J. M. Grigsby, P. G. Heasler, B. Malinovic, M. G. Plys, J. L. Stewart, J. J. Toth, and D. A. Turner. 1995. *Preliminary Safety Criteria for Organic Watch List Tanks and the Hanford Site*. WHC-SD-WM-SARR-033, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Wells, D. 1994. *Radioactivity in Columbia River Sediments and Their Health Efforts*. Washington State Department of Health, Olympia, Washington.

Westinghouse Hanford Company (WHC). 1989. *Quality Assurance Manual*. WHC-CM-4-2, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1991a. *Environmental Compliance*. WHC-CM-7-5, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1991b. *Operational Environmental Monitoring*. WHC-CM-7-4, Westinghouse Hanford Company Richland, Washington.

Westinghouse Hanford Company (WHC). 1996a. *Environmental Releases for Calendar Year 1995*. WHC-EP-0527-5, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1996b. *Summary of Radioactive Solid Waste Received in the 200 Areas During Calendar Year 1995*. WHC-EP-0125-8, Westinghouse Hanford Company, Richland, Washington.

Wiggins, W. D., G. P. Ruppert, R. R. Smith, L. L. Reed, L. E. Hubard, and M. L. Courts. 1995. *Water Resources Data, Washington Water Year 1994*. WA-94-1, U.S. Geological Survey Water, Tacoma, Washington.

Wiggins, W. D., G. P. Ruppert, R. R. Smith, L. L. Reed, L. E. Hubard, and M. L. Courts. 1996. *Water Resources Data, Washington Water Year 1995*. U.S. Geological Survey Water, Tacoma, Washington.

Wilson, R. H., ed. 1965. *Evaluation of Radiological Conditions in the Vicinity of Hanford for 1964*. BNWL-90, Pacific Northwest Laboratory, Richland, Washington.

Wilson, R., and E. S. C. Crouch. 1987. "Risk Assessment and Comparisons: An Introduction." *Science* 236 (4799):267-270.

Woodruff, R. K., R. W. Hanf, and R. E. Lundgren, eds. 1992. *Hanford Site Environmental Report for Calendar Year 1991*. PNL-8148, Pacific Northwest Laboratory, Richland, Washington.

Woodruff, R. K., R. W. Hanf, and R. E. Lundgren, eds. 1993. *Hanford Site Environmental Report for Calendar Year 1992*. PNL-8682, Pacific Northwest Laboratory, Richland, Washington.

U.S. Department of Energy Orders

DOE Order 232.1. "Environment, Safety, and Health Reporting."

DOE Order 451.1. "National Environmental Policy Act Compliance Program."

DOE Order 5000.3B. "Occurrence Reporting and Processing of Operations Information."

DOE Order 5400.1. "General Environmental Protection Program."

DOE Order 5400.5. "Radiation Protection of the Public and the Environment."

DOE Order 5484.1. "Environmental Protection, Safety, and Health Protection Information Reporting Requirements."

DOE Order 5700.6C. "Quality Assurance."

DOE Order 5820.2A. "Radioactive Waste Management."

Acts

American Indian Religious Freedom Act. Public Law 95-341, August 11, 1978. 92 Stat. 469 (Title 42).

Archaeological Resources Protection Act. Public Law 96-95, October 31, 1979. 93 Stat. 721 (Title 16).

Clean Air Act. Public Law 88-206, 42 USC 7401 et seq., as amended.

Clean Water Act. Public Law 95-217, December 27, 1977. 91 Stat. 1566 and Public Law 96-148.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Public Law 96-150, December 11, 1980. 94 Stat. 2767 (Title 26).

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.).

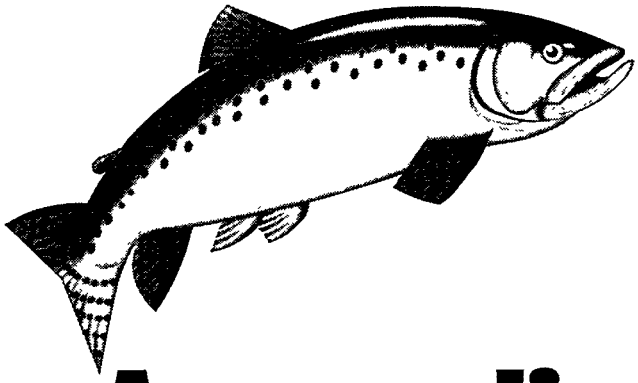
Pollution Prevention Act. Public Law 101-508, 1990, 104 Stat. 1388-321 (41 USC 13101 et seq.).

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.).



Appendixes

Appendix A

Additional Monitoring Results for 1995

Appendix A

Additional Monitoring Results for 1995

This Appendix contains additional information on 1995 monitoring results, supplementing the data summarized in the main body of the report. More detailed information is available in the companion 1995 report by L. E. Bisping, *1995 Surface Environmental Surveillance Data* (PNNL-11140, Pacific Northwest National Laboratory, Richland, Washington).

Table A.1. Radionuclide Concentrations Measured in Columbia River Water at Priest Rapids Dam, 1995 Compared to Values from the Previous 5 Years

Radionuclide[b]		1995 No. of Samples	1995 Concentration,[a] pCi/L (10^{-6} µCi/L) Maximum	1995 Concentration,[a] pCi/L (10^{-6} µCi/L) Average	1990-1994 No. of Samples	1990-1994 Concentration,[a] pCi/L Maximum	1990-1994 Concentration,[a] pCi/L Average	Ambient Surface Water Quality Standard,[c] pCi/L
Composite System								
Alpha		12	0.800 ± 0.581	0.346 ± 0.158	59	1.67 ± 1.30	0.532 ± 0.114	15
Beta		12	3.36 ± 1.64	1.46 ± 0.42	59	5.17 ± 2.50	1.28 ± 0.42	50
^{3}H		12	39.7 ± 9.1	34.4 ± 1.8	59	114 ± 16	44.6 ± 2.9	20,000
^{90}Sr		12	0.114 ± 0.048	0.0801 ± 0.0116	58	0.178 ± 0.084	0.0860 ± 0.0074	8
^{99}Tc		12	0.260 ± 0.540	-0.0794 ± 0.0796	58	1.23 ± 2.79	-0.186 ± 0.334	900
^{234}U		12	0.248 ± 0.052	0.212 ± 0.015	58	0.444 ± 0.129	0.235 ± 0.014	--[d]
^{235}U		12	0.0293 ± 0.0160	0.00612 ± 0.00486	58	0.0316 ± 0.0393	0.00942 ± 0.00214	--
^{238}U		12	0.240 ± 0.054	0.179 ± 0.018	58	0.350 ± 0.111	0.185 ± 0.011	--
U-Total		12	0.490 ± 0.114	0.397 ± 0.028	58	0.826 ± 0.279	0.429 ± 0.025	--
Continuous System								
^{129}I	D	4	0.00000410 ± 0.00000070	0.00000360 ± 0.00000054	16	0.000129 ± 0.0000129	0.0000192 ± 0.0000161	--
$^{239,240}Pu$	P	4	0.0000549 ± 0.0000298	0.0000306 ± 0.0000184	19	0.0000969 ± 0.0000395	0.0000225 ± 0.0000104	--
	D	4	0.0000715 ± 0.0000817	0.0000269 ± 0.0000327	19	0.000627 ± 0.000207	0.0000677 ± 0.0000689	--

(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 Section 4.2, "Surface Water and Sediment Surveillance").
(c) Appendix C, Table C.1.
(d) Dashes indicate no concentration guides are available.

Table A.2. Radionuclide Concentrations Measured in Columbia River Water at the 300 Area Water Intake, 1995 Compared to Values from the Previous 5 Years

Radionuclide[b]	1995 No. of Samples	1995 Concentration,[a] pCi/L (10^{-6} µCi/mL) Maximum	1995 Concentration,[a] pCi/L (10^{-6} µCi/mL) Average	1990-1994 No. of Samples	1990-1994 Concentration,[a] pCi/L Maximum	1990-1994 Concentration,[a] pCi/L Average	Ambient Surface Water Quality Standard,[c] pCi/L
Composite System							
Alpha	4	1.49 ± 0.93	1.05 ± 0.30	20	1.44 ± 1.02	0.658 ± 0.188	15
Beta	4	3.63 ± 1.70	1.95 ± 1.42	20	10.3 ± 13.7	1.77 ± 0.94	50
^{3}H	4	197 ± 22	129 ± 52	20	214 ± 22	144 ± 17	20,000
^{90}Sr	4	0.417 ± 0.098	0.159 ± 0.172	20	1.37 ± 0.28	0.164 ± 0.132	8
^{99}Tc	4	0.196 ± 0.536	0.0635 ± 0.102	20	52.4 ± 7.0	2.91 ± 5.22	900
^{234}U	4	0.391 ± 0.098	0.349 ± 0.031	20	0.559 ± 0.095	0.337 ± 0.055	--[d]
^{235}U	4	0.0287 ± 0.0278	0.0168 ± 0.0098	20	0.034 ± 0.019	0.0127 ± 0.0047	--
^{238}U	4	0.374 ± 0.073	0.312 ± 0.056	20	0.478 ± 0.085	0.276 ± 0.046	--
U-Total	4	0.747 ± 0.213	0.678 ± 0.066	20	1.05 ± 0.19	0.626 ± 0.101	--

(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 Section 4.2, "Surface Water and Sediment Surveillance").
(c) Appendix C, Table C.1.
(d) Dashes indicate no concentration guides are available.

