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Hanford Site

1996 Environmental Report

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

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RECIPIENTS:

THE HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR (CY) 1996 (PNNL-11472), RICHLAND, WASHINGTON, AUGUST 1997

The Hanford Site Environmental Report is prepared and published annually by the U.S. Department of Energy (DOE), Richland Operations Office (RL) for distribution to local, state, and federal government agencies, Congress, the public, and the news media. The purpose of the report is to provide the reader with the most recent information available on Hanford Site environmental management activities and compliance issues.

This report includes information for CY 1996 and contains sections summarizing the results of environmental monitoring efforts on and around the site, information on Hanford's conformance to environmental permits, and the status of the site's compliance with federal, state, and local regulations. It also discusses important issues and actions for both CY 1996 and early CY 1997.

The report was prepared for RL by the Pacific Northwest National Laboratory (PNNL) and other site contractors and describes programs conducted by PNNL, the Research and Development Contractor; Fluor Daniel Hanford, Inc. (FDH), the Management and Integration Contractor; Bechtel Hanford, Inc. (BHI), the Environmental Restoration Contractor; MACTEC-ERS, a prime contractor to DOE's office in Grand Junction, Colorado, which is performing work at Hanford for RL; and numerous subcontractor and enterprise companies at Hanford.

If you have any questions or comments, you may contact me or Dana Ward, of the Environmental Assurance, Permits, and Policy Division, on (509) 372-1261.

Sincerely,

John D. Wagoner
Manager

EAP:DCW

Enclosure:
Hanford Site Environmental
Report for 1996

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PNNL-11472
UC-602

Hanford Site Environmental Report for Calendar Year 1996

Editors
R. L. Dirkes
R. W. Hanf

August 1997

Prepared by personnel from Pacific Northwest National Laboratory, Fluor Daniel Hanford, Inc. and its subcontractors and enterprise companies, Bechtel Hanford, Inc., and MACTEC-ERS 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.

This Hanford Site environmental report is prepared annually pursuant to DOE Orders 5400.1 and 231.1, "Environment, Safety, and Health Reporting," and DOE (1995a), *Environment, Safety and Health Reporting Manual*, 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 report is produced for the DOE Richland Operations Office, Environmental Assurance, Permits and Policy Division by the Pacific Northwest National Laboratory's Public Safety and Resource Protection Program. Pacific Northwest National Laboratory is operated by Battelle for DOE. Battelle is 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 selected subcontractors and enterprise companies of Fluor Daniel Hanford, Inc. (the site management and integration contractor). Bechtel Hanford, Inc. (the environmental restoration contractor) and MACTEC-ERS also prepared or 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 obtained from Mr. R. W. (Bill) Hanf, Pacific Northwest National Laboratory, P.O. Box 999, Richland, Washington 99352 (rw_hanf@pnl.gov) while supplies last or can be purchased from the National Technical Information Center, Springfield, Virginia 22161.

This 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 at http://www.hanford.gov/docs/annualrp96/.

Inquiries regarding this report may be directed to Mr. D. C. (Dana) Ward, DOE Richland Operations Office, Environmental Assurance, Permits and Policy Division, P.O. Box 550, Richland, Washington 99352 (dana_c_ward@rl.gov), or to Mr. R. L. (Roger) Dirkes, Pacific Northwest National Laboratory, P.O. Box 999, Richland, Washington 99352 (rl_dirkes@pnl.gov).

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Summary

This Hanford Site environmental report is prepared annually to summarize environmental data and information, to describe environmental management performance, to demonstrate the status of compliance with environmental regulations, and to highlight major environmental programs and efforts.

The report is written to meet 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 1996 of compliance with environmental regulations
- describe the environmental programs at the Hanford Site
- discuss estimated radionuclide exposure to the public from 1996 Hanford Site activities
- present information on effluent monitoring and environmental surveillance, including groundwater protection and monitoring
- discuss activities to ensure quality.

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

The Hanford Site and its Mission

The Hanford Site in southcentral Washington State is approximately 1,450 km^2 (560 mi^2) 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. Approximately 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 the Columbia River in the northern portion of the Hanford Site (containing reactors used primarily for plutonium production; now all shut down)
- 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 (formerly used for plutonium processing; now focused on waste management)
- the 300 Area, near the southern border of the Hanford Site (containing laboratories, support facilities, and former reactor fuel manufacturing facilities)
- 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, 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 underground waste storage tanks, Environmental Restoration Disposal Facility, Plutonium Finishing Plant, Central Waste Complex, Low-Level Burial Grounds, B Plant/Waste Encapsulation Facility, Effluent Treatment 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; the cleanup and disposal of more than 100 facilities have begun.

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 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 the following:

- Fluor Daniel Hanford, Inc.
- 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 Washington State 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

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 1996.

A key element in Hanford's compliance program is the Hanford Federal Facility Agreement and Consent Order (also known as the 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 1996, a total of 512 enforceable Tri-Party Agreement milestones and 223 unenforceable target dates were completed on or ahead of schedule. Sixty-four milestones scheduled for 1996 were completed.

Comprehensive Environmental Response, Compensation, and Liability Act

This Act established a program to ensure that sites contaminated by hazardous substances are cleaned up by responsible parties or the government. The Act primarily covers waste cleanup of inactive sites.

Preliminary assessments conducted for the Hanford Site revealed approximately 2,200 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.

In 1996, the Hanford Site was in compliance with requirements of the Comprehensive Environmental Response, Compensation, and Liability Act. Cleanup is under way at various sites in the 100, 200, and other areas. Full-scale remediation of waste sites began in the 100 Areas in 1996. The Environmental Restoration Disposal Facility opened in the 600 Area in 1996; a central disposal site for contaminated soil generated during cleanup.

Emergency Planning and Community Right-To-Know Act

This 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 Act 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 1996 Hanford Site's emergency and hazardous chemical inventory was issued to the State Emergency Response Commission, local county emergency management committees, and local fire departments in March 1997. The inventory report contained information on hazardous materials in storage across the site. A toxic chemical release inventory report was issued in August 1996, which provided details regarding releases, offsite transfers, and source reduction activities involving ethylene glycol, the sole toxic chemical used in excess of regulatory thresholds during 1995. No such reporting thresholds were exceeded in 1996. During 1996, the Hanford Site was in compliance with the reporting and notification requirements contained in this Act.

Resource Conservation and Recovery Act

This Act establishes regulatory standards for the generation, transportation, storage, treatment, and disposal of hazardous wastes. The 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. The Washington State Department of Ecology implements the state's regulations, which are often more stringent. The 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 the Act and Washington State regulations. These units are required to operate under the 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 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 tanks, which are regulated as treatment, storage, and disposal facilities.

Clean Air Act

The purpose of this 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 require applicable controls and annual reporting of all radioactive air emissions. The Hanford Site operates under a license for such emissions. The conditions specified in the license will be incorporated into the Hanford Site air operating permit, scheduled to be issued in 1997.

Revised Clean Air Act requirements for radioactive air emissions were issued in December 1989. Emissions from the Hanford Site are within the state and EPA offsite emissions standard of 10 mrem/yr. Nearly all Hanford Site sources currently meet the procedural requirements for flow measurement, emissions measurement, quality assurance, and sampling documentation.

The local air authority (the Benton County Clean Air Authority) regulations pertain to detrimental effects, fugitive dust, open burning, odor, opacity, and asbestos handling. The Authority has also been delegated responsibility to enforce the EPA asbestos regulations under the revised Clean Air Act. The site remains in compliance with the regulations.

Clean Water Act

This Act applies to point discharges to waters of the United States. At the Hanford Site, the regulations are applied through National Pollutant Discharge Elimination System permits that govern effluent discharges to the Columbia River. The permits specify discharge points (called outfalls), effluent limitations, and monitoring requirements. Several permit exceedences occurred at the 300 Area Treated Effluent Disposal Facility in 1996 despite the use of best available technology. Preparations for a modification to the facility's discharge permit are under way.

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 1996, 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 site is currently in compliance with an agreement to store these wastes beyond the regulatory limit. 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 specific chapters of the Revised Code of Washington apply to storage and use of pesticides. In 1996, the Hanford Site was in compliance with these requirements.

Endangered Species Act

Many rare species of native plants and animals are known to occur on the Hanford Site. Two of these (bald eagle and peregrine falcon) are listed by the U.S. Fish and Wildlife Service as endangered or threatened. Others are listed by the Washington State Department of Fish and Wildlife as endangered, threatened, or sensitive species. Hanford Site activities complied with the Endangered Species Act in 1996.

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. In 1996, the Hanford Site was in compliance with these Acts.

National Environmental Policy Act

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

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 1996 were reported to DOE and 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 Hanford Reading Room located on the campus of Washington State University at Tri-Cities, Richland, Washington. There were no emergency occurrence or environmentally significant unusual occurrence reports filed in 1996. There were 15 off-normal environmental release-related occurrence reports filed during 1996.

Environmental Monitoring Information

Environmental monitoring of the Hanford Site consists of 1) effluent monitoring and 2) environmental surveillance, including groundwater 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 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.

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 onsite facilities are approaching levels practically indistinguishable from the naturally occurring radioactivity present everywhere. This decrease translates to a very small offsite radiation dose attributable to site activities. The 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 1996 are not significantly different from totals in 1995.

Near-Facility Environmental Monitoring

The near-facility environmental monitoring program is designed to protect the environment adjacent to facilities and ensure compliance with federal, state, and local regulations. Specifically, this 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, vadose zone monitoring, soil and vegetation, external radiation, and investigative sampling (which can include wildlife) 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 58 locations near nuclear facilities: 4 located in the 100-N Area, 4 in the 100-K Area, 38 in the 200 Areas, 3 at the Environmental Restoration Disposal Facility, 4 at the 100-D,DR Area, 3 at the 100-B,C Area, 1 near the

300 Area Treated Effluent Disposal Facility, and 1 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 within approximately 500 m (1,500 ft) of 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, strontium-90, cesium-137, plutonium-239,240, and uranium were consistently detectable in the 100-N and 200 Areas. Cobalt-60 was consistently 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 strontium-90, plutonium-238, plutonium-239,240, uranium, tritium, and gamma-emitting radionuclides. Radiological analyses of sediment and aquatic vegetation samples were performed for strontium-90, plutonium-239,240, 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 (i.e., 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 2.0 to 12.5 pH standard 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 EPA drinking water standard for public water supplies.

Groundwater springs along the 100-N Area shoreline are sampled annually to verify the reported radionuclide releases to the Columbia River from past N Reactor operations. 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 1996, the concentrations detected in shoreline springs samples were highest in springs nearest the effluent monitoring well.

Near-Facility Radiological Surveys. In 1996, there were approximately 4,016 ha (9,923 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 burial grounds, covered ditches, cribs, and tank farms. 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), though 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 1996.

Vadose Zone Monitoring. The inactive liquid effluent facilities vadose zone 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 1996, 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 ensure 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. The number of sampling locations at the 100-N Area were reduced by approximately 50% in 1996.

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. The radiation rates measured in the N Springs area continued to decline in 1996, reflecting discontinued discharges to the 1301-N Liquid Waste Disposal Facility and the continuing decay of its radionuclide inventory.

The 1996 thermoluminescent dosimeter results indicate that direct radiation levels are highest near facilities that had contained or received liquid effluent from N Reactor. These facilities primarily include the 1301-N and 1325-N Liquid Waste Disposal Facilities. Because the results for these two facilities were noticeably higher than those for other 100-N Area thermoluminescent dosimeter locations, they were approximately 9% lower than exposure levels measured at these locations in 1995.

This is the fourth 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 as a result of their proximity to radioactive waste storage areas or stored radioactive rail equipment.

Five new thermoluminescent dosimeter locations were established in the 100-D,DR Area during the fourth quarter of 1996 to evaluate environmental restoration activities at the 116-D-7 and 116-DR-9 Liquid Waste Disposal Facilities. Although no comparative data are available because of the recent placement of these dosimeters, the fourth quarter analyses indicate readings comparable to offsite background levels.

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 1996 by thermoluminescent dosimeters was 120 mrem/yr, which equaled the average dose rate measured in 1995.

Two new thermoluminescent dosimeter locations were established at the Environmental Restoration Disposal Facility during the fourth quarter of 1996 to evaluate the disposal activities currently in progress. Although no comparative data are available because of the recent placement of these dosimeters, the fourth quarter analyses indicate readings comparable to offsite background levels.

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 1996 was 120 mrem/yr. This represents a decrease of 14% compared to the average dose rate of 140 mrem/yr measured in 1995. The average annual dose rate at the 300 Area Treated Effluent Disposal Facility in 1996 was 85 mrem/yr, which represents an increase of 5% compared to the average dose rate of 81 mrem/yr measured in 1995.

The average annual dose rate measured in the 400 Area in 1996 was 83 mrem/yr, which represents an increase of 8% compared to the average dose rate of 77 mrem/yr measured in 1995.

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 indicated radioactive contamination was present
- to conduct preoperational surveys that quantified 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 1996 included air, water, soil (including sediment and radioactive specks), paint chips, vegetation (e.g., mosses, lichens, tumbleweeds), and wildlife (e.g., deer mice, starlings, pocket gopher).

Investigative samples were collected where known or suspected radioactive contamination was present or to verify radiological conditions at project sites. In 1996, 53 such samples were analyzed for radionuclides, and 43 showed some level of contamination. In addition, 62 contamination incidents were reported and disposed of without isotopic analyses, though 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 and sediment, drinking water, food and farm products, fish and wildlife, soil and vegetation, external radiation levels, and groundwater.

Air Surveillance

Radioactive materials in air were sampled continuously at 40 locations onsite, at the site perimeter, and in nearby and distant communities. Nine 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 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 1996, 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 were 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 1996 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 0.000003% 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 8 of the 15 onsite air samples, with the maximum concentration at 0.002% of the DOE derived concentration guide of 9 pCi/m^3. Strontium-90 was also detected at three of the seven perimeter locations and at two of the six distant locations. The maximum concentration at the perimeter location was less than 0.0004% of the DOE derived concentration guide and at the distant location less than 0.0002% of the DOE derived concentration guide.

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 0.06% of the DOE derived concentration guide of 0.02 pCi/m^3.

Uranium isotopic concentrations (uranium-234, uranium-235, and uranium-238) were similar onsite, at the perimeter, and at the distant locations for 1996. The uranium concentrations were 0.03% of the 0.1-pCi/m^3 DOE derived concentration guide.

No samples were collected in 1996 to test for nonradionuclides.

Surface Water and Sediment Surveillance

The Columbia River was one of the primary environmental exposure pathways to the public during 1996 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 groundwater. 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 concentration of tritium was 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 1996 revealed elevated tritium concentrations along the Benton County shoreline near the 100-N Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse. Total uranium concentrations were elevated along the shorelines of both Benton and Franklin Counties 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 groundwater seepage and irrigation return canals on the east shore of the river.

Several metals and anions were detected both upstream and downstream of the Hanford Site. Nitrate concentrations were elevated along the Franklin County shoreline of the Old Hanford Townsite, 300 Area, and Richland Pumphouse transects and likely resulted from groundwater seepage associated with extensive irrigation north and east of the Columbia River. With the exception of aluminum, iron, and nitrate which had the higher 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 1996 were less than Washington State ambient surface water quality criteria levels for acute toxicity, except for silver and cadmium that both exceeded the criteria for a few samples. The chronic toxicity levels for lead and selenium were occasionally exceeded in Columbia River transect samples. Volatile organic compounds (chloroform, toluene, and trichloroethylene) were occasionally detected in Columbia River water in 1996.

Samples of Columbia River surface sediments were collected in 1996 from permanently flooded monitoring sites above McNary Dam (downstream of the site), above Priest Rapids Dam (upstream of the site), and along the Hanford Reach. Strontium-90 was the only radionuclide to exhibit consistently higher median concentrations at McNary Dam compared to the other locations. The median concentration of cobalt-60 was highest in sediment collected along the Hanford Reach. Sediment samples were also collected from five periodically inundated riverbank springs in 1996. The concentrations of radionuclides in sediment collected from riverbank springs were similar at all locations and were comparable to sediment collected behind Priest Rapids Dam.

Detectable concentrations of most metals were found in all Columbia River sediment samples with the exception of silver, which was below the detection limit for all samples. Median concentrations of most metals were highest in McNary Dam sediments. The highest median concentration of chromium was found in riverbank spring sediment.

Water samples were collected from six Columbia River shoreline springs in 1996. All radiological contaminant concentrations measured in riverbank spring water in 1996 were less than the DOE derived concentration guides. However, tritium concentrations 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. All other radionuclides were below the Washington State ambient surface water quality criteria.

All nonradiological contaminants measured in riverbank springs located on the Hanford shoreline in 1996 were below the Washington State ambient surface water acute toxicity levels with the exception of cadmium in the 100-F Area spring; chromium(IV) in springs in the 100-B, 100-D, and 100-F Areas; and copper in the 100-F and 300 Areas springs. The Washington State ambient surface water chronic toxicity levels for cadmium, chromium, selenium, and zinc were exceeded at some locations. It should be noted that riverbank spring sampling protocols do not lend themselves 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. Nitrate concentrations were the highest in the 100-D Area

and the Old Hanford Townsite springs. Concentrations of volatile organic compounds were similar to previous years with most compounds below the detection limits. Chloroform (100-B and 100-D Areas), tetrahydrofuran (100-B Area), and trichloroethylene (100-B Area) were the only volatile organic compounds detected.

Water was collected from three onsite ponds located near operational areas in 1996. Although the ponds were not accessible to the public and did not constitute a direct offsite environmental impact during 1996, 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 uranium-238 in water samples from West Lake, radionuclide concentrations in the onsite pond water were below the 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 1996 were similar to those observed during past years. However, the tritium concentrations in the 1996 samples from the Fast Flux Test Facility pond were lower than observed in 1995. The elevated concentrations in 1995 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.

Irrigation water from the Riverview canal was sampled three times in 1996 to determine radionuclide concentrations. The radionuclide concentrations in offsite irrigation water were below the derived concentration guides and ambient surface water quality criteria levels.

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 DE&S Hanford, Inc.; nonradiological monitoring was conducted by DynCorp Tri-Cities Services, Inc. Radiological results are discussed in this report; nonradiological results are reported directly to the Washington State Department of Health.

During 1996, radionuclide concentrations in 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.

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, vegetables, fruit, and wine were collected from areas around the site and were analyzed for cobalt-60, strontium-90, iodine-129, cesium-137, and tritium.

Most of the farm products sampled did not contain measurable concentrations of these radionuclides. Iodine-129 was found at slightly elevated levels in milk samples from downwind locations. The levels were low, they have been decreasing over the past 6 years, and they are now indistinguishable between upwind and downwind locations. Tritium concentrations in wine have been reported in the past at levels higher than could be confirmed at other analytical laboratories (split samples). Recently, it was discovered that these high concentrations were caused by alcohol in the initial sample distillate; the alcohol produced spuriously high results. The problem was eliminated by removing the alcohol from the sample before analysis.

Fish and Wildlife Surveillance

Analyses of fish and wildlife samples for radionuclides in 1996 indicated that some species had accumulated radionuclides at concentrations greater than background levels. Strontium-90 was detected in the offal (i.e., carcass without most of the muscle and viscera) of Columbia River bass and carp at levels slightly exceeding those found in fish collected upstream of Hanford in the Priest Rapids Dam reservoir. There was no apparent difference between concentrations of strontium-90 in Hanford Reach carp and background carp collected in 1996. Cesium-137 was detected in one bass fillet sample; all other fish and wildlife muscle samples did not have measurable concentrations of cesium-137. Strontium-90 was detected in all deer bone samples analyzed in 1996. Concentrations were similar to levels observed in prior years and did not indicate exposure to elevated levels of strontium in the environment. The mean concentration of strontium-90 (0.07 ± 0.005 pCi/g, wet weight) in pheasant bone was similar to levels observed over the preceding 5 years and exceeded concentrations observed in background samples collected from 1991 through 1995 by a factor of two. Collectively, the levels of radionuclides measured in Hanford fish and wildlife indicated 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 1996. Sampling will be conducted periodically in the future consistent with ongoing site cleanup activities.

External Radiation Surveillance

Radiological dose rates were measured at both onsite and offsite locations using thermoluminescent dosimeters. Radionuclides contributing to these measured doses were of natural and artificial origin. In 1996, terrestrial dose rates did not change significantly from those measured in 1995. The annual average background dose rate measured in distant communities was 71 ± 1 mrem/yr compared to the 1995 average measurement of 72 ± 8 mrem/yr. The 1996 annual average perimeter dose rate was 88 ± 10 mrem/yr; in 1995, the average measured was 86 ± 8 mrem/yr at the same locations. All onsite dosimeters averaged 86 ± 5 mrem/yr in 1996; in 1995, the onsite average was 86 ± 4 mrem/yr. Thermoluminescent dosimeters along the Columbia River shoreline had an annual average of 89 ± 7 mrem/yr in 1996; in 1995, the average was 103 ± 12 mrem/yr. On average, the dose rate along the 100-N Area shoreline (129 ± 30 mrem/yr) was approximately 50% higher than the typical shoreline dose rate (82 ± 3 mrem/yr).

Groundwater Protection and Monitoring

Monitoring of radiological and chemical constituents in groundwater at the Hanford Site was performed to characterize physical and chemical trends in the flow system, establish groundwater quality baselines, assess groundwater remediation, and identify new or existing groundwater problems. Groundwater monitoring was also performed to verify compliance with applicable environmental laws and regulations and to fulfill commitments made in official DOE documents. Samples were collected from approximately 800 wells to determine the distributions of radiological and chemical constituents in Hanford Site groundwater. In addition, hydrogeologic characterization and modeling of the groundwater flow system were used to assess the monitoring network and to evaluate potential impacts of groundwater contamination.

During 1996, groundwater surveillance and monitoring activities were restructured into the Groundwater Monitoring Project. This project incorporates sitewide groundwater monitoring mandated by DOE Orders with near-field groundwater monitoring conducted to ensure that operations in and around specific waste disposal facilities comply with applicable regulations. Groundwater monitoring was required by the Resource Conservation and Recovery Act at 26 waste treatment, storage, and disposal units. Monitoring status and results for each of these units are summarized in this report.

To assess the quality of groundwater, concentrations measured in samples were compared with the EPA drinking water standards and the DOE derived concentration guides. Groundwater is used for drinking at three locations on the Hanford Site. In addition, water supply wells for the city of Richland are located near the southern boundary of the Hanford Site. Radiological constituents including cobalt-60, strontium-90, technetium-99, iodine-129, cesium-137, plutonium, tritium, uranium, total alpha, and total beta were detected at levels greater than the drinking water standard in one or more onsite wells. Concentrations of strontium-90, plutonium, tritium, and uranium were detected at levels greater than the derived concentration guides.

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 EPA drinking water standard. The spread of this plume farther south than the 300 Area is restricted by the groundwater flow away from the Yakima River and the recharge ponds associated with the north Richland well field. Groundwater with tritium at levels above the drinking water standard also discharges to the Columbia River at the 100-N Area. 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.

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 and 200-East Areas also contain strontium-90 at levels greater than the derived concentration guide. Strontium-90 is found at levels greater than the EPA 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.

Technetium-99 concentrations greater than the EPA drinking water standard were 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 and 200-West Areas and adjacent 600 Area. Groundwater in one well completed in the upper basalt-confined aquifer in the northern part of the 200-East Area had technetium-99 concentrations above the drinking water standard. Increases in technetium-99 concentrations at wells near the S-SX and T Tank Farms are being evaluated as possible indications of groundwater contamination from tank leaks.

Iodine-129 was detected at levels greater than the EPA 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 plumes share common sources. 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 was also found at concentrations above the drinking water standard in the southern part of the 200-West Area and extending into the 600 Area. There is a smaller iodine-129 plume in the northcentral part of the 200-West Area.

Cobalt-60 was detected above the EPA drinking water standard in the 600 Area north of the 200-East Area in one well completed in the unconfined aquifer and in one well completed in the confined aquifer.

Cesium-137 was detected in one well in the 200-East Area and one well in the 200-West Area. Concentrations at the 200-East Area well were greater than the EPA drinking water standard.

Uranium was detected at levels greater than the EPA drinking water standard in wells in the 100-F, 100-H, 200-East, 200-West, 300, and 600 Areas. Groundwater with uranium concentrations greater than the drinking water standard appears to be discharging to the Columbia River from the 300 Area. Wells near U Plant in the 200-West Area had concentrations greater than the DOE derived concentration guide.

Plutonium was detected in groundwater 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 Washington State were also present in Hanford Site groundwater. These were carbon tetrachloride, chloroform, chromium, cyanide, fluoride, nitrate, tetrachloroethylene, and trichloroethylene.

An extensive plume of carbon tetrachloride at levels greater than the EPA drinking water standard was found in groundwater 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 the drinking water standard.

Chromium was found at levels greater than the EPA 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 EPA drinking water standard in one 600 Area well north of the 200-East Area.

Fluoride was measured at levels greater than the EPA primary drinking water standard in the 200-West Area.

Nitrate concentrations exceeded the EPA drinking water standard at locations in all 100 Areas, with the exception of the 100-B Area. Those 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. Some of the nitrate in the 600, 1100, and north Richland areas is believed to result from offsite sources.

Tetrachloroethylene was detected at levels below the EPA drinking water standard.

Trichloroethylene was found at levels greater than the EPA drinking water standard in the 100-F Area and the nearby 600 Area. Trichloroethylene was also detected at levels greater than the drinking water standard in the 100-K, 200-West, and 300 Areas and near the Horn Rapids Landfill in the southern part of the Hanford site.

Potential Doses from 1996 Hanford Operations

In 1996, potential doses to the public resulting from exposure to Hanford Site 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 computer code and Hanford-specific parameters. The potential dose to

the maximally exposed individual in 1996 from site operations was 0.007 mrem (0.00007 mSv) compared to 0.02 mrem (0.0002 mSv) calculated for 1995. The radiological dose to the population within 80 km (50 mi) of the site, estimated to be 380,000 persons, from 1996 site operations was 0.2 person-rem (0.002 person-Sv), which is slightly less than the 1995 calculated population dose of 0.3 person-rem (0.003 person-Sv). The average per-capita dose from 1996 site operations was 0.0005 mrem (0.000005 mSv). The national average dose from background sources is 300 mrem/yr (3 mSv/yr), and the current DOE radiological dose limit for a member of the public is 100 mrem/yr (1 mSv/yr). Therefore, the average individual potentially received 0.0005% of the DOE standard and 0.0007% of the national average background. Special exposure scenarios not included in the dose estimates above include the ingestion of game animals residing on the site and exposure to radiation at a publicly accessible location with the maximum exposure rate. Doses from these scenarios would have also been small compared to the DOE dose limit. Radiological dose through the air pathway was 0.005% of the EPA limit of 10 mrem/yr.

Other Hanford Site Environmental Programs

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

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

The Hanford Meteorology Station is located on the 200 Areas 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 1996 was 12.9 km/h (8.0 mi/h), which was 0.5 km/h (0.3 mi/h) above normal; the peak gust for the year was 39 km/h (55 mi/h).

Precipitation for 1996 totaled 31.0 cm (12.2 in.), 195% of normal, with 146.0 cm (57.5 in.) of snow recorded. 1996 was the snowiest year on record.

Temperatures for 1996 ranged from -27.8°C (-18°F) in January and February to 42.8°C (109°F) in August.

Wildlife inhabiting the site is monitored to determine the status and condition of the populations and to assess effects of 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. 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.

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 management of archaeological, historical, and traditional cultural resources is provided in a manner consistent with federal laws.

The community-operated environmental surveillance program was initiated in 1990 to increase the public's involvement in and awareness of Hanford's surveillance program. Nine citizen-operated radiological surveillance stations were operating in 1996.

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 of the American National Standards Institute/American Society of Mechanical Engineers 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.

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Helpful Information

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Helpful Information

The following information is provided to assist the reader in understanding this 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.

Units of Measurement

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).

Table H.1. Names and Symbols for Units of Measure

Symbol	Name	Symbol	Name
Temperature		**Length**	
°C	degree Celsius	cm	centimeter (1×10^{-2} m)
°F	degree 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 foot per second	ha	hectare (1×10^4 m^2)
gpm	gallon per minute	km^2	square kilometer
mph	mile per hour	mi^2	square mile
Volume		ft^2	square foot
cm^3	cubic centimeter	**Mass**	
ft^3	cubic foot	g	gram
gal	gallon	kg	kilogram (1×10^3 g)
L	liter	mg	milligram (1×10^{-3} g)
m^3	cubic meter	µg	microgram (1×10^{-6} g)
mL	milliliter (1×10^{-3} L)	ng	nanogram (1×10^{-9} g)
yd^3	cubic yard	lb	pound
		wt%	weight percent
		Concentration	
		ppb	parts per billion
		ppm	parts per million

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
acre	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	0.035	oz	oz	28.349	g
metric ton	1.1	ton	ton	0.9078	metric ton

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 (e.g., picocuries per liter). 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. Nuclear disintegrations 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 may 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.

Radiological Dose Units

The amount of radiation received by a living organism is expressed in terms of radiological dose. Radiological 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 (to humans). A dose of 1 millirem has a biological effect similar to the dose received from about a 1-day exposure to natural background radiation. An acute (short-term) dose of 100 to 400 rem (100,000 to 400,000 millirem) can cause radiation sickness in humans. An acute exposure to 400 to 500 rem (400,000 to

Table H.3. Names and Symbols for Units of Radioactivity

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

Table H.4. Names and Symbols for Units of Radiation Dose

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

500,000 millirem), if left untreated, has a 50% chance of causing death. Exposure to lower amounts of radiation (1,000 millirem or less) produces no observable effect, but long-term (delayed) effects are not known. For most people, the annual average exposure to naturally produced radiation is around 300 millirem. Medical and dental x-rays and air travel add to this total. (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. The unit "rad," or radiation absorbed dose, is also used in this report. The rad is a measure of the energy absorbed by any material, whereas a rem only relates to both the amount of radiation energy absorbed by humans and its effect on human tissues.

Additional information on radiation and dose terminology can be found in Appendix B, "Glossary." A list of the radionuclides discussed in this report and their half-lives is included in Table H.5.

Chemical and Elemental Nomenclature

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

Understanding the Data Tables

Total Propagated Analytical Uncertainty (Two-Sigma Error)

Some degree of inherent uncertainty is associated with all analytical measurements. This uncertainty is the consequence of a series of minor, often unintentional or unavoidable inaccuracies related to collecting and analyzing the samples. These inaccuracies could include errors associated with reading or recording the result, handling or processing the sample, calibrating the counting instrument, and numerical rounding. With radionuclides, inaccuracies can also result from the randomness of radioactive emissions.

Many of the individual measurements in this report are accompanied by a plus/minus (±) value, referred to as the total propagated analytical uncertainty (or two-sigma error). For samples that are prepared or manipulated in the laboratory prior to counting (counting the number of radioactive emissions from the sample), the total propagated analytical uncertainty includes both the counting uncertainty and the uncertainty connected with sample preparation and chemical separations. For samples that are not manipulated in the laboratory before counting, the total propagated analytical uncertainty only accounts for the uncertainty associated with counting the sample. The uncertainty associated with samples that are analyzed but not counted includes only the analytical process uncertainty.

Table H.5. Radionuclide Nomenclature[a]

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
^{3}H	tritium	12.35 yr	^{137}Cs	cesium-137	30 yr
^{7}Be	beryllium-7	53.44 d	^{152}Eu	europium-152	13.3 yr
^{14}C	carbon-14	5,730 yr	^{154}Eu	europium-154	8.8 yr
^{40}K	potassium-40	1.3×10^{8} yr	^{155}Eu	europium-155	5 yr
^{51}Cr	chromium-51	27.7 d	^{212}Pb	lead-212	10.6 h
^{60}Co	cobalt-60	5.3 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	^{232}Th	thorium-232	1.4×10^{10} yr
^{90}Sr	strontium-90	29.1 yr	U or uranium[b]	uranium total	---
^{95}Zr	zirconium-95	63.98 d	^{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	^{238}U	uranium-238	4.5×10^{9} yr
^{106}Ru	ruthenium-106	368.2 d	^{238}Pu	plutonium-238	87.7 yr
^{113}Sn	tin-113	115 d	^{239}Pu	plutonium-239	2.4×10^{4} yr
^{125}Sb	antimony-125	2.8 yr	^{240}Pu	plutonium-240	6.5×10^{3} yr
^{129}I	iodine-129	1.6×10^{7} yr	^{241}Pu	plutonium-241	14.4 yr
^{131}I	iodine-131	8 d	^{241}Am	americium-241	432.2 yr
^{134}Cs	cesium-134	2.1 yr			

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

The total propagated analytical uncertainty gives information on what the measurement (or result) might be if the same sample were counted again under identical conditions. The uncertainty implies that approximately 95% of the time a recount or reanalysis of the same sample would give a value somewhere between the reported value minus the uncertainty and the reported value plus the uncertainty.

If the reported concentration is smaller then its associated uncertainty (e.g., 40 ± 200), the sample may not contain the radionuclide. Such low concentration values are considered to be below detection, meaning the concentration of the radionuclide in the sample is so low that it is undetected by the method and/or instrument.

Standard Error of the Mean

Just as individual values are accompanied by counting uncertainties, mean values (averages) 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 (e.g., 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. As with total propagated analytical uncertainty, two times the standard error of the mean implies that approximately 95% of the time the next calculated mean will fall somewhere between the reported value minus the standard error and the reported value plus the standard error.

Median, Maximum, and Minimum Values

Median, maximum, and minimum values are reported in some sections of this report. A median value is the middle value when all the values are arranged in order of increasing or decreasing magnitude. For example, the median value in the series of numbers, 1 2 3 3 4 5 5 5 6, is 4. The maximum value would be 6 and the minimum

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^-	nitrite
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
F^-	fluoride	Ti	titanium
Fe	iron	Tl	thallium
HCO_3^-	bicarbonate	V	vanadium
Hg	mercury		

value would be 1. Maximum, minimum, and median values are reported when there are too few analytical results to accurately determine the statistical uncertainty.

Negative Numbers

There is always a small amount of natural radiation in the environment. The instrumentation used in the laboratory to measure radioactivity in Hanford Site environmental media are sensitive enough to measure the natural, or background, radiation along with any contaminant radiation in a sample. To obtain a true measure of the contaminant level in a sample, the natural, or background, radiation level must be subtracted from the total amount of radioactivity measured by an instrument. Because of the randomness of radioactive emissions, and the very low concentrations of some contaminants, it is possible to obtain a background measurement that is larger than the actual contaminant measurement. When the larger background measurement is subtracted from the smaller contaminant measurement, a negative result is generated. The negative results are reported because they are useful when conducting statistical evaluations of the data.

Understanding Graphic Information

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

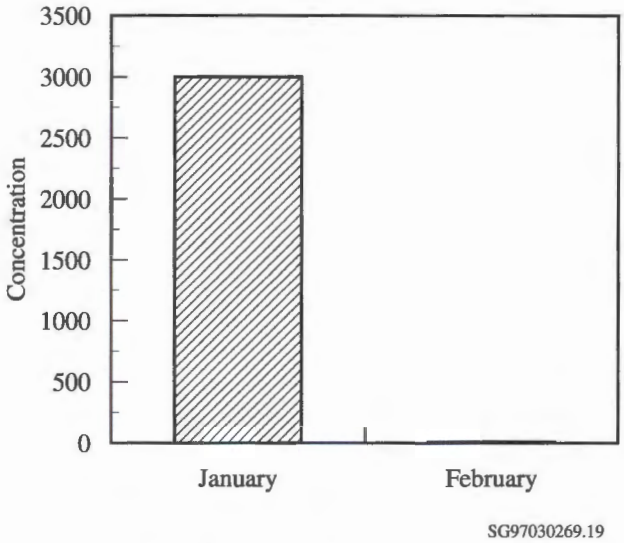

Figure H.1. Data Plotted Using a Linear Scale

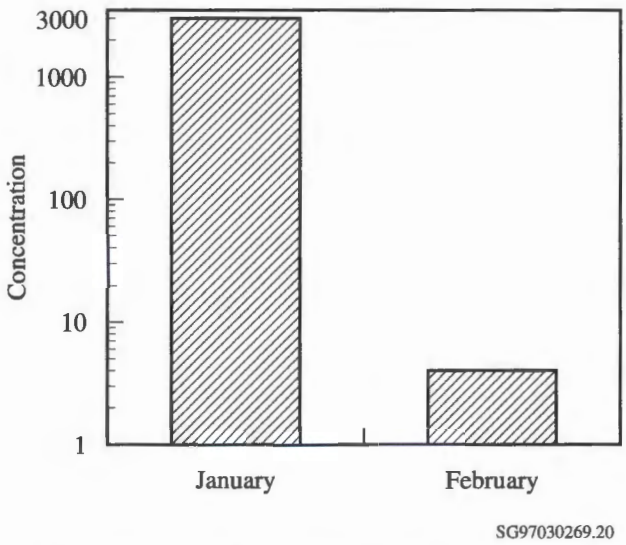

Figure H.2. Data Plotted Using a Logarithmic Scale

The mean (also called average) and median (the middle value when scores are arranged in increasing or decreasing 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 (total propagated analytical uncertainty or 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 that it is less than 0.9, and a 2.5% chance that 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 statistically similar. 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.

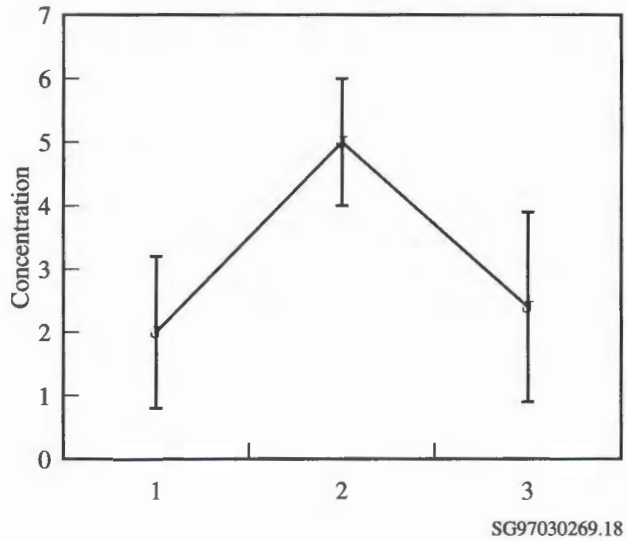

Figure H.3. Data with Error Bars Plotted Using a Linear Scale

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

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.

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.

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Introduction

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1.0 Introduction

This Hanford Site environmental report is produced through the joint efforts of the principal site contractors (Pacific Northwest National Laboratory, Fluor Daniel Hanford, Inc. and its subcontractors, Bechtel Hanford, Inc. and its subcontractors, MACTEC-ERS, and the Hanford Environmental Health Foundation) and other organizations and agencies involved in environmental 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 Groundwater Monitoring Program, the Near-Facility Environmental Monitoring Program, the vadose zone characterization programs, 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 that provided in this report should consult the technical documents cited in the 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 approximately 1,450 km^2 (approximately 560 mi^2) located north of the city of Richland and the confluence of the Yakima and Columbia Rivers. 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 approximately 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 and 24,120 ha (513,700 and 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.

Estimates for 1995 placed population totals for Benton and Franklin Counties at 131,000 and 44,000, respectively (Washington State Office of Financial Management 1995a). When compared to the 1990 census data (U.S. Bureau of the Census 1994) in which Benton County had 112,560 individuals and Franklin County's population totaled 37,473 individuals, the current population totals reflect the continued growth occurring in these two counties.

Within each county, the 1995 estimates distributed the Tri-Cities population as follows: Richland 36,270, Pasco 22,500, and Kennewick 48,130. The combined populations of Benton City, Prosser, and West Richland totaled 13,320 in 1995. The unincorporated population of Benton

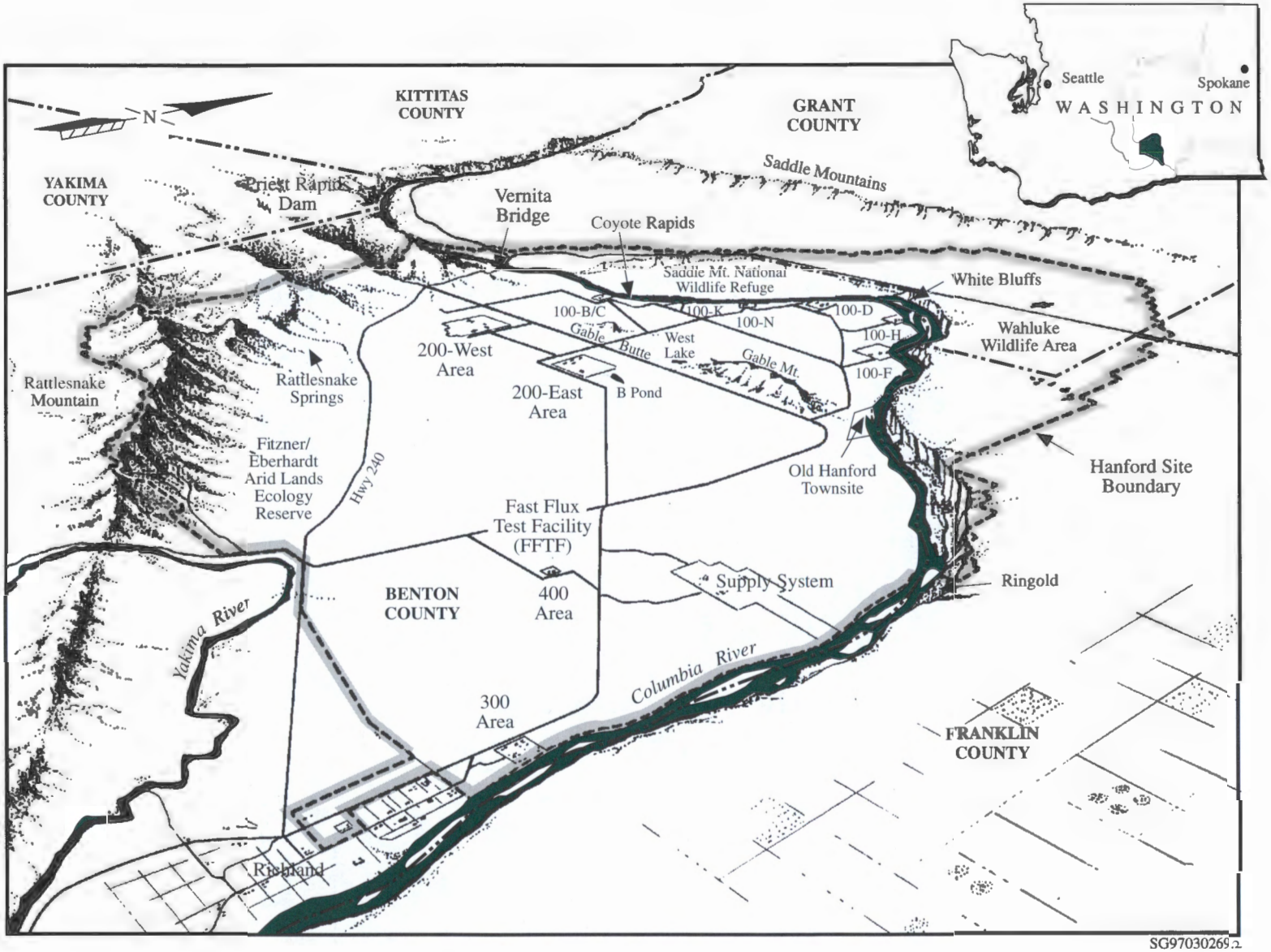

Figure 1.0.1. The Hanford Site and Surrounding Area

County was 33,280. In Franklin County, incorporated areas other than Pasco have a total population of 3,230. The unincorporated population of Franklin County was 18,270 (Washington State Office of Financial Management 1995a).