Table A.3. Radionuclide Concentrations Measured in Columbia River Water at the Richland Pumphouse, 1995 Compared to Values from the Previous 5 Years

Radionuclide[b]		1995 No. of Samples	1995 Concentration,[a] pCi/L (10^{-6} µCi/mL) Maximum	1995 Concentration,[a] pCi/L (10^{-6} µCi/mL) Average	1990-1994 No. of Samples	1990-1994 Concentration,[a] pCi/L Maximum	1990-1994 Concentration,[a] pCi/L Average	Ambient Surface Water Quality Standard,[c] pCi/L
Composite System								
Alpha		12	1.47 ± 0.85	0.565 ± 0.216	79	3.38 ± 1.53	0.714 ± 0.165	15
Beta		12	3.40 ± 1.67	1.30 ± 0.62	79	9.18 ± 2.99	1.20 ± 0.43	50
^{3}H		12	114 ± 15	79.0 ± 14.9	59	211 ± 23	100 ± 8	20,000
^{90}Sr		12	0.126 ± 0.074	0.0847 ± 0.0103	77	0.175 ± 0.073	0.0876 ± 0.0073	8
^{99}Tc		12	0.296 ± 0.551	-0.0330 ± 0.0984	58	6.47 ± 2.70	0.165 ± 0.328	900
^{234}U		12	0.447 ± 0.081	0.282 ± 0.054	78	0.499 ± 0.134	0.262 ± 0.018	--[d]
^{235}U		12	0.048 ± 0.0220	0.00985 ± 0.00794	78	0.0386 ± 0.0245	0.00992 ± 0.00206	--
^{238}U		12	0.286 ± 0.060	0.207 ± 0.024	78	0.528 ± 0.136	0.212 ± 0.017	--
U-Total		12	0.781 ± 0.163	0.499 ± 0.080	78	1.05 ± 0.30	0.483 ± 0.035	--
Continuous System								
^{129}I	D	1	0.0000571 ± 0.0000047	0.0000571	16	0.000168 ± 0.000020	0.000108 ± 0.000018	--
$^{239,240}Pu$	P	1	0.0000564 ± 0.0000256	0.0000564	19	0.0000698 ± 0.0000285	0.0000172 ± 0.0000073	--
	D	1	0.0000240 ± 0.0000482	0.0000240	19	0.00215 ± 0.000376	0.000188 ± 0.000227	--

(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 Section 4.2, "Surface Water and Sediment Surveillance").
(c) Appendix C, Table C.1.
(d) Dashes indicate no concentration guides are available.

Table A.4. Radionuclide Concentrations Measured in Columbia River Water Along Cross Sections of the Hanford Reach, 1995

Transect/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Minimum	Mean
Vernita Bridge				
^{3}H	16	39.2 ± 9.0	29.1 ± 8.3	33.6 ± 1.5
^{90}Sr	16	0.134 ± 0.060	0.0305 ± 0.103	0.0842 ± 0.0170
U-Total	16	0.581 ± 0.136	0.353 ± 0.091	0.432 ± 0.035
100-N Area				
^{3}H	10	70.0 ± 11.4	33.3 ± 8.6	38.7 ± 7.1
^{90}Sr	10	0.168 ± 0.115	0.0212 ± 0.0870	0.0882 ± 0.0341
^{99}Tc	10	0.156 ± 0.732	-0.482 ± 1.21	-0.209 ± 0.126
U-Total	10	0.484 ± 0.113	0.392 ± 0.101	0.433 ± 0.020
100-F Area				
^{3}H	10	37.9 ± 9.0	33.1 ± 8.7	36.0 ± 0.8
^{90}Sr	10	0.0907 ± 0.0584	0.0274 ± 0.0477	0.0707 ± 0.0120
U-Total	10	0.497 ± 0.140	0.358 ± 0.103	0.433 ± 0.024
Old Hanford Townsite				
^{3}H	10	190 ± 21.1	34.1 ± 8.7	52.9 ± 30.6
^{90}Sr	10	0.116 ± 0.055	0.0624 ± 0.0472	0.0886 ± 0.0084
^{99}Tc	10	-0.276 ± 1.16	-0.837 ± 1.27	-0.535 ± 0.129
U-Total	10	0.451 ± 0.110	0.344 ± 0.095	0.385 ± 0.019
300 Area				
^{3}H	10	128 ± 15.9	25.0 ± 8.0	48.6 ± 19.9
^{90}Sr	10	0.120 ± 0.102	0.0198 ± 0.0404	0.0844 ± 0.0180
U-Total	10	0.609 ± 0.153	0.380 ± 0.102	0.474 ± 0.051
Richland Pumphouse				
^{3}H	40	224 ± 23.3	25.6 ± 8.3	51.7 ± 12.7
^{90}Sr	40	0.476 ± 0.100	0.0305 ± 0.107	0.117 ± 0.035
U-Total	40	0.751 ± 0.170	0.297 ± 0.082	0.439 ± 0.033

(a) Maximum and minimum values are ±2 total propagated analytical uncertainty. Mean values are ±2 standard error of the mean.

Table A.5. Select Provisional U.S. Geological Survey Columbia River Water Quality Data, 1995[a]

Analysis	Units	Vernita Bridge (upstream) No. of Samples	Maximum	Median	Minimum	Richland Pumphouse (downstream) No. of Samples	Maximum	Median	Minimum	Washington Ambient Surface Water Quality Standard[b]
Temperature	°C	4	20.0	15.0	3.5	3	19.0	11.5	3.5	20 (maximum)
Dissolved oxygen	mg/L	4	13.2	11.2	9.1	3	12.6	12.2	9.2	8 (minimum)
Turbidity	NTU[c]	4	1.7	1.2	0.7	3	2.1	1.1	1.1	5 + background
pH	pH units	4	8.2	8.0	8.0	3	8.2	8.1	8.0	6.5 - 8.5
Fecal coliform	#/100 mL	4	8	2[d]	1	3	6	5[d]	3	100
Suspended solids, 105°C	mg/L	1	2	2	2	2	6	5	4	--[e]
Dissolved solids, 180°C	mg/L	4	85	79	71	3	87	84	81	--
Specific conductance	µS/cm[f]	4	148	137	132	3	152	140	137	--
Total hardness, as $CaCO_3$	mg/L	4	70	60	56	3	70	63	60	--
Phosphorus, total	mg/L	4	0.01	<0.01	<0.01	3	0.02	<0.01	<0.01	--
Chromium, dissolved	µg/L	0	NR[g]	NR	NR	3	<1	<1	<1	--
Dissolved organic carbon	mg/L	4	3.3	3.0	2.3	3	3.5	3.2	3.0	--
Iron, dissolved	µg/L	4	15	9	3	3	14	10	6	--
Ammonia, dissolved, as N	mg/L	4	0.02	0.02	<0.015	3	<0.015	<0.015	<0.015	--
Nitrogen, total Kjeldahl, as N	mg/L	4	0.4	0.4	0.2	3	0.4	0.4	0.3	--
Nitrite + Nitrate, dissolved, as N	mg/L	4	0.25	0.08	<0.05	3	0.27	<0.05	<0.05	--

(a) Provisional data from USGS National Stream Quality Accounting Network (NASQAN), subject to revision.
(b) See Appendix C, Table C.1.
(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 in Columbia River and Riverbank Spring Sediment, 1995 Compared to Values from the Previous 5 Years