The 1994 estimates of racial categories (Washington State Office of Financial Management 1994) indicate that Asians represent a lower proportion and individuals of Hispanic origin represent a higher proportion of the racial distribution in Benton and Franklin Counties than those in Washington State.

Benton and Franklin Counties account for 3.2% of Washington State's population (Washington State Office of Financial Management 1995b). In 1995, the population demographics of Benton and Franklin Counties were quite similar to those found within Washington State. The population in Benton and Franklin Counties under the age of 35 was 55%, compared to 51% for the state. In general, the population of Benton and Franklin Counties was somewhat younger than that of the state. The 0- to 14-year-old age group accounted for 26.8% of the total bicounty population as compared to 22.8% for the state. In 1995, the 65-year-old and older age group constituted 9.7% of the population of Benton and Franklin Counties compared to 11.6% for the state.

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 nine retired plutonium production reactors, including the dual-purpose N Reactor. The 100 Areas occupy approximately 11 km^2 (4 mi^2).

- The 200-West and 200-East Areas are located on a plateau and are approximately 8 and 11 km (5 and 7 mi), respectively, south of the Columbia River. The 200 Areas cover approximately 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 approximately 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, and 400 Areas.

Support areas near the site in north Richland include the 1100 and Richland North Areas. The 1100 Area includes site support services such as general stores and transportation maintenance. 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 Area. During 1996, the 3000 Area was cleaned up and vacated by DOE and its contractors. All land and facilities within the area were turned over to the Port of Benton and the 3000 Area designation was retired.

Other facilities (office buildings) 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 U.S. 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. Planning is currently under way to transfer management of the Fitzner/Eberhardt Arid Lands Ecology Reserve from the DOE to the U.S. Fish and Wildlife Service. That plan calls for the eventual designation of the reserve as part of the National Wildlife Refuge system.

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 for gravitational wave studies.

Much of the above information is from Neitzel (1996), where more detailed information can be found.

Historical Site Operations

The Hanford Site was established in 1943 to use technology 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. The site was selected by the U.S. Army Corps of Engineers because it was remote from major populated areas and had 1) ample electrical power from Grand Coulee Dam, 2) a functional railroad, 3) clean water from the nearby Columbia River, and 4) sand and gravel that could be used for constructing large concrete structures. For security, safety, and functional reasons, the site was divided into numbered areas (see 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 transuranic 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 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 sent to process trenches or shipped to a solar evaporation facility in the 100-H Area (183-H Solar Evaporation 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 (Section 4.8, "Groundwater Protection and Monitoring Program," Figures 4.8.23, 4.8.24, 4.8.25, and 4.8.26). 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

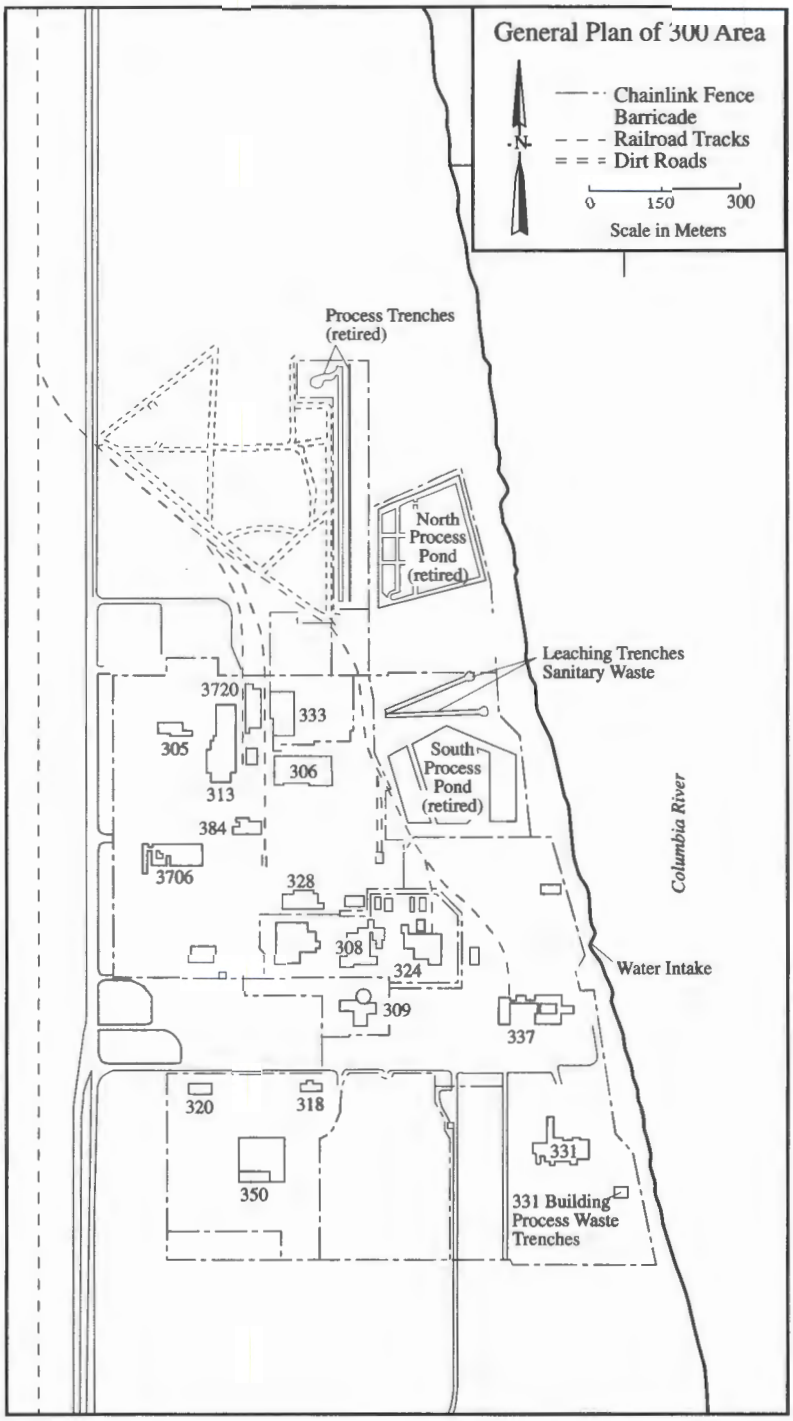

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Figure 1.0.2. The 300 Area, Located Just North of Richland

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, the irradiated fuel was shipped to the 200 Areas for processing. The fuel was shipped in casks by rail in specially constructed railcars. Most of the irradiated fuel produced by the N Reactor from the early 1970s to the early 1980s was the result of electrical production runs. This material was not weapons grade, so was never processed for recovery of plutonium.

Beginning in 1975, N Reactor irradiated fuel was shipped to the K East and K West Fuel Storage Basins for temporary storage where it remains today. This fuel accounts for the majority of the total fuel inventory currently stored underwater in the K Basins. From the early 1980s until its shutdown in 1987, the N Reactor operated to produce weapons-grade material. Electrical production continued during this operating period but was actually a byproduct of the weapons production program. The majority of weapons-grade material produced during these runs was processed in the 200-East Area at the Plutonium-Uranium Extraction Plant prior to its shutdown. The remainder is stored in the K Basins.

The 200 Areas

The 200-East and 200-West Areas are located on a plateau approximately 11 and 8 km (7 and 5 mi), respectively, south of the Columbia River. These areas house 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 solutions containing ammonium hydroxide/ammonium nitrate/ammonium fluoride 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 that contained 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 site 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 discharged to the soil in covered trenches at the BC Cribs area south of the 200-East Area. Cooling water and steam conden sates 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 Reduction-Oxidation Plant and Plutonium-Uranium Extraction Plant used solvent extraction techniques to separate plutonium from leftover uranium and radioactive waste products. Most of the irradiated fuel produced at the site was processed at either of these two plants. 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)

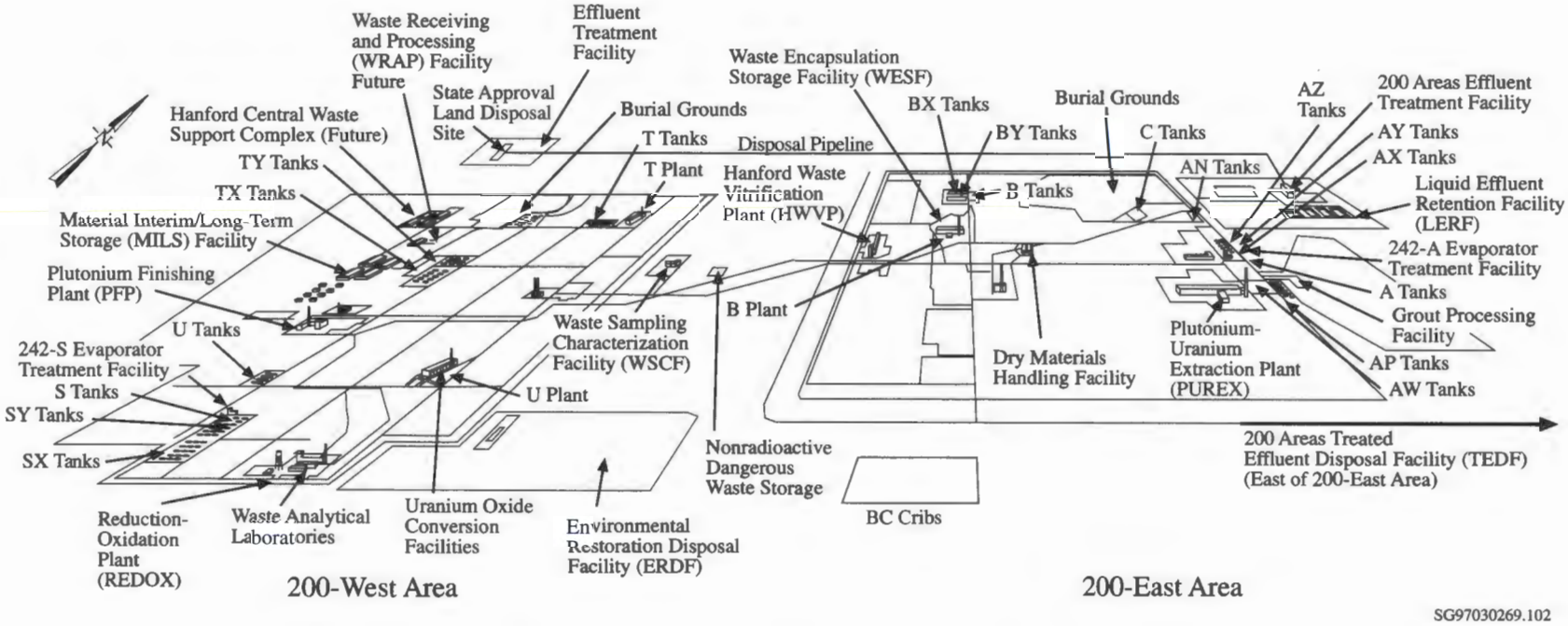

Figure 1.0.3. Waste Storage and Disposal Facilities in the 200 Areas

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. 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 the soil 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 S 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 weapons 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 separations 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 Z Plant (later called the Plutonium Finishing Plant) for further processing.

The purpose of Plutonium Finishing Plant operations was to convert the plutonium nitrate into plutonium metal blanks (buttons) that were manufactured offsite 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 Plutonium Finishing Plant was discharged via open ditch to U Pond. High-level solid 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 is the Fast Flux Test Facility located approximately 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 approximately 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. The facility is presently under consideration for a short-term mission in the production of tritium. Tritium, a necessary ingredient in some nuclear weapons, decays relatively quickly so must be replenished. The production of medical isotopes is also under consideration as a long-term mission. Medical isotopes are radioactive elements that are useful for the treatment of medical conditions such as cancer.

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 site have focused on developing new waste treatment and disposal technologies and cleaning up contamination left over from historical operations.

The current site mission includes the following:

- **management of wastes** and the handling, storage, and disposal of radioactive, hazardous, mixed, or sanitary wastes from current operations

- **stabilizing facilities** by transferring them from an operating mode to a surveillance and maintenance mode

- **maintenance and cleanup** of several hundred inactive radioactive, hazardous, and mixed waste disposal sites (there are over 2,200 waste sites of all kinds at Hanford); remediation of contaminated groundwater; and **surveillance, maintenance, and decommissioning** of inactive 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 the following:

- Fluor Daniel Hanford, Inc., the management and integration contractor, is the prime contractor under the Project Hanford Management Contract awarded in 1996. The Project Hanford Management Contract encompasses the majority of the work under way at the Hanford Site as it relates to DOE's mission to clean up the site. Major subcontractors of Fluor Daniel Hanford, Inc. and their areas of responsibility are as follows.

  - Lockheed Martin Hanford Corporation - responsible for tank waste remediation systems. With 177 underground waste containment tanks at the site, they will ascertain the contents and determine what is to be done with the materials.

  - Waste Management Federal Services of Hanford, Inc. - responsible for waste management. They will use existing technology to accelerate treatment and disposal of waste, reduce the need for waste storage, and minimize waste disposition.

  - DE&S Hanford, Inc. - responsible for the spent fuel project. This project will address the cleanup efforts associated with the waste and fuel rods stored in the K Basins.

  - B&W Hanford Company - responsible for the facility stabilization project. They will examine contaminated structures and make the appropriate recommendations as to the best remedial actions.

  - Numatec Hanford Corporation - responsible for technology implementation and nuclear engineering. They will provide application technology as needed to all cleanup contractors.

  - DynCorp Tri-Cities Services, Inc. - responsible for infrastructure services. They will provide nonnuclear-related support in the areas of site operation, property management, utilities, facility maintenance, and site services.

- 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 surveillance and maintenance of inactive past-practice waste sites and inactive facilities; remediation of past-practice waste sites and contaminated groundwater; closure of Resource Conservation and Recovery Act land-based treatment, storage, and disposal units; and decontamination and decommissioning of facilities. The Bechtel Team includes two preselected subcontractors: CH2M Hill and ThermoAnalytical, Inc.

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

- MACTEC-ERS is a prime contractor to DOE Grand Junction Office and is performing vadose zone characterization and monitoring work beneath single-shell underground waste storage tanks in the 200 Areas.

In addition, several enterprise companies were created to provide services to Fluor Daniel Hanford, Inc. and its six

major subcontractors. These enterprise companies and their areas of responsibility include the following:

- B&W Protec, Inc. - provides safeguard and security services, including material control and accountability, physical security, information security, and other security activities.

- SGN Eurisys Services Corporation - provides engineering and technical support in the areas of tank waste remediation systems engineering and construction, spent fuel conditioning, and engineering testing and technology.

- Lockheed Martin Services, Inc. - provides telecom munications and network engineers, information systems, production computing, document control, records management, and multimedia services.

- Fluor Daniel Northwest, Inc. - provides a variety of professional services to the subcontractors, including construction, engineering, finance, accounting, and materials management.

- DE&S Northwest - provides nuclear and nonnuclear services in the area of quality assurance and related activities.

- Waste Management Federal Services, Inc. Northwest - provides air and groundwater sampling, well installation and maintenance, permit modification, groundwater modeling, and geophysical evaluations.

Major Operations and Activities

Waste Management

Current waste management activities at the site include the management of high- and low-level defense wastes in the 200-East and 200-West Areas (see 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, K Basins, Environmental Restoration Disposal Facility, Plutonium Finishing Plant, B Plant/Waste Encapsulation Storage Facility, T Plant, Effluent Treatment Facility, Central Waste Complex, Transuranic Storage and Assay Facility, 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. Concerns had been raised about the potential for explosions from ferrocyanide and/or organic fuels or hydrogen gas accumulation in the waste tanks. DOE and external oversight groups have concluded that there is no imminent danger to the public from either situation. Lockheed Martin Hanford Corporation 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 K Basins are currently being used to store N Reactor irradiated fuel. In 1995, the strategy for transitioning irradiated fuel from wet storage in these basins to dry interim storage in the 200-East Area was further developed. This strategy supports completion of fuel removal from the K Basins 3 years ahead of the target date of December 2002 (agreed to by DOE and the regulators).

The Plutonium-Uranium Extraction Plant formerly processed irradiated reactor fuel to extract plutonium and uranium. Plant operation was stopped in December 1988. From December 1989 through March 1990, the plant completed a stabilization run to process the fuel remaining in the plant. After the stabilization run, the plant began a transition to a "standby condition." In December 1992, DOE directed the plant 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 has been flushed from the plant.

The Plutonium Finishing Plant 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 while awaiting 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, emptying of shipping containers, and development testing were completed in 1995. Future plans are to complete stabilization and cleanout of the Plutonium Finishing Plant.

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 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 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 200 Areas Effluent Treatment Facility, which started operations in November 1995. The concentrated waste from the evaporator is returned to the double-shell tanks. The 200 Areas Effluent Treatment Facility was constructed near the 200-East Area to remove regulated chemical constituents from the 242-A Evaporator process condensate. The effluent treatment facility is also being used to treat effluent removed from facilities being deactivated and for the treatment of groundwater. The recovered chemicals are packaged in 208-L (55-gal) drums and transferred to the Central Waste Complex. The treated effluent is discharged to the state-approved land disposal site located north of the 200-West Area.

Solid waste is received at the Central Waste Complex from all radioactive waste generators at the Hanford Site and any offsite generators 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 at least the year 2001, 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 (operations began 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 and low-level wastes 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 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 repackaging 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 and 1996, 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).

Facility Stabilization

The Facility Stabilization Project mission is to transfer those Hanford Site facilities for which it has responsibility from an operating mode to a surveillance and maintenance mode. This includes providing for the safe storage of nuclear materials and reducing risks from hazardous materials and contamination. The project will also conduct the deactivation of primary systems to effectively reduce risks to human health and the environment. These activities will allow the lowest surveillance and

maintenance cost to be attained while preparing the facilities for final disposition under the Environmental Restoration Project.

Presently, the Facility Stabilization Project is engaged in five major deactivation projects at Hanford. Each is in a different stage of completion, and each presents a host of technical and management challenges. The major projects are the Plutonium-Uranium Extraction Plant, the Plutonium Finishing Plant, B Plant/Waste Encapsulation and Storage Facility, 300 Area Stabilization, and the Advanced Reactors Transition.

Environmental Restoration

Environmental Restoration Project activities include surveillance and maintenance and decontamination and decommissioning of facilities; surveillance, maintenance, characterization, and cleanup of inactive waste sites; and monitoring and remediation of contaminated groundwater.

The Decontamination and Decommissioning Project conducts surveillance and maintenance of inactive/surplus facilities awaiting decommissioning, provides for the transition of surplus facilities from other programs into the Decontamination and Decommissioning Project, conducts asbestos abatement sitewide, and does the actual decommissioning/demolition of buildings.

The surveillance and maintenance activities associated with the inactive 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 200 facilities in the program.

The Radiation Area Remedial Action Project is responsible for the surveillance, maintenance, and decontamination or stabilization of approximately 400 inactive waste sites on the Hanford Site. These include cribs, ponds, ditches, trenches, unplanned release sites, and burial grounds. These sites are maintained by performing periodic surveillances, radiation surveys, herbicide applications, and by initiating timely responses to identified problems. The overall objective of this project is to maintain these sites in a safe and stable configuration until final remediation strategies are identified and implemented. The main focus of this objective is to prevent the contaminants contained in these sites from spreading in the environment.

The Remedial Action Project is responsible for conducting the actual cleanup of contaminated inactive waste sites. The groundwater project is responsible for monitoring and remediating contaminated groundwater resulting from past releases at inactive waste sites and other Hanford Site operations.

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.

Surface barrier testing and monitoring continue at the Hanford Site. The Environmental Restoration Program constructed a prototype surface barrier in 1994, which is now in its third year of rigorous testing. The major phase of testing is scheduled for completion in September 1997. The barrier is intended to prevent intrusion of water into underground waste and covers an actual waste crib located in the 200-BP-1 Operable Unit in the 200-East Area. Despite 2 years of above-normal precipitation and an imposed irrigation treatment (totaling three times the long-term average precipitation), there has been no net infiltration (drainage) of water through the soil barrier. Vegetation established on the surface of the barrier has been effective in removing all available precipitation and test water. The barrier has been stable, exhibiting no settlement during the 2 years of testing. Wind and water erosion and biotic intrusion also have been minimal. The only measurable erosion occurred during the first 3 months of operation, when soil surfaces were bare. In contrast to barrier soil surfaces, gravel and rock side slopes, which are nearly free of vegetation, have experienced significant drainage. While advective drying of the rock surfaces has reduced drainage well below that which was expected, the drainage has amounted to 40% or more of the winter precipitation. Barrier testing suggests that vegetation on the side slopes may be important for final design. Studies will continue through fiscal year 1997 to document water balance parameters, erosion losses, biotic intrusion, and side slope performance.

Initial field testing of an in situ groundwater cleanup technology, called redox manipulation, was performed during 1995. An injectable redox barrier using sodium dithionite as the reductant was successfully tested in the 100-H Area to address chromate contamination. During 1996, monitoring activities at the In Situ Redox Manipulation Field Site continued with favorable results. Oxygen and hexavalent chromium have remained below detection limits in the test zone for more than a year following the test injection. Concentrations of mobilized trace metals and sulfate have also continued to decrease during this time. Monitoring of the site will continue during 1997. Effects of the test injection on concentrations downgradient of the test site will be studied as the normal groundwater gradient reestablishes itself following the high Columbia River water levels in 1996.

DOE's Tanks Focus Area tested and demonstrated a mobile robotic system called the Light-Duty Utility Arm. This system can position a variety of scientific instruments, cameras, and small-scale retrieval devices within the underground radioactive waste storage tanks. The arm was officially transferred from the developers to the first set of users, the Tanks Waste Remediation System Characterization Program on September 10, 1996. On September 27, the arm was deployed into Tank 241-T-106 with a high-resolution stereographic video system to inspect the tank dome, risers, and walls. Valuable inspection data were recorded. In addition to its uses at the Hanford Site, the system will be used for studies at two other DOE sites: the Waste Heel Removal Project at the Idaho National Engineering and Environmental Laboratory and the Gunite and Associated Tanks Treatability Study at Oak Ridge National Laboratory.

The Light-Duty Utility Arm will be used as part of the Hanford Tanks Initiative. By the year 2000, this initiative is scheduled to 1) retrieve hard heel (solid) waste from Tank 241-C-106 and establish retrieval performance criteria, 2) develop retrieval performance criteria supporting readiness to close single-shell tanks, 3) demonstrate characterization technologies, 4) demonstrate alternate retrieval technologies, and 5) establish risk/performance data for waste retrieval options. This project was formed by the Tanks Focus Area and Tank Waste Remediation System.

The Laser Ablation/Mass Spectrometer System uses a chemical analysis method that can determine the amount of most elemental/isotopic constituents in tank waste samples without sample preparation. Developed and produced by the Pacific Northwest National Laboratory, Westinghouse Hanford Company, and ICF Kaiser Hanford Company, this tool will reduce the time and costs required to analyze tank waste core samples. In September 1996, the system was deployed in an analytical chemistry laboratory hot cell at the Hanford Site.

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 1996 effluent monitoring and waste management and chemical inventory programs are summarized in Section 3.1, "Facility Effluent Monitoring," and Section 3.4, "Waste Management and Chemical Inventories."

Near-Facility Environmental Monitoring Program

The Near-Facility Environmental Monitoring Program is responsible for facility-specific environmental monitoring immediately adjacent to onsite facilities. 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 and waste management and restoration activities and to monitor emissions from diffuse/fugitive sources. Results for the 1996 programs are summarized in Section 3.2, "Near-Facility Environmental Monitoring."

Tank Farms Vadose Zone Baseline Characterization Project

This project is tasked with characterizing and establishing baseline levels of manmade radionuclides in the vadose zone beneath the single-shell tanks in the 200 Areas. The primary objective of the project is to detect and identify gamma-emitting radionuclides and

determine their concentrations. Results for the 1996 vadose zone characterization project are summarized in Section 3.3, "Vadose Zone Characterization and Monitoring."

Sitewide Environmental Surveillance and Groundwater Monitoring Programs

The main focus of the sitewide environmental surveillance program 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 1996 sitewide environmental surveillance program are summarized in Section 4.0, "Environmental Surveillance Information."

Extensive groundwater monitoring is conducted onsite to document the distribution and movement of groundwater contamination, to assess the movement of contamination into previously uncontaminated areas, to protect the unconfined aquifer from further contamination, and to provide an early warning when contamination of groundwater does occur. Sampling is also conducted to comply with state and federal requirements. A description of the monitoring program and a summary of the monitoring results for 1996 are described in Section 4.8, "Groundwater Protection and Monitoring Program."

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

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2.0 Environmental Compliance Summary

This section briefly describes how environmental compliance is being achieved for the Hanford Site. Included are subsections describing 1) 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 occurrences.

It is the stated policy of DOE that all activities be carried out in compliance with all applicable local, state, and federal environmental laws and regulations, DOE Orders, Secretary of Energy Notices, DOE Headquarters and Richland Operations Office directives, policies and guidance. This includes those specific requirements, actions, plans, and schedules identified in the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement; Ecology et al. 1989) and other compliance or consent agreements. The DOE Richland Operations Office recognizes the importance of maintaining a proactive program of self-assessment and regulatory compliance reporting to ensure that environmental compliance is achieved and maintained at the Hanford Site.

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2.1 Stakeholder and Tribal Involvement

D. G. Black

Many entities have a role in DOE's mission of environmental restoration and waste management. Stakeholders include local, state, and federal regulatory agencies; environmental groups; regional communities; Indian tribes; and the public. 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 local, state, and federal government agencies are responsible for monitoring and enforcing compliance with applicable environmental regulations at the Hanford Site. The major agencies include the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology, Washington State Department of Health, and 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. DOE, through compliance audits and its directives to field offices, initiates and assesses actions for compliance with environmental requirements. The primary requirements address environmental air quality, water quality, land use, cultural resources, and waste management.

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 certain enforcement authorities 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 operating agencies as provided by federal law. For example, the Washington State Department of Health has direct authority under the Clean Air Act to enforce the federal program for regulating radionuclide air emissions at the Hanford Site. Where federal 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. There is also 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.

Hanford Federal Facility Agreement and Consent Order

The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement; Ecology et al. 1989) is an agreement among the Washington State Department of Ecology, EPA, 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.

The Tri-Party Agreement has continued to evolve as cleanup of the Hanford Site has progressed. Significant changes to the Tri-Party Agreement have been negotiated between the Washington State Department of Ecology, the EPA, and the DOE to meet the changing conditions and needs of the cleanup. The most complex changes were worked out in 1993 with further modifications each year since. All significant changes to the Tri-Party Agreement undergo a process of public involvement that ensures the communication and addressing of the public's values prior to final approvals. Copies of the Tri-Party Agreement are publicly available at the DOE's Hanford Reading Room located on the campus of Washington State University at Tri-Cities, 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 at 1-800-321-2008. Requests by mail can be sent to:

Hanford Mailing List: Informational Mailings
P.O. Box 1000 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 support a number of Native American foods and medicines and is the location of sacred places that are important in sustaining tribal cultures. The tribes hope to use these resources in the future and want to assure themselves that the Hanford environment is clean and healthy.

The DOE American Indian Policy (DOE Order 1230.2) states, "American Indian Tribal Governments have a special and unique legal and political relationship with the Government of the United States, defined by history, treaties, statutes, court decisions, and the U.S. Constitution." In recognition of this relationship, DOE and each tribe interact and consult directly. 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, the Hanford Site Technology Coordination Group as well as informal groups working on issues such as the Columbia River Comprehensive Impact Assessment, land use planning, and cultural resources. The tribes have made presentations to DOE and the contractors on treaty rights, tribal sovereignty, the United States 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 (40 CFR 300.600) authorizes state governors to designate a state lead trustee to coordinate all state trustee responsibilities. The 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 the 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 the state of Washington 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 framework for integrated communications and public involvement for the Hanford Site outlines the DOE commitment to and plan for involving the public in decisions. DOE's Richland Operations Office of External Affairs is responsible for establishing the planning and scheduling of 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 public information and involvement activities are conducted for Tri-Party Agreement decisions. The Community Relations Plan was developed and negotiated among DOE, Washington State Department of Ecology, and EPA Region 10 with public comment and was jointly approved in 1990. The 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 is also 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 DOE's Richland Operations Office of External Affairs at (509) 376-7501.

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 many advisory groups created by DOE at weapons production cleanup sites across the national DOE complex. The Board comprises 32 members who 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, groundwater monitoring and remediation, releases to the Columbia River via N Springs, worker health and safety, local economic transition issues, and public involvement.

Hanford Site Technology Coordination Group

In November 1989, the DOE Headquarters' 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 four major problem areas (subsurface contaminants, 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) subsurface contaminants, 2) tanks, 3) mixed waste, and 4) decontamination and decommissioning.

The Management Council is chaired by DOE's 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 Tribe, and the Confederated Tribes of the Umatilla Indian Reservation. The site management and integration contractor, the environmental restoration contractor, and the site research-and-development contractor each have 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 the following:

- 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.

As of early 1997, activities of the Hanford Site Technology Coordination Group resulted in $18 million of leveraged funds between the site and the DOE Headquarters Office of Science and Technology for demonstration and deployment projects. The group was instrumental in securing funding for the tanks initiative, C Reactor interim safe storage, and several other technology proposals.

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2.2 Compliance Status

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This section summarizes the activities conducted to ensure that the Hanford Site is in compliance with federal environmental protection statutes and related state and local environmental protection regulations. Also discussed is the status of 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, 1996 Performance

The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement; Ecology et al. 1989) was signed on May 15, 1989 by the DOE, the EPA, and the Washington State Department of Ecology. The Tri-Party Agreement is a legally enforceable document that establishes a schedule and framework for the cleanup of the Hanford Site. Specifically, the Tri-Party Agreement commits the DOE to achieve compliance 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 including the state's implementing regulations.

In 1996, there were 64 specific cleanup commitments scheduled for completion under the terms of the Tri-Party Agreement. All 64 commitments were completed on or before their required due dates.

From 1989 through 1996, a total of 512 enforceable Tri-Party Agreement milestones and 223 unenforceable target dates had been completed on or ahead of schedule. Two enforceable milestones were missed and five were completed later than scheduled.

Highlights of the work accomplished in 1996 under the terms of the Tri-Party Agreement are listed in Section 2.3, "Accomplishments and Issues."

Environmental Management Systems Development

On October 1, 1996, Fluor Daniel Hanford, Inc., the new site management and integration contractor, signed a letter of commitment to support the DOE Richland Operations Office request that it develop an environmental management system at the Hanford Site. This system is to be consistent with the principles of the International Organization of Standards (ISO) 14000-series of standards (Cascio 1996).

An environmental management system provides a systematic approach by organizations to develop an environmental policy and to fulfill commitments made in the policy. Through planning, implementation, checking, management review, and continuous improvement, organizations become more efficient in managing their environmental activities.

The ISO 14001 standard (American Society for Testing and Materials 1996) is one of several tools available in the series for specific guidance on development of an environmental management system and shares common management system principles with the ISO 9000-series of quality system standards (Peach 1997). The difference is that ISO 9000 addresses quality and customer needs, whereas ISO 14000 addresses the needs of a broad range of interested parties for environmental protection. Another tool similar to the ISO 14000-series being pursued by the Hanford Site includes the interagency voluntary protection program.

Because the Hanford Site has been closely regulated by environmental agencies and the DOE, many environmental management system elements are in place. It may be possible to develop an ISO 14001-consistent environmental management system by adapting the existing management system elements. To evaluate management system elements that exist under the Fluor Daniel Hanford, Inc. umbrella against the ISO 14001 standard, a gap analysis

was conducted by Hanford contractors in late 1996, and a needs assessment report was generated for Fluor Daniel Hanford, Inc. and its major subcontractors. The information collected for the gap analysis and needs assessment is being combined with a schedule for use in developing an environmental management system implementation plan for the Hanford Site. The final plan is scheduled for submittal to DOE by July 1, 1997.

The environmental restoration contractor is reviewing its existing management system to evaluate its elements against the ISO 14001 standard. The gap analysis and needs assessment are being combined and will result in an environmental management system implementation plan by July 1997. The plan will recommend actions and responsibilities for bringing the environmental management system into conformance with the ISO 14001 standard.

The research-and-development contractor evaluated its environmental management system against ISO 14001 standards in 1996 and a gap analysis was prepared. The system includes values of the ISO 14001 standard as well as the Chemical Manufacturer's Association's Responsible Care® program. Battelle Memorial Institute, which operates the Pacific Northwest National Laboratory for the DOE, has partner status in Responsible Care®. System improvements have been identified through the gap analysis. The Pacific Northwest National Laboratory's system, while separate, will coordinate with the environmental management system being developed by the management and integration contractor.

Environmental Performance Indicator Program

The environmental performance indicator program is in development as part of the Integrated Safety Management System Plan scheduled for completion in late fiscal year 1997. The program will be finalized for integration with the plan, and will be reviewed and revised accordingly. The environmental performance indicator program is based on the development of an "environmental event" definition that can be used to implement environmental performance measures to support an effective environmental protection program. The approach is to establish a baseline of environmental events. This baseline will provide a means to evaluate the premise that a relationship exists between the number of lesser environmental events or "questionable practices" and the number of significant environmental events (i.e., the greater the number of questionable practices, the greater the probability of a more significant event). An environmental event is defined as any event that if allowed to persist or escalate would result in one or more of the following actions or circumstances:

- threaten public health and safety
- result in an environmental occurrence report being generated (DOE Order 232.1)
- be placed on a facility's open item (uncompleted action) list
- be placed on a facility status report (e.g., Plutonium Finishing Plant Morning Status Report)
- be reported on an internal or external facility inspection or evaluation report as a finding or an observation
- be placed on the Hanford Action Tracking System
- be a potential threat to an environmental/ecological resource, regardless of the severity
- trigger any local, state, or federal reporting requirement or action level; or, otherwise raise interest or concern of such agencies.

An example of a questionable practice would be continuous, small, nonreportable spills or releases such as with petroleum products. Securing a commitment by all employees to look for questionable practices is a key aspect of bringing about an environmental step change at the Hanford Site. If all employees become sensitive to a condition that might develop into a more significant environmental event and early mitigation action taken, progression to a more significant event would be prevented. In addition to heightening employee awareness, it is expected that questionable practices also would routinely be identified through an evaluation of self-assessment, regulatory inspection, or formal audit results and by environmental information collection and trending. More significant environmental events or consequences could include regulatory reportable events, notice of correction, notice of violation, fines, and penalties.

The incentive fee paid to the Pacific Northwest National Laboratory in 1996 was tied to a number of performance

indicators set by DOE. Several of these indicators were related to environmental performance, including some innovative "leading" indicators (i.e., indicative of future performance) such as waste reduction in several different waste categories and correction of previously identified waste management noncompliances. Fees paid to the management and integration contractor are based on meeting performance agreements. These agreements cover specific actions required to proceed with the site's cleanup mission. This fee payment concept began with contract transition in October 1996.

Environmental Information Collecting and Trending

To initiate the environmental information collection and trending aspect of this approach, information for the following environmental events will initially be collected and trended:

- all spills/releases/permit exceedances
- notices of correction/notices of violation
- environmental occurrences (as defined by DOE Order 232.1)
- Resource Conservation and Recovery Act permit facility-wide inspection findings
- 90-day accumulation area time extensions.

Attention must be given to the cumulative impact of increasing questionable practices. A small increase in each of these may not appear significant unless added together. Therefore, information on these events will be collected individually but reported collectively on one control chart. Initially, spills and releases also will be reported separately for special attention and to limit overshadowing of the other events. Explanations for trends will be addressed individually, as warranted.

Periodically, the environmental event list subject to information collection and trending will be evaluated and modified if necessary. Before any changes are made to the list, a review will be requested from project and line management so that any resource and/or schedule impacts can be fully assessed and planned for.

Comprehensive Environmental Response, Compensation, and Liability Act

Environmental Restoration Disposal Facility

The July 1996 opening of the Environmental Restoration Disposal Facility, 3 months ahead of schedule, was a major step toward full-scale cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act. The 1.5-million-m^3 (2.0-million-yd^3) earthen facility is located near the 200-West Area and is constructed with double liners and a leachate collection system. The facility will serve as a central disposal site for contaminated soil generated during the Hanford cleanup. Wastes generated during site investigations, decontamination and decommissioning of facilities, and Resource Conservation and Recovery Act sites undergoing closure can be disposed of at the facility in accordance with a Comprehensive Environmental Response, Compensation, and Liability Act record of decision or action memorandum.

Waste Site Remediation Projects

Full-scale remediation of waste sites began in the 100 Areas in 1996. Early in the year, a design for remediation of wastes in the 100-B,C Area was completed based on Record of Decision (1995), followed by the completion of designs for remediation of waste sites in the 100-D and 100-H Areas and for additional sites in the 100-B,C Area. Remediation of liquid waste disposal sites in the 100-B,C Area occurred throughout the year, and remediation of similar sites in the 100-D Area began in November. In 1996, 87,000 metric tons (96,000 tons) of contaminated soil had been excavated from sites in the 100-B,C and 100-D Areas and disposed of at the Environmental Restoration Disposal Facility. In addition, nearly 3,100 m^3 (4,100 yd^3) of contaminated soil excavated as part of a test in 1995 to see if waste was treatable were disposed of at the facility.

A plan proposing excavation of contaminated soils at liquid waste disposal sites in the 300 Area was issued for public review. In July, Record of Decision (1996a) was

signed and design for remediation was initiated. Additional evaluations are under way to address solid waste disposal sites in the 300 Area.

Groundwater Projects

Chromium-contaminated groundwater that underlies portions of the 100-D, 100-H, and 100-K Areas (the 100-HR-3 and 100-KR-4 Operable Units) is of potential concern to the Columbia River ecosystem and prompted an interim remedial measure to address the movement of chromium to the river. Chromium is toxic to aquatic organisms, particularly those that use the riverbed sediment as habitat (e.g., fall chinook salmon) (DOE 1995b, 1995c). In 1994, a groundwater extraction system was installed in the 100-D Area to test chromium removal using ion exchange technology. An interim Record of Decision (1996b) was signed that approved full-scale implementation of groundwater extraction and chromium treatment systems in the three areas. The test system continued to operate until September 1996 when it was shut down to allow construction of the full-scale systems (DOE 1995d). From January through September 1996, the test system treated 17.6 million L (4.6 million gal) of contaminated groundwater and recovered 14 kg (31 lb) of chromium. Construction of the full-scale systems began in October 1996 and is expected to be completed in 1997. Extensive performance monitoring will be conducted to determine how effectively and efficiently the systems are working at removing chromium from the aquifer. Information gained from experience with this interim remedial measure will be used to help select a final remediation alternative for groundwater underlying the 100 Areas.

As part of the remedial investigations being conducted under the Comprehensive Environmental Response, Compensation, and Liability Act, groundwater samples have been obtained from a variety of sampling locations along the Columbia River shoreline. Most attention to date has been focused on chromium-contaminated groundwater in the 100-D,DR and 100-H Areas. The Columbia River along these areas provides distinctive riverbed materials for salmon to use as spawning habitat (Dauble and Watson 1990). Early life stages of salmon are susceptible to the toxic effects of chromium. Alevin that emerge from the eggs and remain in riverbed sediment are particularly vulnerable to contamination carried by groundwater, which discharges into the river through the riverbed.

Environmental restoration decisions regarding the need for interim remedial measures to protect the river from chromium contamination were being developed in 1995. A field project was started in early 1995 to obtain better insight on chromium contamination that is carried into the river environment by groundwater flow. Divers emplaced sampling tubes into the riverbed sediment and collected samples of sediment pore water, which was analyzed for hexavalent chromium–the most toxic variety. Sampling tubes were also emplaced at multiple depths in the aquifer at adjacent shoreline locations. With these new observational data, it became possible to describe chromium contamination along the entire pathway, from Hanford Site sources, across the shoreline region, and on to the point of exposure by a sensitive receptor.

Initial field activities were conducted along the 100-H Area shoreline and consisted primarily of collecting riverbed sediment pore water (Hope and Peterson 1996a). A second, more comprehensive phase of the project was conducted in the 100-D,DR Area during October and November 1995 (Hope and Peterson 1996b). Hexavalent chromium at concentrations exceeding the EPA's 11-µg/L ambient water quality criteria (EPA 1996) for protection of aquatic organisms was found at several locations in each reactor area. The majority of substrate sampling sites did not reveal chromium contamination at the 46-cm (18-in.) sediment depth sampled. Chromium concentrations in shoreline aquifer sampling tubes adjacent to the elevated substrate sampling sites also exceeded the 11-µg/L standard and, in some cases, the EPA maximum contaminant level for drinking water (100 µg/L) (EPA 1996).

The field work in the 100-D,DR Area confirmed the previously poorly characterized area of contamination along the shoreline in the western part of the area. It has been suggested that chromium was moved into this area during the reactor operating years, when large mounds were created on the natural water table by the disposal of reactor coolant (Connelly 1997). A new monitoring well has been installed (well 199-D4-1) to better define the nature and extent of this contamination, and four additional wells are planned to be installed during the summer 1997.

The carbon tetrachloride plume in the 200-West Area (underlying the 200-ZP-1 Operable Unit) covers approximately 9 km^2 (3.5 mi^2). In 1994, a pilot-scale pump-and-treat system was initiated to test the removal of carbon tetrachloride and other organics from the groundwater using liquid phase activated carbon, with the treated groundwater reinjected to the aquifer. Based on the success of the test, a record of decision was signed in March 1995 requiring implementation of a larger system. The pilot-scale system continued to operate as Phase I of the remedial action until the larger Phase II system, capable of

pumping and treating 580 L/min (150 gal/min), started up in August 1996. Phase I, which operated from April 1995 through July 1996, treated 21.4 million L (5.6 million gal) of contaminated groundwater and recovered 63.7 kg (140 lb) of carbon tetrachloride. From August 1996 through December 1996, the Phase II system treated 20.2 million L (5.3 million gal) of contaminated groundwater and recovered 200.2 kg (440 lb) of carbon tetrachloride.

Another groundwater plume in the 200-West Area (underlying the 200-UP-1 Operable Unit) contains uranium and technetium-99. In 1994, a pilot-scale pump-and-treat system was initiated to test the removal of these contaminants from groundwater using ion exchange. The treated groundwater is reinjected to the aquifer. In 1995, a proposed plan was issued identifying expansion of the existing system as the preferred alternative for an interim remedial action. Public comments suggested that the 200 Areas Effluent Treatment Facility be considered as an alternative to expanding the existing system, resulting in a reevaluation of the alternatives. In early 1997, a record of decision was signed that requires the groundwater extracted from the 200-UP-1 Operable Unit wells to be pumped to the 200 Areas Effluent Treatment Facility for treatment. The pilot-scale system operated throughout 1996, treating 88.3 million L (23.3 million gal) of contaminated groundwater and removing 24.9 kg (54.8 lb) of uranium.

Strontium contamination in the groundwater underlying the 100-N Area is a potential concern to the nearby Columbia River. A groundwater extraction and treatment system was started up in September 1995 and successfully operated throughout 1996. During the year, the system processed 86 million L (23 million gal) of contaminated groundwater and removed approximately 0.1 Ci of strontium-90. Meanwhile, two corrective measures studies evaluating long-term remedies for decontaminating groundwater and waste sites in the 100-N Area were prepared and submitted to the Washington State Department of Ecology. Proposed remedies are expected to undergo public review in 1997.

Vadose Zone Project

A system that extracts carbon tetrachloride vapor from the vadose zone beneath the 200-West Area began in February 1992 and continued through 1996. The soil vapor is passed through granulated activated carbon, which absorbs the carbon tetrachloride. The carbon is then shipped offsite for treatment. In 1996, the system removed approximately 5,720 kg (12,610 lb) of carbon tetrachloride from the vadose zone. Because the rate of removal dropped off substantially in 1996, a study was initiated in November 1996 to determine whether the system was still effective and how it could best be operated.

N Area Project

The N Area Project was established to coordinate cleanup activities in the 100-N Area and currently includes deactivation and remediation of facilities.

In 1996, 68 facilities in the 100-N Area were deactivated and made ready for decommissioning and 15 facilities were excessed/demolished. Ninety-five percent of the contaminated water and over half the contaminated sludge were removed from the Emergency Dump Basin. Also, 1,500 spent fuel canisters as well as large quantities of contaminated equipment were removed from the N Reactor Fuel Storage Basin. With an emphasis on waste minimization, nearly 155,000 L (41,000 gal) of uncontaminated waste oils were removed from tanks in the 100-N Area and burned for energy recovery; 390 m^3 (13,700 ft^3) of contaminated materials were removed, decontaminated, and released as nonradioactive materials for excess, reuse, recycle, or disposal; and 201 metric tons (222 tons) of steel were recycled following demolition of their storage tanks. A Comprehensive Environmental Response, Compensation, and Liability Act engineering evaluation/cost analysis that evaluated alternatives for disposing of contaminated waste from 100-N Area deactivation was issued for public review in 1996, and an action memorandum was signed that authorizes the waste to go to the Environmental Restoration Disposal Facility for a substantial cost savings over other alternatives.

Decommissioning Project

In 1995, DOE and EPA signed a national agreement to decommission contaminated facilities under Comprehensive Environmental Response, Compensation, and Liability Act authority. This agreement was implemented at the Hanford Site in 1996 with the preparation of a Comprehensive Environmental Response, Compensation, and Liability Act engineering evaluation/cost analysis for decommissioning facilities in the 100-B,C Area. After public review, an action memorandum was signed in January 1997 authorizing certain facilities to be removed and the waste disposed under the Comprehensive Environmental Response, Compensation, and Liability Act.

The most visible decontamination and decommissioning project in 1996 was the demolition of two 53-m- (175-ft-) high water towers at the C Reactor. In addition, decommissioning was completed for the 190-D complex, the 183-C facility, the 183-H Solar Evaporation Basins, and the 104-B tritium vault and laboratory.

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 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: 1) emergency planning (Sections 301-303), 2) emergency release notification (Section 304), 3) inventory reporting (Sections 311-312), and 4) toxic chemical release inventory reporting.

Section 301 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 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: 1) Benton County Department of Emergency Management, 2) Franklin County Office of Emergency Management, and 3) Grant County Department of Emergency Management. During 1996, information regarding the storage of hazardous chemicals and associated hazards was provided to these organizations.

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. During 1996, 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 (Title 29, Code of Federal Regulations, Part 1910, Section 1200 [29 CFR 1910.1200]). 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 a 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 and October 1996 and January 1997, covering changes occurring in calendar year 1996. The 1996 *Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1997a) was issued in March 1997.

Under Section 313, facilities must report total annual releases of certain listed toxic chemicals. The Pollution

Prevention Act adds additional information requirements to the submittal, and Executive Order 12856 (EPA 1993) 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 1995 toxic chemical release inventory report (DOE 1996a) was issued in August 1996. This report consisted of information regarding releases, offsite transfers, and source reduction activities involving ethylene glycol, the sole toxic chemical used in excess of applicable activity thresholds during 1995. The toxic chemical release reporting status for 1996 was confirmed in May 1997. Evaluation of toxic chemical use information showed that no reporting thresholds were exceeded in 1996.

Table 2.2.1 provides an overview of 1996 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 (benzene, cadmium and cadmium compounds, carbon tetrachloride, chloroform, chromium and chromium compounds, cyanides, dichloromethane, lead and lead compounds, mercury and mercury compounds, methyl ethyl ketone, methyl isobutyl ketone, nickel and nickel compounds, tetrachloroethylene, toluene, trichloroethane, trichlorethylene, and xylene[s]). This program seeks to reduce releases of pollutants through avoidance or reduction in the generation of pollutants at their source.

The 17 priority chemicals targeted for reduction in this program are a subset of the chemicals listed in Section 313 of this Act. The thresholds listed in the Act are used to determine participation. DOE was committed to reducing the releases of these 17 priority chemicals by 50% (compared to the 1988 baseline) by 1995, and this commitment was met for the Hanford Site. 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 1996.

The Hanford Site pollution prevention program was designed to meet the requirements of DOE Orders 5400.1 and 5820.2A, *The Waste Minimization/Pollution Prevention Cross Cut Plan 1994* (DOE 1994b), EPA program guidance, and Washington State pollution prevention

Table 2.2.1. Emergency Planning and Community Right-to-Know Act Compliance Table, 1996[a]

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

(a) "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) These notifications apply to the Hanford Site but were completed prior to 1996.
(c) Extremely Hazardous Substance.
(d) Material Safety Data Sheet.
(e) Toxic Chemical Release Inventory.

planning requirements Washington Administrative Code (WAC) 173-307. The major elements of the program are 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 is 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 making 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 Facility Resource Conservation and Recovery Act Permit

The Hanford Facility Resource Conservation and Recovery Act permit (#WA7890008967) was issued by the Washington State Department of Ecology and EPA in August 1994 and has been in effect since late September 1994 (e.g., DOE 1997b). 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 Washington State's dangerous waste regulations (WAC 173-303), 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 1996, 40 Part A Form 3s, 1 Part A Form 1, and 1 Part B permit application were certified and submitted to the Washington State Department of Ecology. In addition, two addenda to previously submitted notices of intent for expansion were filed with the Washington State Department of Ecology, and four closure actions were completed.

Resource Conservation and Recovery Act Groundwater Monitoring Project Management

Table 2.2.2 lists 28 Resource Conservation and Recovery Act facilities and units (or waste management areas) that require groundwater monitoring and their monitoring status. Samples were collected from approximately 240 wells in 1996. This is a reduction from 300 sampled wells in 1995 and reflects primarily the DOE's groundwater project integration effort and discontinued sampling at closed or inactive Resource Conservation and Recovery Act facilities. The groundwater samples were analyzed for a variety of dangerous waste constituents and site-specific constituents, including selected radionuclides. The constituent lists meet the minimum Resource Conservation and Recovery Act regulatory requirements and are integrated to supplement other groundwater project (e.g., sitewide surveillance) requirements at Hanford. One new Resource Conservation and Recovery Act well was installed in 1996 to fulfill groundwater monitoring requirements for the 216-A-37-1 Crib in the 200-East Area.

The 183-H Solar Evaporation Basins in the 100-H Area and the 300 Area Process Trenches are included in the sitewide Resource Conservation and Recovery Act permit (#WA7890008967) and are subject to final-status regulations. A final-status groundwater monitoring program for the 183-H Solar Evaporation Basins was initiated in September 1995. The 300 Area Process Trenches initiated final-status groundwater monitoring in December 1996. The other sites listed in Table 2.2.2 are subject to interim-status regulations at this time. Table 2.2.2 also lists the year the sites will be incorporated (Part B

Table 2.2.2. Hanford Site Interim- and Final-Status Groundwater Monitoring

TSD[a] Units	Interim-Status TSD[a] Unit Groundwater Monitoring: Indicator Parameter Evaluation[b]	Interim-Status TSD[a] Unit Groundwater Monitoring: Groundwater Quality Assessment, Date Initiated	Final-Status TSD[a] Unit Groundwater Monitoring: Detection Evaluation	Final-Status TSD[a] Unit Groundwater Monitoring: Compliance Evaluation	Regulatory Requirements	Associated (CERCLA)[c] Groundwater Operable Units	Year Scheduled for Part B or Closure
120-D-1 Ponds	X				40 CFR 265.93(b) WAC 173-303-400	100-HR-3	1998[d]
183-H Solar Evaporation Basins				X	WAC 173-303-645 (10)	100-HR-3	1994[d]
1301-N LWDF[e]	X				40 CFR 265.93(b) WAC 173-303-400	100-NR-2	1999[d]
1324-N/NA Pond	X				40 CFR 265.93(b) WAC 173-303-400	100-NR-2	1998[d]
1325-N LWDF[e]	X				40 CFR 265.93(b) WAC 173-303-400	100-NR-2	1999[d]
216-B-3 Pond		X, 1990			40 CFR 265.93(d) WAC 173-303-400	200-PO-1	2000[d]
216-A-29 Ditch	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	2000[d]
216-A-10 Crib[f]	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	>2000[d]
216-A-36B Crib[f]	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	>2000[d]
216-A-37-1 Crib[f]		X, 1997			40 CFR 265.93(d) WAC 173-303-400	200-PO-1	>2000[d]
216-B-63 Trench	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	>2000[d]
216-S-10 Pond	X				40 CFR 265.93(b) WAC 173-303-400		>2000[d]

Table 2.2.2. (contd)

TSD[a] Units	Interim-Status TSD[a] Unit Groundwater Monitoring: Indicator Parameter Evaluation[b]	Interim-Status TSD[a] Unit Groundwater Monitoring: Groundwater Quality Assessment, Date Initiated	Final-Status TSD[a] Unit Groundwater Monitoring: Detection Evaluation	Final-Status TSD[a] Unit Groundwater Monitoring: Compliance Evaluation	Regulatory Requirements	Associated (CERCLA)[c] Groundwater Operable Units	Year Scheduled for Part B or Closure
216-U-12 Crib		X, 1993			40 CFR 265.93(d) WAC 173-303-400	200-UP-1	>2000[d]
LERF[g]	X				40 CFR 265.93(b) WAC 173-303-400		>2000[h]
LLBG[i] WMA-1[j]	X				40 CFR 265.93(b) WAC 173-303-400		>2000[h]
LLBG[i] WMA-2[j]	X				40 CFR 265.93(b) WAC 173-303-400		>2000[h]
LLBG[i] WMA-3[j]	X				40 CFR 265.93(b) WAC 173-303-400		>2000[h]
LLBG[i] WMA-4[j]	X				40 CFR 265.93(b) WAC 173-303-400	200-ZP-1	>2000[h]
LLBG[i] WMA-5[j]	Discontinued in 1995				40 CFR 265.93(b) WAC 173-303-400		>2000[h]
WMA-A-AX[j] SST[k]	X				40 CFR 265.93(b) WAC 173-303-400		>2000[d]
WMA-B-BX-BY[j] SST[k]		X, 1996			40 CFR 265.93(d) WAC 173-303-400		1998[d]
WMA-C[j] SST[k]	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	>2000[d]
WMA-S-SX[j] SST[k]		X, 1996			40 CFR 265.93(d) WAC 173-303-400	200-UP-1	1998[d]
WMA-T[j] SST[k]		X, 1993			40 CFR 265.93(d) WAC 173-303-400	200-ZP-1	1998[d]

Table 2.2.2. (contd)

TSD[a] Units	Interim-Status TSD[a] Unit Groundwater Monitoring: Indicator Parameter Evaluation[b]	Interim-Status TSD[a] Unit Groundwater Monitoring: Groundwater Quality Assessment, Date Initiated	Final-Status TSD[a] Unit Groundwater Monitoring: Detection Evaluation	Final-Status TSD[a] Unit Groundwater Monitoring: Compliance Evaluation	Regulatory Requirements	Associated (CERCLA)[c] Groundwater Operable Units	Year Scheduled for Part B or Closure
WMA-TX-TY[j] SST[k]		X, 1993			40 CFR 265.93(d) WAC 173-303-400	200-ZP-1	1998[d]
WMA-U[j] SST[k]	X				40 CFR 265.93(b) WAC 173-303-400	200-ZP-1	1998[d]
316-5 Area Process Trenches[l]		X		X (1996 to final status)	WAC 173-303-645 (10)	300-FF-5	1996[d]
NRDWL[m]	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	>2000[d]

(a) Treatment, storage, and/or disposal.
(b) Specific parameters (pH, specific conductance, total organic carbon, and total organic halogen) used to determine if a facility is affecting groundwater quality. Exceeding the established limits means that additional evaluation and sampling are required (groundwater quality assessment). An X in the column indicates whether an evaluation was needed or an assessment was required.
(c) Comprehensive Environmental Response, Compensation and Liability Act.
(d) Closure/postclosure plan; treatment, storage, and/or disposal unit will close under final status.
(e) Liquid waste disposal facility.
(f) 216-A-10, 216-A-36B, and 216-A-37-1 cribs will be combined in fiscal year 1997 into one Resource Conservation and Recovery Act monitoring unit. Resource Conservation and Recovery Act monitoring will be performed according to interim-status groundwater quality assessment requirements.
(g) Liquid Effluent Retention Facility.
(h) Part B permit; treatment, storage, and/or disposal unit will operate under final-status regulations beginning in year indicated.
(i) Low-Level Burial Ground.
(j) Waste Management Area.
(k) Single-Shell Tank.
(l) At the end of calendar year 1996, these will move from an interim-status assessment monitoring evaluation (required by regulatory consent agreement and compliance order [Ecology and EPA 1986]) to a final-status compliance monitoring evaluation.
(m) Nonradioactive Dangerous Waste Landfill.
> = Beyond the year 2000.

or closure) into the Hanford Facility Resource Conservation and Recovery Act permit.

Resource Conservation and Recovery Act groundwater monitoring has been discontinued at the 2101-M Pond and at Low-Level Burial Ground Waste Management Area 5 in the 200-West Area. The 2101-M Pond was certified clean and was closed by the state in October 1995; groundwater monitoring ceased in June 1995. Monitoring at Low-Level Burial Ground Waste Management Area 5 in the 200-West Area was discontinued because the site remains inactive and has never operated; it, therefore, did not require monitoring. In May 1995, the Washington State Department of Ecology directed DOE to begin a groundwater quality assessment monitoring program at the S-SX single-shell tank farms in the 200-West Area in accordance with WAC 173-303-400 and 40 CFR 265.93(d). This was in response to a finding that specific conductance in downgradient wells exceeded the critical mean for the waste management area. A groundwater quality assessment monitoring program was initiated at the S-SX Tank Farms in August 1996.

The results of groundwater monitoring are discussed in Section 4.8, "Groundwater Protection and Monitoring Program."

Resource Conservation and Recovery Act Inspections

Regulatory agency inspections at the Hanford Site by the Washington State Department of Ecology in 1996 increased by 25% over the number of inspections performed in 1995. The increase was mainly due to an increase in the number of regulatory agency inspectors and the development of the air operating permit scheduled to be issued in 1997 by the Washington State Department of Ecology. DOE and its 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 1996. Each of these notices lists specific violations. There were 12 notices of violation and warning letters in 1996. Of the 12, 3 have had all corrective actions completed and have been closed. Two of the 1996 issues were formal violations, with one that resulted in a $90,000 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 DOE for noncompliant conditions at the 222-S Laboratory in the 200-West Area. An inspection was conducted in September 1996 in response to an event where the mixing of incompatible chemicals caused a plastic container to pressurize and breach, spraying the room with acid solution. No one was injured. The letter outlined six violations concerning hazardous waste storage and management. Corrective measures were begun after the September 1996 inspection. Another inspection in February 1997 showed that corrective actions had not been completed to the Washington State Department of Ecology's satisfaction. The Washington State Department of Ecology announced in May 1997 a fine in the amount of $90,000 for failing to correct all of the violations. DOE and its contractors are continuing to work with the Washington State Department of Ecology to ensure that their expectations for waste management at the 222-S Laboratory are met.

- The Washington State Department of Ecology issued a voluntary compliance letter, which was followed by a formal notice of penalty. The issue concerned the storage of incompatible waste in a product storage cabinet at the 306-E Development, Fabrication, and Testing Laboratory in the 300 Area. The fine was paid and the notices have been informally closed.

- The Washington State Department of Ecology issued a voluntary compliance letter for conditions found at the 3705-D and 3706-D facilities in the 300 Area. These facilities house photographic developing equipment. The Washington State Department of Ecology had waste designation and generator record-keeping concerns with some of the generated wastes. DOE and the management and integration contractor continue to discuss these concerns with the Washington State Department of Ecology.

- The Washington State Department of Ecology issued a voluntary compliance letter for acceptance of potentially incompatible waste into the Central Waste Complex in the 200-West Area. The waste was generated by the Lawrence Berkeley National Laboratory, Berkeley, California. The issue stemming from this investigation is that Central Waste Complex personnel failed to verify that the waste generator was properly designating the waste prior to shipping it to the Central Waste Complex. All corrective measures have been met. A letter has been received from the Washington State Department of Ecology closing out this issue.

- The Washington State Department of Ecology issued a notice of penalty in the amount of $5,000 for an alleged violation revealed through an investigation into dangerous waste management at the 183-H Solar Evaporation Basins closure project. Specifically, the notice states that training requirements, as specified in the closure plan, were not met.

Clean Air Act

The Washington State Department of Health's Division of Radiation Protection enforces state regulatory controls for radioactive air emissions as allowed under the Clean Air Act, Section 118. These controls are applicable to federal facilities such as the Hanford Site. WAC 246-247 requires applicable controls and annual reporting of all radioactive air emissions. The Hanford Site operates under a state license for such emissions. 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 and the state program under WAC 173-401. The air operating permit will include both radioactive emissions now covered by licenses and nonradioactive emissions.

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. The 1989 requirements for flow and emissions measurements, quality assurance, and sampling documentation have been implemented at nearly all Hanford Site sources.

Reporting and monitoring requirements necessitate evaluation of all radionuclide emission points on the Hanford Site to determine those subject to continuous emission measurement requirements in 40 CFR 61, Subpart H. In February 1994, the hazardous air pollutants federal facility compliance agreement for the Hanford Site were approved. This agreement was signed by the EPA Region 10 and DOE, and 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 61. All Federal Facility Compliance Act milestones were met during 1996.

EPA has delegated authority to Washington State for regulating certain hazardous pollutants under the National Emission Standards for Hazardous Air Pollutants (40 CFR 61). These standards are designed to protect the public from hazardous air pollutants (e.g., arsenic, asbestos, beryllium, mercury, radionuclides, and vinyl chloride). The Washington State Department of Ecology enforces state regulatory controls for air contaminants as allowed under the Washington Clean Air Act, Revised Code of Washington (RCW) 70.94. These requirements (e.g., WAC 173-400 and 173-460) specify applicable controls, reporting, notifications, permitting, and general standards for the Hanford Site sources.

Pursuant to 40 CFR 61, Subpart M, EPA has promulgated regulations specifically addressing asbestos emissions. These regulations apply at the Hanford Site in building demolition and/or renovation and waste disposal operations. The asbestos is handled according to the *Hanford Site Asbestos Abatement Plan* (Bechtel Hanford, Inc. 1995). 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.

Title VI of the Clean Air Act of 1990 Amendments requires regulation of the use and disposal of ozone-depleting substances through the requirements in 40 CFR 82. The site management and integration contractor was assigned the lead by DOE 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 the sitewide implementation plan (DOE 1994c) that was prepared and issued during 1994. This implementation plan is being 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. The Benton County Clean Air Authority has been delegated the authority to enforce EPA asbestos regulations under the national emission standards for hazardous air pollutants (40 CFR 61). In 1996, the site maintained compliance with the regulations.

During 1996, 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.

Clean Air Act Enforcement Inspections

The DOE and its contractors are working to resolve outstanding compliance findings from the Washington State Departments of Health and Ecology inspections. Each of these findings lists specific violations. There were four Washington State Department of Health notices in 1996. There was one Washington State Department of Ecology notice of violation and it is closed. A brief summary of the most significant of these issues follows.

- The Washington State Department of Health issued a notice of violation and compliance order to DOE after two inspectors were denied access into portions of B Plant's emission units in the 200-East Area The compliance order required the DOE to initiate a new standard of access for regulators. As a result, a standard set of requirements was formally issued. The Washington State Department of Health determined the response was satisfactory and later closed this issue by formal letter.

- The Washington State Department of Health issued a notice of correction for records retrievability stemming from an inspection in the tank farms in the 200 Areas. DOE requested technical assistance from the Washington State Department of Health, and meetings were held to discuss the time frame for retrieving required documents. The Washington State Department of Health determined that a 24-hour retrieval time for required documents will be the standard, with some exceptions. Formal notification of the new standard has not been received, so this issue remains open.

- The Washington State Department of Ecology issued a notice of violation for the historical operation of the steam boiler plants in the 200-East, 200-West, and 300 Areas. The Washington State Department of Ecology alleges that the DOE is in violation of state regulations for failure to apply for and obtain the required state prevention of significant deterioration permit, operated the 300 Area boiler without a permit, and violated the requirement to meet emission limits set for the boiler. DOE and Washington State Department of Ecology agreed to a consent order and the notice of violation is closed.

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 (40 CFR 122) 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. The EPA indicated in a conference call that DOE could discontinue monitoring of the outfalls without a permit modification, with the exception of the well that monitors N Springs at the 100-N Area. A formal response has not been received from the EPA. The remaining active outfalls at Hanford include two located in the 100-K Area (outfalls 003 and 004) and one in the 300 Area (outfall 013). There were two instances of noncompliance, one related to pH and the other to oil and grease, for this permit in 1996 (Table 2.2.3).

Permit #WA-002592-7 covers the 300 Area Treated Effluent Disposal Facility, which had 10 permit exceedences in 1996. All 10 cases were the result of effluent levels exceeding the National Pollutant Discharge Elimination System permit limits. This disposal facility was in normal operations and meeting design specifications at the time of these events. All indications suggest that the 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. Preparations for permit renegotiations are under way in accordance with the 1-year operating history review period specified when the permit was issued. A revised permit is expected to be issued in 1997.

The site is covered by two storm water permits (WAR-00-000F, WAR-10-000F). In compliance with these permits, the annual comprehensive site compliance evaluation was performed and documented, and the pollution prevention plan was updated. No instances of noncompliance occurred in 1996.

Refer to Table 2.2.3 for a summary of all water permit exceedances and noncompliances in 1996.

Table 2.2.3. Water Permit Exceedances or Noncompliances

Permit Type	Outfall	Parameter	Date(s) Exceeded	Comments
National Pollutant Discharge Elimination System	004 (100-KE Area)	pH	December 1996	None
National Pollutant Discharge Elimination System	1301 (N Springs, 100-N Area)	Oil and grease	October 1996	Postulated that petroleum-contaminated groundwater plume migrated to well vicinity. Plume is being addressed as a Comprehensive Environmental Response, Compensation, and Liability Act action
National Pollutant Discharge Elimination System	300 Area Treated Effluent Disposal Facility	Cyanide	January 1996	Laboratory analysis did not meet all requirements
National Pollutant Discharge Elimination System	300 Area Treated Effluent Disposal Facility	Total suspended solids	February 1996, May 1996	None
National Pollutant Discharge Elimination System	300 Area Treated Effluent Disposal Facility	Copper	March 1996, May 1996, November 1996, December 1996	None
National Pollutant Discharge Elimination System	300 Area Treated Effluent Disposal Facility	Arsenic	July 1996, December 1996	None
National Pollutant Discharge Elimination System	300 Area Treated Effluent Disposal Facility	Bioassay	August 1996	Statistically significant reduction in fathead minnow growth rate
State Waste Discharge Permit	200 Areas Effluent Treatment Facility	Sulfate	August 1996, November 1996	Attributed to dissolution of calcium sulfate in soil surrounding monitoring wells
State Waste Discharge Permit	200 Areas Effluent Treatment Facility	Iron	May 1996	Attributed to corrosion products in old piping
State Waste Discharge Permit	400 Area Secondary Cooling Water	Total dissolved solids	September 1996, November 1996	Cooling towers identified as source. System operations were modified

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. Waste discharge permit applications are being submitted to the Washington State Department of Ecology for all liquid effluent streams required by the consent order. One liquid waste discharge permit was issued by the Washington State Department of Ecology in 1996 for 400 Area secondary cooling water.

Two noncompliances with the Effluent Treatment Facility permit (ST-4500) occurred when elevated levels of sulfate were detected in groundwater monitoring wells near the state-approved land discharge outfall. The elevated sulfate levels were attributed to calcium sulfate being dissolved in the soil surrounding the monitoring wells.

A noncompliance issue at the Effluent Treatment Facility occurred when elevated levels of iron were detected in the facility's effluent. The elevated iron levels were attributed to corrosion products on old piping becoming suspended in the effluent.

The miscellaneous streams plan and schedule (DOE 1994d) was approved by the Washington State Department of Ecology in February 1995. This plan and schedule address how and when the remaining miscellaneous streams will become compliant with state regulations. The plan and schedule proposed that categorical permits be submitted to ensure the efficient use of both state and federal resources in the permit development. The first categorical permit application for hydrotest (pressure test), construction, and maintenance discharges was submitted to the Washington State Department of Ecology in November 1995. Permit issuance is expected in 1997. A second permit application for cooling water and condensate discharges was developed and submitted to the Washington State Department of Ecology in September 1996. A third categorical permit application will be prepared for storm-water discharges. This application is expected to be transmitted to the Washington State Department of Ecology in September 1997.

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 (WAC 246-290). In 1996, all drinking water systems on the site were in compliance with requirements and agreements. There are currently 12 surface-water and groundwater systems at Hanford.

Toxic Substances Control Act

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

Electrical transformers have been sampled and characterized. Fourteen transformers (those having a polychlorinated biphenyl concentration greater than 500 ppm) remain in service. Schedules have been developed and are being followed for the replacement and disposal of these transformers.

Defueled, decommissioned reactor compartments shipped by the United States Navy to the Hanford Site for disposal contain small quantities of polychlorinated biphenyls, which are tightly bound in the composition of solid materials such as thermal insulation, cable coverings, and rubber. Because polychlorinated biphenyls 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 Washington State Department of Ecology has issued a dangerous waste permit.

Nonradioactive polychlorinated biphenyl waste is stored and disposed of in accordance with 40 CFR 761 requirements. Radioactive polychlorinated biphenyl waste remains in storage onsite pending the development of adequate treatment and disposal technologies and capacities. A DOE-wide federal facilities compliance agreement, allowing the storage of radioactive polychlorinated biphenyl wastes beyond the regulatory limit set forth in 40 CFR 761, was approved in August 1996. This agreement includes a requirement for submittal of an annual report to EPA describing the wastes being stored. The first report was submitted to DOE Headquarters to allow consolidation and submittal by February 8, 1997, the date required in the Federal Facility Compliance Act. Also in 1996, the Pacific Northwest National Laboratory continued research under a research-and-development permit from the EPA to study degradation of polychlorinated biphenyls in waste matrices.

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. At the Hanford Site, all pesticides are applied by commercial pesticide operators who are listed on one of two commercial pesticide applicator licenses. In 1996, 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 (i.e., bald eagle and peregrine falcon) are listed by the U.S. Fish and Wildlife Service as endangered or threatened. Others are listed by the Washington State Department of Fish and Wildlife as endangered, threatened, or sensitive species (Appendix F). The site wildlife monitoring program is discussed in Section 6.2, "Ecosystem Monitoring (Plants and Wildlife)."

Bald eagles, a threatened species, are seasonal visitors to the Hanford Site. Prior to 1992, only a few nesting attempts had been observed on the site, and none were successful. Beginning in 1994 (in compliance with the Hanford Site's bald eagle management plan (Fitzner and Weiss 1994) and Section 7 of the Endangered Species Act), access roads in the nesting areas are closed each year from January 15 until the potential nesting birds either successfully rear their young or abandon the nest sites. If nesting activities at the historic nest sites are not observed in January and early February, then access roadways are not restricted. In 1996, a new nest was built by a pair of eagles, and all access roads were immediately closed. Despite these efforts, the eagles eventually left the area without successfully nesting.

As part of the National Environmental Policy Act review process, an ecological review is conducted on all projects both on and off the site to evaluate the potential of affecting federally and/or state-listed species within the proposed project area (Neitzel 1996). The ecological review includes quantifying impacts that might result, and identifying mitigation strategies to minimize or eliminate such impacts. Reviews have been conducted on an ongoing basis. There were no additional compliance issues during 1996.

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 historic 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 buildings, and management of a repository for federally owned archaeological

collections. In 1996, 271 reviews were requested and 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. DOE cooperates with Native Americans by providing site access for organized religious activities.

There were no compliance issues during 1996.

National Environmental Policy Act

The National Environmental Policy Act requires preparation of an environmental impact statement to analyze the impacts associated with 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, would require the preparation of an environmental impact statement. Certain types of actions may fall into categories that have already been analyzed by DOE and have been determined not to result in a significant environmental impact. These actions, which are categorical exclusions, are exempt from further National Environmental Policy Act review. Typically, over 20 categorical exclusions are documented annually at the Hanford Site, involving a wide variety of actions by multiple contractors.

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 Council on Environmental Quality National Environmental Policy Act regulations (40 CFR 1500-1508), DOE National Environmental Policy Act implementation procedures (10 CFR 1021), and DOE Order 451.1. In accordance with DOE Order 451.1, DOE documents prepared for Comprehensive Environmental Response, Compensation, and Liability Act projects are required to incorporate National Environmental Policy Act values such as analysis of cumulative, offsite, ecological, and socioeconomic impacts to the extent practicable in lieu of preparing separate National Environmental Policy Act documentation.

Recent Environmental Impact Statements

A final environmental impact statement for Plutonium Finishing Plant stabilization at the Hanford Site was issued in May 1996 (DOE 1996b). The proposed action would clean out inactive Plutonium Finishing Plant complex facilities (except the storage areas), stabilize reactive residual plutonium-bearing materials to a form suitable for long-term storage, and store the stabilized material until final storage and disposition decisions are made. The Record of Decision was issued in July 1996 (61 Federal Register [FR] 36352).

A final environmental impact statement for management of spent nuclear fuel from the K Basins at the Hanford Site was issued in February 1996 (DOE 1996c). The proposed action would remove spent nuclear fuel from the K Basins for storage in a new facility in the 200-East Area pending availability of a repository for disposal or future decision for reuse of the material. Sludge, water, and debris from the K Basins also would be disposed of at the Hanford Site in existing facilities. The purpose for this action is to prevent the release of radionuclides through the soil column to the Columbia River in the event of the failure of the K Basins. The Record of Decision was issued in March 1996 (61 FR 10736).

A final environmental impact statement, prepared by the United States Navy and adopted by DOE for disposal of decommissioned, defueled cruiser, Ohio class, and Los Angeles class naval reactor plants at the Hanford Site was issued in April 1996 (U.S. Department of the Navy 1996). The proposed action would remove naval reactor compartments from cruisers and Ohio and Los Angeles class submarines. The compartments would be transported to the Hanford Site for shallow land disposal. The environmental impact statement was adopted by DOE in April 1996. The Record of Decision was issued in July 1996 (61 FR 41596).

A final environmental impact statement for the Hanford Reach of the Columbia River was issued in June 1994 (National Park Service 1994). The proposed action would designate the Hanford Reach of the Columbia River a recreational river under the National Wild and Scenic Rivers System, and designate the Wahluke Slope and Columbia River corridor areas of the DOE's Hanford Site a wildlife refuge under the U.S. Fish and Wildlife Service. The Record of Decision was issued in July 1996 (Babbitt 1996).

A final environmental impact statement, coprepared by the Washington State Department of Ecology and DOE, for the Hanford Site's tank waste remediation system was issued in August 1996 (DOE and Ecology 1996). The proposed actions would retrieve radioactive wastes from double- and single-shell waste tanks at the Hanford Site and stabilize wastes in forms suitable for disposal. The Record of Decision was issued in February 1997 (62 FR 8693).

Programmatic Environmental Impact Statements in Progress

A programmatic environmental impact statement is being prepared by DOE Headquarters Office of Environmental Restoration and Waste Management. The environmental impact statement will evaluate a broad range of alternatives for the configuration of new and expanded waste management facilities. A draft environmental impact statement was issued in August 1995.

Site-Specific Environmental Impact Statements In Progress

A programmatic environmental impact statement is being prepared for the Hanford Remedial Action Program. The proposed action would develop a coordinated strategy for remediation of hazardous and radioactive waste sites through a comprehensive land use plan (also being prepared). A draft environmental impact statement was issued in August 1996. It is expected that the final environmental impact statement will be issued during 1997.

Hanford Site Permitting Summary

The Hanford Site has obtained, or is in the process of obtaining, numerous environmental permits. The permits and their status are summarized in *Annual Hanford Site Environmental Permitting Status Report* (Thompson 1996). For Resource Conservation and Recovery Act permitting, the Hanford Site is considered a single facility and has been issued one EPA identification number. The identification number encompasses over 60 treatment, storage, and/or disposal units. (Three additional identification numbers were effective in January 1997. However, these do not apply to treatment, storage, and disposal facilities.) The initial permit was issued for less than the entire facility because all units cannot be permitted simultaneously. The permit, through the permit modification process, will eventually incorporate all units.

Implementation of the Clean Air Act is facilitated by several permits. Title V of the Act requires an air operating permit for major stationary sources. The Hanford Site is applying for an air operating permit expected to be issued in November 1997. A prevention of significant deterioration permit covers the airborne discharge of certain pollutants from Hanford facilities. Significant increases in allowed emissions require an approved modification of the permit. Air permitting regulatory approvals must be obtained prior to constructing or modifying facilities that emit regulated pollutants. To date, 29 approvals have been obtained from the Washington State Department of Ecology, 146 from the Washington State Department of Health, and 95 from the EPA. These numbers change as a result of continuing activities that require air permitting. The regulatory authority differs for each agency.

The sitewide and 300 Area Treated Effluent Disposal Facility pollutant discharge elimination system permits govern liquid process effluent discharges to the Columbia River. The national pollutant discharge storm-water general permit governs storm-water discharges to the Columbia River. Waste discharge permits are required by WAC 173-216. These permits are summarized earlier in this section under "Liquid Effluent Consent Order."

Other Hanford Site permitting addressed in the permitting status report (Thompson 1996) includes research, development, and demonstration; solid waste handling; onsite sewage systems; and permitting of underground petroleum storage tanks.

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2.3 Accomplishments and Issues

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This section describes DOE's progress in meeting its mission at the Hanford Site. Ongoing compliance self-assessments, knowledge gained in implementing Tri-Party Agreement (Ecology et al. 1989) milestones, and communications with stakeholders continue to identify environmental compliance issues. Relevant 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

Sixty-four Tri-Party Agreement milestones scheduled for 1996 were completed. Highlights of the work with the associated milestone numbers include the following:

- awarded privatization contracts for the treatment of wastes in 177 underground storage tanks (Milestone M-60-08)
- completed procurement of laboratory services to handle 80% or more of the low-level analytical requirements for the Environmental Restoration/ Waste Management Programs at the Hanford Site (Milestone M-14-04)
- completed vapor characterization for all ferrocyanide Watch List underground waste storage tanks (Milestone M-40-03)
- completed vapor characterization for all organic Watch List underground waste storage tanks (Milestone M-40-08)
- initiated construction of Project W-058 for replacement of the cross-site transfer system for transfer of underground storage tank waste between the 200-East and 200-West Areas (Milestone M-43-07A)
- issued the final environmental impact statement Record of Decision for the Plutonium Finishing Plant (Milestone M-83-01-T01; DOE 1996b)
- completed remediation of 31 waste sites in the 1100 Area (Milestone M-16-05A-T3) (the EPA removed the area from the National Priorities List)
- initiated operation of a 580-L/min (150-gal/min) treatment system for removal of carbon tetrachloride at the 200-ZP-1 Operable Unit in the 200-West Area, treating over 320 million L (83 million gal) of groundwater (Milestone M-16-04A)
- began remedial actions for the 100-BC-1 Operable Unit (Milestone M-16-08A) and 100-DR-1 Operable Unit (Milestone M-16-07A), both in the 100 Areas
- completed construction and initiated operation of the Environmental Restoration Disposal Facility with over 28,000 m^3 (37,000 yd^3) of contaminated soil disposed (Milestone M-70-00)
- issued the *Long-Term Facility Decommissioning Plan* (DOE 1996d; required by Tri-Party Agreement Section 8.3.1)
- issued a revision to the single-shell tank closure work plan in May 1996 (DOE 1996e; in support of Milestone M-45-06 for closure of underground waste storage tanks in the 200 Areas)
- completed all high-priority field investigations in the 100 Areas (multiple Milestone M-15-00 commitments)
- completed design for Project W-178, construction of interim-status tank system upgrades for the 219-S tank system in the 200-West Area (Milestone M-32-02-T01)

- completed construction of the Waste Receiving and Processing Facility, Module 1 in the 200-West Area (Milestone M-18-01)

- completed the pumping of free liquids (interim stabilization) of one single-shell underground waste storage tank (tank T-107 in the 200-West Area, Milestone M-41-27-T01)

- initiated construction of the Sodium Storage Facility at the Fast Flux Test Facility (Milestone M-81-01)

- completed removal of mixed wastes from the 324 Building tanks in the 300 Area (Milestone M-89-01)

- deactivated 22 N Reactor associated facilities, bringing the total to 75 of 83 facilities (no specific milestone: activity supports cleanup goals of the Tri-Party Agreement)

- maintained safe storage of 2,100 metric tons (2,300 tons) of spent fuel from K Basins (no specific milestone: activity supports cleanup goals of the Tri-Party Agreement)

- successfully negotiated the sixth amendment to the Tri-Party Agreement, implementing a single regulator approach to streamline regulatory oversight at Hanford (no specific milestone: activity supports cleanup goals of the Tri-Party Agreement).

Since the last issue of this report, new negotiated changes to the Tri-Party Agreement established 99 new enforceable milestones and 25 new unenforceable target dates.

A summary of the significant changes to the Tri-Party Agreement follows.

Facility Transition Approved Changes

There were two approved change requests related to facility transition during 1996.

The M-82 series of Tri-Party Agreement milestones was created for the B Plant Transition Project. This project's mission is to place B Plant and its ancillary facilities into a safe, environmentally sound, and stable condition that requires minimal long-term surveillance and maintenance. The overall goal of this project is to complete B Plant facility transition (Phase I) by September 1998, and transfer B Plant to the environmental restoration contractor in fiscal year 1999 for cost-effective, long-term surveillance and maintenance. At the completion of Phase I, transition will be complete, necessary preclosure actions will be complete and/or approved, and Phase II (surveillance and maintenance) will begin. Transition of B Plant will result in a reduction of the hazards and risks associated with these facilities until the facility disposition phase (Phase III) is initiated. When transition is completed, it is expected that funds (no longer needed at B Plant) will be available for other site environmental management activities.

Interim milestone M-20-21A was revised, replacing the requirement for B Plant to prepare and submit a Resource Conservation and Recovery Act Part B permit application with the requirement to submit a B Plant preclosure work plan. This action is appropriate for the facility because it has no future mission.

Waste Management Program Approved Changes

The M-19 milestones were revised. This change is an alternative to constructing and operating the waste receiving and processing 2A facility on the Hanford Site. The revised strategy employs several parallel paths to accomplish the facility's mission for treating contact-handled (material that can be handled nonremotely) low-level mixed waste. The new milestones require that waste treatment and/or direct disposal begin by the planned date and continue at a rate equaling or exceeding the rate previously planned for the facility. A new major milestone established this treatment/disposal rate as a requirement through fiscal year 2002.

Milestone M-33-00 was established to 1) prompt the development of milestones necessary for the storage, treatment/processing, and disposal of Hanford Site solid wastes and hazardous materials not yet covered under the agreement and 2) prompt the development and incorporation of agreement modifications designed to aid in achieving integrated management of all aspects of Hanford Site cleanup (including but not limited to waste and materials management, remedial action, and site closure).

To meet these objectives, the parties negotiated agreement modifications in 1996 under change request numbers L-96-01, M-90-96-01, M-91-96-01, and M-92-96-01.

The changes reflect the parties recognition that effective management of Hanford cleanup and waste and materials management demands a fully coordinated approach. In addition, these changes have been developed recognizing that a number of Hanford's special nuclear materials may no longer be needed for their original purposes and have no clearly identified future use. Specific waste/materials project management milestones were established under new major milestones M-90-00, M-91-00, and M-92-00.

Milestone M-90-00 and its subelements govern the acquisition of new facilities, modification of existing facilities, and/or modification of planned facilities necessary for the interim storage of Tank Waste Remediation System high-level waste and other high-level waste forms in canisters and for interim storage and disposal of low-activity waste.

Milestone M-91-00 and its subelements govern the acquisition of new facilities, modification of existing facilities, and/or modification of planned facilities necessary for the storage, processing, and disposal of Hanford Site transuranic waste, low-level mixed waste, and greater-than-category 3 waste. (Greater-than-category 3 refers to waste exceeding certain established radioactivity limits for disposal.)

Milestone M-92-00 governs the acquisition of new facilities, modification of existing facilities, and/or modification of planned facilities necessary for the storage, treatment/processing, and disposal of Hanford Site cesium and strontium capsules, unirradiated uranium, bulk sodium, and 300 Area special case waste (a category of miscellaneous wastes).

Tank Waste Remediation System Approved Changes

DOE completed an analysis of privatization of low-activity waste pretreatment and immobilization options for cleanup of the radioactive and hazardous tank wastes in the single- and double-shell underground storage tanks at Hanford. The Tank Waste Remediation System mission is to conceptualize, develop, design, construct, and operate the physical systems and technologies necessary to retrieve waste from these 177 tanks located in the 200-East and 200-West Areas and convert the waste into a solid suitable for ultimate disposal. Under the privatization approach, private companies under contract with DOE will treat Hanford's tank wastes and return a treated product to DOE.

Pollution Prevention Program

The Hanford Site Pollution Prevention Program is a combination of three programs developed and maintained by their respective contractors: Bechtel Hanford, Inc., Pacific Northwest National Laboratory, and Fluor Daniel Hanford, Inc. The program is an organized, comprehensive, and continual effort to systematically reduce the quantity and toxicity of hazardous, radioactive, mixed, and sanitary wastes. Also, the program fosters the conservation of resources and energy, the reduction of hazardous substance use, and the prevention or minimization of pollutant releases to all environmental media from all operations and site cleanup activities.

The program is designed to satisfy DOE requirements, executive orders, and state and federal regulations and requirements. In accordance with sound environmental management, preventing pollution through source reduction is the first priority in this 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 and recycling are not possible or practical. Environmentally safe disposal is the last option.