Location	Radionuclide	1995 Number of Samples	1995 Concentration, pCi/g Maximum[b]	1995 Concentration, pCi/g Median	1990-1994[a] Number of Samples	1990-1994[a] Concentration, pCi/g Maximum[b]	1990-1994[a] Concentration, pCi/g Median
River Sediment							
Priest Rapids Dam	^{60}Co	4	0.0100 ± 0.0126	-0.00111	20	0.0379 ± 0.0493	0.00290
	^{137}Cs	4	0.505 ± 0.061	0.434	20	1.02 ± 0.14	0.484
	^{155}Eu	4	0.101 ± 0.050	0.0513	20	0.107 ± 0.084	0.0454
	$^{239,240}Pu$	4	0.0106 ± 0.0022	0.00764	20	0.0175 ± 0.0032	0.00868
	^{90}Sr	4	0.0157 ± 0.0048	0.0124	20	0.0224 ± 0.0078	0.0132
	^{235}U	4	0.317 ± 0.167	0.137	20	0.137 ± 0.155	0.0372
	^{238}U	4	2.23 ± 0.71	1.43	20	1.71 ± 0.65	0.835
White Bluffs Slough	^{60}Co	1	0.114 ± 0.025	0.114	5	0.0977 ± 0.0258	0.0740
	^{137}Cs	1	0.693 ± 0.077	0.693	5	0.925 ± 0.103	0.733
	^{155}Eu	1	0.0498 ± 0.0371	0.0498	5	0.0646 ± 0.0820	0.0522
	$^{239,240}Pu$	1	0.00314 ± 0.00113	0.00314	5	0.00726 ± 0.00174	0.00402
	^{90}Sr	1	0.00517 ± 0.00303	0.00517	5	0.0133 ± 0.0045	0.00654
	^{235}U	1	0.155 ± 0.119	0.155	5	0.191 ± 0.044	0.0267
	^{238}U	1	1.66 ± 0.49	1.66	5	2.30 ± 0.26	0.828
100-F Slough	^{60}Co	1	0.0275 ± 0.0106	0.0275	5	0.0369 ± 0.024	0.0240
	^{137}Cs	1	0.486 ± 0.054	0.486	5	0.758 ± 0.082	0.149
	^{155}Eu	1	0.0162 ± 0.0276	0.0162	5	0.0636 ± 0.0477	0.0518
	$^{239,240}Pu$	1	0.00242 ± 0.00082	0.00242	5	0.00153 ± 0.00069	0.000907
	^{90}Sr	1	0.00220 ± 0.00515	0.00220	5	0.00468 ± 0.00328	0.00367
	^{235}U	1	0.00191 ± 0.00160	0.00191	5	0.0587 ± 0.0266	0.0352
	^{238}U	1	0.121 ± 0.016	0.121	5	1.40 ± 0.16	0.878
Hanford Slough	^{60}Co	1	0.315 ± 0.046	0.315	5	0.0850 ± 0.0219	0.0284
	^{137}Cs	1	0.572 ± 0.067	0.572	5	0.516 ± 0.060	0.105
	^{155}Eu	1	0.0781 ± 0.0382	0.0781	5	0.0848 ± 0.0793	0.0700
	$^{239,240}Pu$	1	0.00729 ± 0.00234	0.00729	5	0.00323 ± 0.00072	0.00174
	^{90}Sr	1	0.00590 ± 0.00331	0.00590	5	0.00806 ± 0.00352	0.00634
	^{235}U	1	0.235 ± 0.159	0.235	5	0.123 ± 0.033	0.0839
	^{238}U	1	2.38 ± 0.88	2.38	5	2.11 ± 0.23	0.942

Table A.6. Radionuclide Concentrations in Columbia River and Riverbank Spring Sediment, 1995 Compared to Values from the Previous 5 Years (contd)

Location	Radionuclide	1995 Number of Samples	1995 Concentration, pCi/g Maximum[b]	1995 Concentration, pCi/g Median	1990-1994[a] Number of Samples	1990-1994[a] Concentration, pCi/g Maximum[b]	1990-1994[a] Concentration, pCi/g Median
Richland	^{60}Co	1	0.0650 ± 0.0223	0.0650	5	0.0754 ± 0.0243	0.0514
	^{137}Cs	1	0.342 ± 0.0420	0.342	5	0.406 ± 0.053	0.310
	^{155}Eu	1	0.0655 ± 0.0339	0.0655	5	0.0771 ± 0.0446	0.0501
	$^{239,240}Pu$	1	0.00231 ± 0.00077	0.00231	5	0.00304 ± 0.00071	0.00199
	^{90}Sr	1	0.00273 ± 0.00271	0.00273	5	0.00301 ± 0.00297	0.000826
	^{235}U	1	-0.112 ± 0.136	-0.112	5	0.136 ± 0.080	0.0794
	^{238}U	1	1.59 ± 0.56	1.59	5	2.33 ± 0.27	1.16
McNary Dam	^{60}Co	4	0.168 ± 0.032	0.0790	20	0.367 ± 0.061	0.129
	^{137}Cs	4	1.02 ± 0.11	0.454	20	1.19 ± 0.14	0.527
	^{155}Eu	4	0.0679 ± 0.0500	0.0484	20	0.154 ± 0.085	0.0784
	$^{239,240}Pu$	4	0.0143 ± 0.0026	0.0112	20	0.0144 ± 0.0018	0.00786
	^{90}Sr	4	0.0392 ± 0.0134	0.0257	20	0.0614 ± 0.0135	0.0266
	^{235}U	4	0.201 ± 0.159	0.182	20	0.119 ± 0.067	0.0379
	^{238}U	4	2.33 ± 0.71	1.98	20	1.98 ± 0.80	1.09
Riverbank Spring Sediment					1993-1994[a]		
100-B Spring	^{60}Co	1	0.0291 ± 0.0097	0.0291	0		
	^{137}Cs	1	0.0953 ± 0.0153	0.0953	0		
	^{155}Eu	1	0.0646 ± 0.0214	0.0646	0		
	^{90}Sr	1	0.00409 ± 0.00499	0.00409	0		
	^{235}U	1	-0.0166 ± 0.136	-0.0166	0		
	^{238}U	1	1.09 ± 0.50	1.09	0		
100-K Spring	^{60}Co	1	0.00734 ± 0.0205	0.00734	0		
	^{137}Cs	1	0.148 ± 0.047	0.148	0		
	^{155}Eu	1	0.131 ± 0.066	0.131	0		
	^{90}Sr	1	0.00125 ± 0.00465	0.00125	0		
	^{235}U	1	0.205 ± 0.135	0.205	0		
	^{238}U	1	1.53 ± 0.54	1.53	0		

Table A.6. Radionuclide Concentrations in Columbia River and Riverbank Spring Sediment, 1995 Compared to Values from the Previous 5 Years (contd)

Location	Radionuclide	1995 Number of Samples	1995 Concentration, pCi/g Maximum[b]	1995 Concentration, pCi/g Median	1993-1994[a] Number of Samples	1993-1994[a] Concentration, pCi/g Maximum[b]	1993-1994[a] Concentration, pCi/g Median
100-F Spring	^{60}Co	1	0.00441 ± 0.0151	0.00441	0		
	^{137}Cs	1	0.190 ± 0.035	0.190	0		
	^{155}Eu	1	0.0370 ± 0.0354	0.0370	0		
	^{90}Sr	1	0.00427 ± 0.00442	0.00427	0		
	^{235}U	1	0.173 ± 0.134	0.173	0		
	^{238}U	1	1.19 ± 1.00	1.19	0		
Hanford Townsite Spring	^{60}Co	1	0.864 ± 0.0149	0.0864	2	0.0900 ± 0.0211	0.0632
	^{137}Cs	1	0.287 ± 0.032	0.287	2	0.250 ± 0.036	0.217
	^{155}Eu	1	0.0616 ± 0.0197	0.0616	2	0.0606 ± 0.0329	0.0558
	^{90}Sr	1	0.00863 ± 0.0111	0.00863	2	0.00682 ± 0.00470	0.00456
	^{235}U	1	0.234 ± 0.141	0.234	2	0.0232 ± 0.0068	0.0104
	^{238}U	1	1.88 ± 0.54	1.88	2	0.974 ± 0.286	0.716
300 Area Spring	^{60}Co	1	0.0155 ± 0.0076	0.0155	2	0.0139 ± 0.0113	0.00125
	^{137}Cs	1	0.0699 ± 0.0120	0.0699	2	0.0736 ± 0.0166	0.0648
	^{155}Eu	1	0.0446 ± 0.0223	0.0446	2	0.126 ± 0.139	0.0951
	^{90}Sr	1	0.00760 ± 0.00654	0.00760	2	0.0124 ± 0.0060	0.00945
	^{235}U	1	0.406 ± 0.165	0.406	2	0.124 ± 0.159	0.0714
	^{238}U	1	5.19 ± 1.09	5.19	2	4.24 ± 0.58	3.72

(a) 1995 river sediment values compared to values from 1990 through 1994; 1995 Riverbank spring sediment values compared to values from 1993 through 1994.
(b) Values are ±2 total propagated analytical uncertainty.