Hanford Site pollution prevention efforts in 1996 helped to prevent the generation of 2,900 m^3 (3,800 yd^3) of radioactive mixed waste, 174 metric tons (191 tons) of Resource Conservation and Recovery Act hazardous/dangerous waste, 342 million L (90 million gal) of process waste water, and 12,600 metric tons (13,800 tons) of sanitary waste. Total savings in 1996 exceeded $15,600,000 for these activities.

During 1996, the Hanford Site recycled 595 metric tons (655 tons) of office paper, 57 metric tons (62 tons) of cardboard, 2,000 metric tons (2,200 tons) of ferrous metal, 175 metric tons (190 tons) of nonferrous metal, 21 metric tons (23 tons) of lead, 22 metric tons (24 tons) of solid chemicals, 86,000 L (23,000 gal) of liquid chemicals, 200 kg (440 lb) of aerosol cans, 8,400 kg (18,500 lb) of fluorescent light tubes, and 48,000 kg (105,000 lb) of lead acid/gel cell batteries. Savings in 1996 exceeded $1,750,000 based on disposal costs.

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" (Olsen 1996) was published in September 1996. The

book outlines 45 initiatives that were implemented and are now in use at locations throughout the Hanford Site.

Environmental and Molecular Science Laboratory

In October 1996, the Environmental and Molecular Science Laboratory was officially dedicated by Secretary of Energy Hazel O'Leary as the William R. Wiley Environmental and Molecular Science Laboratory. This dedication highlighted a year where construction neared completion. Major pieces of research equipment were received and installed in the facility, including a new state-of-the-art computing system and an ion accelerator. The movement of staff into the facility is scheduled to begin in early spring 1997, which will commence the beginning of research activities in this new facility. 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 contaminants at government and industrial sites across the country.

The city of Richland issued an industrial waste-water permit (CR-IU005) to DOE that allows for process waste water from the laboratory to be discharged to the city of Richland's publicly owned treatment works. The permit was issued in accordance with the provisions of city ordinances in October 1996 and expires in October 2001. The discharge permit requires monthly effluent monitoring and reporting of the analytical data to the city. Additionally, as required by the permit, an accidental spill prevention plan was developed and submitted to the city. This plan describes measures taken to prevent, control, and mitigate the effects of accidental releases of hazardous materials from the laboratory to the city.

Spent Fuel Project Activities

In February 1994, the Spent Nuclear Fuel Project was established 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 approximately 80% of the inventory currently stored across the national DOE complex. The majority of Hanford's inventory consists of approximately 2,100 metric tons (2,300 tons) of irradiated N Reactor fuel stored in the K Basins.

In 1996, the project continued to make progress on its accelerated strategy for moving the wet-stored K Basin fuel away from the Columbia River and into a new dry storage facility in the 200-East Area (the Canister Storage Building). Construction of the building is in progress; the walls of all three below-grade vaults were completed in 1996. As construction continues, designs are being finalized and fabrication and construction activities on other parts of the project are being started. The cold vacuum drying process is an example. With the help of our stakeholders, a site for the process was selected, and site grading was completed. Construction of the building is scheduled to begin in early 1997.

Facility Stabilization Project

The Facility Stabilization Project mission is to transfer those Hanford facilities for which it has responsibility from an operating mode to a long-term surveillance and maintenance mode. This includes providing for the safe storage of nuclear materials and reducing risks from hazardous materials and contamination. Under the project, the deactivation of primary systems to effectively reduce risks to human health and the environment will also be conducted. These activities will allow the lowest surveillance and maintenance cost to be attained while awaiting determination of a facility's final disposition and possible turnover to the DOE Headquarters Environmental Restoration Program.

Section 8.3.1 of the Tri-Party Agreement requires DOE to submit a long-term facility decommissioning plan to the Washington State Department of Ecology and the EPA. This plan provides a mechanism by which the three parties will address decommissioning of existing and future facilities on the Hanford Site. The plan was issued as required (DOE 1996d) and identified key and nonkey facilities. For the key facilities, a long-term "road map" showed the approximate time periods that the key facilities would undergo transition, surveillance and maintenance, and/or final disposition. The road map is for use by the three parties to assist in the planning process to integrate and prioritize work.

Currently, the Facility Stabilization Project is engaged in five major deactivation projects at Hanford. Each is in a

different stage of completion and each presents a host of technical and management challenges. The major projects are the Plutonium-Uranium Extraction Plant, the Plutonium Finishing Plant, B Plant/Waste Encapsulation and Storage Facility, 300 Area Stabilization, and the Advanced Reactors Transition. The mission of each program and its accomplishments during 1996 are summarized below.

Plutonium-Uranium Extraction Plant

The mission of the Plutonium-Uranium Extraction Deactivation Project is to transition the facility to a long-term, low-cost surveillance and maintenance state that is safe and environmentally secure. This deactivation will remove, reduce, and/or stabilize the radioactive sources and hazardous substances within the complex in a safe, cost-effective manner, with a goal of becoming a model for future facility transition projects. When transition is complete, the plant will be left unoccupied and locked, pending eventual decontamination and decommissioning.

The schedule for completion of this deactivation has been accelerated from the original date of October 1997 to May 1997. During the course of 1996, major progress was made toward support of the accelerated completion date, including transfer of nuclear material, reclassification of the facility from "fissile" to "limited control," and deactivation of the criticality alarm system.

Additional stabilization activities in 1996 involved the removal of 60,000 L (16,000 gal) of organic solvent. This followed the recovery and sale of 700,000 L (180,000 gal) of nitric acid in 1995. Other activities in 1996 included the disposal of the residual uranium removed from the acid as well as flushing of canyon vessels. Facility modifications included the shutdown of the steam supply system; isolation of the canyon; and sealing all routes to underground storage tanks, cribs, and ponds. The ventilation and filtering system was reconfigured, and a new electrical distribution system was installed to support long-term facility surveillance. Additionally, the over 100 metric tons (110 tons) of remaining depleted uranium oxide at the Uranium TriOxide Plant in the 200-West Area were removed and disposed.

Plutonium-Uranium Extraction Plant staff provided orientation and training to future surveillance and maintenance personnel and hosted deactivation technical exchanges to share information and "lessons-learned." During 1996, Plutonium-Uranium Extraction Plant personnel met all Tri-Party Agreement milestones ahead of schedule and under budget (the multiyear project is approximately $20 million under budget).

Plutonium Finishing Plant

The Plutonium Finishing Plant mission is to stabilize, repackage, immobilize, and/or properly dispose of plutonium-bearing materials in the plant; to deactivate the processing facilities; and to provide for the safe and secure storage of special nuclear materials until final disposition.

During 1996, the Plutonium Finishing Plant's environmental impact statement Record of Decision was approved (61 FR 36352). The Record of Decision provides the DOE's decision to implement a select group of alternatives for removing readily retrievable material held up in equipment, piping, etc., from the facility and for stabilizing or cementing stored and retrievable plutonium-bearing material.

Stabilization activities included the sale of 12,000 L (3,200 gal) of concentrated nitric acid; the transfer of 28,000 L (7,400 gal) of aluminum nitrate nanohydrate to the Idaho National Engineering and Environmental Laboratory; and the transfer of approximately 9,500 L (2,500 gal) of sodium hydroxide to underground double-shell waste storage tanks in the 200 Areas. Also during 1996, approximately 900 items from earlier facility cleanout efforts were encapsulated in cement for disposal; approximately 100 items from the plutonium storage vault were repackaged; 52 items of reactive plutonium-bearing ash materials were thermally stabilized and packaged for interim safe storage; and approximately 220 kg (485 lb) of sand, slag, and crucible material were encapsulated in cement for disposal.

Facility activities included cleanout and removal of plutonium-contaminated ductwork and flushing and isolation of chemical storage and processing tanks.

Engineering studies and development tests were performed in 1996 to validate the technology and safe operating criteria for solution stabilization activities, including testing of a prototype direct denitration calciner for conversion of plutonium nitrate solutions to stable plutonium dioxide powder. Construction and startup of a full-scale operating calciner is scheduled for 1997.

Preliminary planning was initiated in 1996 to support deactivation of the processing areas of the plant once

stabilization activities have been completed. A deactivation plan was completed for the Plutonium Reclamation Facility, and a deactivation program management plan for the Plutonium Finishing Plant is scheduled to be completed in 1997.

A Resource Conservation and Recovery Act closure plan was developed and submitted to the Washington State Department of Ecology to support the eventual closure of the 241-Z Treatment and Storage Facility.

While stabilization and deactivation planning activities were ongoing, efforts to ensure the safe and secure storage of special nuclear materials continued. Modifications to plant systems were made to facilitate international safeguards under the auspices of the International Atomic Energy Agency. Additional efforts were made to characterize vault inventories and to develop a material storage container compatible with long-term storage standards.

B Plant/Waste Encapsulation and Storage Facility

The B Plant Project mission is to deactivate the facility and place it into a configuration suitable for long-term surveillance.

During 1996, planning for accelerated deactivation of B Plant was completed. Transition documents, such as the end point criteria document and the project management plan, were prepared. Key milestones were negotiated with the Washington State Department of Ecology in accordance with the Tri-Party Agreement.

Facility deactivation activities began in earnest in 1996 with removal of regulated liquids from all 100 chemical feed tanks in B Plant and the isolation of 77 of 86 canyon tanks and 40 of 44 operating gallery tanks completed. All clean bulk chemicals were excessed or disposed of, including 53,000 L (14,000 gal) of sodium hydroxide and 6 metric tons (6.6 tons) of sodium nitrite. Outdoor radiological areas were reduced by more than 4,600 m^2 (5,500 yd^2).

Chemical washing of 38,000 L (10,000 gal) of process solvent was completed, reducing the radiological contamination (over 70,000 Ci removed) and allowing the liquid to be removed from the facility. Removal of this flammable liquid, in turn, allowed some 20 operational systems required for the safe storage of these solvents to be deactivated, reducing annual maintenance and surveillance costs by $2 million.

The Waste Encapsulation and Storage Facility Project mission is to provide safe interim storage of encapsulated radioactive material. Facility systems and structures are being upgraded to ensure their continued future operability.

During 1996, 25 cesium capsules from offsite were returned and consolidated at the Waste Encapsulation and Storage Facility. Work was initiated on replacement of the cooling system and installation of other systems required to provide services that had historically been obtained through B Plant, thus developing the Waste Encapsulation and Storage Facility into a fully operational stand-alone facility.

300 Area Stabilization

The 300 Area Stabilization Project currently has two subprojects: 1) 300 Area Fuel Supply Shutdown and 2) 324/327 Buildings Facilities Transition. The mission of the fuel supply shutdown subproject is to complete deactivation and closure activities while maintaining the complex in compliance with regulations until turnover to the DOE Headquarters Environmental Restoration Program.

During 1996, major reductions of accumulated low-level waste and areas of contamination were accomplished in the fuel supply shutdown subproject. A second Resource Conservation and Recovery Act clean closure was completed with the Washington State Department of Ecology's acceptance of the 304 Concretion facility documentation. Over 700 metric tons (770 tons) of uranium billets were packaged and shipped to the United Kingdom. Phase I of building shutdown and stabilization was completed at the 304 and 303-M buildings and the 311 Material Transfer facility. Also a major task of excessing spare parts and nuclear materials from fuel supply shutdown facilities was completed during 1996.

The 324/327 Buildings were transferred to the Facility Stabilization Project in November 1996. These facilities are involved in selected stabilization activities in response to Tri-Party Agreement milestones (B cell clean out and high-level vault tank closures) and the vulnerability assessments (cesium capsule removal and legacy fuel removal). Transition documents, including an end point criteria document and a deactivation project management plan, are being developed to guide future deactivation activities.

During 1996, a Resource Conservation and Recovery Act closure plan was submitted to the Washington State

Department of Ecology and waste removal from the 324 facility's high-level vault tank system was completed (both Tri-Party Agreement milestones), including treatment and disposition of the waste. Removal of highly radioactive dispersible waste from the 324 Building was also completed.

Advanced Reactors Transition

The Advanced Reactors Transition Project has three subprojects: 1) Fast Flux Test Facility, 2) Fuels and Materials Examination Facility, and 3) Nuclear Energy and Plutonium Recycle Test Reactor/309 Building. The mission of the Advanced Reactors Transition Project is to safely transition these facilities to a deactivated state.

In November 1995, DOE revised its direction to the facility stabilization project related to the Fast Flux Test Facility, halting any irreversible deactivation activities and, in January 1997, direction was received to place the facility in "hot standby" while alternative future missions for the reactor are explored (i.e., medical isotope and/or tritium production). A decision on the Fast Flux Test Facility's future is expected in December 1998.

Construction was completed on the Sodium Storage Facility, intended for storage of Fast Flux Test Facility coolant, in October 1996. Sodium will not be transferred to this facility in the near future, pending the outcome of the 1998 decision on the future of the plant.

Fast Flux Test Facility deactivation activities completed in 1996 included removal of over 60 highly radioactive fuel components, washing and placing the components in interim storage casks, and transporting the casks to the 400 Area interim storage area. Additionally, reactor vessel immersion heaters were installed and three polychlorinated biphenyl transformers were removed.

Nuclear fuel was removed from the 308 Building (a DOE Nuclear Energy Program subproject), and deactivation activities for this building were completed. Nuclear Energy Program legacy test loop piping and hardware removal was completed from the 335 and 335-A Buildings.

Cleanout of the 309 Building (Plutonium Recycle Test Reactor) rupture loop ion exchange vault was completed, and characterization was performed on the rupture loop annex.

A Resource Conservation and Recovery Act partial clean closure was completed for the 105-DR Large Sodium Fire Facility in 1996. This facility is in the process of being transitioned to the DOE Headquarters Environmental Restoration Program for final disposition. Resource Conservation and Recovery Act closures were also completed for the 4843 Alkali Metal Storage Facility and the 3718-F Alkali Metal Treatment and Storage Facility. The 4843 closure is awaiting acceptance by the Washington State Department of Ecology. Soil sampling still needs to be performed in the vicinity of 3718-F prior to final closure certification for that facility.

Sodium test loops in the 300 Area were dismantled as part of the DOE Nuclear Energy Program Legacy Program in 1996. Approximately 600 L (160 gal) of nonradioactive elemental sodium was transferred to an offsite vendor. This program will continue in 1997.

Tank Waste Remediation System Activities

Waste Tank Status

The status of the 177 waste tanks as of December 1996 was reported in Hanlon (1997). 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
  - 0 (all 18 single-shell tanks were removed from the Watch List in 1996)
- number of flammable gas tanks on the Watch List
  - 19 single-shell tanks
  - 6 double-shell tanks
- number of organic tanks on the Watch List
  - 20 single-shell tanks.

So far, 115 single-shell tanks have been stabilized, with the tank stabilization program to be completed in 2000. At the end of 1996, 108 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 to date of radioactive waste leakage from single-shell tanks is 2.3 million to 3.4 million L (600,000 to 900,000 gal).

During 1996, pumping occurred in six single-shell tanks. Portions of Tanks 241-T-104, T-107 (which was declared stabilized when pumping was completed), T-111, S-108, S-110, and BY-109 were pumped.

During 1996, the BX, TX, and TY Tank Farms were declared controlled, clean, and stable. Controlled, clean, and stable means that all pumpable liquids removed from the tanks, all abandoned equipment removed, data recorded electronically, all potential openings sealed, automated surveillance operations installed, and surface contamination cleaned up.

Waste Tank Safety Issues

The Waste Tank Safety Program, now called Safety Issue Resolution Projects, 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 projects serve 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 are being evaluated and mitigated first. The tasks to resolve safety issues are planned and implemented in the following logic sequence: 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) monitor waste storage 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 followed depends on whether the waste requires treatment or can be stored safely by implementing strict controls.

Safety Issue Resolution Projects 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 1996, there were 38 tanks on the Watch List: 25 flammable gas tanks, 20 organic tanks, and 1 high-heat tank (some of the tanks are included under more than one category). These tanks were identified in accordance with the Defense Authorization Act, Section 3137, "Safety Measures for Waste Tanks at Hanford Nuclear Reservation" (1990). In 1996, all 18 ferrocyanide tanks were removed from the Watch List, and the issue was deemed resolved by DOE and the Defense Nuclear Facilities Safety Board.

Watch List Tanks

In early 1991, all Hanford Site high-level waste tanks were evaluated and organized into categories to ensure increased attention and monitoring. Other safety concerns, including the possibility of nuclear criticality in a waste tank, have also been addressed.

Ferrocyanide. The ferrocyanide safety issue, which was an earlier concern, involved the potential for uncontrolled exothermic reactions of ferrocyanide and nitrate/nitrite mixtures (Postma et al. 1994a). If ferrocyanide is present, laboratory studies have shown that temperatures must exceed 250°C (482°F) for a reaction to propagate. The hottest temperature in ferrocyanide tanks formerly on the Watch List is 53°C (127°F) and decreasing. In October 1990, an unreviewed safety question was declared for the former ferrocyanide tanks 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). There were originally 24 ferrocyanide tanks on the Watch List: 4 were removed in 1993, 2 in 1994, 4 in June 1996, and 14 in September 1996. The ferrocyanide levels have decreased by at least 90%, and in some cases by 99%, over those originally added to the tanks. Experimental studies (Lilga et al. 1996) and core samples from 10 of the ferrocyanide tanks show that hydrolysis and radiolysis of the ferrocyanide occurred and sufficient fuel to be of concern is no longer present (Meacham et al. 1996a). DOE approved resolution of the ferrocyanide safety issue in December 1996.

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 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. Two spare mixer pumps are available in the event 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 for tank 241-SY-101 to be removed from the unreviewed safety question list was received in June 1996. In November 1996, the unreviewed safety question for the other tanks was expanded to cover 176 underground waste tanks (241-SY-101 is not included) and all auxiliary tank farm tanks. Standard hydrogen monitoring systems are being added to a number of these waste tanks.

Additional instrumentation for determining waste properties and tank behavior has been developed for use in the flammable gas tanks. These instruments include viscometers for measuring the viscosity of the waste in the tanks, in-tank void fraction meters that determine the amount of gas in a given volume of waste, retained gas samplers that capture a waste sample in a gas-tight chamber and allows the gas composition and volume to be measured after the apparatus is brought into a hot cell, and gas characterization systems that allow a broad spectrum of dome-space gases (including hydrogen, ammonia, and nitrous oxide) to be continuously monitored in selected tanks. All of these devices became operational in 1996.

In November 1996, more stringent 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 a 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 is approved for tanks because they 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 scheduled for retrieval, starting in 1998, and transfer of the 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 retrieval program, a refrigerated chiller system has been installed to remove radioactive decay heat and the heat generated by the waste transfer pumps. The chiller is scheduled to come on-line in 1997.

The Tri-Party Agreement milestone for resolution of the high-heat safety issue is scheduled for September 2001, with an interim milestone to start retrieval of the waste in tank 241-C-106 by October 1997. This interim milestone is being renegotiated to start sluicing in September 1998.

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 (Meacham et al. 1996b). 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 weight percent, 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 sampling 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 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, Meacham et al. 1996b), making them less hazardous. In addition, work by Barney (1996) shows that most organic complexants used during nuclear fuel reprocessing at the Hanford Site and the primary degradation products of tributyl phosphate are water soluble in nitrate/nitrite salt solutions. Thus, a high percentage of reactive organic chemicals are removed from the single-shell tanks when their pumpable liquid supernatant is pumped out as part of the interim stabilization process for the single-shell tanks.

During 1995 and 1996, waste samples from the organic tanks were taken to determine the quantities of organic constituents present in each tank. Most of the organics found have been of low energy. None of the samples show any tendency to propagate when tested in a special tube propagation calorimeter (Fauske 1996a, 1996b). Tank characterization reports have been or are being prepared for each of the sampling events. 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). In 1996, an extensive effort was put forth to provide the technical basis for resolving the criticality safety issue. Technical studies were completed that showed a criticality event within a high-level waste tank is not likely during storage (Bratzel et al. 1996). 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 pretreatment processes. A request to close the criticality safety issue was forwarded to DOE for approval in September 1996. It is expected to be approved during 1997. The Tri-Party Agreement milestone for resolution of the criticality safety issue is scheduled for September 1999.

Vadose Zone Characterization Near Single-Shell Underground Waste Storage Tanks

DOE Grand Junction Office has been tasked with performing a baseline characterization of the vadose zone beneath the single-shell underground waste storage tanks at Hanford. The contractor performing this work for the Grand Junction Office is MACTEC-ERS (formerly Rust Geotech, Inc.). This characterization work is being accomplished in an effort to comply with Resource Conservation and Recovery Act requirements to identify contamination sources and to determine the nature and extent of the contamination under the single-shell tanks.

The characterization program involves establishing a baseline of contaminant distribution by assaying the gamma-emitting radionuclides in the vadose zone (i.e., the vadose zone consists of the unsaturated sediment between the ground surface and the groundwater table). The assays are performed by logging the existing boreholes surrounding the tanks with spectral gamma ray logging systems. The assays identify the current baseline conditions in terms of the nature and extent of the gamma-emitting radionuclides. The baseline study provides a basic understanding of contaminant distribution from which comprehensive characterization programs can be developed and it provides a baseline from which to compare future monitoring data to identify changes.

The characterization program began in 1995 and by the end of 1996, 490 boreholes surrounding 86 tanks had been logged out of a total of 750 boreholes surrounding

134 tanks. The log data were analyzed and a tank summary data report was prepared for each tank. On completion of the data reports for each tank, a more comprehensive tank farm report will be prepared that will correlate the vadose zone information throughout the tank farm.

In 1996, the remaining four tank summary data reports for the SX Tank Farm in the 200-West Area were completed (the first nine data reports were completed in 1995). Also in 1996, all 12 tank summary data reports were completed for the BY Tank Farm in the 200-East Area, and all 12 data reports were completed for the U Tank Farm in the 200-West Area. Finally, 6 of the 18 data reports were completed for tanks in the TX Tank Farm. The first tank farm report (the SX Tank Farm) was also published in 1996.

Information from the SX Tank Farm produced in 1995 showed cesium-137 contamination from the tanks was deeper in the vadose zone than was previously expected. Cesium-137 was found as deep as 38 m (125 ft) at some locations. This is the depth of many of the SX Tank Farm monitoring boreholes; therefore, the maximum depth of the cesium-137 contamination migration could not be determined. Previous computer models predicted cesium-137 would stay within a few meters (feet) of the base of the tanks and would not move deep into the vadose zone. Therefore, questions were raised as to whether the contamination was deposited deep in the vadose zone by transport through the sediment or if it traveled along unsealed boreholes.

Also, as a part of the vadose zone characterization at the SX Tank Farm, questions were raised about the source of a technetium-99 plume in the groundwater beneath the tanks. An extensive investigation of the groundwater data was conducted by Hanford personnel and it was determined that the S and SX Tank Farm complex was the source of the groundwater contamination. This was later confirmed in an independent investigation by the Washington State Department of Ecology. As a result, a groundwater assessment order was issued by the Washington State Department of Ecology for the S and SX Tank Farm complex and a groundwater assessment plan was prepared. The assessment is ongoing.

To help resolve questions raised by the vadose zone characterization findings, DOE formed an independent panel of experts to review the data and recommend a course of action to confirm or refute the findings of the vadose zone characterization program. Under the guidance of the independent panel, two new boreholes were drilled in the SX Tank Farm.

The boreholes were drilled with a percussion hammer drilling method. The first borehole showed contamination drag-down from the drilling operation had occurred and it did not intercept a large plume of contamination as expected. For the second borehole, the drill stem was modified to minimize contamination drag-down during drilling, and drag-down did not occur. This borehole intercepted relatively high levels of contamination to total depth at 40 m (130 ft), confirming the presence of cesium-137. This also confirmed that the contamination moved through the formation to the deep vadose zone, and the borehole pathway was not the cause for the deep contamination migration.

Finally, as a part of the vadose zone investigation, four tanks in the SX Tank Farm were reevaluated to reassess the volume of contamination that leaked from the tanks. The new leak estimates were at least an order of magnitude higher than the original leak estimates, demonstrating a need for additional investigation at all single-shell tanks.

In summary, the new data obtained under the vadose zone characterization program has identified that, in some cases, the groundwater has been impacted by tank leaks. Improved contaminant transport models calibrated with the new data will help to better define the nature and extent of contamination.

For a more comprehensive description of the single-shell tank vadose zone characterization program, the results of that program for 1996, and references to detailed reports, the reader is referred to Section 3.3, "Vadose Zone Characterization and Monitoring."

Waste Immobilization

Approximately 215 million L (55 million gal) 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, including 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 immobilized low-radioactivity fraction will be disposed of in a near-surface facility on the Hanford Site in a retrievable form. The immobilized 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 immobilization of the tank wastes.

During 1996, a change request was approved changing Tri-Party Agreement milestones to allow DOE to proceed with the planned privatization of the initial pretreatment and immobilization function of the Tank Waste Remediation System program. DOE and private companies are unwilling to commit immediately to full-scale facilities on a fixed-price basis because of uncertainties with the waste characteristics, the effectiveness of the technology, and the basis for accepting the deliverables. Consequently, the approach to privatization will be conducted in two phases.

The first phase will be a proof-of-concept/commercial demonstration phase. This phase will involve pretreatment and vitrification of the low-level waste. High-level waste separated in the pretreatment process would either be stored on an interim basis until sufficient quantities are collected to make it cost effective to process or vitrified as an option in this phase. This phase would select multiple contractors to design and obtain permits for facilities. The objectives of this phase are to 1) demonstrate technologies and processes in a production-level environment; 2) treat and immobilize sufficient waste to demonstrate early progress in remediating the tank situation to the stakeholders; 3) better understand the costs, risks, and benefits of a fixed-price privatization framework; 4) ascertain the financial viability of the private marketplace to accomplish the Tank Waste Remediation System mission; 5) establish conditions for DOE to be a "smart buyer" and for private industry to be a "smart provider" of treated waste products for Phase II; and 6) to balance the private vendors' objectives with DOE's objectives.

Phase I will be divided into subphases. Part A is a 20-month period used to establish the technical, operational, regulatory, and financial elements required by the contractors to provide waste treatment services at fixed unit prices. During this period, DOE will determine whether to authorize the contractor to perform Part B. Part B is a 10- to 14-year period established to provide waste treatment services in privatized facilities. DOE will order a minimum quantity of waste treatment services during this phase and may provide additional orders.

The second phase will be the full-scale production phase. Facilities will be sized so all of the remaining waste can be processed and immobilized on a schedule that will accommodate removing the waste in single-shell tanks by 2018. Objectives of the full-scale production phase are to 1) implement the lessons learned from Phase I; 2) process all tank waste into forms suitable for final disposal while meeting environmental, health, and safety requirements to achieve process competition and cost savings throughout the phase; 3) meet or exceed the Tri-Party Agreement benchmark performance milestones; and 4) balance the private vendor's objectives with DOE's objectives. At the end of any contract, the contractor will deactivate all contractor-provided facilities.

During 1996, DOE issued a contract to two private firms to start work on Phase I, Part A. The two firms are British Nuclear Fuels Ltd. and Lockheed Martin Advanced Environmental Systems.

Solid Waste Management Activities

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. Having started operations in March 1997, the Waste Receiving and Processing Facility Module 1 is staffed to analyze, characterize, and prepare drums and boxes for disposal of waste resulting from plutonium operations at Hanford. The Tri-Party Agreement mandates construction and operation of this module. Wastes destined for the Waste Receiving and Processing Facility include Hanford's current inventory of more than 37,000 drums of stored waste as well as materials generated by future site cleanup activities across the DOE complex. Consisting primarily of clothing, gloves, face masks, small tools, and particulates suspected of being contaminated with plutonium, waste containers may also contain other radioactive materials and hazardous components. Processed waste that qualifies as low-level waste and meets disposal requirements will be buried directly at the Hanford Site. Low-level waste not meeting burial requirements will be

treated in the Waste Receiving and Processing Facility to meet the requirements or will be prepared for future treatment at other onsite or offsite treatment, storage, and disposal facilities. Waste determined in the facility to be transuranic will be certified and packaged for shipment to the Waste Isolation Pilot Plant, Carlsbad, New Mexico for permanent storage. 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 began operations in March 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 approximately 6,800 drums of waste annually for 30 years.

Radioactive Mixed Waste Disposal Facilities

The Radioactive Mixed Waste Disposal Facilities are the first in DOE's national complex for disposal of radioactive mixed wastes. These facilities are located in the low-level burial grounds in the 200-West Area and are designated Trench 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 were not in use in 1996. The facilities consist of rectangular landfills with approximate base dimensions of 76 by 30 m (250 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 designed to comply with Resource Conservation and Recovery Act requirements–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 June 1997. This facility comprises three buildings that have a total storage capacity of approximately 2,800 m^3 (3,700 yd^3). The project is currently going through the operational readiness review process. The facility will be operated under the Central Waste Complex interim safety basis that was approved by DOE in March 1997.

T Plant Complex

The function of the T Plant complex in the 200-West Area is to provide waste processing and decontamination services for the Hanford Site. Two facilities are used to provide these services: the T Plant canyon and 2706-T. Other areas around these facilities are also used to support these services. The T Plant complex is a Resource Conservation and Recovery Act-permitted facility, which can store waste for greater than 90 days and perform treatment in tanks and other containers. T Plant's waste handling activities in 1996 included the following:

- performing verification of wastes being shipped to solid waste facilities for storage or disposal
- repackaging and/or sampling waste to meet solid waste acceptance criteria or to determine acceptability of waste for treatment
- treating dangerous and mixed wastes to meet Resource Conservation and Recovery Act requirements for land disposal
- decontaminating equipment to allow for reuse or disposal as waste.

Plans for upgrading the T Plant liquid waste storage tank system were finalized in 1996. These upgrades will make T Plant's tank system fully compliant with the regulations and will allow for improved liquid waste handling capabilities. Construction started in January 1997 with completion expected by September 1999.

Thermal Treatment Contracts

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 Corporation. The contract is for 5 years, with five 1-year renewal options. Waste processing is scheduled to begin in fiscal year 2001.

Two additional requests for proposals for thermal treatment of waste were issued in April 1997. One defines the requirements for treating nondebris inorganic mixed waste during fiscal year 1998 with an option for additional treatment during fiscal year 1999. The other covers treatment of mixed waste debris during fiscal year 1999 with options for additional treatment in fiscal years 2000 and 2001. Treatment contractors may propose treatment at facilities on their site or may propose to install portable/temporary facilities on the Hanford Site. Contract award is planned for September 1997.

Navy Reactor Compartments

Seven defueled United States Navy reactor compartment disposal packages were received and placed in Trench 94 in the 200-East Area during 1996. This brings the total number received to 61. The compartments originate from decommissioned nuclear-powered submarines.

The reactor compartment disposal packages are being regulated by Washington State as dangerous waste because of the presence of lead used as shielding and by EPA because of the presence of small amounts of polychlorinated biphenyls tightly bound within the composition of solid materials such as thermal insulation, cable coverings, and rubber. Also, the compartments are regulated as mixed waste because of radioactivity in addition to dangerous waste.

325 Building Hazardous Waste Treatment Units

The 325 Building hazardous waste treatment units in the 300 Area receive, store, and treat mixed and dangerous waste generated by Pacific Northwest National Laboratory programs. The units consist of the Shielded Analytical Laboratory and the Hazardous Waste Treatment Unit.

The Shielded Analytical Laboratory is a facility that has a dual role as an analytical laboratory and a treatment facility. The laboratory performs tank treatment and bench-scale treatment of high dose rate laboratory waste (2,000 rem/h capability).

The Hazardous Waste Treatment Unit is a treatment facility that contains fume hoods and gloveboxes for mixed waste treatment. The unit performs bench-scale treatment of mixed and dangerous waste from various Pacific Northwest National Laboratory programs and also treats transuranic and transuranic mixed waste by neutralization and stabilization.

These units are currently operating under interim-status conditions. Final status is expected in December 1997.

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 processes double-shell tank waste into a concentrate (that is returned to the tanks) and a process condensate stream. The evaporator had one processing campaign in 1996. Dilute waste from the double-shell tanks was processed, resulting in an average waste volume reduction of 88.5% while producing 4.8 million L (1.3 million gal) of process condensate. Two campaigns are scheduled for 1997.

Effluent treatment and disposal capabilities are available to support the continued operation of the evaporator. The 200 Areas Effluent Treatment Facility near the 200-East Area was constructed to treat the process condensate. The process condensate is temporarily stored in the Liquid Effluent Retention Facility while awaiting treatment in the 200 Areas Effluent Treatment Facility. Cooling water and nonradioactive steam condensate from the evaporator will be discharged to the 200 Areas Treated Effluent Disposal Facility starting in 1997.

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 200 Areas Effluent Treatment Facility. Each basin has a capacity of 24.6 million L (6.5 million gal). Spare capacity equal to the volume of one basin is reserved 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 0.9-m- (3.0-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 5.3 million L (1.4 million gal) of process condensate was stored in the basins at the end of 1996.

200 Areas Effluent Treatment Facility

The 200 Areas Effluent Treatment Facility (near the 200-East Area) 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 filtration, 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 facility began operation in December 1995 and has a 30-year design life. Approximately 37.5 million L (9.9 million gal) of waste water were treated in 1996.

The treated effluent from this facility is sampled to verify that the concentrations of radioactive and hazardous waste constituents have been reduced to acceptable levels, then discharged via a dedicated pipeline to a state-approved land disposal structure. The disposal facility (200-West Area) consists of an underground drain field. The percolation rates for the field have been established by site testing and evaluation of 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 that exempts the treated process condensate from the requirements of dangerous 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 feed stream a dangerous waste subject to WAC 173-303. 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 WAC 173-216. The discharge permit requires monitoring of the effluent groundwater 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 208-L (55-gal) drums. The 200 Areas 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 mixed waste trench 218-W-5 in the 200-West Area.

200 Areas Treated Effluent Disposal Facility

The 200 Areas 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 this 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 WAC 173-216 without further treatment.

This 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), though the discharge permit presently limits the average monthly flow to 2,400 L/min (640 gal/min). Approximately 760 million L (200 million gal) of treated effluent were discharged in 1996. 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 groundwater 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 noncontact radioactive processes. The laboratory services are particularly critical to Hanford Site cleanup activities, including tank waste remediation efforts.

This 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 coprecipitation to remove heavy metals, resin ion exchange to remove mercury, and ultraviolet light/hydrogen peroxide oxidation to destroy organics and cyanide. Sludge from the iron coprecipitation process is dewatered and used for backfill. The treated liquid effluent is monitored and discharged through an outfall to the Columbia River under a National Pollutant Discharge Elimination System permit. 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. This facility began operating in December 1994 and treated approximately 350 million L (92 million gal) of waste water in 1996.

340 Waste Handling Facility

The 340 Waste Handling 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 accumulated waste is pumped into railcars and transported to the 200-East Area 204-AR Unloading Facility for neutralization and transfer to double-shell tanks for storage. The 340 facility does not have a Resource Conservation and Recovery Act permit for storage; therefore, wastes cannot be stored for more than 90 days.

The 340 facility will cease receiving waste in September 1998. A new waste handling facility with storage and truck loadout capability will be provided. The 340 facility will then be cleaned, decontaminated, and decommissioned.

300 Area Process Sewer Upgrades

Upgrades to the 300 Area process sewer system were completed in 1996. A proposal to reline the existing piping was approved by the regulators. The process involved camera surveillance and cleanout of the piping, installation of resin-impregnated polyester felt fiber in the pipe walls, and thermal curing by heating the water. Lateral pipelines were cut using robotics, and new access holes and cleanouts were constructed as needed. Additional process sewer lines and storm-water connections were installed. The existing pump station, which serves buildings in the southeastern 300 Area, was refurbished. Drummed residue from pipe cleanout was sent to disposal.

The process sewer system collects cooling water, steam condensate, and other liquid effluents generated in 300 Area laboratories, research facilities, and office buildings. The waste water is treated in the 300 Area Treated Effluent Disposal Facility.

Phase II Liquid Effluent Streams

DOE has committed to implement "best available technology/all known and reasonable treatment" for nine waste-water streams and to permit the streams under WAC 173-216 by October 1997. This activity is required by the Washington State Department of Ecology Consent Order #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 in the 200-East Area.

Project W-252, "Phase II Effluent Treatment and Disposal," will connect the following streams to the 200 Areas Treated Effluent Disposal Facility: 242-A Evaporator cooling water, 242-A Evaporator steam condensate, 284-E Power Plant waste water (including 282-E and 283-E), and B Plant/Waste Encapsulation Storage Facility cooling water. Another stream, the 241-A Tank Farm cooling water, is to be connected to the 200 Areas Treated Effluent Disposal Facility as part of Project W-030. Construction on Project W-252 is scheduled to be completed in April 1997 and startup is planned for June 1997. A supplemental discharge permit application was submitted in November 1996 so that additional streams can be disposed of to the 200 Areas Treated Effluent Disposal Facility. The permitted capacity of the facility will increase to a total average yearly flow rate of 4,540 L/min (1,200 gal/min) and a total average monthly flow rate of 12,900 L/min (3,400 gal/min).

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 #DE 91NM-177. The *Plan and Schedule for Disposition and Regulatory Compliance for Miscellaneous Streams* (DOE 1994d) 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 173-218). The commitments established in the plan and schedule include annually updating the miscellaneous streams inventory (through 1998), registering injection wells, submitting 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. Categorical permit applications are to be submitted for the following:

- hydrotesting, maintenance, and construction discharges (application submitted November 1995)
- cooling water discharges and uncontaminated steam condensate (application submitted September 1996)
- storm-water discharges.

Another categorical permit was planned for surface-water and safety shower discharges. These streams will be included in an existing permit or eliminated. A best management practices report was submitted to the Washington State Department of Ecology in August 1996 and included recommendations of preferred options and an implementation schedule.

Revegetation and Mitigation Planning

DOE and the Hanford Natural Resource Trustees are working cooperatively to plan and provide effective input to restoration and mitigation actions for the proposed remediation sites. The contributors are supporting DOE in this effort. Revegetation/mitigation plans will include the use of native plant species (seeds and shrubs) as appropriate to restore the areas disturbed by remediation activities.

DOE Richland Operations Office and the environmental restoration contractor work cooperatively with the Natural Resource Trustees on the mitigation action plans for the various remedial action projects. The plans describe the planning and implementation of appropriate mitigation measures for areas disturbed during remediation. Mitigation measures include avoidance, minimization, rectification, or compensation of impacted resources.

The *Hanford Site Biological Resources Management Plan* (DOE 1996f) was developed to provide DOE and its contractors with a consistent approach to protect biological resources and monitor, assess, and mitigate impacts to them from site development and environmental cleanup and restoration activities. This comprehensive plan provides a framework to enable Hanford Site resource professionals to effectively fulfill their responsibilities and address tribal, resource agency, and other stakeholder concerns about the site's biological resources. The policies and guidelines described in the plan were developed based on legal requirements and policy initiatives that direct an ecosystem management approach toward resources management.

The *Hanford Site Biological Resources Mitigation Strategy Plan* (DOE 1996g), containing strategy that is part of the broader biological resource policy contained in the biological resources management plan (DOE 1996f), is designed to aid DOE in balancing its primary missions of waste cleanup, technology development, and economic diversification with its stewardship responsibilities for the biological resources it administers. This biological resources mitigation strategy will help to ensure consistent and effective implementation of mitigation recommendations and requirements, ensure mitigation measures for biological resources meet the responsibilities of DOE under the law, enable Hanford Site development and cleanup projects to anticipate and plan for mitigation needs via early identification of mitigation requirements, and provide guidance to Hanford personnel in implementing mitigation in a cost-effective and timely manner.

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2.4 Environmental Occurrences

R. L. Smithwick

Onsite and offsite environmental releases of radioactive and regulated materials during 1996 were reported to DOE and other 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 1996, 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's Hanford Reading Room located on the campus of Washington State University at Tri-Cities, 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 1996.

An unusual occurrence is defined in the DOE Order 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 no environmentally significant unusual occurrence reports filed during 1996 for site contractors.

Off-normal environmental occurrences are classified in the DOE Order 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 15 off-normal environmental release-related occurrence reports filed at the Hanford Site during 1996. These occurrences were determined to be either hazardous substance/regulated pollutants/oils or hazardous material contamination or potential concerns/issues. Several of these occurrences are discussed in Section 2.2, under the Resources Conservation and Recovery Act Inspections, Clean Air Act Enforcement Inspections, and Clean Water Act subsections. The following summarizes some of the other off-normal occurrences not previously discussed.

Off-Normal Occurrences

100-N Emergency Dump Basin Contaminated Sediment Spill

On December 12, 1996, at approximately 10:10 a.m., contaminated solidified sediment from the 100-N Emergency Dump Basin in the 100-N Area was spilled to the ground while offloading a hauling container from a transporter. The spill occurred at a temporary staging area, posted as a radiological material area, at the Environmental Restoration Disposal Facility. Initial radiological readings from the contaminated sediment on the ground were reported to onsite project management to be 60 dpm alpha/100 cm^2, 5,926 beta gamma/100 cm^2, and 7 mR/h on contact. The spill was cleaned up. To prevent further incidents, procedural changes were made and lessons learned were drafted and issued to all involved personnel.

Annual Emission Limit Exceeded at 105-KE Basin

The 105-KE Basin in the 100-K Area exceeded the annual emission limit for plutonium-241 as set forth in *Radioactive Air Emissions Notice of Construction Debris Removal, 105-KE Basin* (DOE 1995e). The projected annual plutonium-241 emission estimate of 4.0×10^{-5} Ci had been accepted by the Washington State Department of Health as a limit. For the period February 1995 through November 1995, there were 1.9×10^{-4} Ci released. The delay in reporting is due to sample processing time at the laboratory. The Washington State Department of Health was originally notified of indi-cations that plutonium-241 concentrations were exceeding projected levels at a September 1995 technical exchange meeting.

Polychlorinated Biphenyl Concentrations Discovered in K Basins Sludge

Chemical characterization data for sludge samples from the 105-KE Basin in the 100-K Area showed polychlorinated biphenyl concentrations between 2 and 220 ppm. These concentrations exceed those known from historical processes. No specific information regarding the source of the polychlorinated biphenyl is available. Therefore, it is unknown if the contamination originated from a spill and, if so, if the spill was reportable under other regulations (e.g., Comprehensive Environmental Response, Compensation, and Liability Act, Toxic Substances Control Act, etc.). In the absence of source identification, this discovery has been conservatively reported as a spill to the National Response Center as required by 40 CFR 761.125.

Facility-Related Monitoring, Waste Management, and Chemical Inventory Information

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3.0 Facility-Related Monitoring, Waste Management, and Chemical Inventory Information

The following sections include information about facility-related environmental monitoring programs at the Hanford Site, including effluent monitoring (Section 3.1), near-facility environmental monitoring (Section 3.2) and vadose zone monitoring (Section 3.3). The management of radioactive and nonradioactive solid and liquid wastes stored or disposed of at Hanford and the types and quantities of hazardous chemicals stored on the site are also discussed (Section 3.4).

The monitoring of effluents and contaminants and the management of wastes and chemical inventories at Hanford Site facilities are necessary to determine the effects these materials may have on the public, workers at the site, and the surrounding environment. Effluent monitoring is conducted by the various site contractors at their facilities pursuant to requirements in DOE Order 5400.1. At Hanford, effluent monitoring includes the collection of samples for analyses, or measurements, of liquid and gaseous effluents for the purposes 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.

Near-facility environmental monitoring consists of the routine monitoring of environmental media near facilities that have the potential to discharge or have discharged, stored, or disposed of radioactive or hazardous contaminants. Monitoring locations are generally associated with major nuclear-related installations and waste storage and disposal units.

Vadose zone monitoring is conducted near selected current or historical waste storage or disposal sites to characterize and establish baseline concentrations of radioactive contaminants in the vadose zone sediments near the sites. Gamma-spectral logging equipment is used within new and existing boreholes to detect, identify, and quantify gamma-emitting radionuclides.

Wastes stored on the site are categorized and managed in accordance with applicable state and federal regulations. Inventories of hazardous chemicals are tracked and reported annually as required by law.

More detailed program, sampling, and waste management information is contained in *Hanford Site Near-Facility Environmental Monitoring Annual Report, Calendar Year 1996* (Perkins et al. 1997), *Hanford Tier Two Emergency and Hazardous Chemical Inventory, Emergency Planning and Community Right-to-Know Act, Section 312* (DOE 1996h), the *Hanford Site Annual Dangerous Waste Report, Calendar Year 1996* (DOE 1997c), and *Summary of Radioactive Solid Waste Received in the 200 Areas During Calendar Year 1996* (Hagel 1997).

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3.1 Facility Effluent Monitoring

B. P. Gleckler

Liquid and airborne effluents that may contain radioactive or hazardous constituents are continually monitored when released to the environment at the Hanford Site. Facility operators perform the monitoring mainly through analyzing samples collected near points of release into the environment. Effluent monitoring data are evaluated to determine the degree of regulatory compliance for each facility or the entire site, as appropriate. The evaluations are also useful in assessing the effectiveness of effluent treatment and control systems and management practices. Major facilities have their own individual effluent monitoring plans, which are part of *Environmental Monitoring Plan, United States Department of Energy, Richland Operations Office* (DOE 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 or periodic confirmatory measurements for most radioactive air emission units and proportional, or grab, sampling for most liquid effluent streams. Liquid and airborne effluents with a potential to contain radioactive materials at prescribed threshold levels are measured for total alpha and beta activity and, as warranted, specific radionuclides. Nonradioactive constituents are also either monitored or sampled, as applicable.

Small quantities of tritium, cobalt-60, strontium-90, technetium-99, ruthenium-106, antimony-125, iodine-129, cesium-134, cesium-137, europium-154, europium-155, radon-220, radon-222, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239,240, plutonium-241, and americium-241 continue to be released to the environment. However, most radionuclides in effluents at the site are approaching levels indistinguishable from background, or natural, 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 prominent dose-contributing radionuclides released from the site over the past years. In 1996, 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 annually submits to EPA and the Washington State Department of Health a report of radioactive airborne emissions from the site (Gleckler et al. 1997), in compliance with National Emission Standards for Hazardous Air Pollutants (40 CFR 61) and Radiation Protection--Air Emissions (WAC 246-247). Data quantifying radioactive liquid and airborne effluents discharged by the site management and integration contractor and its subcontractors and the environmental restoration contractor are reported to DOE annually in the environmental releases report (Gleckler 1997). Monitoring results for liquid streams regulated by the National Pollutant Discharge Elimination System permit are reported to EPA. Monitoring results from liquid effluent streams regulated by WAC-173-216 are reported to the Washington State Department of Ecology. Nonradioactive air emissions are reported annually 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. Emissions having the potential to exceed 1% of the 10-mrem/yr standard for offsite doses are continuously monitored.

The continuous monitoring of radioactive emissions involves analyzing samples collected at points of discharge to the environment, usually from a stack or vent. Samples are analyzed for total alpha activity, total beta

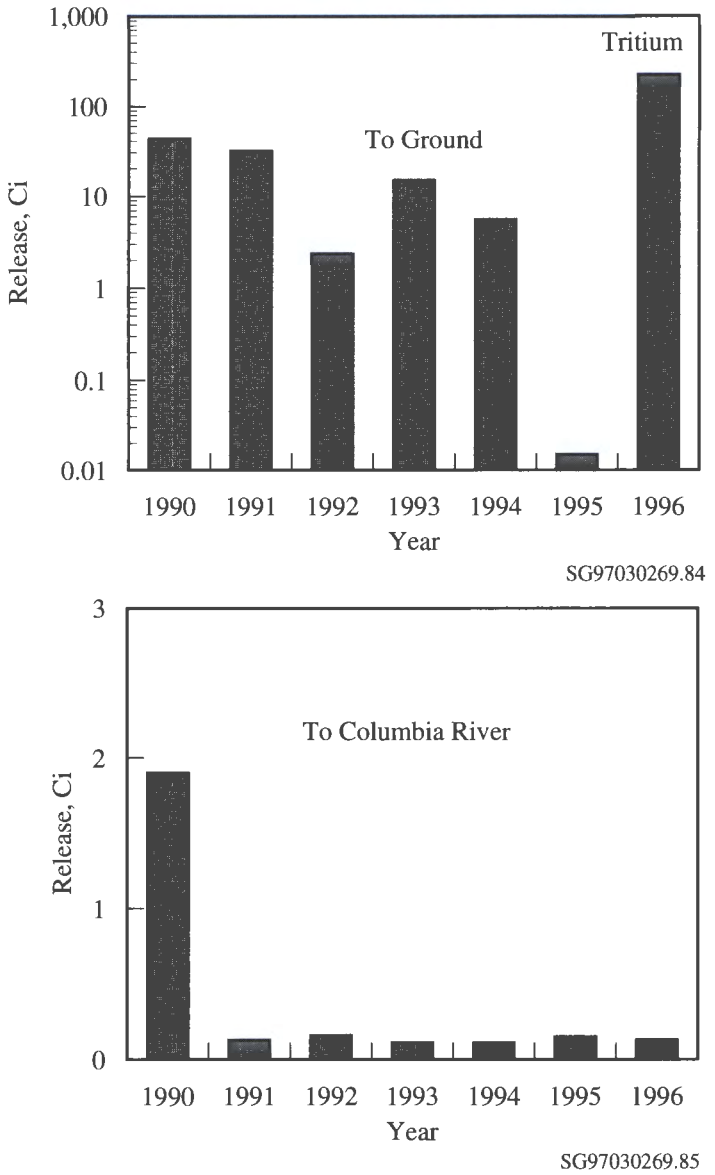

Figure 3.1.1. Liquid Releases of Selected Radionuclides from Site Facilities, 1990 Through 1996

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) the sampling criteria given in contractor environmental compliance manuals, and 3) the potential each radionuclide has to contribute to the offsite public dose. Continuous air monitoring systems with alarms are also used at selected discharge points when a potential exists for radioactive emissions to exceed normal operating ranges by levels requiring immediate personnel alert.

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

- In the 100 Areas, emissions originate from the deactivation of the N Reactor Fuel Storage Basin, the two 100-K Area water-filled storage basins (K Basins) containing irradiated fuel, a recirculation facility that filters radioactive water from the N Reactor basin that was used for storage of irradiated fuel, a room used for cleaning contaminated tools and equipment,

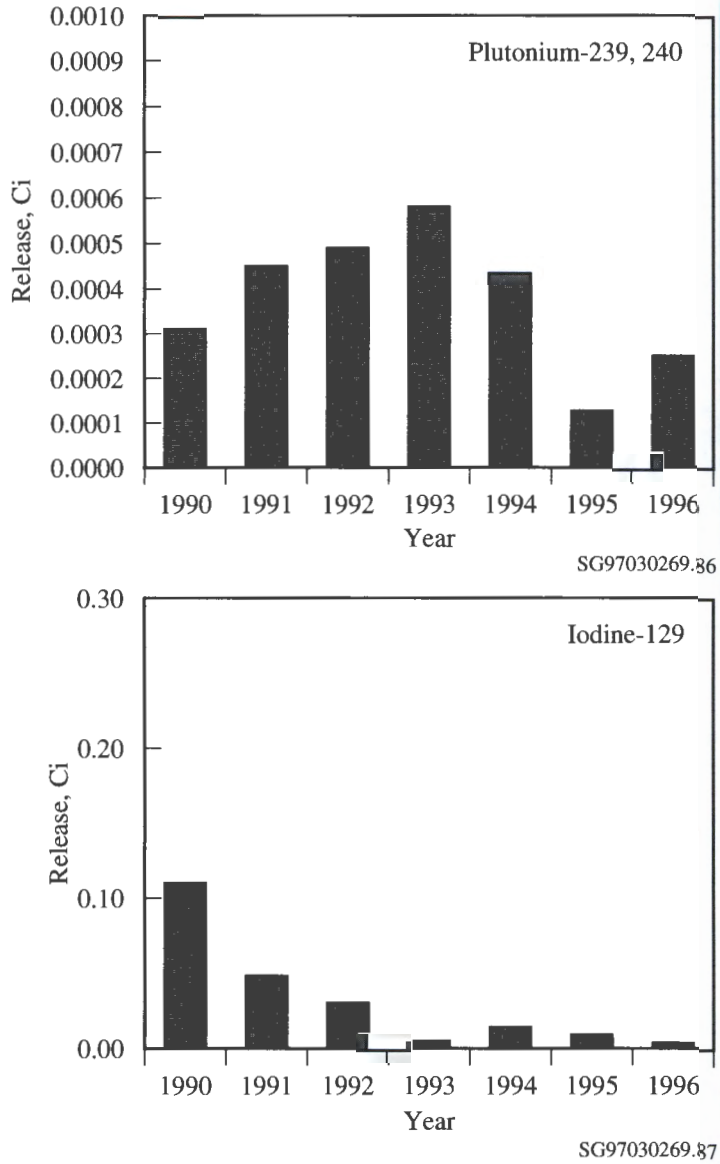

Figure 3.1.2. Airborne Releases of Selected Radionuclides from Site Facilities, 1990 Through 1996

and a radiochemistry laboratory. Six radioactive emission points were active in the 100 Areas during 1996.

- The 200 Areas contain inactive facilities for nuclear fuel chemical separations and reprocessing, waste handling and disposal facilities, and steam generation plants using fossil fuels. Primary sources of radionuclide emissions are the Plutonium-Uranium Extraction Plant, Plutonium Finishing Plant, T Plant, 222-S Analytical Laboratory, underground tanks for storage of high-level radioactive waste, and waste evaporators. During 1996, 63 radioactive emission 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, 325 Applied Chemistry Laboratory, 327 Post-Irradiation Laboratory, and 340 Vault and Tanks. Radioactive emissions arise from research-and-development and waste handling activities. During 1996, 32 radioactive emission discharge points were active in the 300 Area.

- The 400 Area has 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 Maintenance and Storage Facility released small quantities of radioactive material to the environment, even though the reactor did not operate in 1996. The 400 Area had four radioactive emission discharge points active during 1996.

- The 600 Area encompasses the remaining portions of the Hanford Site not assigned to other areas. One minor radioactive emission point was active during 1996, the 6652-H Ecology Laboratory on the Fitzner/ Eberhardt Arid Lands Ecology Reserve; its releases have been incorporated with 400 Area releases.

A summary of the Hanford Site's 1996 radioactive airborne emissions is provided in Table 3.1.1. Several constituents not detected or not measured are included in the table for historical comparisons.

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, 241-AP Tank Farm, and 241-AW Tank Farm. Ammonia emissions are monitored only when activities at these facilities are capable of generating them. In 1996, the 242-A Evaporator operated during the month of May, producing reportable ammonia emissions. The 200-West Area tank farms produced reportable ammonia emissions in 1996 also. The ammonia releases from the 242-A Evaporator and tank farms in the 200 Areas are summarized in Table 3.1.2.

Operating power plants 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 Washington State in WAC-173-400. Power plant 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 the 1996 emissions of nonradioactive constituents (it should be noted that 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 wastewater 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 sites in 1996. A summary of radioactive liquid effluents discharged to the 200 Areas' ground disposal facilities in 1996 is provided in Table 3.1.3. Table 3.1.4 summarizes data on radionuclides in liquid effluents released from the 100 Areas to the Columbia River. These measurements are used to determine potential radiation doses to the public. Several constituents not detected are included in the tables for historical comparisons.

Nonradioactive Hazardous Materials in Liquid Effluents

Nonradioactive hazardous materials in liquid effluents are monitored in the 100, 200, 300, and 400 Areas. These effluents are typically discharged to cribs, ponds, ditches, trenches, and the Columbia River. Effluents entering the Columbia River at designated discharge points are sampled and analyzed to determine compliance with the National Pollutant Discharge Elimination System permit for the site. Should chemicals in liquid effluents exceed quantities reportable under the Comprehensive Environmental Response, Compensation, and Liability Act, the release totals are reported immediately to the EPA. If emissions remain stable at predicted levels, they may be reported annually with EPA's permission. In Section 2.0, Table 2.2.3 contains a synopsis of the National Pollutant Discharge Elimination System and State Waste Discharge permit violations in 1996.

Table 3.1.1. Release Estimates of Hanford Site Radionuclide Air Emissions, 1996

Radionuclide	Half-Life	Release, Ci[a]				
		100 Areas	200-East Area	200-West Area	300 Area	400 Area
^{3}H (as HTO)[b]	12.3 yr	NM	NM	NM	1.8×10^{0}	3.6×10^{0}
^{3}H (as HT)[b]	12.3 yr	NM	NM	NM	1.7×10^{0}	NM
^{60}Co	5.3 yr	5.1×10^{-7}	7.7×10^{-10}	ND	ND	NM
^{65}Zn	244.4 d	ND	ND	ND	ND	NM
^{90}Sr	29.1 yr	2.9×10^{-5}	6.2×10^{-5}[c]	3.6×10^{-4}[c]	2.0×10^{-5}[c]	9.0×10^{-9}[c]
^{95}Zr	64.02 d	ND	ND	ND	ND	NM
^{106}Ru	368 d	5.4×10^{-7}	9.5×10^{-8}	NM	ND	NM
^{113}Sn	115.1 d	ND	ND	NM	ND	NM
^{125}Sb	2.77 yr	1.9×10^{-7}	2.0×10^{-6}	NM	ND	NM
^{129}I	1.6×10^{7} yr	NM	3.9×10^{-3}	NM	ND	NM
^{131}I	8.040 d	NM	ND	NM	ND	ND
^{134}Cs	2.1 yr	1.3×10^{-8}	3.0×10^{-9}	ND	ND	NM
^{137}Cs	30 yr	5.1×10^{-5}	5.5×10^{-4}	6.5×10^{-7}	3.3×10^{-6}	5.5×10^{-6}[d]
^{152}Eu	13.6 yr	ND	ND	ND	ND	NM
^{154}Eu	8.8 yr	4.5×10^{-7}	ND	ND	ND	NM
^{155}Eu	5 yr	1.9×10^{-7}	ND	ND	ND	NM
^{220}Rn	56 s	NM	NM	NM	5.4×10^{1}	NM
^{222}Rn	3.8 d	NM	NM	NM	5.0×10^{-1}	NM
Uranium, depleted	$\geq 2.445 \times 10^{5}$ yr	NM	NM	NM	ND[e]	NM
^{238}Pu	87.7 yr	5.2×10^{-7}	2.2×10^{-7}	4.2×10^{-6}	1.9×10^{-8}	NM
$^{239,240}Pu$	2.4×10^{4} yr	4.5×10^{-6}[f]	6.7×10^{-6}[f]	2.4×10^{-4}[f]	$.9 \times 10^{-6}$[f]	8.3×10^{-7}[f]
^{241}Pu	14.4 yr	4.1×10^{-5}	1.7×10^{-5}	3.5×10^{-4}	NM	NM
^{241}Am	432 yr	2.0×10^{-6}	9.2×10^{-6}	3.7×10^{-5}	7.0×10^{-8}	NM

(a) 1 Ci = 3.7×10^{10} Bq; NM = not measured; ND = not detected.
(b) HTO = tritiated water vapor; HT = elemental tritium.
(c) This value includes total beta release data. Total beta and unspecified beta results assumed to be ^{90}Sr for dose calculations.
(d) The 400 Area's ^{137}Cs value is derived fully from total beta measurements.
(e) 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).
(f) 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, 1996[a]

Constituent	Release, kg[b]		
	200-East Area	200-West Area	300 Area
Particulate matter	1.78×10^{3}	2.91×10^{1}	1.23×10^{4}
Nitrogen oxides	2.00×10^{5}	1.54×10^{4}	4.16×10^{4}
Sulfur oxides	2.46×10^{5}	1.03×10^{2}	1.68×10^{5}
Carbon monoxide	6.76×10^{4}	7.27×10^{1}	3.78×10^{3}
Lead	1.73×10^{2}	1.81×10^{-2}	2.24×10^{1}
Volatile organic compounds[c]	1.35×10^{3}	1.73×10^{2}	2.12×10^{2}
Ammonia[d]	7.07×10^{3}	3.32×10^{3}	NM[e]
Arsenic	1.85×10^{2}	8.55×10^{-3}	1.32×10^{1}
Beryllium	2.50×10^{1}	5.09×10^{-3}	4.85×10^{-1}
Cadmium	1.47×10^{1}	2.24×10^{-2}	2.44×10^{1}
Chromium	5.37×10^{2}	9.67×10^{-2}	1.48×10^{1}
Cobalt	NE[e]	NE	1.40×10^{1}
Copper	3.37×10^{2}	5.70×10^{-1}	3.21×10^{1}
Formaldehyde	7.55×10^{1}	8.24×10^{-1}	4.68×10^{1}
Manganese	7.42×10^{2}	2.85×10^{-2}	8.55×10^{0}
Mercury	5.47×10^{0}	6.11×10^{-3}	3.70×10^{0}
Nickel	4.41×10^{2}	3.66×10^{-2}	2.69×10^{2}
Polycyclic organic matter	NE	3.20×10^{2}	6.35×10^{3}
Selenium	6.70×10^{1}	4.78×10^{-2}	4.39×10^{0}
Vanadium	4.62×10^{1}	1.42×10^{-1}	3.49×10^{2}

(a) The estimate of volatile organic compound emissions do not include emissions from certain laboratory operations.
(b) Multiply kg by 2.205 to convert to lb.
(c) Produced from fossil fuel burning for steam generation and electrical generators.
(d) Ammonia releases are from the 200-East Area tank farms, 200-West Area tank farms, and operation of the 242-A Evaporator.
(e) NM = Not measured; NE = No emissions.

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, Comprehensive, and Liability Act.

There were three releases reported under the Act's reportable quantity or WAC 173-303-145 requirements by Hanford contractors in 1996. Effective July 12, 1995, the reportable quantity for ethylene glycol was increased from 0.454 to 2,270 kg (1 to 5,005 lb) by the final rule (60 FR 30926). The number of reportable ethylene glycol releases have been significantly reduced as a result of the change in the reportable quantity. Table 3.1.5 contains a synopsis of 1996 reportable spills pursuant to the Act and WAC 173-303-145.

Table 3.1.3. Radionuclides in Liquid Effluents Discharged to Ground Disposal Facilities in the 200 Areas, 1996

Radionuclide	Half-Life	Release, Ci[a]
^{3}H	12.3 yr	2.2×10^{2}
^{14}C	5,730 yr	8.5×10^{-5}
^{90}Sr	29.1 yr	1.5×10^{-4}
^{99}Tc	2.6×10^{6} yr	1.5×10^{-4}
^{106}Ru	368 d	ND[b]
^{113}Sn	115.1 d	ND
^{125}Sb	2.77 yr	ND
^{134}Cs	2.1 yr	ND
^{137}Cs	30 yr	6.7×10^{-6}
^{152}Eu	13.6 yr	ND
^{154}Eu	8.8 yr	ND
^{155}Eu	5 yr	ND
^{234}U	2.445×10^{5} yr	2.0×10^{-4}
^{235}U	7.04×10^{8} yr	ND
^{238}U	4.47×10^{9} yr	1.5×10^{-4}
^{238}Pu	87.7 yr	2.4×10^{-5}
$^{239,240}Pu$	2.4×10^{4} yr	2.6×10^{-5}
^{241}Am	432 yr	9.3×10^{-5}

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

Table 3.1.4. Radionuclides in Liquid Effluents Discharged to the Columbia River from the 100 Areas, 1996

Radionuclide	Half-Life	Release, Ci[a]
^{3}H	12.3 yr	1.3×10^{-1}
^{60}Co	5.3 yr	2.3×10^{-3}
^{90}Sr	29.1 yr	1.2×10^{-1}
^{106}Ru	368 d	ND[b]
^{125}Sb	2.77 yr	3.5×10^{-3}
^{134}Cs	2.1 yr	ND
^{137}Cs	30 yr	3.8×10^{-3}
^{154}Eu	8.8 yr	ND
^{155}Eu	5 yr	1.2×10^{-3}
^{238}Pu	87.7 yr	4.0×10^{-5}
$^{239,240}Pu$	2.4×10^{4} yr	ND
^{241}Am	432 yr	1.1×10^{-4}

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

Table 3.1.5. Comprehensive Environmental Response, Compensation, and Liability Act and Washington Administrative Code Reportable Spills, 1996

Material	Occurrence	Quantity	Location
Radioactive water	1	8.6×10^{-6} Ci, ^{90}Sr 2.7×10^{-4} Ci, ^{137}Cs	105-KW Basin
Ammonium bifluoride and ferric chloride hexahydrate	1	0.5 kg, NH_4F_2 1.2 kg, ferric chloride hexahydrate	Sent to Richland Landfill
Polychlorinated biphenyl	1	Undetermined	105-KE Basin
Raw sewage/water	1	Undetermined	MO-398 Building

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3.2 Near-Facility Environmental Monitoring

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Several types of environmental media are sampled and various radiological measurements are taken near nuclear facilities to monitor the effectiveness of contamination control in waste management and restoration activities and effluent treatment and control practices. These include air, surface and spring waters, 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 1996 for each of these are summarized below. Additional data and more detailed information may be found in *Hanford Site Near-Facility Environmental Monitoring Annual Report, Calendar Year 1996* (Perkins et al. 1997).

Near-Facility Environmental Monitoring at the Hanford Site

Near-facility (near-field) 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 with 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; WAC 246-247; and 40 CFR 61.

Routine monitoring activities include sampling and monitoring ambient air, water from surface-water disposal units, external radiation dose rate, 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 1996 are summarized in Table 3.2.1, which shows the type, quantity, and location of samples collected.

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 (e.g., 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 of Air Samples and Analytes of Interest

Radioactivity in air was sampled by a network of continuously operating samplers at 58 locations near nuclear facilities: 4 in the 100-N Area, 4 the 100-K Area, 38 in the 200 Areas, 3 at the Environmental Restoration Disposal Facility, 4 at the 100-D,DR Area, 3 at the 100 B,C Area,

Table 3.2.1. Near-Facility Routine Environmental Samples and Locations, 1996

Sample Type	Total Number of Sample Locations	Operational Area						
		100-B,C	100-D,DR	100-K	100-N	ERDF[a]	200/600	300/400
Air	58	3	4	4	4	3	39[b]	1
Water	11	0	0	0	9	0	2	0
External radiation	156	0	5	11	54[c]	2	63	21
Soil	78	0	0	0	7	0	54	17
Vegetation	76	0	0	0	10	0	49	17

(a) Environmental Restoration Disposal Facility.
(b) Includes one station located at the Wye Barricade.
(c) Thirty thermoluminescent dosimeters and 24 survey points.

1 near the 300 Area Treated Effluent Disposal Facility, and 1 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 [1,500 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. 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, 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 analyzed for plutonium-238, plutonium-239,240, strontium-90, uranium-234, uranium-235, uranium-238, and gamma-emitting radionuclides (e.g., cesium-137, cobalt-60). Samples from the 100-K Area were also analyzed for americium-241 and plutonium-241.

Radiological Results for Air Samples

Of the radionuclide analyses performed, cesium-137, plutonium-239,240, strontium-90, and uranium were consistently detectable in the 100-N and 200 Areas. Cobalt-60 was consistently 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 1996 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 (DOE Order 5400.5) are reference values that are used as indexes of performance (Appendix C, Table C.5). The data indicate a large degree of variability. In general, air 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.

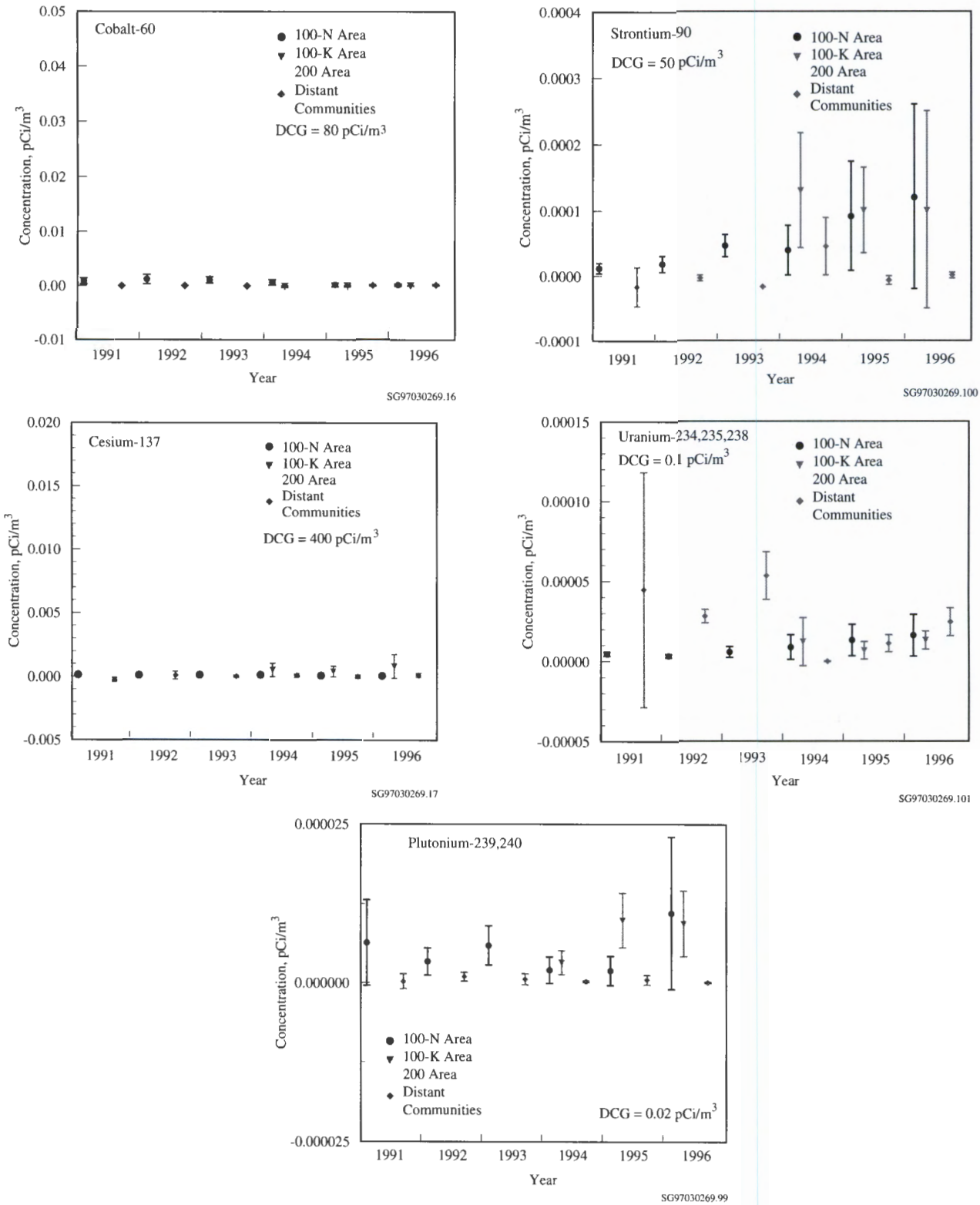

Figure 3.2.1. Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Air Samples Compared to Those in Distant Communities, 1991 Through 1996. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

100-B,C Area

Near-facility air sampling was conducted at the 100-B,C remediation site through a network of three continuous air samplers. Monitoring began in July 1996, and the analytical results indicated that the concentrations were much less than the DOE derived concentration guides and only slightly greater than levels measured offsite.

100-D,DR Area

Near-facility air sampling was conducted at the 100-D,DR remediation site through a network of four continuous air samplers. Monitoring began in November 1996, and the analytical results indicated that the concentrations were much less than the DOE derived concentration guides and only slightly greater than levels measured offsite.

100-K Area

Analytical results from 100-K Area ambient air samples show quantities of strontium-90, cesium-137, plutonium-239,240, plutonium-241, and americium-241 that were slightly above detection levels. These levels were much less than the DOE derived concentration guides; however, they were greater than levels measured offsite. Facility emissions decreased substantially in 1996, and radionuclide concentrations seen in the ambient air samples were near detection limits. The 1996 results did not differ significantly from those measured in 1995.

100-N Area

Analytical results from ambient air samples taken in the 100-N Area continued to be at or near Hanford Site 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.

200 Areas

Analytical results from ambient air samples taken in the 200 Areas were at or near Hanford Site background concentrations 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 of strontium-90, plutonium-239,240, and uranium were comparable to those measured in the 100-N Area.

Environmental Restoration Disposal Facility

Near-facility air sampling was conducted at the Environmental Restoration Disposal Facility remediation site through a network of continuous air samplers. This network utilized two existing Hanford Site monitors for upwind monitoring and was supplemented by three additional air monitors that provided downwind monitoring. Monitoring began in June 1996, and the analytical results indicated that the concentrations were much less than the DOE derived concentration guides and only slightly greater than levels measured offsite.

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. Two surface-water disposal units in the 200 Areas were sampled during 1996: the 200-East Area Powerhouse Ditch and the 216-B-3C Expansion Pond.

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

Samples from surface-water disposal units and Columbia River shoreline springs were collected from various locations in the operational areas. 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* (Westinghouse Hanford Company 1991a). 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 onsite by the Waste Sampling and Characterization Facility in 1996. Analyses included uranium, tritium, strontium-90, plutonium-238, plutonium-239,240, and gamma-emitting radionuclides. Radiological analyses of sediment and aquatic vegetation samples were performed for uranium, strontium-90, plutonium-239,240, 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 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.

Radiological 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 results were much less than the standards cited in the *Hanford Site Radiological Control Manual* (HSRCM 1994).

Table 3.2.2. Radiological Results for Liquid Samples from Surface-Water Disposal Units (pCi/L), 200 Areas, 1996

Sample Location	Number of Samples		^{3}H[a]	^{90}Sr	^{137}Cs	^{238}Pu	$^{239,240}Pu$	$^{Total}U$
200-East Powerhouse Ditch	12	Mean	1.7×10^{2}	1.2×10^{-4}	ND[b]	ND	$<3.7 \times 10^{-5}$	3.8×10^{-4}
		Maximum	3.8×10^{2}	1.2×10^{-3}	ND	ND	2.0×10^{-4}	7.7×10^{-4}
216-B-3C Expansion Pond (200-East Area)	12	Mean	2.0×10^{2}	1.5×10^{-3}	ND	2.0×10^{-4}	1.7×10^{-5}	2.0×10^{-4}
		Maximum	4.7×10^{2}	1.5×10^{-3}	ND	2.0×10^{-4}	1.7×10^{-5}	5.2×10^{-4}
		DCG[c]	2.0×10^{6}[d]	1,000	3,000	40	30	500

(a) The detection limit for tritium is 300 pCi/L .
(b) ND = Not detected.
(c) DCG = DOE derived concentration guide (DOE Order 5400.5).
(d) Using uranium-234 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, 1996

Sample Location	Number of Samples	^{90}Sr	^{137}Cs	$^{239,240}Pu$	$^{Total}U$ (g/g)
216-B-3C Expansion Pond (200-East Area)	1	0.35	0.47	0.23	2.4×10^{-9}
200-East Powerhouse Ditch	1	0.73	ND[a]	0.48	3.4×10^{-9}

(a) ND = Not detected.

Table 3.2.4. Radiological Results for Sediment Samples from Surface-Water Disposal Units (pCi/g, dry wt), 200 Areas, 1996

Sample Location	Number of Samples	^{90}Sr	^{137}Cs	$^{239,249}Pu$	$^{Total}U$ (g/g)
216-B-3C Expansion Pond (200-East Area)	1	3.8	7.9	0.78	1.9×10^{-10}
200-East Powerhouse Ditch	1	0.26	0.076	4.30	3.0×10^{-9}

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 groundwater. Radionuclides enter the Columbia River along the riverbank region known as N Springs. Releases into the river at N Springs are calculated based on analysis of weekly samples collected from monitoring well 199-N-46 located near the shoreline. A more detailed discussion of the release calculations may be found in *Environmental Releases for Calendar Year 1996* (Gleckler et al. 1997).

Groundwater springs along the 100-N Area shoreline are sampled annually to verify that the reported radionuclide releases to the Columbia River are conservative (i.e., not under reported). To verify releases, conservatively high radionuclide concentrations in samples collected from well 199-N-46 are used, multiplied by the estimated groundwater discharge into the river. The N Springs groundwater flow rate was estimated using a computer model developed by Gilmore et al. (1992). The estimated groundwater flow rate used to calculate 1996 releases from N Springs was 43 L/min (11 gal/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 groundwater migration route that has the highest concentrations of radionuclides.

In 1996, the concentrations detected in samples from shoreline springs were highest in springs nearest well 199-N-46. All of the concentrations were lower than those measured in the well. The data from shoreline springs sampling are summarized in Table 3.2.5.

Table 3.2.5. Concentration (pCi/L) of Radionuclides in 100-N Area Columbia River Shoreline Springs, 1996

Radionuclide	Facility Effluent Monitoring Well 199-N-46	Shoreline Springs Maximum	Shoreline Springs Average	DCG[a]
Tritium	20,000	16,100	2,490	2,000,000
Cobalt-60	NA[b]	5.84	1.85	5,000
Strontium-90	14,000	5,780	811	1,000

(a) DCG = DOE derived concentration guide (DOE Order 5400.5).
(b) NA = Not analyzed.

Nonradiological Results for Surface-Water Disposal Units

Nonradiological 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 state and federal drinking water standard for public water supplies (WAC 246-249, 40 CFR 141).

Radiological Surveys

Radiological surveys are used to monitor and detect radiological contamination on the Hanford Site. The two main types of posted radiological controlled areas are underground radioactive material and contamination areas.

Underground radioactive material areas are posted areas with contamination contained below the soil surface. These areas are typically stabilized cribs, burial grounds,

Table 3.2.6. Nonradiological Results for Water Samples from Surface-Water Disposal Units, 200 Areas, 1996

	pH				Nitrate (NO_3), mg/L		
Sample Location	No. of Samples	Mean	Maximum	Minimum	No. of Samples	Mean	Maximum
200-East Powerhouse Ditch	52	8.2	8.7	6.6	4	0.17	0.32
216-B-3C Expansion Pond (200-East Area)	52	8.9	9.3	7.8	4	0.16	0.32

and covered ponds, trenches, and ditches. Barriers over the contamination sources are used to inhibit radionuclide transport to the surface environs. These areas are surveyed at least annually to document the current radiological status. The radiologically contaminated areas have been reposted to meet the new requirements outlined in HSRCM (1994). The postings include contamination, high contamination (activity of >100,000 dpm/100 cm^2 beta/gamma or >10,000 dpm/100 cm^2 alpha), soil contamination, underground radioactive material, radiological buffer, and radiation/high radiation. For continuity between annual reports issued in 1995 and 1996, the use of contamination area in this report includes contamination, high contamination, and soil contamination areas.

Contamination/soil contamination areas may or may not be associated with an underground radioactive material structure. A breach in the barrier of an underground radioactive material area may result in the growth of contaminated vegetation. Insects or animals may burrow into an underground radioactive material area and 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 contaminate an area that is not related to a subsurface structure. All types of contamination areas may be susceptible to contamination migration. All known contamination areas are surveyed at least annually to document the current radiological status.

In 1996, the Hanford Site had approximately 4,016 ha (9,923 acres) of posted outdoor contamination areas and 550 ha (1,360 acres) of posted underground radioactive material areas not including active facilities. The number of hectares (acres) of contamination areas is approximately eight times larger than the underground radioactive material areas. This is primarily because of the BC Cribs controlled area located south of the 200-East Area. This area was initially posted as a radiologically controlled area in 1958 because of widespread speck contamination and encompassed approximately 1,000 ha (2,500 acres). Additional investigative surveys were conducted adjacent to the BC Cribs controlled area in 1996, and the area was enlarged to 3,831 ha (9,466 acres). Table 3.2.7 lists the acreage for contamination areas and underground radioactive material areas, showing the net change from 1995 to 1996. A global positioning system was used in 1996 to measure the surface areas more accurately than in past years. Area measurements for 1996 have been entered into the Hanford Geographical Information 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 also being identified. Table 3.2.8 indicates the changes resulting from stabilization activities during 1996. Approximately 21 ha (52 acres) were reclassified from contamination/soil contamination areas to underground radioactive material areas and 2,831 ha (6,995 acres) were posted as soil contamination areas. This large increase in contamination/soil contamination area is due to posting changes in the BC Cribs controlled area (Figure 3.2.2). Newly identified areas may have resulted from contaminant 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 have identified areas of contamination that were previously undetected.

It was estimated that the external dose rate at 80% of the identified outdoor contamination areas was less than 1 mrem/h, though direct dose rate readings from isolated radioactive specks (a particle with a diameter less than 0.6 cm [0.25 in.]) could have been considerably higher.

Table 3.2.7. Outdoor Contamination Status, 1996

Hanford Site Area	Contamination Areas,[a] ha (acres)		Net Change,[b] ha (acres)		Underground Radioactive Material Areas,[c] ha (acres)		Net Change,[b] ha (acres)	
100-B,C	8	(20)		0	39	(96)		0
100-D,DR	0.1	(0.2)	-3	(7)	39	(96)	3	(7)
100-F	0.7	(1.7)	-7	(17)	33	(82)	3	(7)
100-H	0.4	(1)		0	14	(35)	1	(2)
100-K	8	(20)	5	(12)	53	(131)	-7	(17)
100-N	29	(73)		0	0.2	(0.5)		0
200-East[d]	64	(158)	-2,194	(5,421)	137	(339)	-14	(35)
200-West[d]	35	(86)	-166	(410)	194	(479)	-483	(1,193)
300	20	(49)	-1	(2)	14	(35)	1	(2)
400		0		0		0		0
600[e]	3,850	(9,513)	3,850	(9,513)	28	(69)	22	(54)
Totals	4,016	(9,923)	1,484	(3,667)	550	(1,360)	-474	(1,171)

(a) Includes areas posted as contamination/soil contamination or as radiologically controlled and areas that had both underground and contamination/soil contamination.
(b) - = Decreases.
(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.
(e) Includes BC Cribs controlled area and waste disposal facilities outside the 200-East Area boundary that received waste from 200-East Area facilities (e.g., 216-A-25, 216-B-3) and waste disposal facilities outside the 200-West Area boundary that received waste from 200-West Area facilities (e.g., 216-S-19, 216-U-11).

Table 3.2.8. Zone Status Change of Posted Contamination Areas, 1996

Location	Zone Change	Area, ha (acres)	
100 Areas	CA to URM[a]	11	(27)
200-East Area	CA to URM	0.5	(1)
200-West Area	CA to URM	3	(11)
300 Area	CA to URM		0
400 Area	CA to URM		0
600 Area	CA to URM	7	(17)
600 Area	NONE to CA	2,831	(6,995)

(a) CA = Contamination/soil contamination area.
URM = Underground radioactive material area.

Contamination levels of this magnitude did not significantly add to dose rates for the public or Hanford Site workers in 1996.

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.

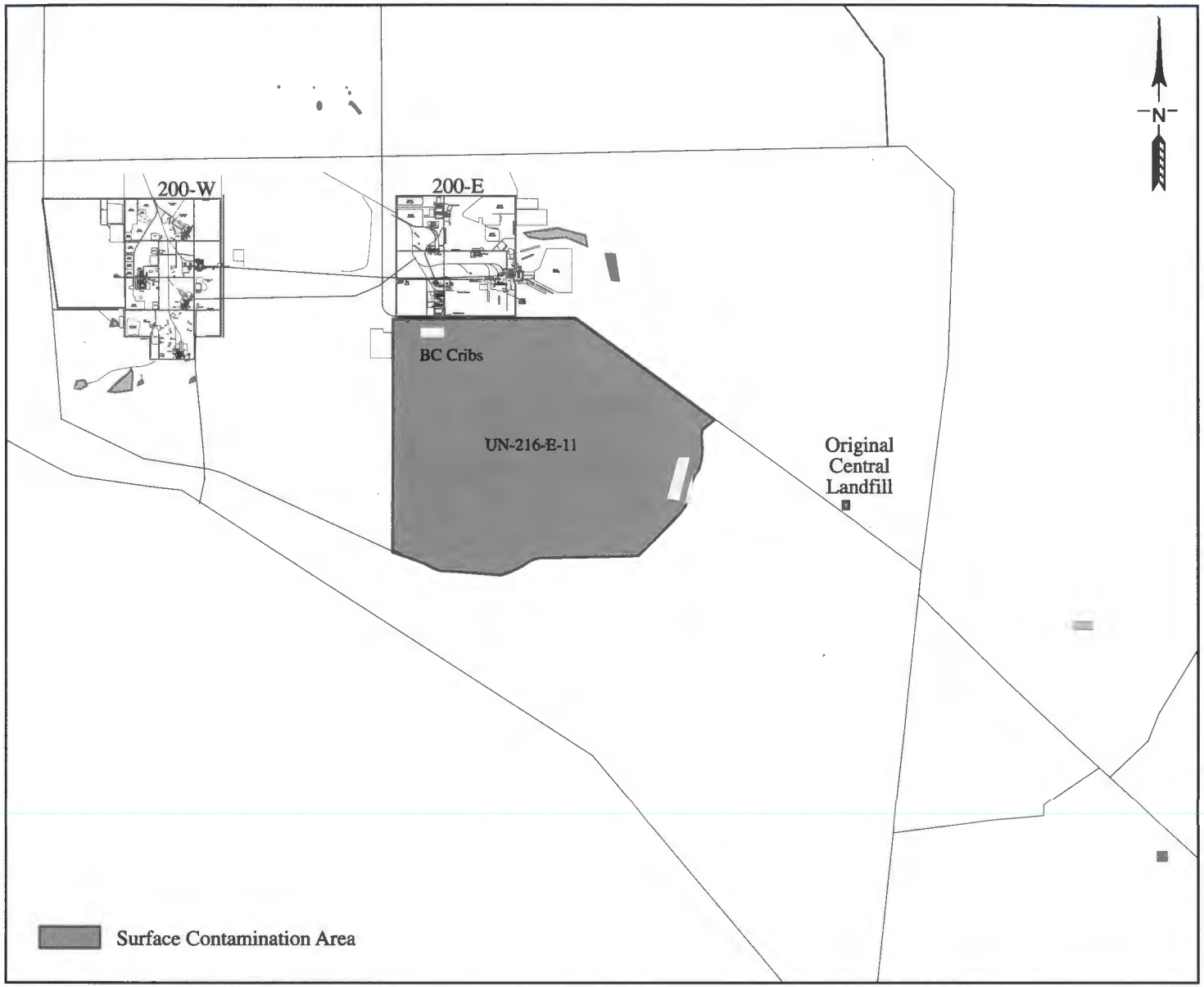

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Figure 3.2.2. Enlarged Soil Contamination Area South of the 200-East Area

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. In 1996, the number of sampling locations was reduced by approximately 50%. The sites that continue to be used are those nearest the liquid waste disposal facilities. Soil sampling in the 200 Areas was modified in 1994 to be more cost effective. Fifty-four soil samples are collected at alternating locations each year. The results of the sampling effort are discussed below.