Table A.7. Median Metal Concentrations in Columbia River Sediment, 1995

Metal	Median Concentration, mg/kg dry weight			
	Priest Rapids Dam	Hanford Reach	McNary Dam	Riverbank Springs
Aluminum	12,000	8,100	20,000	7,900
Antimony	4.3	3.7	5.5	3.8
Arsenic	NR[a]	NR	NR	5.3
Barium	92	64	150	61
Beryllium	0.32	0.20	0.66	0.23
Cadmium	4.2	2.2	2.9	1.0
Calcium	5,100	4,800	5,800	5,900
Chromium	21	17	26	36
Cobalt	7.7	6.7	11	5.5
Copper	25	23	33	19
Iron	20,000	20,000	29,000	17,000
Lead	21	23	7.6	24
Magnesium	5,700	4,400	6,300	3,900
Manganese	290	230	590	254
Nickel	20	13	21	14
Potassium	1,500	1,200	2,500	890
Selenium	NR	NR	NR	0.17
Silver	0.93	0.92	1.4	0.80
Sodium	400	390	440	320
Thallium	NR	NR	NR	1.2
Tin	4.9	6.9	6.3	4.4
Vanadium	48	56	55	50
Zinc	420	350	270	160

(a) NR = not reported.

Table A.8. Radionuclide Concentrations Measured in Riverbank Spring Water, 1995 Compared to Values from the Previous 5 Years

Location/Radionuclide	1995 No. of Samples	1995 Concentration,[a] pCi/L (10^{-6} µCi/L) Maximum	1995 Concentration,[a] pCi/L (10^{-6} µCi/L) Median	1990-1994 No. of Samples	1990-1994 Concentration,[a] pCi/L Maximum	1990-1994 Concentration,[a] pCi/L Median	Washington Ambient Surface Water Quality Standard, pCi/L
100-B Spring							
Alpha	1	2.44 ± 1.24	2.44	4	3.54 ± 1.78	1.61	15[b]
Beta	1	12.4 ± 2.6	12.4	4	38.1 ± 4.6	9.63	50
^{3}H	1	22,500 ± 1,730	22,500	4	14,300 ± 1,190	13,400	20,000
^{90}Sr	1	0.0198 ± 0.149	0.0198	4	0.0724 ± 0.109	0.0150	8
^{99}Tc	1	25.3 ± 3.2	25.3	4	23.5 ± 4.18	10.1	900
U-total	1	3.16 ± 0.40	3.16	4	1.98 ± 0.282	1.65	--
100-K Spring							
Alpha	1	0.609 ± 0.722	0.609	2	1.63 ± 1.23	1.50	15[b]
Beta	1	1.84 ± 1.61	1.84	2	3.60 ± 2.53	3.16	50
^{3}H	1	19,700 ± 1,530	19,700	2	18,300 ± 1,470	18,050	20,000
^{90}Sr	1	-0.0244 ± 0.116	-0.0244	2	0.106 ± 0.129	0.0375	8
^{99}Tc	1	-0.0211 ± 0.512	-0.0211	2	0.805 ± 0.579	0.628	900
U-total	1	1.27 ± 0.22	1.27	2	2.28 ± 0.32	2.24	--
100-N Spring							
Alpha	1	0.0426 ± 0.356	0.0426	5	8.92 ± 13.8	1.67	15[b]
Beta	1	1.48 ± 1.49	1.48	5	24,100 ± 1,730	8.79	50
^{3}H	1	12,000 ± 969	12,000	5	30,900 ± 2,380	28,500	20,000
^{90}Sr	1	0.0790 ± 0.104	0.0790	5	10,900 ± 2,020	0.129	8
^{99}Tc	1	0.842 ± 0.617	0.842	5	2.44 ± 0.68	2.09	900
U-total	1	0.239 ± 0.078	0.239	3	2.47 ± 0.37	0.771	--
100-D Spring							
Alpha	2	1.28 ± 0.83	1.10	4	2.90 ± 1.91	1.92	15[b]
Beta	2	9.30 ± 2.39	5.72	4	20.8 ± 3.3	13.4	50
^{3}H	2	5,870 ± 531	2,980	4	12,500 ± 1,040	7,270	20,000
^{90}Sr	2	3.96 ± 0.87	2.01	4	9.41 ± 1.78	5.72	8
^{99}Tc	2	-0.117 ± 0.542	-0.150	4	0.0782 ± 0.522	-0.00680	900
U-total	2	1.25 ± 0.21	0.768	4	1.92 ± 0.28	1.40	--
100-H Spring							
Alpha	1	3.91 ± 1.64	3.91	4	4.59 ± 1.93	4.38	15[b]
Beta	1	39.4 ± 4.7	39.4	4	69.1 ± 7.05	61.6	50
^{3}H	1	1,100 ± 194	1,100	4	1,190 ± 236	1,140	20,000
^{90}Sr	1	12.4 ± 2.4	12.4	4	25.2 ± 4.5	17.9	8
^{99}Tc	1	136 ± 15	136	4	133 ± 15	87.2	900
U-total	1	7.95 ± 1.01	7.95	4	8.35 ± 1.22	6.12	--

Table A.8. Radionuclide Concentrations Measured in Riverbank Spring Water, 1995 Compared to Values from the Previous 5 Years (contd)

Location/Radionuclide	1995 No. of Samples	1995 Concentration,[a] pCi/L (10^{-6} µCi/L) Maximum	1995 Concentration,[a] pCi/L (10^{-6} µCi/L) Median	1990-1994 No. of Samples	1990-1994 Concentration,[a] pCi/L Maximum	1990-1994 Concentration,[a] pCi/L Median	Washington Ambient Surface Water Quality Standard, pCi/L
100-F Spring							
Alpha	1	3.73 ± 1.71	3.73	1	2.61 ± 1.40	2.61	15[b]
Beta	1	1.74 ± 1.63	1.74	1	2.04 ± 1.63	2.04	50
^{3}H	1	1,620 ± 233	1,620	1	623 ± 215	623	20,000
^{90}Sr	1	-0.0303 ± 0.0427	-0.0303	1	0.0986 ± 0.0906	0.0986	8
^{99}Tc	1	NR[c]	NR	1	-0.0303 ± 0.629	-0.0303	900
U-total	1	3.37 ± 0.46	3.37	1	4.62 ± 0.67	4.62	--
Old Hanford Townsite							
Alpha	1	0.821 ± 0.854	0.821	6	4.88 ± 2.17	3.26	15[b]
Beta	1	6.12 ± 2.08	6.12	6	94.9 ± 137	28.8	50
^{3}H	1	22,200 ± 1,710	22,200	6	173,000 ± 12,700	148,000	20,000
^{90}Sr	1	0.0823 ± 0.115	0.0823	4	0.123 ± 0.167	-0.244	8
^{99}Tc	1	6.11 ± 1.09	6.11	6	131 ± 16	114	900
^{129}I	1	0.0638 ± 0.0057	0.0638	1	0.0435 ± 0.347	0.0435	1
U-total	1	2.32 ± 0.34	2.32	4	4.29 ± 0.52	3.38	--
300 Area							
Alpha	1	41.6 ± 8.8	41.6	6	110 ± 21.2	72.6	15[b]
Beta	1	6.42 ± 2.03	6.42	6	29.3 ± 4.7	17.8	50
^{3}H	1	11,600 ± 940	11,600	6	11,300 ± 954	9,700	20,000
^{90}Sr	1	0.195 ± 0.11	0.195	4	0.198 ± 0.107	0.132	8
^{99}Tc	1	13.5 ± 1.9	13.5	5	12.7 ± 2.0	2.07	900
^{129}I	1	0.00492 ± 0.00063	0.00492	1	0.00439 ± 0.00042	0.00439	1
U-total	1	86.9 ± 9.2[d]	86.9[d]	6	129 ± 12	82.4	--

(a) Maximum values are ±2 total propagated analytical uncertainty.
(b) Total alpha activity (excluding uranium).
(c) NR = not reported.
(d) 1995 result is the sum of uranium-234 and uranium-238 concentrations. Uranium-235 was not reported.