Collection of Soil and Vegetation Samples and Analytes of Interest

The sampling methods and locations used are discussed in detail in Westinghouse Hanford Company (1991a). Radiological analyses of soil and vegetation samples included strontium-90, plutonium-239,240, uranium, and gamma-emitting radionuclides.

Radiological Results for Soil Samples

Of the radionuclide analyses performed, cobalt-60, strontium-90, cesium-137, plutonium-239,240, and uranium were consistently detectable. Soil concentrations for these radionuclides were elevated near and within facility boundaries when compared to concentrations measured offsite in 1996. Figure 3.2.3 shows average soil values for 1996 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. 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.

100-N Area

As a result of the shutdown of N Reactor and associated facilities, the analytical results from soil samples collected in the 100-N Area in 1996 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 strontium-90, cesium-137, and plutonium-239,240, 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 Areas were higher than those measured from the 100 and 200 Areas and slightly lower than levels measured in 1995. Uranium was expected in these samples because it was used during past fuel fabrication operations in the 300 Area.

Radiological Results for Vegetation Samples

Of the radionuclide analyses performed, cobalt-60, strontium-90, cesium-137, plutonium-239,240, 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 1996. Figure 3.2.4 shows average vegetation values for 1996 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 1996. Except for strontium-90 (a fission product) detected in vegetation at the 100-N Area, the predominant radionuclides are generally activation products in the 100 Areas, fission products in the 200 Areas, and uranium in the 300 Area).

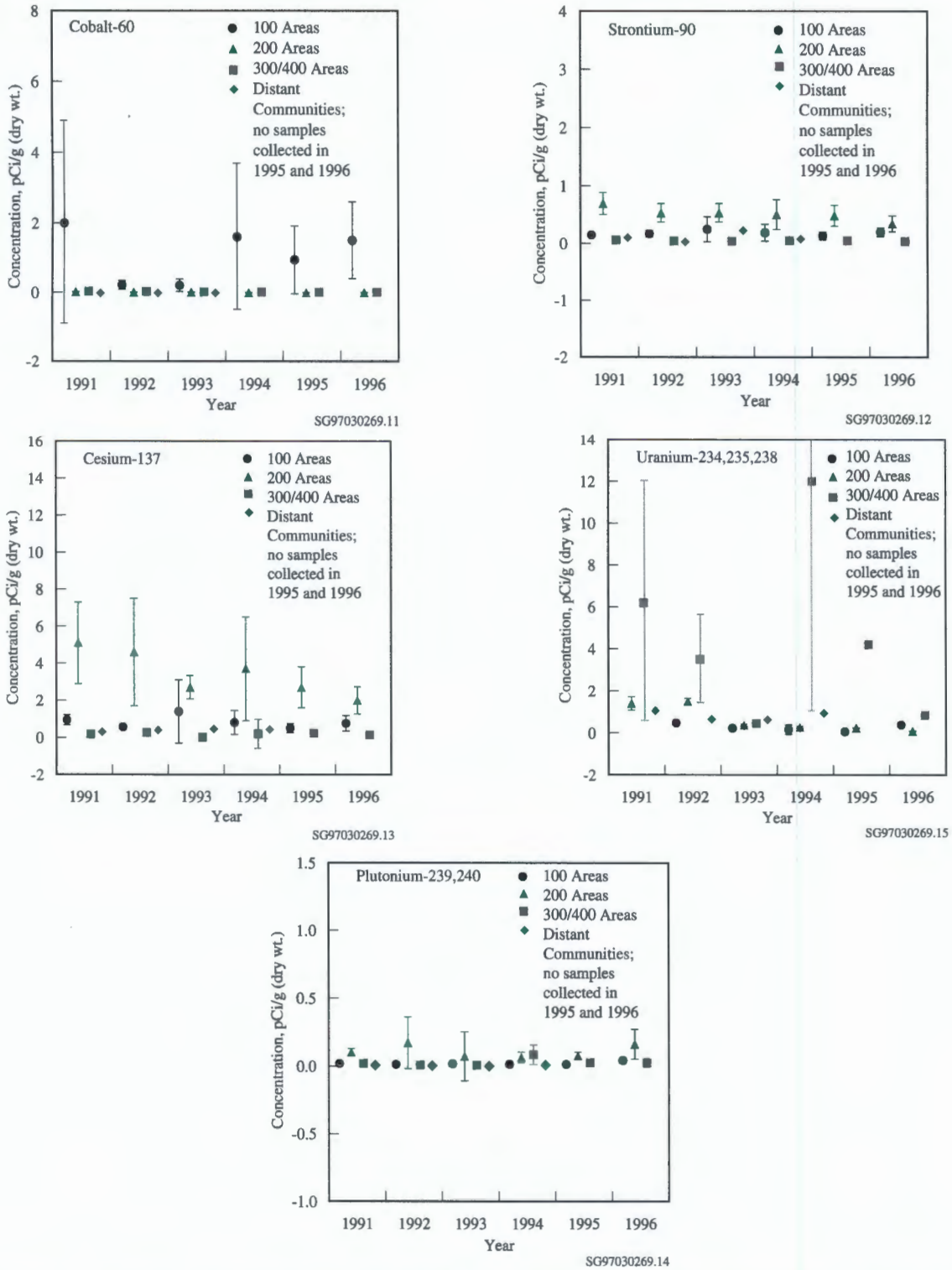


Figure 3.2.3. Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Soil Samples Compared to Those in Samples in Distant Communities, 1991 Through 1996. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols. The 1994, 1995, and 1996 100 Areas data include the 100-N Area only.

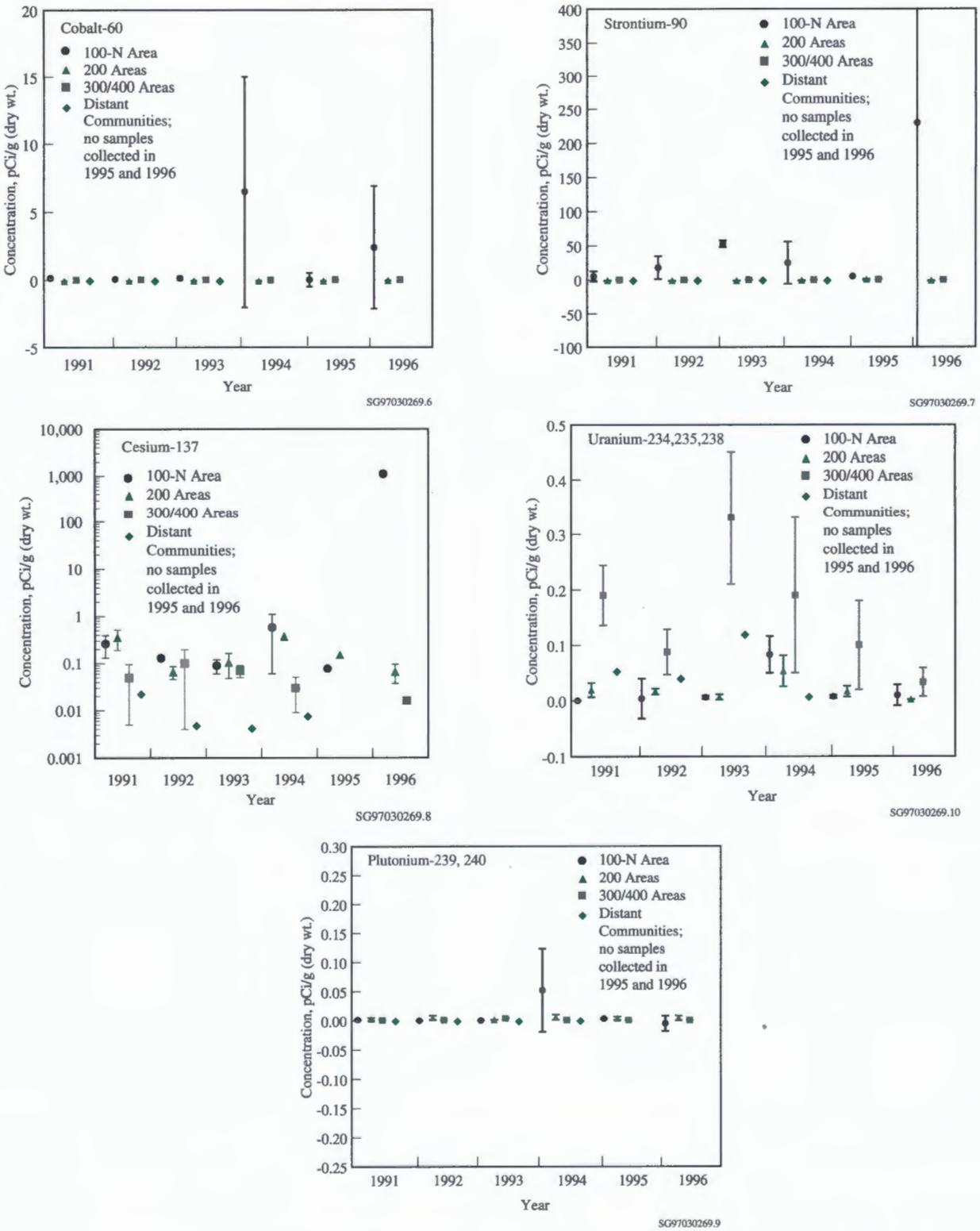


Figure 3.2.4. Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Vegetation Samples Compared to Those in Samples in Distant Communities, 1991 Through 1996. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols. The 1994, 1995, and 1996 100 Areas data include the 100-N Area only.

100-N Area

Analytical results from vegetation samples collected in the 100-N Area in 1996 were comparable to those seen in 1995, with one notable exception observed at a sampling location near the retired 1301-N Liquid Waste Disposal Facility. This sample displayed elevated concentrations of cobalt-60, strontium-90, and cesium-137 and slightly elevated concentrations of plutonium-238 and plutonium-239,240. Otherwise, the values observed for strontium-90 in samples collected near the N Springs were typically higher than those seen in the remaining locations at 100-N Area. Generally, 1996 radionuclide levels in 100-N Area vegetation 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 1996 in the 200 Areas were comparable to those seen in 1995. 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 1996, 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 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 monitored near facilities and waste handling, storage, and disposal sites to measure, assess, and control the impacts of operations.

Radiological Field Measurements

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 to gather dose rate information 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 Westinghouse Hanford Company (1991a).

Results of Radiological Field Measurements

Radiation Surveys

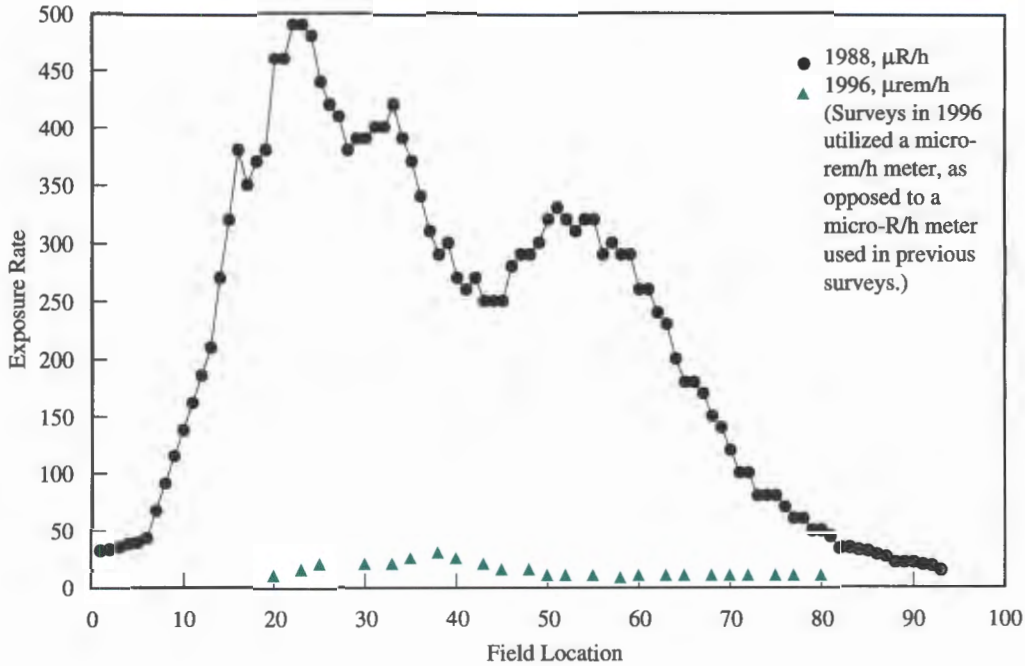
A hand-held micro-rem meter was used to survey points along the N Springs. Radiation measurements were taken at a height of approximately 1 m (3.28 ft). Prior to 1995, a micro-R meter was used for this survey. This instrument is known to over respond to low-energy gamma radiation. Since 1995, the micro-rem meter has been used to provide a more accurate measurement of the exposure rate. Figure 3.2.5 shows the overall shape of the curve for 1996, 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.

Thermoluminescent Dosimeters

100-D,DR Area. Five new thermoluminescent dosimeter monitoring sites were established in the 100-D,DR Area at the end of the third quarter of 1996 to evaluate environmental restoration activities at the 116-D-7 and 116-DR-9 Liquid Waste Disposal Facilities. Because only 48 days of data were collected at these sites during 1996, the thermoluminescent dosimeter results were extrapolated to 1 year, resulting in an average of 88 mrem/yr, which is comparable to offsite ambient background levels. Table 3.2.9 summarizes the 1996 results.

100-K Area. This is the fourth year that thermoluminescent dosimeters have been placed in the 100-K Area, surrounding the K Basins and adjacent reactor buildings. Three of the thermoluminescent dosimeters have, as expected, shown consistently elevated readings (ranging from 3.5 to 24 times greater than the overall 100-K Area average) because of their proximity to radioactive waste storage areas or stored radioactive rail equipment. Table 3.2.9 summarizes the 1996 results.

100-N Area. The 1996 thermoluminescent dosimeter results indicate that direct radiation levels are highest



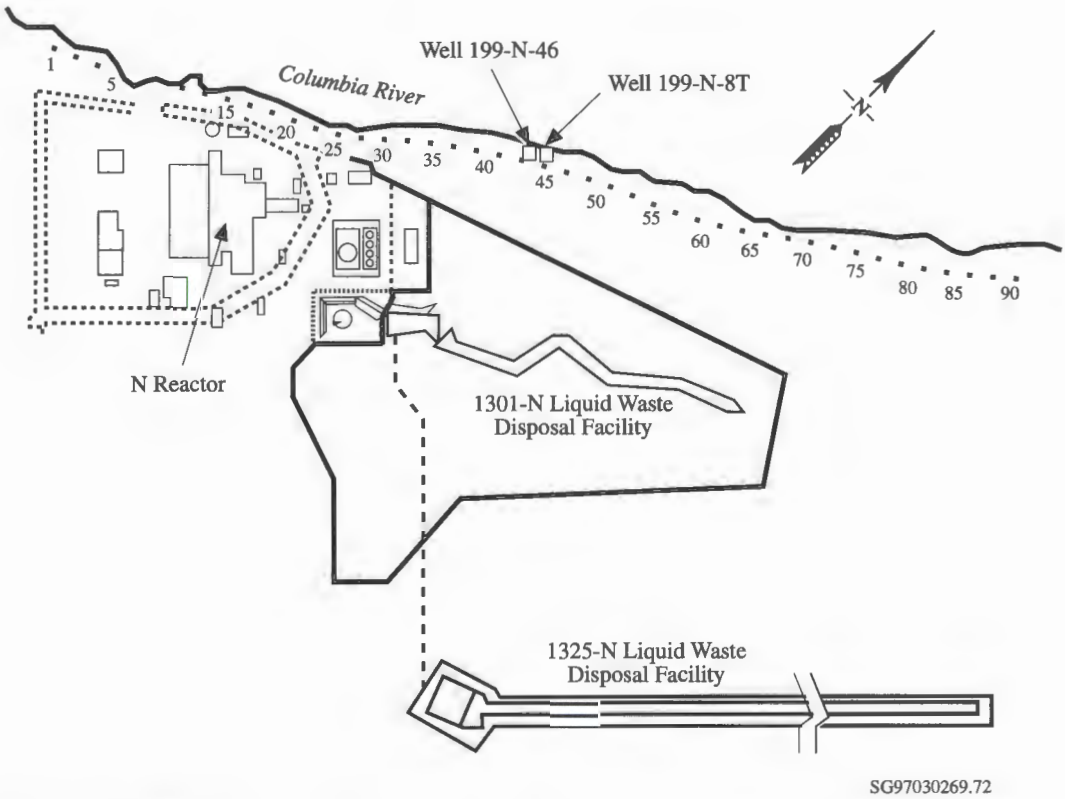


Figure 3.2.5. Radiation Survey Measurements Along the 100-N Area Shoreline, 1988 and 1996

Table 3.2.9. Thermoluminescent Dosimeter Results for Waste Handling Facilities in the Operations Areas (mrem/yr, based on 24 h/d), 1995 and 1996

Area	Number of Locations, 1996	1995 Maximum	1995 Mean	1996 Maximum	1996 Mean	% Change[a]
100-D[b]	5	NA[c]	NA	92	88	NA
100-K	11	2,800	390	2,250	480	23
100-N	30 (23)[d]	13,000	1,300	9,200	1,150	-11
200/600	63	700	120	500	120	0
ERDF[e]	2	NA	NA	100	100	NA
300	8	310	140	240	120	-14
300 TEDF[f]	6	84	81	87	85	5
400	7	81	77	92	83	8

(a) Numbers indicate a decrease (-) or increase from the 1995 mean.
(b) Thermoluminescent dosimeter (TLD) network established for fourth quarter of 1996.
(c) Not applicable.
(d) Seven TLDs were removed from the 100-N network as a result of budget cuts prior to the third quarter of 1996.
(e) ERDF = Environmental Restoration Disposal Facility.
(f) TEDF = Treated Effluent Disposal Facility.

near facilities that had contained or received liquid effluent from 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 9% lower than exposure levels measured at these locations in 1995. Overall, dose rates measured at all locations in the 100-N Area in 1996 were approximately 13% lower than those measured in 1995. Decreases are the result of decay of the radionuclide inventories in the facilities and deactivation activities that occurred in 1996. The results of the 100-N Area thermoluminescent dosimeter readings are presented in Table 3.2.9.

200 Areas. Table 3.2.9 summarizes the results for the 63 thermoluminescent dosimeter locations used in 1995 and 1996 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 1996, 120 mrem/yr, was similar to the 1995 measurement.

Environmental Restoration Disposal Facility. Two new thermoluminescent dosimeter monitoring sites were established in the Environmental Restoration Disposal Facility at the end of the third quarter of 1996 to evaluate environmental restoration disposal activities. Because data for only one quarter were collected at these sites during 1996, there is no comparative information available. The thermoluminescent dosimeter analyses results were extrapolated to 1 year, resulting in an average of 100 mrem/yr.

300/300 Treated Effluent Disposal Facility/ 400 Areas. Table 3.2.9 compares 1996 thermoluminescent dosimeter results to those of 1995 for these areas and facilities. The highest dose rates in the 300 Area were measured near the 340 Waste Handling Facility. The average annual dose rate measured in the 300 Area in 1996 was 120 mrem/yr, which is a decrease of 14% compared to the average dose rate of 140 mrem/yr measured in 1995. The average annual dose rate at the 300 Area Treated Effluent Disposal Facility in 1996 was 85 mrem/yr, which is an increase of 5% compared to the average dose rate of 81 mrem/yr measured in 1995. The average annual dose rate measured in the 400 Area in 1996 was 83 mrem/yr, which is an increase of 8% compared to the average dose rate of 77 mrem/yr measured in 1995.

Investigative Sampling

Investigative sampling was conducted in the operations areas to confirm the absence or presence of radioactive and/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) had created a potential for contaminants to spread
- 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, including counting errors, for these investigations, including field instrument and dose readings, where appropriate, are provided in Perkins et al. (1997).

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 of Investigative Samples and Analytes of Interest

Investigative samples collected in 1996 included paint chips, soil (including radioactive specks), vegetation (primarily tumbleweeds), freshwater clams, a caterpillar, a honey bee comb, darkling beetles, a harvester ant mound, a Western toad, a gopher snake, rock dove (domestic pigeon) feces, owl pellets, starlings, northern pocket gophers, mouse feces, and deer mice (Table 3.2.10).

Methods for collecting or otherwise obtaining investigative samples are described in Westinghouse Hanford Company (1991a). Field monitoring was conducted to detect radioactivity before samples were collected. Field monitoring results are expressed as counts per minute when a Geiger-Müeller 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 (pCi/g), except for extremely small samples and then in pCi per sample (pCi/sample). Maximum concentrations, rather than averages, are presented in this subsection; however, because of the high error values that result in less than (<) values, these less than numbers are not cited in the text when maximum values are being discussed.

Radiological Results for Investigative Samples

Investigative samples (e.g., paint chips, soil, etc.) were collected where known or suspected radioactive contamination was present or to verify radiological conditions at project sites. In 1996, 53 samples, comprising approximately 70 individual specimens, were analyzed for radionuclides and 43 showed measurable levels of contamination. Another 62 contamination incidents were reported, and the material was disposed of without isotopic analyses (though field instrument readings were recorded) during cleanup operations. A detailed data summary of all known radioactive contamination incidents in the operations areas during 1996 is provided in Perkins et al. (1997).

Paint Chips

In 1996, two instances occurred where contaminated paint chips, one from the east perimeter fence of the TX Tank Farm and another from the southeast perimeter fence of the SX Tank Farm, both in the 200-West Area, were found during routine radiation surveys. The contamination was cleaned up and the TX Tank Farm sample was submitted for radionuclide analyses. The highest radionuclide concentrations were cesium-137 (780,000 pCi/g) and strontium-90 (2,400 pCi/g). Analytical results are provided in Table 3.2.10.

Soil

In 1996, five investigative soil samples were collected, one from a slightly contaminated ant mound near the

Table 3.2.10. Investigative Samples Collected from the Operational Areas, 1996

Sample Type	Collection Area (Number of Samples)	Elevated Radionuclide	Maximum Concentration, pCi/g
Paint chips	200-West Area (1) (10-g sample)	^{60}Co	<78
		^{90}Sr	2,400
		^{137}Cs	780,000
		^{238}Pu	<53
		$^{239,240}Pu$	<53
		$^{Total}U$	0.33
Soil	200-East Area (2)	^{60}Co	<2.3
		^{90}Sr	53
		^{137}Cs	7,200
		^{238}Pu	<7.9
		$^{239,240}Pu$	<7.9
		$^{Total}U$	0.15
Soil	200-West Area (2)	^{60}Co	<0.047
		^{90}Sr	370
		^{137}Cs	0.23
		^{238}Pu	<230
		$^{239,240}Pu$	<230
		$^{Total}U$	0.03
Ant mound (soil)	200-East Area (1)	^{60}Co	<0.21
		^{90}Sr	42
		^{137}Cs	28
		^{238}Pu	<0.059
		$^{239,240}Pu$	0.12
		$^{Total}U$	0.009
Mosses and lichens	200-West Area (2)	^{60}Co	<0.067
		^{90}Sr	0.74
		^{137}Cs	0.55
		^{238}Pu	<180
		$^{239,240}Pu$	120
		$^{Total}U$	0.019
Vegetation	200-East Area (1)	^{60}Co	<4.1
		^{90}Sr	7,000
		^{137}Cs	<4.6
		$^{Total}U$	0.065
Tumbleweeds	200-East Area (2)	^{60}Co	<8.4
		^{90}Sr	8,100
		^{137}Cs	<10
		^{238}Pu	<5.5
		$^{239,240}Pu$	<5.5
		$^{Total}U$	0.078

Table 3.2.10. (contd)

Sample Type	Collection Area (Number of Samples)	Elevated Radionuclide	Maximum Concentration, pCi/g
Tumbleweeds	200-West Area (2)	^{60}Co	<2.6
		^{90}Sr	1,300,000
		^{137}Cs	0.67
		^{238}Pu	<1.0
		$^{239,240}Pu$	<1.0
		$^{Total}U$	0.09
Freshwater clams	200-East Area (1) (50-g sample, shell and body)	^{60}Co	<9.0
		^{90}Sr	10
		^{137}Cs	<13
		^{238}Pu	<0.26
		$^{239,240}Pu$	<0.26
		$^{Total}U$	0.018
Caterpillar	200-East Area (1)	^{60}Co	<340
		^{90}Sr	3,300
		^{137}Cs	<450
		^{238}Pu	<150
		$^{239,240}Pu$	<150
		$^{Total}U$	0.029
Honey bee comb	200-East Area (1) (not including honey)	^{60}Co	<0.049
		^{90}Sr	1,800
		^{137}Cs	16
		^{238}Pu	<0.84
		$^{239,240}Pu$	<0.84
		$^{Total}U$	0.01
Darkling beetles	200-West Area (1) (10-g sample)	^{60}Co	<110
		^{90}Sr	160
		^{137}Cs	<180
		^{238}Pu	<44
		$^{239,240}Pu$	<44
		$^{Total}U$	0.047
Western toad	100-N Area (1) (whole body)	^{60}Co	46
		^{90}Sr	310
		^{137}Cs	850
		^{238}Pu	62,000
		$^{239,240}Pu$	120,000
		$^{Total}U$	0.057
Gopher snake	200-East Area (1) (whole body)	^{60}Co	<0.73
		^{90}Sr	230
		^{137}Cs	61
		^{238}Pu	<0.56
		$^{239,240}Pu$	<0.56
		$^{Total}U$	0.00013

Table 3.2.10. (contd)

Sample Type	Collection Area (Number of Samples)	Elevated Radionuclide	Maximum Concentration, pCi/g
Pigeon feces	200-West Area (1) (0.2-kg sample)	^{60}Co	<0.095
		^{90}Sr	3.0
		^{137}Cs	5.4
		^{238}Pu	<0.07
		$^{239,240}Pu$	<0.07
		$^{Total}U$	380
Owl pellets	200-West Area (1) (1.0-kg sample)	^{60}Co	<0.16
		^{90}Sr	8.4
		^{137}Cs	2.2
		^{238}Pu	<0.70
		$^{239,240}Pu$	<0.70
		$^{Total}U$	43
Starlings	100-K Area (6) (2 samples)[a]	^{60}Co	0.16
		^{90}Sr	96
		^{137}Cs	84
		^{238}Pu	0.65
		$^{239,240}Pu$	1,000
		$^{Total}U$	0.0004
Northern pocket gopher	200-West Area (2)	^{60}Co	<0.62
		^{90}Sr	6,000
		^{137}Cs	<1.5
		^{238}Pu	0.94
		$^{239,240}Pu$	0.63
		$^{Total}U$	0.002
Mouse feces	200-East Area (2) (10-g samples)	^{60}Co	<1,100
		^{90}Sr	640,000
		^{137}Cs	15,000
		^{238}Pu	<660
		$^{239,240}Pu$	<660
		$^{Total}U$	0.16
Mouse feces	200-West Area (1) (10-g sample)	^{60}Co	62,000
		^{90}Sr	7,800,000
		^{137}Cs	490,000
		^{238}Pu	18,000
		$^{239,240}Pu$	82,000
		$^{Total}U$	130
Mouse urine[b] (wipes from traps)	3000 Area (2)	^{60}Co	<30
		^{90}Sr	7,700
		^{137}Cs	<68
		^{238}Pu	<16
		$^{239,240}Pu$	<16
		$^{Total}U$	0.002

Table 3.2.10. (contd)

Sample Type	Collection Area (Number of Samples)	Elevated Radionuclide	Maximum Concentration, pCi/g
Mouse nest	200-East Area (1)	^{60}Co	<1.3
		^{90}Sr	350,000
		^{137}Cs	810
		^{238}Pu	1.7
		$^{239,240}Pu$	5.6
		$^{Total}U$	0.01
Mouse nest	600 Area (1)	^{60}Co	0.44
		^{90}Sr	74,000
		^{137}Cs	173
		^{238}Pu	<0.5
		$^{239,240}Pu$	<0.5
		$^{Total}U$	0.01
Deer mice	200-East Area (25) (16 samples,[c] whole body)	^{60}Co	<9.1
		^{90}Sr	1,000,000
		^{137}Cs	51,000
		^{238}Pu	4,200
		$^{239,240}Pu$	13,000
		$^{Total}U$	0.37
Deer mice	200-West Area (2) (whole body)	^{60}Co	<1.7
		^{90}Sr	9,300
		^{137}Cs	390
		^{238}Pu	<2.8
		$^{239,240}Pu$	3.0
		$^{Total}U$	0.0019
Deer mice	600 Area (2) (whole body)	^{60}Co	<1.1
		^{90}Sr	11,000
		^{137}Cs	27
		^{238}Pu	<2.0
		$^{239,240}Pu$	<2.0
		$^{Total}U$	0.0004
Deer mouse and wash[b]	3000 Area (1) (whole body)	^{60}Co	<20
		^{90}Sr	1,200
		^{137}Cs	<31
		^{238}Pu	<9.4
		$^{239,240}Pu$	<9.4
		$^{Total}U$	0.0002

(a) Six individuals were collected and combined into two samples.
(b) Picocuries per sample (pCi/sample).
(c) Twenty-five individuals were collected and combined into 16 samples.

241-ER-152 Diversion Box in the 200-East Area. The highest radionuclide concentrations were cesium-137 (7,200 pCi/g) in a sample collected above the inactive pipeline to the decommissioned 216-A-25 Pond north of the 200-East Area and strontium-90 (370 pCi/g) collected west of the 218-W-4B Burial Ground and northeast of the 2401-W Building on the west side of the 200-West Area. Analytical results are provided in Table 3.2.10. The contaminated areas were cleaned up and posted. In addition, 32 incidents of contaminated soil or specks were found during cleanup operations and disposed of in low-level burial grounds.

In 1996, the number of contamination incidents, the range of radiation dose levels, and radionuclide concentrations generally were within historical ranges. Areas of special soil sampling that were outside radiological control areas and had radiation levels greater than radiological control limits (Westinghouse Hanford Company 1991b) were posted as surface contamination areas.

Vegetation

In 1996, four tumbleweed samples, one unidentified vegetation sample, and two moss and lichen samples were analyzed for radionuclide concentrations. Maximum concentrations are provided in Table 3.2.10. The maximum radionuclide concentration (found in 200-West Area tumbleweeds) consisted primarily of strontium-90 (1,300,000 pCi/g). The moss and lichen samples contained a measurable quantity of plutonium-239,240 (120 pCi/g), which bears further investigation to determine if moss and lichens act as environmental "sinks" for radionuclides. In addition, 14 instances of contaminated vegetation (mostly tumbleweeds) were recorded in the operational areas in 1996. This vegetation was discovered during remedial operations, surveyed with field instruments, and disposed of in low-level burial grounds. The field instrument readings for the vegetation ranged from <1 to 210 mrad/h (approximately 100 to >1,000,000 cpm). During 1996, the numbers of contaminated vegetation samples, radioactivity levels, and range of radionuclide concentrations were all within historical ranges (Perkins et al. 1997). Historically, the greatest number of contaminated vegetation samples (42) were submitted for analyses in 1978 (Johnson et al. 1994).

Wildlife

In 1996, 41 wildlife and wildlife-related samples (e.g., feces, nests, etc.) were collected either as part of an integrated pest management program designed to limit the exposure to and potential contamination of animals with 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 preventive measures designed to deter 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.

Thirty-seven of the 41 special animal samples (50 of the 54 individuals) analyzed in 1996 showed detectable levels of contamination (see Table 3.2.10). This compares to 22 contaminated samples (of 25) that were analyzed in 1995 and 16 (of 27) in 1994. This is not considered an unusual increase because the numbers of samples submitted depended on opportunity (i.e., increased human activity to decommission an inactive facility) rather than exact numbers submitted from established sampling points. The maximum radionuclide concentrations in 1996 were for cobalt-60 (62,000 pCi/g in mouse feces from the 241-S-151 Diversion Box in the 200-West Area); strontium-90 (1,000,000 pCi/g from a deer mouse captured at the 241-ER-152 Diversion Box in the 200-East Area and 7,800,000 pCi/g in mouse feces from the 241-S-151 Vent Station in the 200-West Area); cesium-137 (51,000 pCi/g in mouse feces from the 200-East Area and 490,000 pCi/g in mouse feces from the 241-S-151 Diversion Box in the 200-West Area); plutonium-238 (4,200 pCi/g in a deer mouse captured at the Plutonium-Uranium Extraction Plant in the 200-East Area, 18,000 pCi/g in mouse feces from the 241-S-151 Diversion Box in the 200-West Area, and 62,000 pCi/g in a Western toad collected at the 105-N Basin in the 100-N Area); and plutonium-239,240 (13,000 pCi/g in a deer mouse from the Plutonium-Uranium Extraction Plant, 82,000 pCi/g in mouse feces at the 241-S-151 Diversion Box, and 120,000 pCi/g in a Western toad collected at the 105-N Basin in the 100-N Area). The increased number of animals submitted for analyses in 1996 was primarily due to an investigation of contaminated deer mice at the 241-ER-152 Diversion Box in the 200-East Area. There were 16 contaminated mice at this facility alone that were captured and analyzed, with the analytical results indicating elevated concentrations of strontium-90 (1,000,000 pCi/g) and cesium-137 (51,000 pCi/g). Pest control operations

continued for 10 days after the last contaminated mouse was captured, and the area was cleaned up and resurfaced with clean gravel.

A contaminated deer mouse captured at the 1301 Building in the former 3000 Area was notable because the building had been transferred to the Port of Benton and was being used as a food bank and is not near any potential radionuclide source. Pest control operations at the facility led to the capture of the mouse, which was submitted for a radiological survey as a routine precaution. It was determined that the contaminated mouse most likely relocated with food collected from one of the operations areas. Extensive trapping found no other mice, contaminated or otherwise, in the building. No food was found to be contaminated as a result of this incident. The building no longer serves as a food bank.

Contaminated animal samples, which were somewhat atypical for the special sample program, included a caterpillar, a honey bee comb, darkling beetles, long-eared owl pellets, and a Western toad. Samples of freshwater clams, even though not contaminated according to field instrument measurements, were submitted for analyses because they were located in a potentially contaminated waste-water basin. The analytical results indicated very low levels of strontium-90 (10 pCi/g). Sample results are summarized in Table 3.2.10.

An increased interest in the northern pocket gopher's activity was raised during a lawsuit against former Hanford Site contractors by people living downwind of the Hanford Site. Two pocket gophers (one captured near the stabilized 216-T-4 Pond and the other in the 218-W-4A Burial Ground Complex, both in the 200-West Area) were submitted for radionuclide analyses. Analytical results for both pocket gophers indicated measurable levels of strontium-90 (3,000 and 6,000 pCi/g, respectively) but other radionuclides were either less-than values or well below background concentrations.

Additionally, there were 15 cases of contaminated wildlife or related samples (e.g., nests or feces) found during cleanup operations that were not analyzed. The numbers of animals found to be contaminated with radioactivity, the radioactivity levels, and the range of radionuclide concentrations were within historical ranges (Johnson et al. 1994).

Special Characterization Sampling

Special characterization projects were conducted or completed in 1996 to verify the radiological and, in some cases, potential hazardous chemical status of several operations. These included the following:

- continued monitoring of ambient air to determine the levels of diffuse fugitive air emissions at four liquid waste disposal sites (116-B-1, B-4, B-5, C-1) in the 100 Areas. The preliminary analytical data and those from the nearby routinely monitored 1301-N Liquid Waste Disposal Facility indicated that emissions from these facilities were below levels of regulatory concern.

- completed preoperational monitoring support of solid waste operations complex projects (Waste Receiving and Packaging and the Central Waste Complex) in the 200-West Area. Issued the *Preoperational/Operational Environmental Survey Report: Solid Waste Operations Complex* (Mitchell and Johnson 1996), 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.

3.3 Vadose Zone Characterization and Monitoring

J. R. Brodeur and R. K. Price

Historically, radionuclides were released into the vadose zone sediment (the unsaturated sediment between the ground surface and the top of the unconfined groundwater aquifer) at the Hanford Site through several hundred effluent discharge facilities (e.g., cribs, ditches) and as a result of leaks and spills from single-shell radioactive waste storage tanks. These discharges, leaks, and spills represent the largest quantity of long-lived (half-life >3 years) radioactive contamination released to the environment from site operations.

In 1996, two programs were under way to characterize and monitor gamma-emitting radionuclides in the vadose zone: one focused on vadose zone monitoring near single-shell radioactive waste tanks; the other involved monitoring near historical effluent disposal sites, which include cribs, ponds, ditches, injection wells, and french drains. The low- and intermediate-level wastes released at the historical effluent disposal facilities may be of greater concern than the high-level contamination leaked or spilled from the tanks because of the large liquid volume associated with these discharges. The large fluid volume could move contaminants deep into the vadose zone and close to the groundwater.

Both programs were designed to characterize and monitor gamma-emitting radionuclides in the vadose zone and focus primarily on establishing existing baseline conditions with minimal emphasis on true monitoring aspects. Once a baseline is established for a particular tank or effluent discharge facility, it can be monitored for either long-term or short-term changes. The intent of long-term monitoring is to detect changes over a 5- to 10-year period that can be used for predictive risk assessments. Short-term monitoring is used to identify recent changes in the vadose zone caused by current operations or tank leaks.

At all vadose zone monitoring and characterization locations, borehole geophysical logging methods were used to obtain information about the distribution of gamma-emitting radionuclides and moisture in existing boreholes. Logging methods were used because they are the most economical means of obtaining information about conditions in the subsurface. For comprehensive characterizations or special investigations, follow-up drilling and sampling can be conducted to identify specific contaminants and to collect geologic samples as needed.

Tank Farms Vadose Zone Baseline Characterization

The tank farms vadose zone baseline characterization program was created primarily to support tank operations. The Resource Conservation and Recovery Act specifies requirements to identify sources of contamination and determine the nature and extent of the contamination that leaked from the single-shell tanks. The characterization program performed that function at the single-shell tank farms in a limited way. The program also established a baseline for tank monitoring and leak detection. Future data can be compared to baseline information to identify changes in vadose zone contamination resulting from the addition or migration of contaminants. The technical plan for this baseline characterization program is documented in DOE (1995f), and the program management plan is provided in DOE (1995g).

A typical tank farm is shown in plan view in Figure 3.3.1 and consists of a collection of from 2 to 18 underground tanks. Most of the tanks are surrounded by monitoring boreholes, which provide access to the subsurface with geophysical logging probes. There are 12 single-shell tank farms at Hanford that contain a total of 149 tanks. There are also 6 double-shell tank farms at Hanford that contain 28 double-shell tanks. However, because no double-shell tanks have ever leaked, the vadose zone baseline characterization project only concerns the single-shell tanks.

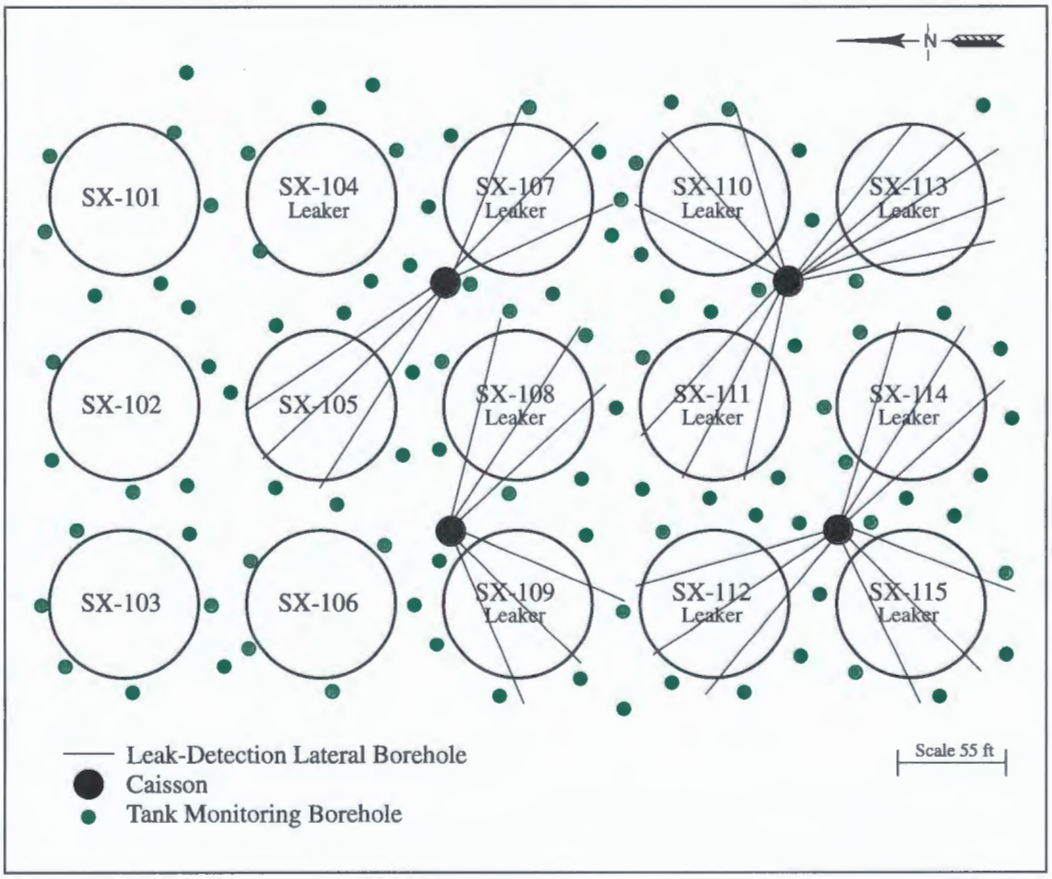


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Figure 3.3.1. Plan View of Single-Shell Underground Waste Storage Tanks in a Hanford Tank Farm

The baseline characterization program involved assaying gamma-emitting radionuclides in the vadose zone around the single-shell tanks. The radionuclides were assayed by logging boreholes near the tanks with calibrated spectral gamma-ray logging systems. The spectral gamma-ray logging systems used high-purity germanium detectors configured to operate in boreholes and calibrated to quantify concentrations of gamma-emitting radionuclides in the sediment. These data were used for a general determination of the nature and extent of contamination.

In 1996, the characterization was limited to the spectral gamma-ray logging assay of existing boreholes. There are a total of 758 boreholes surrounding 134 single-shell tanks. The intent was to extract as much information as possible from the boreholes to produce a basic understanding of contamination distribution. This assay method is a relatively low-cost screening method for obtaining preliminary data and can also be used to help identify areas requiring further characterization.

Once the baseline characterization is complete, more comprehensive characterizations focusing on significant areas of contamination can begin. The characterizations can be used to determine the distribution of nongamma-emitting radionuclides (i.e., technetium-99 or uranium), which are not determined under the current program.