Table A.9. Concentrations of Polycyclic Aromatic Hydrocarbons (PAH) in Air, 1995

Analyte	200-East SE Concentration,[a] pg/m³ Maximum	200-East SE Concentration,[a] pg/m³ Average	300 Area Concentration,[a] pg/m³ Maximum	300 Area Concentration,[a] pg/m³ Average	Rattlesnake Springs Concentration,[a] pg/m³ Maximum	Rattlesnake Springs Concentration,[a] pg/m³ Average	pg/m³ Risk-Based[b] Concentration
Phenanthrene	1,200	800 ± 720	3,000	2,500 ± 980	3,400	1,400 ± 2,700	NA[c]
Fluoranthene	180	140 ± 90	570	460 ± 230	650	320 ± 440	150,000,000 N[d]
Pyrene	94	58 ± 62	530	380 ± 250	240	110 ± 180	110,000,000 N
Fluorene	360	170 ± 340	610	270 ± 470	130	50 ± 110	150,000,000 N
Chrysene	51	30 ± 36	400	150 ± 330	37	26 ± 22	1,000,000 C[e]
Benzo(b)fluoranthene	72	43 ± 48	240	130 ± 190	50	33 ± 30	10,000 C
Anthracene	8.2	5.6 ± 4.7	160	116 ± 92	110	38 ± 100	1,100,000,000 N
Benz(a)anthracene			62	36 ± 74			10,000 C
Indeno(123-cd)pyrene	5	3.4 ± 4.7	62	35 ± 48	8.1	8.1	10,000 C
Acenaphthene	13	13	43	27 ± 33	7.7	3.5 ± 7.3	220,000,000 N
Benzo(k)fluoranthene	15	9 ± 12	44	25 ± 41	8.1	3.5 ± 8	100,000 C
Benzo(g,h,i)perylene	0.65	0.65	48	23 ± 44			NA
Dibenzo(a,h)anthracene			16	16			1,000 C
Acenaphthylene			24	16 ± 23			220,000,000 N

(a) Average ±2 standard error of the calculated mean.
(b) From *U.S. EPA Region III Risk-Based Concentration Table*, R. L. Smith, February 9, 1995. The listed values are the lowest of the carcinogenic (target cancer risk 1 x 10^{-6}) and non-carcinogenic (target hazard quotient of 1.0) risk-based concentrations.
(c) NA = not available.
(d) N = non-carcinogenic risk.
(e) C = carcinogenic risk.

Table A.10. Concentrations of Polychlorinated Biphenyls (PCBs) in Air, 1995

PCB Number	200-East SE Concentration,[a] pg/m³ Maximum	200-East SE Concentration,[a] pg/m³ Average	300 Area Concentration,[a] pg/m³ Maximum	300 Area Concentration,[a] pg/m³ Average	Rattlesnake Springs Concentration,[a] pg/m³ Maximum	Rattlesnake Springs Concentration,[a] pg/m³ Average
101	150	150	270	160 ± 330	180	110 ± 140
138	190	110 ± 180	240	130 ± 200	210	100 ± 160
87	120	120	190	110 ± 170	140	100 ± 110
118	220	140 ± 230	300	150 ± 270	250	89 ± 210
105	120	120	160	70 ± 150	130	54 ± 130
153	140	140	190	68 ± 160	160	53 ± 140
28	89	89	70	70	40	40 ± 1.9
52	86	86	82	58 ± 53	28	25 ± 8.9
187	24	24	35	9.4 ± 34	29	29
44			46	46	17	17
128	45	45	60	20 ± 53	51	17 ± 46
18					15	15
180	34	18 ± 45	42	15 ± 37	36	12 ± 32
170	14	7.8 ± 18	17	7.2 ± 13	15	8.8 ± 17
49	16	16	74	45 ± 81	9	6.5 ± 7.1
183	13	13	19	7.2 ± 20	15	4.1 ± 15
195	0.90	0.90	0.96	0.96	0.84	0.84
104					0.73	0.73
184			0.32	0.32	0.54	0.54
Total PCBs[b,c]	1,100	490 ± 530	1,700	660 ± 720	1,300	500 ± 550

(a) Average ±2 standard error of the calculated mean.
(b) Sum of the individual congeners.
(c) Risk-based concentration of 810 pg/m³ for a 1 x 10^{-6} target carcinogenic risk for total PCBs: from *U.S. EPA Region III Risk-Based Concentration Table*, R. L. Smith, February 9, 1995. Risk-based concentrations were not available for the individual PCBs.

Table A.11. Concentrations of Chlorinated Pesticides in Air, 1995

Analyte	200-East SE Concentration,[a] pg/m³ Maximum	200-East SE Concentration,[a] pg/m³ Average	300 Area Concentration,[a] pg/m³ Maximum	300 Area Concentration,[a] pg/m³ Average	Rattlesnake Springs Concentration,[a] pg/m³ Maximum	Rattlesnake Springs Concentration,[a] pg/m³ Average	pg/m³ Risk-Based Concentrations[b]
Endosulfan I	1,300	590 ± 1,010	13,000	3,500 ± 6,500	1,200	550 ± 990	22,000,000 N[c]
Endosulfan II	120	89 ± 89	2,100	750 ± 2,400	120	66 ± 92	22,000,000 N
g-BHC[d]	71	39 ± 59	150	80 ± 120	65	30 ± 60	4,800 C[e]
a-BHC	120	85 ± 57	98	78 ± 33	93	68 ± 37	990 C
Methoxyclor	160	98 ± 180	98	69 ± 83	102	42 ± 106	NA[f]
Hexachlorbenzene	120	40 ± 110	140	55 ± 120	63	38 ± 72	3,900 C
4,4'-DDE	38	27 ± 35	98	52 ± 74	42	22 ± 31	18,000 C
Dieldrin	14	9.7 ± 8.6	80	41 ± 59	8.5	7.6 ± 2.6	390 C
Endosulfan sulfate	17	8.1 ± 15	63	28 ± 62	16	8 ± 15	NA
4,4'-DDT	30	13 ± 29	48	26 ± 31	36	14 ± 30	18,000 C
d-BHC	15	9.1 ± 18	30	22 ± 22	6.9	5.3 ± 4.7	3,500 C[g]
g-Chlordane	11	6.4 ± 9.7	28	12 ± 23	3.9	3.4 ± 1.5	4,900 C
2,4'-DDT	4.6	3.8 ± 2.3	12	8.3 ± 7.7	3.3	2.9 ± 1.2	18,000 C
Trans Nonachlor	2.8	2.8	17	7.7 ± 12	0.44	0.44	NA
Mirex	1.3	1.3	5.3	3.4 ± 5.4			3,500 C
a-Chlordane	1.4	0.87 ± 1.6	7.9	3.2 ± 8.2			4,900 C

(a) Average ±2 standard error of the calculated mean.
(b) From: *U.S EPA Region III Risk-Based Concentration Table*, R. L. Smith, February 9, 1995. The listed values are the lowest of the carcinogenic (target cancer risk 1 x 10^{-6}) and non-carcinogenic (target hazard quotient of 1.0) risk-based concentrations.
(c) N = non-carcinogenic risk.
(d) BHC = hexachlorocyclohexane; g-BHC is also called lindane.
(e) C = carcinogenic risk.
(f) NA = not available.
(g) Risk-based concentration for technical BHC.

Appendix B

Glossary

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 Ci = 3.7×10^{10} 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."

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 - The interaction of an organism with a physical agent (e.g., radiation) or a chemical agent (e.g., arsenic) of interest. Also used as a term for quantifying x and gamma radiation fields (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. The mean, X, was computed as:

$$X = \frac{1}{n} \sum_{i=1}^{n} X_i$$

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.

rad - The basic unit of absorbed dose of radiation.

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.

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 - Virtually synonymous with radionuclide.

radionuclide - A species of atoms having a particular number of photons (Z), a particular number of neutrons (A), and a particular atomic weight (N = Z + A) that happens to emit radiation. Carbon-14 is a radionuclide. Carbon-12 is not and is called just a "nuclide."

rem - A unit of dose equivalent and effective dose equivalent.

risk - The probability that a detrimental health effect will occur.

roentgen (R) - Unit of X ray or gamma ray exposure measured in air, historically used to describe external radiation levels. An exposure of one roentgen typically causes an effective dose of one rem.

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 and effective 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 - Uranium metal or oxide and its metal container that has been used to power a nuclear reactor. It is highly radioactive and typically contains fission products, plutonium, and residual uranium.

standard deviation - An indication of the dispersion or variability of a set of results around their average.

standard error of the mean - A measure of the precision of a mean of observed values, that is, an estimate of how close a mean of observed values is expected to be to the true mean. The standard error of the mean is 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 - A device containing 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 absorbed dose to the thermoluminescent dosimeter.

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.

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

Appendix C

Standards and Permits

K. A. Saldi, E. J. Antonio, and G. W. Patton

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 public health, ecological, or aesthetic considerations. The primary environmental quality standards and permits applicable to Hanford operations in 1995 are listed in the following tables. The State of Washington has promulgated water quality standards for the Columbia River, Washington Administrative Code 173-201A. 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 Table C.2. Select surface freshwater quality criteria for toxic pollutants are included in Table C.3.

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 new limits for public radiation dose and gives guidance for keeping radiation exposures to members of the public as low as reasonably achievable. 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 in regulating and licensing non-DOE nuclear facilities (i.e., nuclear power plants). Table C.4 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 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.5 lists selected DOE Derived Concentration Guides for radionuclides of particular interest at the Hanford Site. The Derived Concentration Guides 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 of the Clean Water Act and the Prevention of Significant Deterioration 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 discussed in Table C.6.

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.
Radioactive substances	Deleterious concentrations of radioactive materials for all classes shall be as determined by the lowest practicable concentration attainable and in no case shall exceed U.S. EPA Drinking Water Regulations for radionuclides, as published in the *Federal Register* for July 9, 1976, or subsequent revisions thereto (see Table C.2).
Toxic substances	Toxic substances shall not be introduced above natural background levels in waters of the state which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department (see Table C.3).

(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
Total 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]	DOE, EPA	Final	WAC 246-290, 40 CFR 141.16
Tritium	Whole body	20,000[d]	EPA		
Beryllium-7	GI (LLI)[e]	6,000[d]	EPA		
Cobalt-60	GI (LLI)	100[d]	EPA		
Strontium-90	Bone marrow	8[d]	EPA		
Technetium-99	GI (LLI)	900[d]	EPA		
Ruthenium-106	GI (LLI)	30[d]	EPA		
Antimony-125	GI (LLI)	300[d]	EPA		
Iodine-129	Thyroid	1[d]	EPA		
Iodine-131	Thyroid	3[d]	EPA		
Cesium-134	GI (S)[f]	20,000[d]	EPA		
Cesium-137	Whole Body	200[d]	EPA		
Europium-154	GI (LLI)	200[d]	EPA		
Europium-155	GI (LLI)	600[d]	EPA		
Uranium		20[g,h]	EPA	Proposed	

(a) Washington State Department of Health.
(b) U.S. Environmental Protection Agency.
(c) Beta and gamma radioactivity from manmade radionuclides. Annual average concentration shall not produce an annual dose equivalent from manmade radionuclides 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) Concentration assumed to yield an annual dose of 4 mrem/yr.
(e) GI (LLI) = gastrointestinal tract (lower large intestine).
(f) (S) = stomach.
(g) µg/L.
(h) Equivalent to a nationwide EPA standard of 30 pCi/L and a sitewide standard of 13.4 pCi/L (see Section 4.8, "Ground-Water Protection and Monitoring Program").

Table C.3. Select Surface Freshwater Quality Criteria for Toxic Pollutants

Compound	Level that Yields Acute Toxicity[a]	Level that Yields Chronic Toxicity[a]	Level to Protect Human Health for the Consumption of Water and Organisms[b]
	µg/L		
Total Recoverable Metals			
Antimony	--	--	14
Arsenic	360.0	190.0	0.018
Cadmium	[c]	[d]	--
Chromium[e] (III)	[f]	[g]	--
(VI)	16.0	11.0	--
Copper	[h]	[i]	
Lead	[j]	[k]	--
Mercury	2.4	0.012	0.14
Nickel	[l]	[m]	610
Selenium	20.0	5.0	--
Silver	[n]	--	--
Thallium	--	--	1.7
Zinc	[o]	[p]	--
Anions			
Cyanide[q]	22.0	5.2	700
Chloride[r]	860,000	230,000	--
Organic Compounds			
Benzene	--	--	1.2
Carbon tetrachloride	--	--	0.25
Chloroform	--	--	5.7
1,2-Dichloroethane	--	--	0.38
Methylene chloride	--	--	4.7
Toluene	--	--	6800
Tetrachloroethylene	--	--	0.8
1,1,2-trichloroethane	--	--	0.60
Trichloroethylene	--	--	2.7
Vinyl chloride	--	--	2
1,4-dichlorobenzene	--	--	400

(a) Washington Administrative Code 173-201A-040.
(b) 40 Code of Federal Regulations 131.36.
(c) exp(1.128[ln(hardness)]-3.828). Hardness expressed as mg $CaCO_3$/L.
(d) exp(0.7852[ln(hardness)]-3.490).
(e) Where methods to measure trivalent chromium are unavailable, these criteria are to be represented by total recoverable chromium.
(f) exp(0.8190[ln(hardness)]+3.688).
(g) exp(0.8190[ln(hardness)]+1.561).
(h) exp(0.9422[ln(hardness)]-1.464).
(i) exp(0.8545[ln(hardness)]-1.465).
(j) exp(1.273[ln(hardness)]-1.460).
(k) exp(1.273[ln(hardness)]-4.705).
(l) exp(0.8460[ln(hardness)]+3.3612).
(m) exp(0.8460[ln(hardness)]+1.1645).
(n) exp(1.72[ln(hardness)]-6.52).
(o) exp(0.8473[ln(hardness)]+0.8604).
(p) exp(0.8473[ln(hardness)]+0.7614).
(q) Criteria based on weak and dissociable method.
(r) Dissolved in association with sodium.

Table C.4. 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.5. 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.6. Environmental Permits

Clean Water Act Permit

See information on Clean Water Act in Section 2.2, "Compliance Status."

Clean Air Act Permits

Prevention of Significant Deterioration 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 Plant and the Uranium-TriOxide 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.

Wildlife Sampling Permits

Scientific Collection Permit WM-0039, issued by Washington State Department of Fish and Wildlife to Pacific Northwest National Laboratory for 1995, covered the collection of food fish, shellfish, and wildlife, including gamefish, for environmental monitoring purposes. Renewed annually.

Federal Fish and Wildlife Permit No. 671877, issued by the U.S. Fish and Wildlife Service to Pacific Northwest National Laboratory, covers the collection of migratory wildlife. Renewed every other year.

Copies of the regulations concerning these permits may be obtained from the following organizations:

State of Washington
Department of Ecology
300 Desmond Drive
Lacey, WA 98503

U.S. Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, WA 98101

U.S. Department of Energy
Richland Operations Office
825 Jadwin Ave.
Richland, WA 99352

References

40 CFR 61. U.S. Environmental Protection Agency, "National Emissions Standard for Hazardous Air Pollutants." *Code of Federal Regulations.*

40 CFR 131.36. U.S. Environmental Protection Agency, "Federally Promulgated Water Quality Standards." *Code of Federal Regulations.*

40 CFR 141. U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations." *Code of Federal Regulations.*

Clean Air Act. Public Law 88-206, as amended, 42 USC 7401 et seq.

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

Appendix D

Dose Calculations

E. J. Antonio

The radiological dose that the public could have received in 1995 from Hanford operations was calculated in terms of the "total effective dose equivalent." The total effective dose equivalent is the sum of the effective dose equivalent from external sources and the committed effective dose equivalent for internal exposure. Effective dose equivalent is a weighted sum of doses to organs and tissues that accounts for the sensitivity of the tissue and the nature of the radiation causing the dose. It is calculated 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. This appendix describes how the doses in this report were calculated. The values given in this report may be compared to standards for radiation protection (Table C.4, Appendix C).

Releases of radionuclides from 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 radiological 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 data used in these calculations are described below.

CRITR2 is used for assessment of radiological doses to aquatic organisms and their predators. Both internal and external doses to fish, crustacea, mollusks, and algae, as well as organisms that subsist on them, such as muskrats, raccoons, and ducks may be estimated using CRITR2 (Baker and Soldat 1992).

The computer program, CAP88-PC, was used to calculate dose to a maximally exposed individual as required by 40 CFR 61, Subpart H, from airborne radionuclide effluents (other than radon) released at DOE facilities. Technical details of the CAP88-PC calculations are provided in detail in the 1995 air emissions report (Gleckler et al. 1996).

Types of Dose Calculations Performed

Calculations of radiological doses to the public from radionuclides released into the environment are performed to demonstrate compliance with applicable standards and regulations.

(a) 1 rem (0.01 Sv) = 1,000 mrem (10 mSv).

DOE requires:

- effective dose equivalent to be used in estimating public doses
- biokinetic models and metabolic parameters given by the International Commission of Radiological Protection to be used when estimating doses
- doses to the public to be calculated using facility effluent data, when environmental concentrations are too low to measure accurately.

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 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 radiological doses were estimated:

1. **"Boundary" Dose Rate (mrem/h and mrem/yr).** The external radiological 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 radiological dose to the collective population within 80 km (50 mi) of the Site was calculated to demonstrate compliance with environmental regulations, confirm adherence to DOE environmental protection policies, and provide information to the public. The 80-km (50-mi) population dose represents the summed products of the individual doses for the number of individuals involved for all exposure pathways.

    Pathways similar to those used for the maximally exposed individual were used to calculate doses to the offsite population. In calculating the effective dose, an estimate was made of the fraction of the offsite population expected to be 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. These crops are widely distributed.

- **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 (33,075 lb/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, radiological 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 below.