Following data collection activities, a vadose zone monitoring summary report was prepared for each tank. Each tank summary data report provided logs of gamma-emitting radionuclide concentrations (Figure 3.3.2) as well as logs of naturally occurring potassium-40, thorium-232, and uranium-238. The report also contained summarized historical information about a tank, such as any occurrence reports or leak history, and provided an analysis and interpretation of the historical gross gamma log data. Each report identified sources of vadose zone contamination, when possible, and provided recommendations for monitoring or future characterizations.

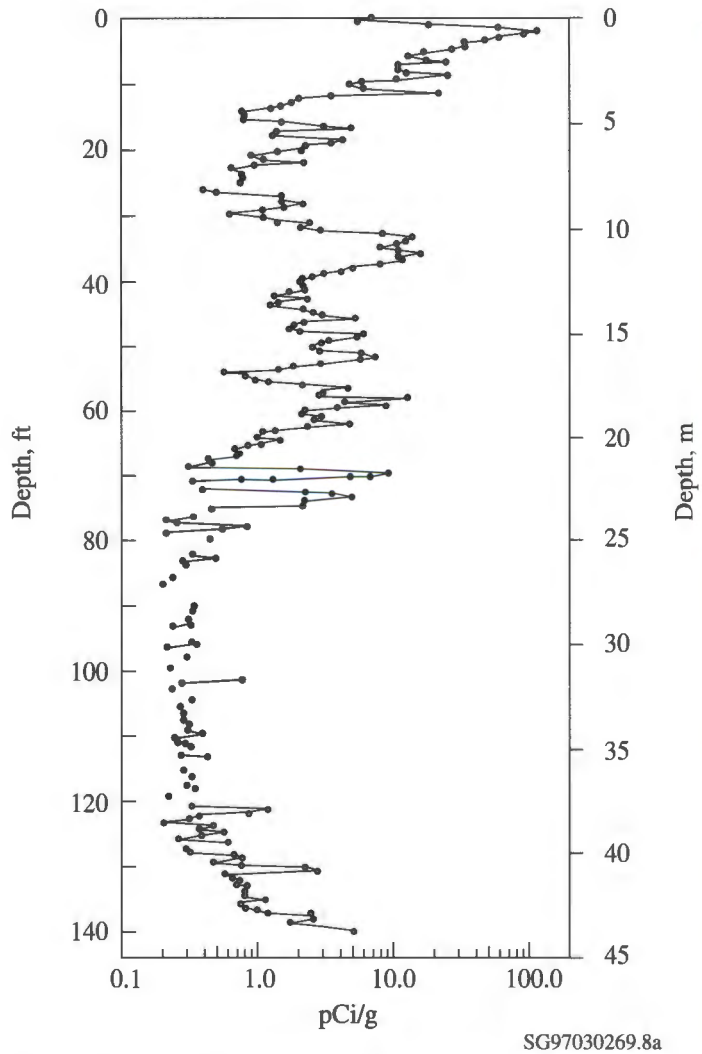

Figure 3.3.2. An Example of a Gamma-Emitting Radionuclide (cesium-137) Concentration Log (borehole 41-02-02)

After completion of a tank summary data report for each tank, a more comprehensive tank farm report was prepared. Each tank farm report provided a correlation of the contamination across the tank farm and included computer-generated visualizations of the contamination. Correlations among boreholes help to determine contamination sources and define the three-dimensional distribution. The visualizations are based strictly on an empirical geostatistical correlation of the data and are used by operations personnel to understand the current distribution of contamination and to identify potential monitoring targets. The report also provides a tank-by-tank review of previous conclusions in the tank summary data reports to reevaluate any inferred contamination sources around each tank.

Data Collection and Analysis

All data acquisition is accomplished with the spectral gamma-ray logging system, which is basically a laboratory quality gamma-ray assay system automated and configured to deliver a germanium detector down a borehole. Data acquisition operations are specified by logging procedures provided in DOE (1995h) and governed by quality assurance procedures specified in DOE (1996i). All data are managed as quality records governed by a records management plan (DOE 1995i); data management is regulated by a quality assurance plan (DOE 1996i).

The spectral gamma-ray logging system equipment was calibrated with a comprehensive base calibration and

biannual field calibrations specified in a calibration plan (DOE 1996j). The base calibration was accomplished using borehole model standards constructed at the DOE Grand Junction Office specifically for borehole logging. The calibration models meet the national uranium counting standards and are certified by the New Brunswick Laboratory (Leino et al. 1994). The base calibration is reported in DOE (1995j). Biannual field calibrations are conducted using borehole calibration models installed at Hanford. The results of these calibrations are reported in biannual reports (e.g., DOE 1996k).

Data analysis involves identifying the specific isotopes detected in the gamma-ray spectra and then calculating the concentrations of those isotopes. Once the isotope concentrations are determined, the data are collated into an isotope-specific log of the radionuclide concentration versus depth, and the data are plotted as a log. Logs of manmade and naturally occurring radionuclides are produced routinely. Details of the data analysis process are documented in a data analysis manual (DOE 1996l).

Data are interpreted by reviewing all the spectral gamma-ray logging system logs from a single borehole and correlating the data with information about the geology, tank history, and historical gross gamma logs. The intent of the individual borehole interpretations is to quantify contamination plumes, identify any obvious contamination sources, and relate contamination distribution patterns to tanks or geology. The origin and cause of the contamination distribution can often be identified by reviewing the current contamination profiles and historical gross gamma logs.

Results for 1996

Baseline Logging and Tank Summary Data Reports

During 1996, borehole geophysical logging operations continued and data acquisition from 234 boreholes surrounding 44 tanks was completed. The boreholes surrounding the tanks in the AX Tank Farm in the 200-East Area and S, TX, and TY Tank Farms in the 200-West Area were logged and all boreholes surrounding four of the tanks in the A Tank Farm (200-East Area) were logged.

Also during 1996 tank summary data reports were completed for all the tanks in the BY Tank Farm (200-East Area), tanks SX-112 through SX-115, six tanks in the TX Tank Farm, and all tanks in the U Tank Farm (200-West Area). Tank summary data reports for tanks SX-101 through SX-111 (200-West Area) were completed in 1995. The tank summary data reports published in 1996 are DOE (1996m through 1996tt).

Activities Related to the SX Tank Farm

The SX Tank Farm in the 200-West Area was frequently the focus of the vadose zone baseline characterization program during 1996. In January 1996, the results and conclusions in the tank summary data reports revealed that cesium-137 contamination from tank leaks had migrated deep into the vadose zone. Cesium-137 contamination was detected at relatively high concentrations deeper than expected (as deep as 38.1 m [125 ft]) in several boreholes. It was previously believed that cesium-137 was relatively immobile in the sediment and that it would migrate only a few meters (feet) from the base of the tanks.

A preliminary review of groundwater contamination data raised questions about the true source of a technetium-99 plume that appeared to originate from the S/SX Tank Farm complex. An extensive review of groundwater monitoring data was conducted by Hanford personnel, and it was determined that the S/SX Tank Farm complex was contributing technetium-99 and chromium to the groundwater. This conclusion was later confirmed in an independent investigation by the Washington State Department of Ecology. As a result, a groundwater assessment order was issued by the Washington State Department of Ecology for the S/SX Tank Farm complex and a groundwater assessment plan was prepared (Caggiano 1996).

The SX Tank Farm report, the first to be produced at Hanford, was completed in 1996 (DOE 1996uu). The report provides the visualizations of the cesium-137 contamination distributed in the sediment beneath the tanks; an example is provided in Figure 3.3.3. The visualizations were developed from an empirical geostatistical correlation of the borehole log data and are subject to the uncertainties of the data. In effect, the visualizations are only valid to the extent that the borehole log data match what is actually in the formation. For example, the visualizations include several known "false plumes" that are the result of some boreholes being contaminated by windblown materials. The suspected false plumes are identified in the tank farm reports. Of greater concern was the fact that the visualizations might be biased by the possibility that contamination migrated up or down the borehole along a gap that potentially exists between the outside of the borehole casings and the sediment. That gap is formed by the cable-tool drilling method that was used to

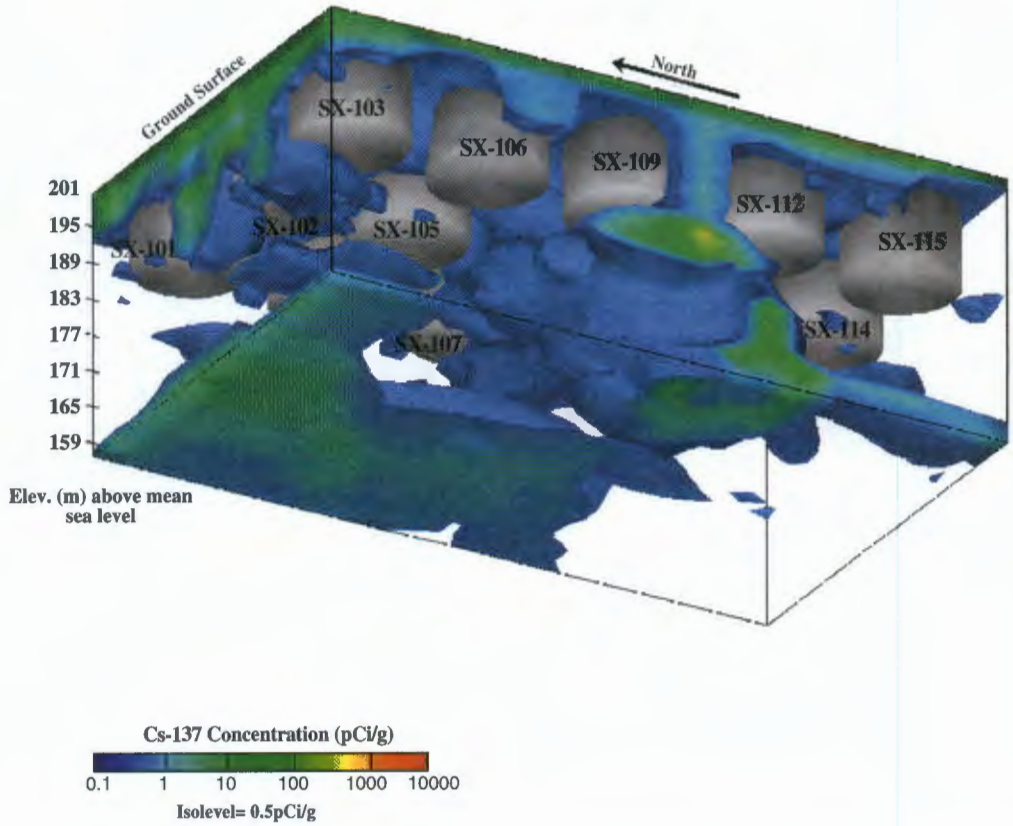

Figure 3.3.3. A Visualization of Cesium-137 Contamination Beneath the SX Tank Farm. Groundwater elevation is 145 m (476 ft).

install most of the monitoring boreholes. It is possible that the sediment was cohesive enough that it did not collapse back around the borehole casing after a borehole was drilled or that significant collapse zones developed in the sediment formation during drilling that produced large voids at depth.

Concerns that the contamination detected deep in the vadose zone at the SX Tank Farm was not actually in the formation but merely the result of contamination moving down the gap between the sediment and the outside of the borehole casings prompted DOE to form an independent panel of experts to perform an assessment of the data. This assessment included reviewing the data and recommending a course of action to confirm or refute the findings of the vadose zone logging characterization work as published in the tank summary data reports. Under the guidance of the independent panel, two new boreholes were drilled in the SX Tank Farm. However, instead of using a cable-tool drilling method as was used to construct the old boreholes, a percussion hammer drilling method was employed in an effort to minimize drag down of contamination and thereby determine if the contamination is really in the formation and not simply a borehole effect. These boreholes were also drilled and logged in successive 3.05-m (10-ft) increments to quantify the amount of contamination being dragged down.

The first borehole (41-12-01) did not intercept a plume of high contamination as expected. The cesium-137 concentration logs showed increases with each successive 3.05-m (10-ft) drilling increment, demonstrating contamination was being dragged down during drilling.

The second borehole (41-09-39) was located 1.65 m (5.4 ft) from an older borehole (41-09-04). Before drilling the second hole, a modification was made to the drill stem that was not made on the first borehole. A small weld lip on the bottom of the casing was ground smooth in an attempt to minimize contamination drag down. As a result, contamination drag down did not occur. This borehole was drilled and logged in the same 3.05-m (10-ft) successive increments as borehole 41-12-01. The successively deeper logs did not show evidence of contamination drag down; therefore, it is assumed that the modifications to the drill stem successfully eliminated drag down.

Borehole 41-09-39 intercepted relatively high levels of contamination to a total depth of 39.62 m (130 ft), confirming the presence of cesium-137 contamination in the formation to that depth. The relatively high cesium-137 concentration at depth, with little to no contamination from drag down, confirmed that contamination is present within the formation deep in the vadose zone and that the borehole was not the primary pathway for contamination migration. The pattern of cesium-137 concentrations in borehole 41-09-39 closely matched the pattern in adjacent borehole 41-09-04, suggesting that the lithology had a significant influence on the migration and deposition of the cesium-137 contamination and providing additional evidence that the cesium-137 contamination had migrated through the formation and not simply along an unsealed borehole.

Finally, as a part of the vadose zone investigation, four tanks in the SX Tank Farm were reevaluated to reassess the volume of contamination that leaked from the tanks. Historical leak models were developed for tanks SX-108, SX-109, SX-111, and SX-112 by the Los Alamos National Laboratory. Table 3.3.1 provides the old leak volume estimates as published in Hanlon (1996) along with the new estimates provided by the Los Alamos National Laboratory.

For three of the four tanks, the new leak volume estimates are over 10 times as high as the previous estimates, demonstrating a need to reassess the leak volume estimates for all of the single-shell tanks.

The initial conclusions and recommendations of the independent expert panel were provided in December 1996 as a three-page draft statement. A final report by the panel was released in early 1997 (Conaway et al. 1997).

Table 3.3.1. Leak Volume Estimates for Tanks SX-108, SX-109, SX-111, and SX-112

Tank	Old Estimate, L (gal)	New Estimate, L (gal)
SX-108	132,000 (35,000)	770,000 (203,000)
SX-109	38,000 (10,000)	420,000 (111,000)
SX-111	7,600 (2,000)	235,000 (62,000)
SX-112	113,000 (30,000)	216,000 (57,000)

Activities Related to the BY Tank Farm

Sixty-nine boreholes surrounding the 12 tanks in the BY Tank Farm in the 200-East Area were logged with the spectral gamma-ray logging systems from July through September 1995. The final tank summary data report for the BY Tank Farm was issued in April 1996 (DOE 1996x). The BY Tank Farm report was issued in early 1997 (DOE 1997d).

Log data were analyzed by identifying the manmade contaminants and calculating the equivalent concentration of a uniformly distributed contaminant. Plots of the contaminant concentrations as a function of depth were prepared for each borehole and were included in the appendixes of the corresponding tank summary data reports.

Potassium-40, thorium-232, and uranium-238 concentrations were also calculated and presented in log formats similar to those used with manmade radionuclides. These data were correlated with lithological information to determine if distinguishable lithologic features are present in the vadose zone beneath the BY Tank Farm and to determine how these features may have contributed to the distribution of the contamination below the tanks.

The spectral gamma-ray log data show cesium-137 is the most abundant and highly concentrated gamma-emitting manmade radionuclide in the vadose zone at the BY Tank Farm. Cobalt-60 was also detected in fairly extensive distributions but at much lower concentrations than cesium-137. Cobalt-60 contamination was often detected at the bottoms of boreholes. Figure 3.3.4 is a visualization of cesium-137 and cobalt-60 contamination in the vadose zone around tanks in the BY Tank Farm. Other gamma-emitting radionuclides detected were antimony-125 and europium-154.

The highest cesium-137 concentrations in the BY Tank Farm were detected adjacent to tank BY-103, which is designated an assumed leaker. Figure 3.3.5 shows the contamination in the vadose zone in the vicinity of tank BY-103. Other high cesium-137 concentrations were detected near the surface in thin zones and appeared to be related to surface spills, pipeline leaks, or the proximity of the boreholes to pipes containing contamination. Cesium-137 was detected throughout the lengths of several boreholes, but concentrations were usually less than 1 pCi/g.

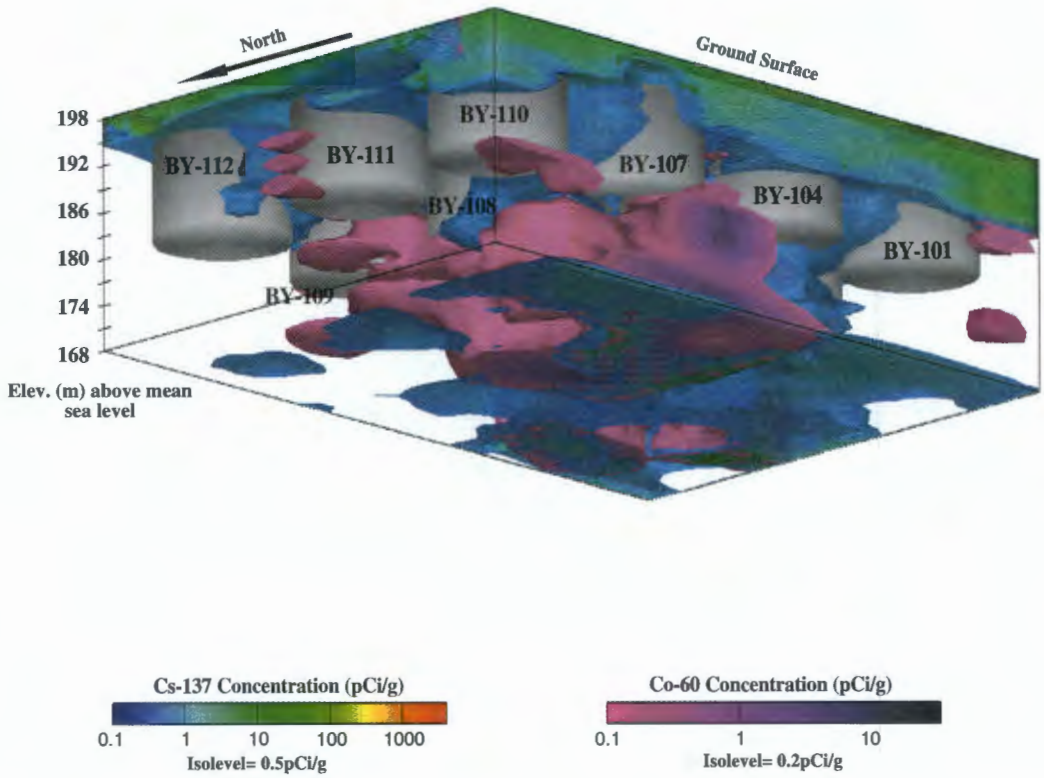

Figure 3.3.4. A Visualization of Contamination in the Vadose Zone at the BY Tank Farm (cesium-137 shown transparent). Groundwater elevation is 125 m (402 ft).

Cobalt-60 was detected around all the tanks in the BY Tank Farm that are known to have leaked. The cobalt-60 concentrations were usually less than 10 pCi/g; however, vertical distributions were extensive. Cobalt-60 was often detected above the bases of the tanks and near the ground surface. The near-surface cobalt-60 was often associated with zones of elevated near-surface cesium-137 contamination, indicating sources from surface spills or pipeline leaks.

A majority of the boreholes in the BY Tank Farm extend to a depth of approximately 30.5 m (100 ft), and the log data from several boreholes indicate significant cobalt-60 concentrations at the bottoms of the boreholes. Cobalt-60 was detected at the bottom of the deepest borehole logged (44 m [145 ft]). The maximum depth extent of the cobalt-60 contamination in the BY Tank Farm is not known; therefore, any impacts of vadose zone contamination on groundwater cannot be directly determined. The depth to groundwater beneath the BY Tank Farm is approximately 76.2 m (250 ft), which is significantly deeper than any of the tank monitoring boreholes.

The presence of cobalt-60 beneath the southern portion of tank BY-110 raises questions concerning the integrity of this tank. Historical documentation reveals evidence of a potential for leakage (i.e., tar rings and unexplained liquid-level decreases); however, neither this information nor the spectral gamma-ray data confirm leakage from this tank.

Tank BY-111 is presently designated a sound tank. Cobalt-60 contamination on the west side of tank BY-111 indicates that this tank has leaked in the past. Historical documentation records liquid-level decreases coinciding with increases in gamma-ray intensities in monitoring boreholes around the west side of this tank. On the basis of this information, it was recommended that this tank be reclassified an assumed leaker.

The potassium-40, thorium-232, and uranium-238 spectral data and the geologic data show good correlation at the contact between the Hanford formation upper gravel sequence and the Hanford formation fine sequence. This contact occurred at approximately 14.63 m (48 ft) in the

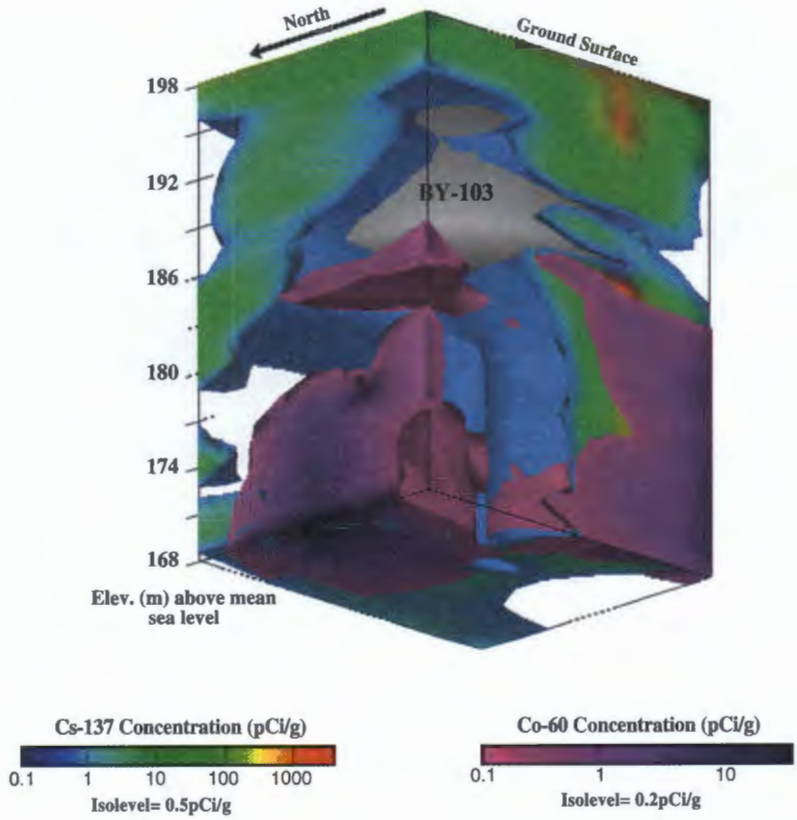

Figure 3.3.5. A Visualization of Contamination in the Vadose Zone at Tank BY-103. Groundwater elevation is 125 m (402 ft).

eastern portion of the BY Tank Farm and is as deep as 18.29 m (60 ft) in the western portion of the tank farm. This contact was distinct in some boreholes; in others it was gradational. The contact may provide a preferential migration pathway for contamination from the tank. No other features were correlatable among boreholes.

Other Tank Farms Baseline Characterization Activities

A new passive spectral gamma-ray logging system was constructed in 1996 for use as a vadose zone contamination monitoring system. This leak verification and monitoring system was designed to rapidly provide an accurate contamination concentration log from previously identified contamination zones.

The new system consists of a basic spectral gamma-ray logging system with three separate sodium-iodide detector probes of differing efficiencies. The three probes are designed to provide a measurement capability over a large dynamic range of contamination concentrations. The sodium-iodide detectors used for the leak verification and monitoring system are much easier to use than the germanium detectors on the spectral gamma-ray logging systems because they do not require cooling to liquid nitrogen temperatures; however, they do not provide the high-energy resolution of a germanium detector that is needed to identify the specific radionuclides. Nevertheless, assays can be highly accurate and precise if a baseline was already established with a germanium detection system.

The leak verification and monitoring system will be used to quickly assay boreholes surrounding tanks suspected of leaking. Although the system will not provide a primary leak-detection method, it can be used to verify that a tank is leaking if new contamination is detected in boreholes surrounding the tanks. The leak verification and monitoring system will also be used to monitor regions where previous gross gamma data show the contamination is moving.

Spectral gamma-ray shape-factor analysis methods were also developed in 1996. These methods allow an analyst to determine the approximate distribution of contamination around a borehole by studying the shape of the gamma-ray spectra from the germanium logging system. The shape-factor analysis method was developed by performing nuclear transport modeling simulations to determine the sensitivity of various spectral parameters to extremes in source distribution. Additional required nuclear transport model simulations will be performed in 1997, and the simulation models will be validated with actual field measurements at the DOE Grand Junction Office borehole calibration facility.

Characterization of Historical Effluent Disposal Sites

Radioactive and hazardous wastes disposed of to the soil column have been the dominant contributors to groundwater contamination at the Hanford Site. Even though disposal of untreated waste water to the ground stopped in 1995, movement of contaminants in the soil column beneath historical effluent disposal sites can still occur. Wastes in the soil column at historical effluent disposal sites at Hanford have been found in the vadose zone and are potential contributors to additional groundwater contamination.

Historically, large volumes (1.6 trillion L [426 billion gal]) of low-level liquid waste were discharged to surface ponds and ditches. Smaller volumes of low- and intermediate-level liquid wastes (53 billion L [14 billion gal]) were discharged to the subsurface in reverse wells, french drains, cribs, and tile fields.

Prior to the mid-1970s, over 450 million L (120 million gal) of high-level liquid wastes were discharged to the vadose zone via cribs and french drains from underground storage tanks containing high-level wastes. The estimated total quantity of radioactive waste was over 65,000 Ci (decayed through December 1989). The high-level radioactive waste that could not be discharged to the environment was transferred to the underground storage tanks. High-level radioactive waste could exceed concentrations of 100 µCi/mL (Routson 1973).

Although ground disposal of untreated wastes has been terminated, the residual contaminated liquid remaining in soil pore spaces following drainage of free liquid at these sites can continue to be a long-term source of groundwater contaminants, especially if a source of moisture (liquid) is available to transport the mobile waste constituents (e.g., enhanced natural infiltration from the coarse gravel coverings, removal of vegetation, leaking water lines, etc.).

Monitoring Results

A recent monitoring survey at the BY Cribs in the 200-East Area with a spectral gamma-ray detector confirmed that the majority of the contamination at the facility is stable and is not continuing to migrate to the groundwater. However, a narrow interval (4 m [13 ft]) within the cobalt-60 contamination plume is migrating, as shown by an unexpected 20% decrease in concentration at a depth of approximately 37.5 m (110 ft). This decrease is apparent when comparing monitoring data collected in December 1994 to baseline data obtained in September 1991 (Figure 3.3.6).

Cesium-137 was not expected to migrate more than 10 m (32.8 ft) below the discharge location except through nonnatural pathways. An example to the contrary was found at the 216-T-19 Crib in the 200-West Area. Monitoring well 200-W15-4 was drilled 20 m (66 ft) from the crib 6 years after discharges to the crib were terminated. A gamma-log survey (Figure 3.3.7) shows the main contaminant plume from the crib at a depth of 12 m (39 ft) with a maximum concentration of more than 33,000 pCi/g. A second cesium-137 contamination interval is located at a depth of 46 m (151 ft) and averages 6 pCi/g. This example was chosen because it shows that the contamination did not migrate down the borehole and was not smeared by the drilling activities. There is currently insufficient information to identify the migration method. The contamination at 47 m (154 ft) suggests that a small fraction of the cesium-137 is not adsorbed onto the soil sediments at the release point (as expected) and has a low soil-retention factor.

Electrical resistivity tomography is a three-dimensional geophysical imaging technique that can map liquids migrating through the vadose zone. Two field tests were recently conducted at a mock tank site. One test was to demonstrate applicability, the second test was to demonstrate alternate sensor deployment. The first test monitored the migration of a liquid solution to a depth of 10.7 m (35 ft) in 5 days. The second demonstration incorporated electrode arrays installed with cone penetrometers. The equipment monitored the migration of a brine solution to a depth of 30.4 m (100 ft) in 12 days. The results of both tests implied that if the leak rate continued, the groundwater at 76.8 m (252 ft) would be impacted in 36 days.

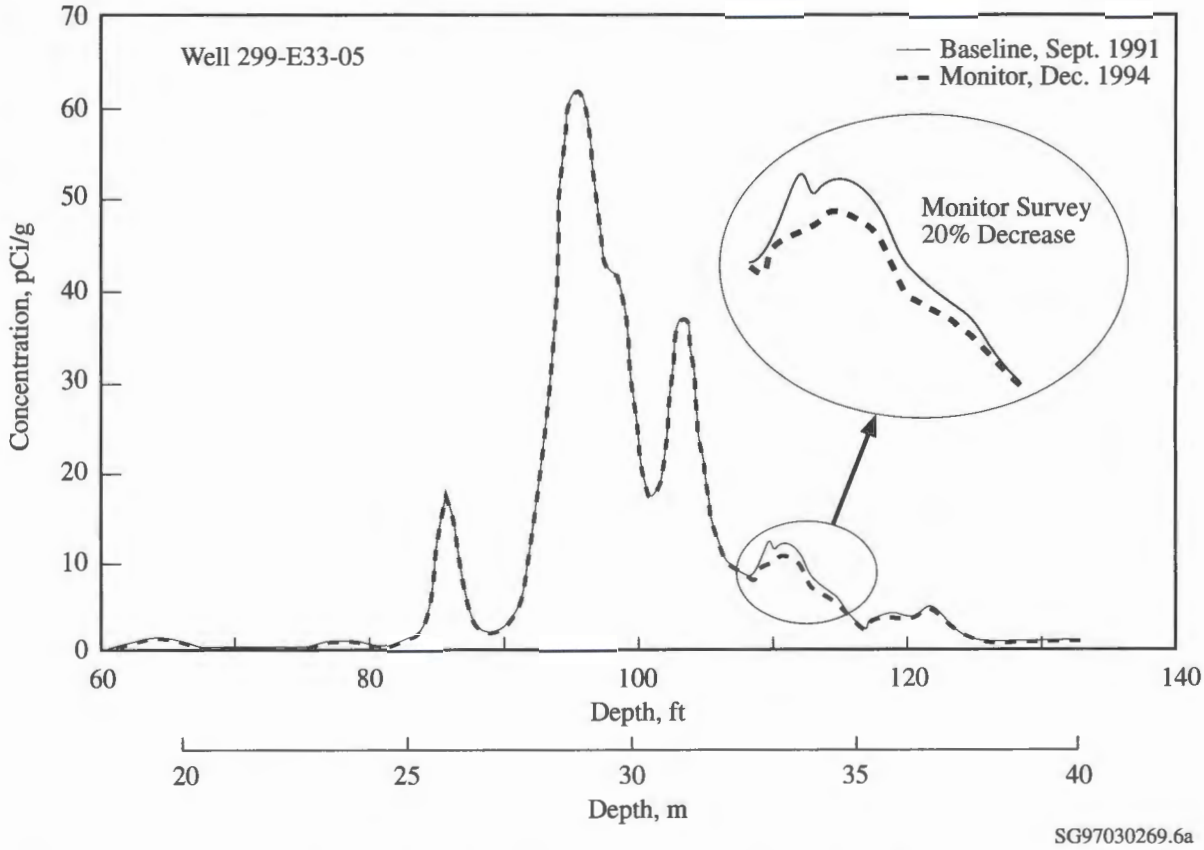

Figure 3.3.6. Concentrations of Cobalt-60 in Vadose Zone Sediments at the BY Cribs, 200-East Area, 1991 and 1994 Data

There is growing evidence that small-volume leaks (approximately 100,000 L [26,420 gal]) and the downward movement of contaminants with high soil-retention factors (cesium-137) can impact the groundwater. This evidence has resulted in efforts to reevaluate contaminant transport models.

Historical discharge of liquid waste to cribs and tile fields in the Plutonium Finishing Plant area resulted in accumulation of an estimated 20,000 Ci of transuranic waste, plutonium-239, and americium-241. On the basis of relative hazard, the Plutonium Finishing Plant cribs are some of the most significant sources of radioactive contamination in the vadose zone at the Hanford Site. Concentrations of transuranic wastes in the soil extend to depths of 30 m (98.4 ft) (Figure 3.3.8). The combination of high acidity and the presence of complexants apparently allowed the transuranic wastes to penetrate deeper into the soil column than expected. Evidence of stability or continued plume migration will be monitored over time by periodic logging in the available boreholes with high-resolution spectral gamma-ray equipment.

A more detailed summary, including original references, of the vadose zone investigations at historical liquid waste disposal sites is provided in Gleckler (1997).

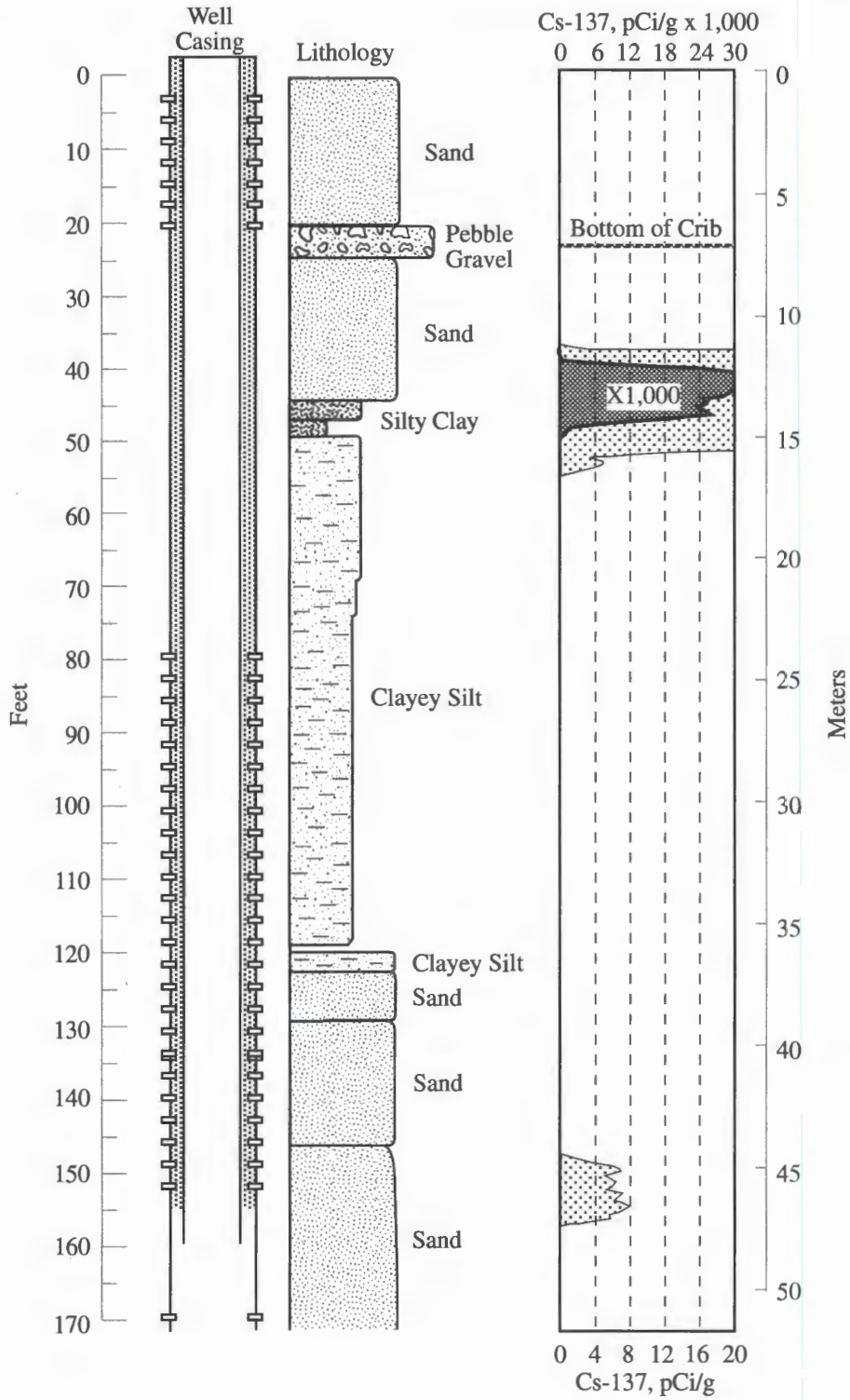

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Figure 3.3.7. Stratigraphy and Gamma-Log Survey Plot for 216-T-19 Crib, 200-West Area

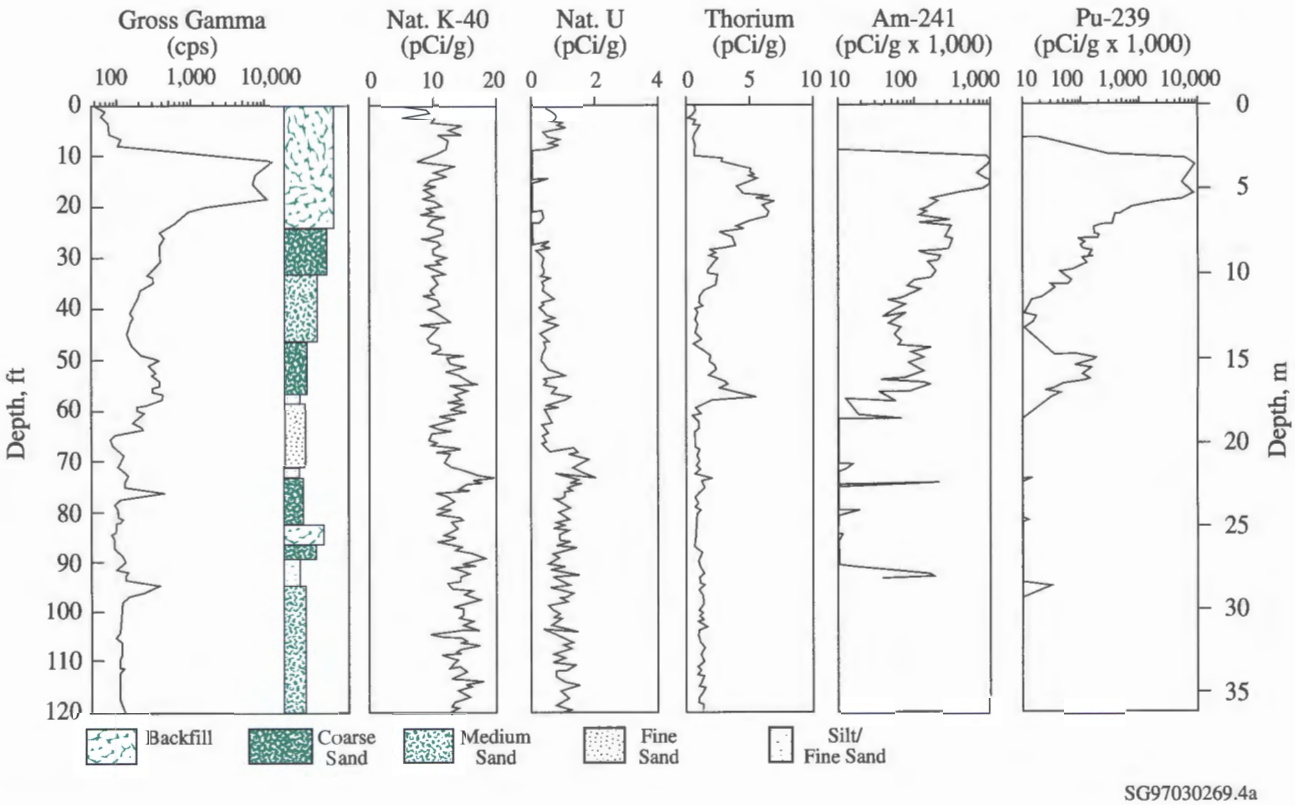

Figure 3.3.8. Logs of Radionuclides in Vadose Zone Sediments Beneath the 216-Z-1A Crib Near the Plutonium Finishing Plant, 200-West Area, 1993

3.4 Waste Management and Chemical Inventories

B. P. Gleckler

Waste Management

Waste produced from Hanford Site cleanup operations is classified as either radioactive, nonradioactive, mixed, or toxic. 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 WAC 173-303. Hanford's hazardous wastes are managed in accordance with WAC 173-303.

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

Approximately 200 Hanford Site facilities have the capacity to generate dangerous and toxic waste. An annual report lists the dangerous wastes and extremely hazardous wastes generated, treated, stored, and disposed of onsite and offsite (DOE 1997c). 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 wastes generated at the Hanford Site have historically been buried near the 200 Areas Solid Waste Landfill; in March 1996, this landfill was closed. Beginning in late December 1995, nondangerous wastes have been disposed of at the City of Richland's Landfill, a municipal landfill located at the southern edge of the Hanford Site boundary. Since February 1996, medical wastes have been shipped to Waste Management of Kennewick. Asbestos has been shipped to Basin Disposal, Inc. in Pasco and the onsite Environmental Restoration Disposal Facility. Starting in March 1996, nonregulated drummed waste has been shipped to Waste Management of Kennewick.

These wastes originate at a number of areas across the site. Examples of these wastes are construction debris, office trash, cafeteria waste, and packaging materials. Other materials and items classified as waste 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. Ash generated at powerhouses in the 200 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 onsite, received, shipped offsite, and disposed of at the Hanford Site (Hagel 1997). 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 1991 through 1996 are shown in Tables 3.4.1 through 3.4.3. Table 3.4.4 provides a detailed summary of the radioactive solid wastes stored or disposed of in 1996.

The quantities of liquid wastes generated in 1996 and stored in underground storage tanks are included in the annual dangerous waste report (DOE 1997c). Table 3.4.5 is a summary of the liquid wastes generated from 1991 through 1996, which are stored in underground storage tanks.

Table 3.4.1. Quantities of Solid Wastes[a] Generated on the Hanford Site (kg)

Waste Category	1991	1992	1993	1994	1995	1996
Mixed	475,370	48,641	150,012	567,670	131,755	199,272
Radioactive	1,069,703	682,684	1,116,616	1,390,647	1,892,636	3,870,461

(a) Solid waste includes containerized liquid waste.

Table 3.4.2. Quantities of Solid Wastes[a] Received from Offsite (kg)

Waste Category	1991	1992	1993	1994	1995	1996
Mixed	23,605	40,897	207,905	96,409	52,796	2,073
Radioactive	629,686	1,010,439	1,587,884	1,355,653	1,306,194	1,668,269

(a) Solid waste contains containerized liquid waste. Solid waste quantities do not include United States Navy submarine reactor compartments.

Table 3.4.3. Quantities of Hazardous Wastes[a] Shipped Offsite (kg)

Waste Category	1991	1992	1993	1994	1995	1996
Containerized	89,354	181,305	123,754	267,113	224,003	589,721
Bulk Solids	0	433,330	250,235	2,872,661	477,648	0
Bulk Liquid	331,905	11,089	94,065	248,917	130,156	98,795
Total	421,259	625,724[b]	468,054[c]	3,388,691[d]	831,807	688,516

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

Chemical Inventories

Types, quantities, and locations of hazardous chemicals are tracked through compliance activities associated with the Emergency Planning and Community Right-To-Know Act (see "Community Right-To-Know Activities" in Section 2.2). The *1996 Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1997a) was issued in March 1997 in compliance with Section 312 of the Act. Table 3.4.6 summarizes the information reported, listing the 10 chemicals stored in greatest quantity on the Hanford Site in 1996.