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 report *1995 Surface Environmental Surveillance Data* (Bisping 1996). These disributions 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 Bisping (1996). 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 exposure pathways, such as irrigation rates, growing periods, and holdup periods, are listed in Table D.1. Certain parameters are specific to the lifestyles of either "maximally exposed" or "average" individuals.

Public Exposure

The offsite radiological 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

DOE established the Hanford Dose Overview Panel to promote consistency and defensibility of environmental dose calculations at Hanford. The Hanford Dose Overview Panel has the responsibility for defining standard, documented computer codes and input parameters to be used for radiological 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 radiological doses (Schreckhise et al. 1993). The calculations were then reviewed by the Dose Overview Panel. Summaries of dose calculation technical details for this report are shown in Tables D.5 through D.9 and in the report *1995 Surface Environmental Surveillance Data* (Bisping 1996).

Table D.1. Food Pathway Parameters Used in Dose Calculations, 1995

	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, 1995

	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	--[a]
Drinking water[b]	730	440

(a) Average individual consumption not identified; radiation doses were calculated based on estimated total annual catch of 15,000 kg (33,075 lb).
(b) Units L/yr.

Table D.3. Residency Parameters Used in Dose Calculations, 1995

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, 1995

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. Technical Details of 100 Areas Airborne Release Dose Calculations, 1995

Facility name	100-N Area
Releases	See Table 3.1.1
Meteorological conditions	1995 annual average, calculated from data collected at the 100-N Area and the Hanford Meteorology Station from January 1995 through December 1995, using the computer code HANCHI
$\overline{X}/Q'$	Maximally Exposed Individual at residence, 4.2×10^{-9} s/m^3 at 41 km SE; Maximally Exposed Individual at food source, 2.9×10^{-9} s/m^3 at 53 km SSE; 80-km population, 1.0×10^{-3} s/m^3 person-s/m^3
Release height	10-m effective stack height
Population distribution	375,000 (see Table D-1, Bisping [1996])
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. Technical Details of 100-N Area Liquid Release Dose Calculations, 1995

Facility name	100-N Area
Releases	See Table 3.1.4
Mean river flow	113,075 ft^3/s (3,200 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. Technical Details of 200 Areas Airborne Release Dose Calculations, 1995

Facility name	200 Areas
Releases	See Table 3.1.1
Meteorological conditions	1995 annual average, calculated from data collected at the Hanford Meteorology Station from January 1995 through December 1995, using the computer code HANCHI
$\overline{X}/Q^{`}$	Maximally Exposed Individual at residence, 1.2×10^{-8} s/m^3 at 34 km SE; Maximally Exposed Individual at food source, 8.7×10^{-9} s/m^3 at 45 km SE; 80-km population, 1.5×10^{-3} person-s/m^3
Release height	89-m effective stack height
Population distribution	376,000 (see Table D-2, Bisping [1996])
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. Technical Details of 300 Area Airborne Release Dose Calculations, 1995

Facility name	300 Area
Releases	See Table 3.1.1
Meteorological conditions	1995 annual average, calculated from data collected at the 300 Area and the Hanford Meteorology Station from January 1995 through December 1995, using the computer code HANCHI
$\overline{X}/Q'$	Maximally Exposed Individual at residence, 8.8×10^{-7} s/m^3 at 1.5 km E; Maximally Exposed Individual at food source, 8.5×10^{-8} s/m^3 at 13 km SSE; 80-km population, 6.5×10^{-3} person-s/m^3
Release height	10 m
Population distribution	282,000 (see Table D-3, Bisping [1996])
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. Technical Details of 400 Area Airborne Release Dose Calculations, 1995

Facility name	400 Area
Releases	See Table 3.1.1
Meteorological conditions	1995 annual average, calculated from data collected at the 400 Area and the Hanford Meteorology Station from January 1995 through December 1995, using the computer code HANCHI
$\overline{X}/Q'$	Maximally Exposed Individual at residence, 9.9×10^{-8} s/m^3 at 11 km SE; Maximally Exposed Individual at food source, 3.2×10^{-8} s/m^3 at 23 km SSE; 80-km population, 4.9×10^{-3} person-s/m^3
Release height	10 m
Population distribution	283,000 (see Table D-4, Bisping [1996])
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.10. Annual Dose to Workers in the 400 Area from Ingestion of Drinking Water Obtained from Ground-Water Wells

Radionuclide	Drinking Water Concentration (pCi/L)[a]	Intake (Bq/yr)[b]	Ingestion Dose Factor (Sv/Bq)[c]	Ingestion Dose (Sv/yr)[rem/yr]
Total Alpha[d]	0.12 ± 0.44	1.1	7.66×10^{-8}	8.2×10^{-8} [8.2×10^{-6}]
Total Beta[e]	6.72 ± 1.82	6.0	1.35×10^{-8}	8.1×10^{-7} [8.1×10^{-5}]
Tritium	8,424 ± 304	75,000	1.73×10^{-11}	1.3×10^{-6} [1.3×10^{-4}]
^{90}Sr	0.004 ± 0.006	0.036	3.85×10^{-8}	1.4×10^{-9} [1.4×10^{-7}]
^{129}I	0.0095 ± 0.001	0.0084	7.46×10^{-8}	6.3×10^{-9} [6.3×10^{-7}]
Total				2.2×10^{-6} [2.2×10^{-4}]

(a) Drinking water concentrations are annual average concentrations obtained from monthly samples taken during 1995 (see Table 4.3.2).
(b) Intake is based on the assumption that a worker ingests 1 L/day of ground water during the entire working year (taken to be 240 days for the analysis). 1 Ci = 3.7×10^{10} Bq.
(c) Ingestion intake-to-dose conversion factors are taken from Eckerman et al. (1988). Where the document lists dose factors for more than one chemical form of a radionuclide, the most soluble chemical form was assumed.
(d) Total alpha concentrations were assumed to be ^{234}U for the purposes of this analysis.
(e) Total beta concentrations were assumed to be ^{137}Cs for the purposes of this analysis.

References

Beck, D. M., and B. A. Napier, M. J. Scott, A. G. Thurman, M. D. Davis, D. B. Pittenger, S. F. Shindle, andN. C. Batishko. 1991. *Hanford Area 1990 Population and 50-Year Projections.* PNL-7803, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E. 1996. *Hanford Site Environmental Data for Calendar Year 1995—Surface and Columbia River.* PNL-XXXXX, Pacific Northwest National Laboratory, Richland, Washington.

DOE Order 5400.5. "Radiation Protection of the Public and the Environment."

Eckerman, K. F., A. B. Wolbarst, and A. C. B. Richardson. 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion. Federal Guidance Report No. 11.* EPA/520/1-88-020, Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C.

Gleckler, B. P., L. P. Diediker, K. Rhoads, E. G. Damberg, and S. J. Jette. 1996. Radionuclide Air Emissions Report for the Hanford Site Calendar Year 1995. DOE/RL-96-37, U.S. Department of Energy, Richland, Washington.

International Commission on Radiological Protection (ICRP). 1979a. *ICRP Publication 30, Part 1, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 2, No. 3/4. Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection (ICRP). 1979b. *ICRP Publication 30, Supplement to Part 1, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 3, No. 1-4, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection (ICRP). 1981a. *ICRP Publication 30, Supplement to Part 2, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 5, No. 1-6, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection (ICRP). 1981b. *ICRP Publication 30, Part 3 Including Addendum to Parts 1 and 2, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 6, No. 2/3, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection (ICRP). 1982a. *ICRP Publication 30, Supplement A to Part 3, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 7, No. 1-3, Pergamon Press, Elsmford, New York.

International Commission on Radiological Protection (ICRP). 1982b. *ICRP Publication 30, Supplement B to Part 3 Including Addendum to Supplements to Parts 1 and 2, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 8, No. 1-3, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection (ICRP). 1988. *ICRP Publication 30, Part 4, Limits for Intakes of Radionuclides by Workers: an Addendum.* Annuals of the ICRP, Vol. 19, No. 4, Pergamon Press, Elmsford, New York.

Napier, B. A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell. 1988a. *Conceptual Representation. Volume 1 of GENII - The Hanford Environmental Radiation Dosimetry Software System.* PNL-6584, Vol. 1, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell. 1988b. *User's Manual. Volume 2 of GENII - The Hanford Environmental Radiation Dosimetry Software System.* PNL-6584, Vol. 2, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell. 1988c. *Code Maintenance Manual. Volume 3 of GENII - The Hanford Environmental Radiation Dosimetry Software System.* PNL-6584, Vol. 3, Pacific Northwest Laboratory, Richland, Washington.

Schreckhise, R. G., K. Rhoads, J. S. Davis, B. A. Napier, and J. V. Ramsdell. 1993. *Recommended Environmental Dose Calculation Methods and Hanford-Specific Parameters.* PNL-3777 Rev. 2, Pacific Northwest Laboratory, Richland, Washington.

Appendix E

Radionuclides Detected by Gamma Spectroscopy (Gamma Scan)

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 E.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

Appendix F

Threatened and Endangered Species

Appendix F

Threatened and Endangered Species

T. M. Poston

Threatened and endangered plants and animals identified on the Hanford Site, as listed by the federal government (50 CFR 17) and Washington State (Washington Natural Heritage Program 1994), are shown in Table F.1. Under a proposed rule (61 FR 7595), the fish and wildlife service has consolidated its listing categories of candidate species from three designations to one. Consequently, a number of previously listed Federal candidate species found on the Hanford Site have been dropped from Federal listing.

No plants or mammals on the federal list of endangered and threatened wildlife and plants (50 CFR 17) are known to occur on the Hanford Site. There are, however, three species of birds on the federal list of threatened and endangered species and several species of both plants and animals that are under consideration for formal listing by the State of Washington. There are 21 candidate species of plants and animals (Table F.2) and 23 monitored plant species Table F.3 listed by the state of Washington.

Table F.1. Federally or Washington State Listed Threatened (T) and Endangered (E) Species Occurring or Potentially Occurring on the Hanford Site

Common Name	Scientific Name	Federal	State
Insects			
Oregon silverspot butterfly[a]	*Speyerra zerone*	T	T
Plants			
Columbia milk-vetch	*Astragalus columbianus*		T
Columbia yellowcress	*Rorippa columbiae*		E
Dwarf evening primrose	*Oenothera pygmaea*		T
Hoover's desert parsley	*Lomatium tuberosum*		T
Northern wormwood[a]	*Artemisia campestris borealis* var. *wormskioldii*		E
Birds			
Aleutian Canada goose[b]	*Branta canadensis leucopareia*	T	E
American white pelican	*Pelecanus erythrorhychos*		E
Bald eagle	*Haliaeetus leucocephalus*	T	T
Ferruginous hawk	*Buteo regalis*		T
Peregrine falcon[b]	*Falco peregrinus*	E	E
Sandhill crane[b]	*Grus canadensis*		E
Mammals			
Pygmy rabbit[a]	*Brachylagus idahoensis*		E

(a) Likely not currently occurring on the Site.
(b) Incidental occurrence.

Table F.2. State Candidate Species Potentially Found on the Hanford Site

Common Name	Scientific Name
Molluscs	
Columbia pebble snail	*Fluminicola* (= *Lithoglyphus*) columbiana
Shortfaced lanx	*Fisherola* (= *Lanx*) *nuttalli*
Birds	
Burrowing owl	*Athene cunicularia*
Common loon	*Gavia immer*
Flammulated owl[a]	*Otus flammeolus*
Golden eagle	*Aquila chrysaetos*
Lewis' woodpecker[a]	*Melanerpes lewis*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Northern goshawk[a]	*Accipter gentilis*
Sage sparrow	*Amphispiza belli*
Sage thrasher	*Oreoscoptes montanus*
Swainson's hawk	*Buteo swainsoni*
Trumpeter swan[b]	*Cygnus columbianus*
Western bluebird[a]	*Sialia mexicana*
Western sage grouse[a]	*Centrocercus urophasianus phaios*
Insects	
Columbia River tiger beetle[b]	*Cinindela colubica*
Reptiles	
Striped whipsnake	*Masticophis taeniatus*
Mammals	
Merriam's shrew	*Sorex merriami*
Pacific western big-eared bat[b]	*Plecotus townsendii townsendii or pallescens*
Pygmy rabbit[a]	*Brachylagus idahoensis*

(a) Reported, but seldom observed on the Hanford Site.
(b) Probable, but not observed, on the Hanford Site.

Table F.3. Washington State Plant Species of Concern Occurring on the Hanford Site

Common Name	Scientific Name	Status[a]
Bristly cryptantha	*Cryptantha interrupta*	M2
Columbia River mugwort	*Artemisia lindleyana*	M3
Crouching milkvetch	*Astragalus succumbens*	M3
Dense sedge	*Carex densa*	S
Desert evening primrose	*Oenothera cespitosa*	S
False pimpernel	*Lindernia anagallidea*	S
Fuzzy-beard tongue penstemon	*Penstemon eriantherus*	M3
Gray cryptantha	*Cryptantha leucophaea*	S
Medic milkvetch	*Astragalus speirocarpus*	M3
Palouse thistle	*Cirsium brevifolium*	M3
Piper's daisy	*Erigeron piperianus*	S
Robinson's onion	*Allium robinsonii*	M3
Rosy balsamroot	*Balsamorhiza rosea*	M3
Shining flatsedge	*Cyperus rivularis*	S
Smooth cliffbrake	*Pellaea glabella*	M3
Southern mudwort	*Limosella acaulis*	S
Squill onion	*Allium scillioides*	M3
Stalked-pod milkvetch	*Astragalus sclerocarpus*	M3
Thompson's sandwort	*Arenaria franklinii* v. *thompsonii*	M2
Tooth-sepal dodder	*Cuscuta denticulata*	M1

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.

Coyote tobacco	*Nicotiana attenuata*	S
Few-flowered blue-eyed Mary	*Collinsia sparsiflora*	S
Palouse milkvetch	*Astragalus arrectus*	S

(a) S = Sensitive, i.e., 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, i.e., taxa with unresolved taxonomic questions.
M3 = Monitor group 3, i.e., taxa that are more abundant and/or less threatened than previously assumed.

Appendix G

Errata from the 1994 Hanford Site Environmental Report

Appendix G

Errata from 1994 Hanford Site Environmental Report

The following lists errors in the published 1994 environmental report (*Hanford Site Environmental Report for Calendar Year 1994*. R. L. Dirkes and R. W. Hanf, editors. 1995. PNL-10574, Pacific Northwest Laboratory, Richland, Washington.)

On page ix, second column, second line from the bottom of the page, 0.05 mrem (5 x 10^{-4} mSv) should be 0.04 mrem (4 x 10^{-4} mSv).

On page 30, first column, second paragraph under Clean Water Act, the 300 Area outfall should be 013, not 003.

On page 40, second column, seventh sentence under ferrocyanide, the tank temperature should be 53.0°C not 530°C.

On page 175, second column, bottom paragraph, third line, there is a callout for Figure 5.6.7. This figure was omitted from the report.

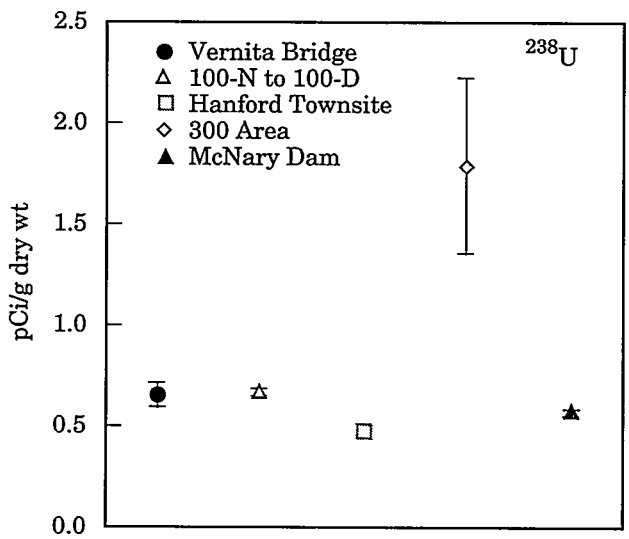


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Figure 5.6.7. Concentrations (±2 standard error of the mean) of Uranium-238 in Milfoil Collected from Five Locations on the Columbia River. As a result of figure scale, some uncertainties are concealed by the point symbol.

On page 185, Figure 5.8.1, the y (vertical) axis should be labeled "Meters Above Mean Sea Level."

On page 239, first column, second paragraph, second line, 0.05 mrem (5 x 10^{-4} mSv) should be 0.04 mrem (4 x 10^{-4} mSv). In line 14, 0.05% should be 0.04%. In line 15, 0.02% should be 0.01%.

On page 242, first column, near the bottom of the page, 0.05 mrem (5 x 10^{-4} mSv) should be 0.04 mrem (4 x 10^{-4} mSv). In column two on the same page in the first paragraph following the bulleted statements, 0.05% should be 0.04%.

On page 243, Table 6.0.1, the combined total for the 200 Areas should be 3.3 x 10^{-2} and the combined total for Pathway Total should be 4.4 x 10^{-2}.

On page 245, second column, second paragraph, 0.05 mrem (5 x 10^{-4} mSv) should be 0.04 mrem (4 x 10^{-4} mSv).

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