Table 3.4.4. Radioactive Solid Wastes Stored or Disposed of in 1996[a]

	Quantity, Ci					
Constituent	Low-Level	Low-Level Mixed	Low-Level Plus[b]	Low-Level Mixed Plus[c]	Transuranic	Transuranic Mixed
^{3}H	1.80×10^{4}	1.34×10^{-2}	0.00	0.00	0.00	0.00
^{14}C	8.13×10^{-3}	4.15×10^{-3}	0.00	6.09×10^{0}	0.00	0.00
^{54}Mn	4.89×10^{1}	2.43×10^{-2}	1.35×10^{-10}	2.70×10^{-10}	0.00	0.00
^{55}Fe	9.76×10^{1}	1.39×10^{-3}	0.00	4.25×10^{4}	0.00	0.00
^{59}Fe	8.00×10^{-6}	1.70×10^{-8}	0.00	0.00	0.00	0.00
^{60}Co	8.90×10^{1}	5.67×10^{-1}	2.70×10^{-10}	1.38×10^{4}	4.30×10^{-1}	5.58×10^{-1}
^{63}Ni	7.10×10^{1}	2.35×10^{-2}	0.00	8.58×10^{4}	0.00	0.00
^{90}Sr	1.58×10^{4}	1.64×10^{1}	8.22×10^{-5}	2.70×10^{-9}	3.33×10^{2}	2.16×10^{1}
^{90}Y	1.58×10^{4}	1.64×10^{1}	8.22×10^{-5}	2.70×10^{-9}	3.33×10^{2}	2.16×10^{1}
^{99}Tc	1.49×10^{1}	8.98×10^{-3}	9.44×10^{-6}	4.17×10^{-5}	1.97×10^{0}	0.00
^{137}Cs	1.30×10^{4}	5.96×10^{0}	7.90×10^{-5}	4.44×10^{-9}	4.99×10^{2}	1.41×10^{2}
^{137m}Ba	1.23×10^{4}	5.64×10^{0}	7.47×10^{-5}	4.20×10^{-9}	4.70×10^{2}	1.34×10^{2}
^{232}Th	1.42×10^{-3}	6.32×10^{-4}	0.00	0.00	0.00	0.00
^{233}U	6.02×10^{-3}	8.42×10^{-6}	0.00	0.00	0.00	0.00
^{234}U	2.24×10^{1}	4.73×10^{-6}	2.92×10^{-5}	1.29×10^{-4}	4.59×10^{-3}	0.00
^{235}U	7.29×10^{-1}	1.17×10^{-1}	1.49×10^{-6}	6.56×10^{-6}	2.50×10^{-4}	1.80×10^{-5}
^{236}U	3.75×10^{0}	7.53×10^{-2}	2.47×10^{-6}	1.09×10^{-5}	9.10×10^{-4}	0.00
^{238}U	3.73×10^{1}	2.13×10^{0}	1.82×10^{-5}	8.06×10^{-5}	6.16×10^{-3}	3.66×10^{-4}
^{237}Np	2.57×10^{-2}	4.99×10^{-5}	0.00	0.00	0.00	2.96×10^{-7}
^{238}Pu	3.78×10^{0}	2.40×10^{-3}	2.50×10^{-4}	0.00	1.17×10^{2}	2.21×10^{1}
^{239}Pu	5.05×10^{0}	4.86×10^{-2}	2.97×10^{-3}	0.00	8.53×10^{2}	3.54×10^{2}
^{240}Pu	2.28×10^{0}	6.99×10^{-3}	6.62×10^{-4}	0.00	2.68×10^{2}	8.47×10^{1}
^{241}Pu	1.45×10^{2}	3.79×10^{-1}	2.14×10^{-2}	1.06×10^{-8}	1.50×10^{4}	2.44×10^{3}
^{242}Pu	1.27×10^{-3}	5.05×10^{-8}	3.93×10^{-8}	0.00	6.58×10^{-2}	7.51×10^{-3}
^{241}Am	5.22×10^{0}	4.18×10^{-2}	1.93×10^{-4}	5.42×10^{-10}	4.01×10^{1}	3.36×10^{1}
^{243}Am	2.65×10^{-1}	3.25×10^{-5}	0.00	0.00	0.00	0.00
^{244}Cm	5.95×10^{0}	2.92×10^{0}	0.00	0.00	0.00	0.00

(a) Currently, 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. The majority of quantities in this category are from the United States Navy submarine reactor compartments disposed of at the Hanford Site.

Table 3.4.5. Quantities of Bulk Liquid Wastes[a] Generated and Stored on the Hanford Site (L)

1991	1992	1993	1994	1995	1996
15,498,826	12,604,981	22,176,538	10,726,296	18,217,841	2,422,000

(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) included in the solid waste category.

Table 3.4.6. Average Balance of Ten Chemicals Stored in Greatest Quantity, 1996

Hazardous Material	Average Daily Balance, kg
Coal	11,000,000
Mineral oil	1,800,000
Sodium	1,200,000
Diesel fuel	720,000
Bentonite	370,000
#6 Fuel oil	370,000
Ethylene glycol	240,000
Unleaded gasoline	120,000
Carbon	92,000
Sulfuric acid	76,000

Environmental Surveillance Information

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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.

Sections 4.1 through 4.8 describe results of the Hanford Site surface and groundwater environmental surveillance programs for 1996 and include, where applicable, information on both radiological and nonradiological constituents. The objectives, criteria, design, and description of these programs are summarized below and provided in detail in the environmental monitoring plan (DOE 1994a). Radiological doses associated with the surveillance results are discussed in Section 5.0, "Potential Radiation Doses from 1996 Hanford Operations." The quality assurance and quality control programs developed for ensuring the value of surveillance data are described in Section 7.0, "Quality Assurance."

Many samples are collected and analyzed for the Hanford Site 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 *Hanford Site Environmental Data for Calendar Year 1996* (Bisping 1997). Additional information on Hanford Site groundwater monitoring can be found in the annual Hanford Site groundwater monitoring report (Hartman and Dresel 1997). The intent of the summaries (Sections 4.1 through 4.8) is to provide current surveillance data, to compare 1996 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 multimedia environmental monitoring effort to measure the concentration of radionuclides and chemicals in environmental media and assess the integrated effects of these materials on the environment and the public. The project collects samples of air, surface water, sediments, soil and natural vegetation (approximately every 5 years), agricultural products, fish, and wildlife. Analytical capabilities include the measurement of radionuclides at very low environmental concentrations and nonradiological chemicals, including metals, anions, thioureas, volatile organic compounds, semivolatile organic compounds, pesticides, and polychlorinated biphenyls. In addition, the project includes the capability to measure ambient external radiation.

Activities inherent in the operation of the Surface Environmental Surveillance Project include 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.

The project focuses on routine releases from DOE facilities on the Hanford Site; however, the project 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 Richland Operations Office 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 DOE Orders and DOE (1991) 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 DOE 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)
  - 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 conditions 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 environmental quality problems.

DOE (1991) 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 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 DOE 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; hazard 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 is designed to meet the listed objectives while considering the environmental characteristics of the site and potential and actual releases from site operations. Surveillance activities focus 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 50 years provide valuable technical background for planning the surveillance design.

The Hanford Site environmental surveillance program historically has focused on radionuclides in various media 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 1996 pathway analysis was based on 1996 source-term data and on the comprehensive pathway and dose assessment methodology included in the Generation II (GENII) computer code (Napier et al. 1988) 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 manual 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) principal release mechanisms; 3) probable environmental fate and transport (including persistence, partitioning, and intermediate transfer) of contaminants of interest; and, most important, 4) 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 routes and 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 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 to be 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 radionuclide 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, along State Highway 240, which runs through the site from Richland to the Vernita Bridge, and along the Columbia River. 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

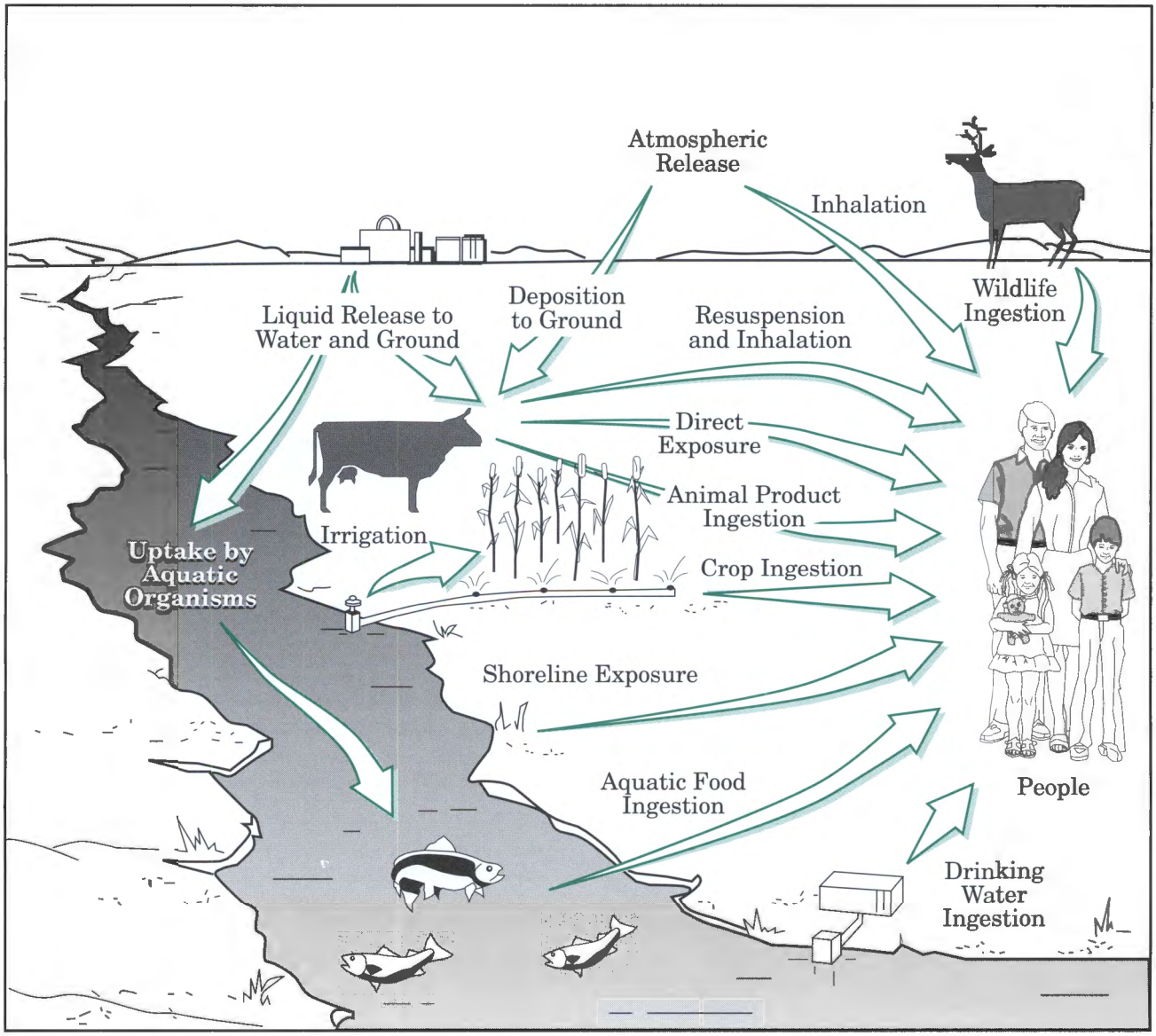

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Figure 4.0.1. Primary Exposure Pathways

established to protect public health. Table 4.0.1 summarizes the sample types and measurement locations in all three zones for 1996.

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, radiological dose assessments should be based on direct measurements of 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

Table 4.0.1. Environmental Surveillance Sample Types and Measurement Locations, 1996

		Sample Locations						
						Columbia River		
Type	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]			
Groundwater[f]	499	499[g]						
Springs water	6						6	
Springs sediment	4						4	
Columbia River	7					2	4	1
Irrigation water	1		1					
Drinking water	7	7						
Columbia River sediments	6					1	3	2
Ponds	3	3						
Foodstuffs	4			3	1			
Wildlife	8	3			1	1[h]	3	
Soil	0							
Vegetation	0							
TLDs[i]	66	24	32[j]	8[d]	2[e]			
Shoreline surveys	16		16					

(a) Surveillance zone 1.
(b) Surveillance zone 2.
(c) Surveillance zone 3.
(d) Includes eight community-operated environmental surveillance stations.
(e) Includes one community-operated environmental surveillance station.
(f) Approximately 800 wells were sampled for all groundwater monitoring programs onsite.
(g) Some onsite wells along the Columbia River are referred to as perimeter locations in the text.
(h) Sample furnished by the Washington State Department of Health.
(i) TLDs = thermoluminescent dosimeters.
(j) Includes locations along the Columbia River.

levels resulting from worldwide fallout and natural sources from those associated with Hanford releases. Therefore, offsite doses in 1996 were estimated using the following methods:

- Doses from monitored air emissions and liquid effluents released to the Columbia River 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 unmonitored resuspended contaminated soils) were estimated from measured airborne concentrations at site perimeter locations.

- Doses from fugitive liquid releases (e.g., unmonitored groundwater 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 1996 Surface Environmental Surveillance Project activities are presented in Sections 4.1 through 4.7 and 5.0 and 7.0.

Groundwater Surveillance

During 1996, groundwater surveillance and monitoring activities at Hanford were restructured into the Groundwater Monitoring Project. This project incorporates sitewide groundwater monitoring mandated by DOE Orders and previously performed under the Groundwater Surveillance Project with near-field groundwater monitoring conducted to ensure that operations in and around specific waste disposal facilities are in compliance with applicable regulations. The objectives of integrating these activities were to improve efficiency of monitoring activities and increase the consistency of interpretations of the groundwater flow system and contaminant distributions.

Collection and analysis of groundwater samples to determine the distributions of radiological and chemical constituents were major parts of the groundwater monitoring effort. In addition, hydrogeologic characterization and modeling of the groundwater flow system were used to assess the monitoring network and to evaluate potential impacts of Hanford Site groundwater contamination. Other activities are data management, interpretation, and reporting. Additional details concerning the Groundwater Monitoring Project are available in Hartman and Dresel (1997).

Surveillance Objectives

Groundwater surveillance was conducted to assess the impacts on groundwater of radiological and hazardous chemicals from the Hanford Site, to provide an integrated assessment of the quality of Hanford Site groundwater, and to evaluate potential offsite impacts from the groundwater pathway. Groundwater monitoring was also performed to verify compliance with applicable environmental laws and regulations and to fulfill commitments. Additional objectives were to characterize physical and chemical trends in the groundwater flow system; establish groundwater quality baselines; provide a continuing, independent assessment of groundwater remediation; and identify new or existing groundwater problems.

Sitewide groundwater monitoring activities previously carried out under the Groundwater Surveillance Project were designed to meet the groundwater monitoring program objectives stated in DOE Order 5400.1 and described above. The impacts of Hanford operations on groundwater have been monitored for more than 50 years under this project and it predecessors. Near-field monitoring of groundwater around specific waste facilities was performed to meet the requirements of 40 CFR 265 and WAC 173-303 and 173-304 as well as applicable DOE Orders (e.g., 5400.1, 5400.5). Groundwater monitoring was also performed in conjunction with cleanup investigations under the Comprehensive Environmental Response, Compensation, and Liability Act.

Surveillance Design

Specific chemicals and radionuclides analyzed at each monitoring well were selected based on past waste disposal activities (Stenner et al. 1988, Diediker and Rokkan 1993) and on previous analysis results. Information on the location of potential contaminant sources and groundwater flow directions was also considered. Selections also involved determining those chemicals and radionuclides important in assessing health risk and for understanding contaminant distribution and movement. Sampling locations and frequencies for 1996 were identified in Bisping (1996).

Groundwater surveillance was conducted using established quality assurance plans (see Section 7.0, "Quality Assurance") and written procedures (Pacific Northwest Laboratory 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 groundwater results.

Groundwater 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, though less extensively than the unconfined aquifer, because it also provides a potential pathway for contaminants to migrate off the Hanford Site. Also, 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 groundwater and to identify and quantify existing, emerging, or potential problems in groundwater quality. Source areas included active waste disposal facilities or facilities that had generated or received wastes in the past. Most of these facilities are located within the 100, 200, and 300 Areas.

However, some sources, such as the Solid Waste Landfill, are located outside the operational areas.

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 groundwater 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 Hanford Site continues. This will provide a continuing assessment of the effect of remediation efforts on groundwater.

Water supplies on and near the Hanford Site potentially provide the most direct route for human exposure to contaminants in groundwater. In 1996, three water supplies provided groundwater for human consumption on the Hanford Site. One well supplied water at the Fast Flux Test Facility, one supplied personnel at the Yakima Barricade guardhouse, and one was located at the Hanford Patrol shooting range (see Section 4.3, "Hanford Site Drinking Water Surveillance"). Water supply wells used by 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 groundwater at locations near the site boundary. Data gathered from wells in a region approximately 2 km (1.2 mi) wide along the boundary helped address objectives of the Groundwater Monitoring Project. These include identifying and quantifying existing, emerging, or potential groundwater quality problems and assessing the potential for contaminants to migrate off the Hanford Site through the groundwater pathway.

To determine the impact of Hanford operations on the environment, 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 groundwater that existed before Hanford operations began are not available. Therefore, concentrations of naturally occurring chemical and radiological constituents in groundwater sampled from wells located in areas unaffected by Hanford operations, including upgradient locations, provide the best estimate of pre-Hanford groundwater 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.

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4.1 Air Surveillance

B. M. Gillespie and G. W. Patton

Atmospheric releases of radioactive material from the Hanford Site to the surrounding region are a potential source of human exposure. Radioactive constituents in air are monitored at a number of locations on and around the site. The influence of Hanford emissions on the local environment 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 analytes tested for at each location 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 (1997).
A detailed description of all radiological sampling and analytical techniques is provided in the DOE (1994a) environmental monitoring plan.

Collection of Air Samples and Analytes Tested for at Each Sample Location

Airborne radionuclides were sampled at 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). Nine of the stations were community-operated environmental surveillance stations (discussed in Section 6.4, "Community-Operated Environmental Surveillance Program") 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 radiological 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 (discussed in Section 6.1, "Climate and Meteorology"). 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 1996). Air sampling locations are listed in Table 4.1.1, along with the analytes tested for at 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 and field surveyed with hand-held instruments for total radioactivity to detect any unusual occurrences. Field measurements of radioactivity in samples were used to monitor changes in environmental conditions that could warrant attention before the more detailed and sensitive laboratory analyses were 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 were increased by combining biweekly samples for nearby locations (or, in some cases, a single location) into quarterly or annual composite samples. The quarterly composite samples were analyzed for specific gamma-emitting radionuclides (Appendix E). The quarterly composites were then used to form annual composite samples (Table 4.1.2). Annual composites were analyzed for strontium-90 and plutonium isotopes, with selected annual composites also analyzed for uranium isotopes or gamma-emitting radionuclides.

Iodine-129 (16 million-year half-life) was sampled at 4 locations by drawing air through a cartridge containing chemically treated, special, low-background petroleum-charcoal positioned downstream of a particle filter. Samples were collected monthly and combined to form quarterly composite samples for each location.

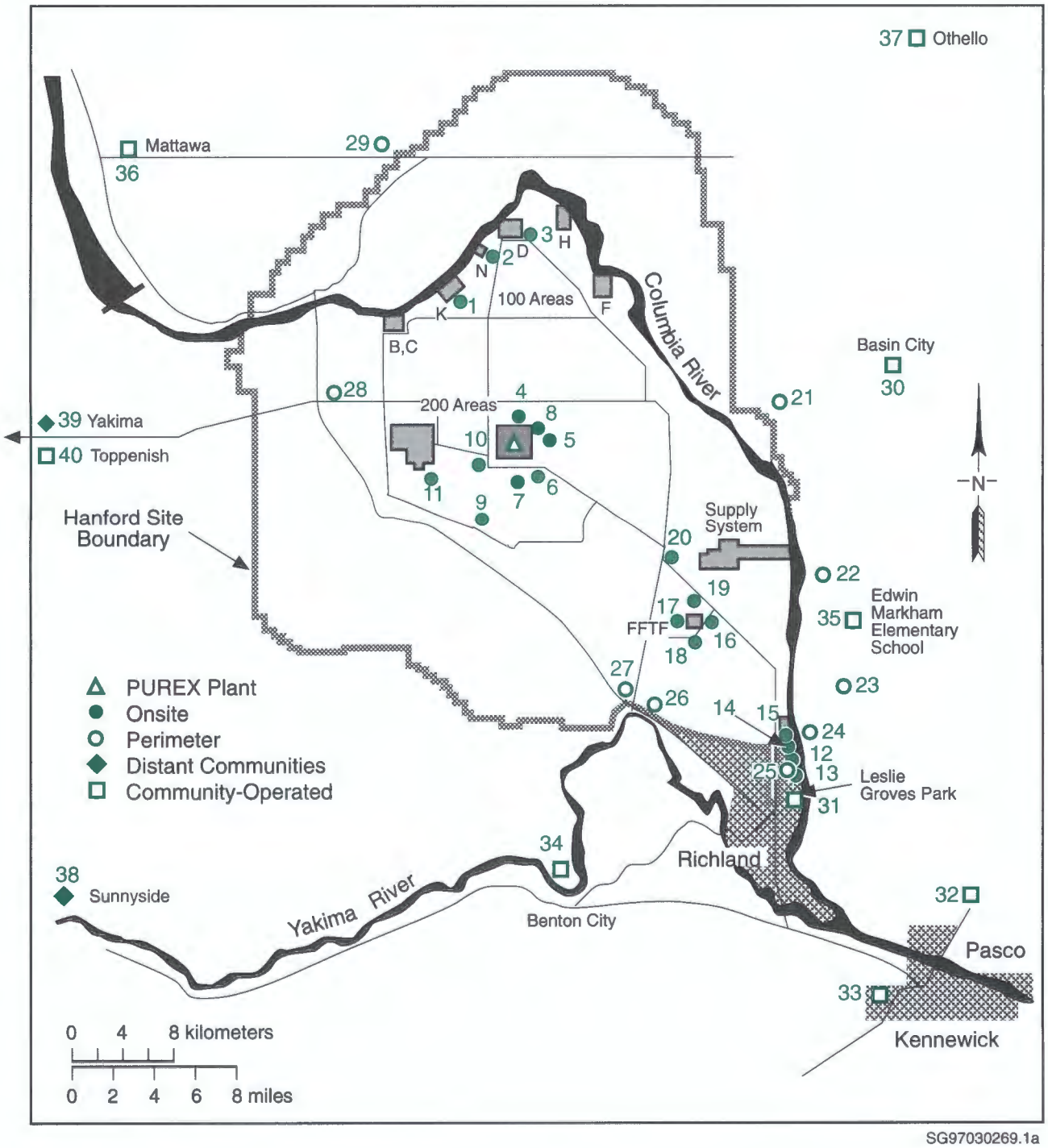

Figure 4.1.1. Air Sampling Locations, 1996 (see Table 4.1.1 for location names)

Table 4.1.1. Air Sampling Locations, Sample Composite Groups, and Analyses, 1996

Map[a] Location	Sampling Location	Analytes[b]	Composite Group	Analytes[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	N of 200-East	Beta	North of 200-East	Gamma - Annual
5	S of 200-East	Beta, alpha	South of 200-East	Gamma, Sr, Pu, U
6	E of 200-East	Beta, alpha	East of 200-East	Gamma, Sr, Pu, U
7	200-East SE	Beta, alpha, ^{3}H, ^{129}I	200-East SE	Gamma, Sr, Pu, U
8	B Pond	Beta, alpha	B Pond	Gamma, Sr, Pu, U
9	Army Loop Camp	Beta, alpha	200-West, South, and East	Gamma, Sr, Pu, U
10	GTE Building	Beta, alpha, ^{3}H		
11	200-West SE	Beta, alpha	200-West	Gamma, Sr, Pu, U
12	300 Water intake	Beta	300 Area	Gamma, Sr, Pu, U
13	300-South Gate	Beta, alpha, ^{3}H		
14	300 Trench	Beta, alpha, ^{3}H	300 NE	Gamma, Sr, Pu, U
15	300 NE	Beta, alpha, ^{3}H		
16	400-East	Beta, alpha, ^{3}H	400 Area	Gamma, Sr, Pu
17	400-West	Beta, alpha		
18	400-South	Beta, alpha		
19	400-North	Beta, alpha		
20	Wye Barricade	Beta, alpha	Wye Barricade	Gamma, Sr, Pu, U
Perimeter				
21	Ringold Met. Tower	Beta, alpha, ^{3}H, ^{129}I	Ringold Met. Tower	Gamma, Sr, Pu
22	W End of Fir Road	Beta, alpha	W End of Fir Road	Gamma, Sr, Pu, U
23	Dogwood Met. Tower	Beta, alpha, ^{3}H	Dogwood Met. Tower	Gamma, Sr, Pu, U
24	Byers Landing	Beta, alpha, ^{3}H, ^{129}I	Byers Landing	Gamma, Sr, Pu, U
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	Yakima Barricade	Gamma, Sr, Pu
29	Wahluke Slope	Beta, alpha, ^{3}H	Wahluke Slope	Gamma, Sr, Pu

Table 4.1.1. (contd)

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

(a) See Figure 4.1.1.
(b) Alpha (total) and beta (total) samples are collected every 2 weeks, ^{3}H samples are collected every 4 weeks, and ^{129}I samples are collected 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, and U analyses are performed on annual composite samples.
(d) A community-operated environmental surveillance station.
(e) Discontinued after March 30, 1996.

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. (1997). 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 nine community-operated environmental surveillance stations (see Section 6.4) located at Basin City Elementary School in Basin City, Edwin Markham Elementary School in north Franklin County, Kiona-Benton High School in Benton City, Leslie Groves Park in Richland, Columbia Basin College in Pasco, Kennewick, Othello, Mattawa, and Heritage College in Toppenish (see Table 4.1.1). These samples were collected by local teachers as 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 alpha, total beta, and specific radionuclides are summarized in Table 4.1.2. Some specific radionuclides (cobalt-60, cesium-134, cesium-137, and europium-154) were occasionally (+94% of results were below detection

Table 4.1.2. Airborne Radionuclide Concentrations in the Hanford Environs, 1996 Compared to Values from Previous Years

Radionuclide	Location Group[a]	1996 No. of Samples	1996 No. of Detects[b]	1996 Maximum[c]	1996 Average[d]	1993-1995 No. of Samples	1993-1995 No. of Detects[b]	1993-1995 Maximum[c]	1993-1995 Average[d]	Derived Concentration Guide[e]
				aCi/m³	aCi/m³			aCi/m³	aCi/m³	
Total alpha	Onsite	425	356	2000 ± 580	520 ± 31	1,374	1,130	2300 ± 620	490 ± 17	
	Perimeter	180	160	2200 ± 600	550 ± 45	564	485	2200 ± 620	520 ± 27	
	Nearby Communities	107	88	1500 ± 490	510 ± 56	311	280	1800 ± 530	530 ± 32	No Standard
	Distant Communities	58	45	1200 ± 430	410 ± 63	173[f]	133	4800 ± 920	490 ± 78	
				pCi/m³	pCi/m³			pCi/m³	pCi/m³	pCi/m³
Tritium	Onsite	99	15	2.8 ± 2.4	0.60 ± 0.12	298	2	610 ± 52	6.9 ± 5.6	
	Perimeter	64	3	5.2 ± 2.4	0.42 ± 0.18	0	0	12 ± 22	1.1 ± 0.29	
	Nearby Communities	39	2	1.4 ± 2.4	0.52 ± 0.14	115	11	120 ± 13	2.6 ± 2.2	100,000
	Distant Communities	31	0	1.3 ± 1.6	0.30 ± 0.17	88	2	5.2 ± 5.0	0.71 ± 0.24	
		1996				1991-1995				
				pCi/m³	pCi/m³			pCi/m³	pCi/m³	
Total beta	Onsite	477	476	0.070 ± 0.0070	0.020 ± 0.0010	2,556	2,554	0.13 ± 0.012	0.020 ± 0.00051	
	Perimeter	203	202	0.098 ± 0.010	0.021 ± 0.0019	1,157	1,153	0.15 ± 0.014	0.019 ± 0.00077	
	Nearby Communities	210	210	0.059 ± 0.0060	0.019 ± 0.0014	856	856	0.10 ± 0.0098	0.019 ± 0.00085	No Standard
	Distant Communities	58	58	0.041 ± 0.0046	0.017 ± 0.0021	305	305	0.12 ± 0.013	0.018 ± 0.0016	
				aCi/m³	aCi/m³			aCi/m³	aCi/m³	aCi/m³
^{90}Sr	Onsite	9	8	160 ± 34	67 ± 38	82	18	4200 ± 810	110 ± 130	
	Perimeter	7	3	35 ± 11	13 ± 8.3	42	8	2300 ± 430	210 ± 180	
	Nearby Communities	4	2	16 ± 16	10 ± 4.9	33	8	6300 ± 1200	260 ± 400	9,000,000
	Distant Communities	2	0	3.2 ± 15	0.92 ± 4.5	21	1	68 ± 120	5 ± 12	
^{129}I	Onsite	4	4	47 ± 7.1	40 ± 6.2	20	20	74 ± 7.2	43 ± 5.7	
	Perimeter	8	8	1.9 ± 0.2	1.2 ± 0.38	40	40	2.5 ± 0.13	1.3 ± 0.19	
	Distant Communities	4	4	0.083 ± 0.01	0.054 ± 0.021	20	20	0.15 ± 0.013	0.075 ± 0.017	70,000,000
^{238}Pu	Onsite	9	1	0.39 ± 0.38	0.064 ± 0.11	82	9	2.0 ± 1.2	0.16 ± 0.14	
	Perimeter	7	0	0.33 ± 0.35	0.056 ± 0.11	41	3	3.1 ± 4.1	0.18 ± 0.28	
	Nearby Communities	4	1	0.24 ± 0.24	0.035 ± 0.16	33	1	1.8 ± 1.6	0.12 ± 0.17	30,000
	Distant Communities	2	0	-0.20 ± 0.21	-0.24 ± 0.087	21	2	2.1 ± 1.9	0.32 ± 0.32	

Table 4.1.2. (contd)

Radionuclide	Location Group[a]	1996 No. of Samples	1996 No. of Detects[b]	1996 Maximum[c] aCi/m³	1996 Average[d] aCi/m³	1991-1995 No. of Samples	1991-1995 No. of Detects[b]	1991-1995 Maximum[c] aCi/m³	1991-1995 Average[d] aCi/m³	Derived Concentration Guide[e] aCi/m³
$^{239,240}Pu$	Onsite	9	4	12 ± 2.5	2.8 ± 3.1	82	41	13 ± 3.0	1.7 ± 0.47	
	Perimeter	7	1	0.82 ± 0.46	0.25 ± 0.20	41	17	2.5 ± 2.0	0.67 ± 0.21	
	Nearby Communities	4	1	0.27 ± 0.42	0.19 ± 0.095	33	14	3.3 ± 1.5	0.74 ± 0.31	20,000
	Distant Communities	2	0	0.16 ± 0.58	0.11 ± 0.11	21	4	3.9 ± 1.3	0.59 ± 0.46	
^{234}U	Onsite	7	7	33 ± 7.2	17 ± 7.4	66	63	3500 ± 330	100 ± 110	
	Perimeter	4	4	45 ± 8.9	27 ± 15	24	24	54 ± 18	28 ± 4.5	
	Nearby Communities	3	3	26 ± 6.6	20 ± 5.7	21	21	44 ± 12	26 ± 3.8	90,000
	Distant Communities	2	2	15 ± 4.3	12 ± 6.3	21	21	40 ± 7.8	23 ± 3.6	
^{235}U	Onsite	7	1	1.2 ± 0.81	0.45 ± 0.35	66	21	370 ± 39	8.8 ± 12	
	Perimeter	4	3	2.1 ± 2.1	1 ± 0.72	24	11	4.3 ± 4.6	1.5 ± 0.46	
	Nearby Communities	3	2	1.4 ± 1.8	1.1 ± 0.34	21	6	4.3 ± 4.8	1.2 ± 0.63	100,000
	Distant Communities	2	0	-0.016 ± 0.76	-0.084 ± 0.14	21	6	11 ± 4	2.0 ± 1.2	
^{238}U	Onsite	7	7	30 ± 5	15 ± 6.6	66	64	2400 ± 230	72 ± 78	
	Perimeter	4	4	40 ± 8.3	25 ± 13	24	24	54 ± 14	26 ± 3.9	
	Nearby Communities	3	3	24 ± 6.4	20 ± 4.3	21	21	40 ± 11	26 ± 3.7	100,000
	Distant Communities	2	2	14 ± 4.1	12 ± 2.5	21	19	230 ± 30	35 ± 21	
^{60}Co	Onsite	39	4	570 ± 250	50 ± 87	190	32	880 ± 490	46 ± 33	
	Perimeter	29	2	740 ± 870	3.3 ± 110	124	11	770 ± 1000	15 ± 44	
	Nearby Communities	19	1	750 ± 440	9.2 ± 150	84	4	520 ± 270	5.8 ± 44	80,000,000
	Distant Communities	9	1	680 ± 440	220 ± 220	47	7	680 ± 640	59 ± 65	
^{137}Cs	Onsite	39	3	570 ± 420	-26 ± 150	190	28	550 ± 440	53 ± 25	
	Perimeter	29	1	380 ± 310	-20 ± 81	124	11	650 ± 410	30 ± 38	
	Nearby Communities	19	2	710 ± 330	130 ± 98	84	5	390 ± 280	25 ± 33	400,000,000
	Distant Communities	9	1	390 ± 290	110 ± 150	47	2	490 ± 270	17 ± 56	

(a) Location groups are identified in Table 4.1.1.
(b) Detect is a result reported greater than the 2-sigma total propagated analytical uncertainty.
(c) Maximum single sample result ± total propagated analytical uncertainty at 2-sigma. Negative concentration values are explained in the section "Helpful Information."
(d) Average of all samples ±2 times the standard error of the mean.
(e) From DOE derived concentration guide (DOE Order 5400.5; see Appendix C, Table C.5).
(f) Two results from the distant communities were excluded as anomolous values through the use of a Q-test (26,300 ± 3,400 aCi/m³ at Sunnyside and 8,000 ± 1,000 aCi/m³ at Yakima [Skoog and West 1980]).

limits) identified in the quarterly or annual composite gamma-ray spectroscopy analyses (see Appendix E) but none of Hanford origin was detected consistently. A detectable value is defined in this section as a value reported above the 2-sigma total propagated analytical uncertainty. The nominal detection limit is defined as the average 2-sigma total propagated analytical uncertainty of the population of reported values.

The average concentration of total alpha radioactivity at the site perimeter was elevated compared to the concentrations measured at distant stations (see 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 the previous 3 years (Figure 4.1.2).

Tritium concentrations measured in 1996 were similar to values reported for 1993 through 1995 (see Table 4.1.2) and did not show the highly elevated concentrations and widely variable results reported for 1991 and 1992 (Woodruff et al. 1993). The 1991 and 1992 results are highly suspect and are likely the result of cross-contamination at the analytical laboratory because even the concentrations at distant locations were high and variable. For 1996, only 20 of the 233 samples analyzed for tritium had results reported above the detection limit. The methodology is capable of detecting concentrations of no less than 1 pCi/m^3 and the majority of the samples had concentrations of tritium below this detection limit. The annual average tritium concentration measured at the site perimeter (0.42 ± 0.18 pCi/m^3) was slightly elevated compared to the annual average value at the distant locations (0.30 ± 0.17 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 1996 was less than 0.0004% of the 100,000-pCi/m^3 DOE derived concentration guide (DOE Order 5400.5).

Total beta concentrations in air for 1996 (Figure 4.1.3) peaked during the winter, repeating a pattern of natural annual radioactivity fluctuations (Eisenbud 1987). The average total beta concentrations were slightly higher at the site perimeter compared to the annual average value at the distant location; however the difference was not statistically significant (log transformed, two-tailed t-test, 5% significance level), indicating that the observed levels were predominantly a result of natural sources and worldwide radioactive fallout.

Thirteen of the 22 strontium-90 results for air samples for 1996 were above the detection limit (see Table 4.1.2). Of the detectable concentrations, eight were onsite locations,

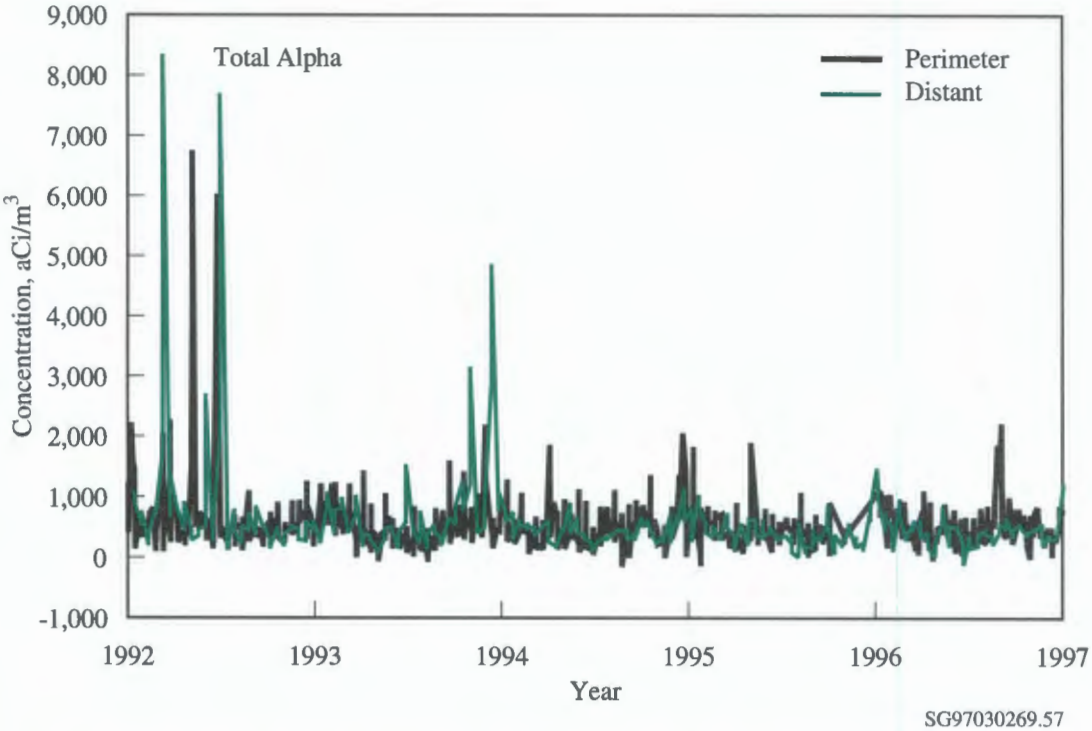

Figure 4.1.2. Total Alpha Radioactivity in Airborne Particulate Samples, 1992 Through 1996

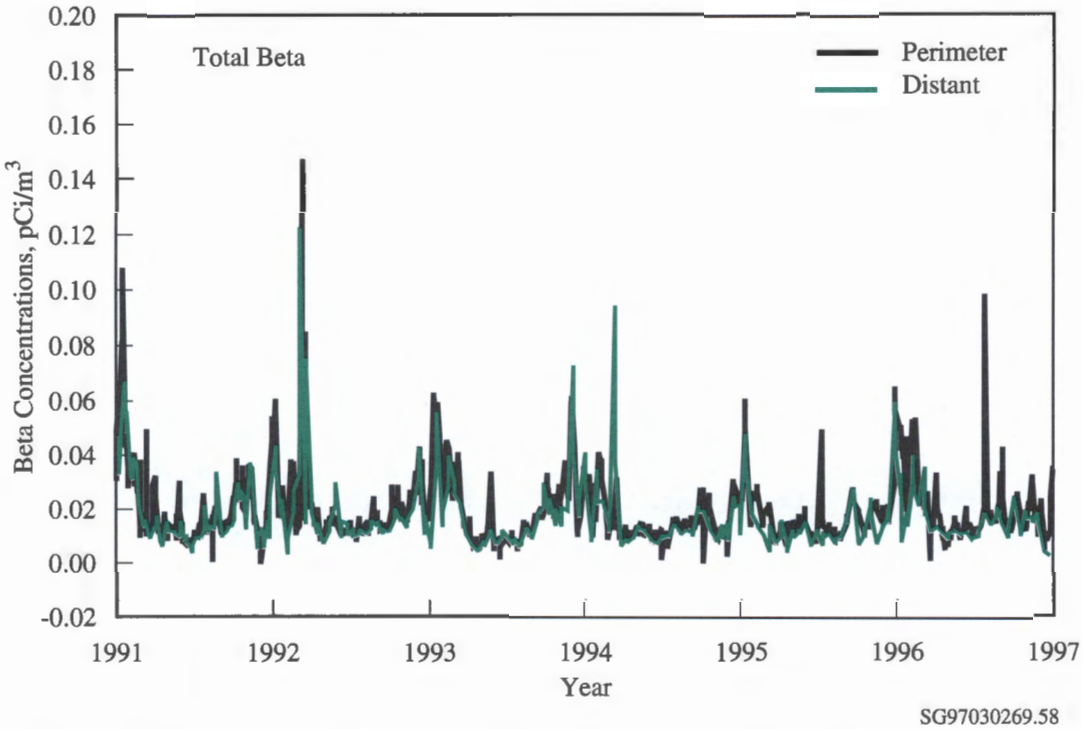

Figure 4.1.3. Total Beta Radioactivity in Airborne Particulate Samples, 1991 Through 1996

three were perimeter locations, and two were nearby community locations. The nominal detection limit of the 22 sample results is 15 aCi/m³. The highest concentration (160 ± 34 aCi/m³) was determined for the 200-East Area composite sample (locations 5, 6 and 7 on Figure 4.1.1) and this concentration is less than 0.002% of the 9-million-aCi/m³ derived concentration guide.

Iodine-129 was sampled downwind of the Plutonium-Uranium Extraction Plant, at two downwind perimeter locations, and at a distant location (Yakima) in 1996 (see Figure 4.1.1). Onsite concentrations in 1996 were elevated compared to those measured at the site perimeter, and perimeter concentrations were higher than those measured at Yakima, the distant location (see Figure 4.1.4 and Table 4.1.2). Iodine-129 concentration differences between these locations were statistically significant (log transformed, two-tailed t-test, 5% significance level) and indicated a Hanford source. Onsite and perimeter air concentrations have remained at their respective levels from 1991 through 1996 (Figure 4.1.4). Onsite air concentrations of iodine-129 were influenced by minor emissions (0.0039 Ci; see 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 1996 (1.2 ± 0.38 aCi/m³) was 0.000003% of the 70-million-aCi/m³ derived concentration guide.

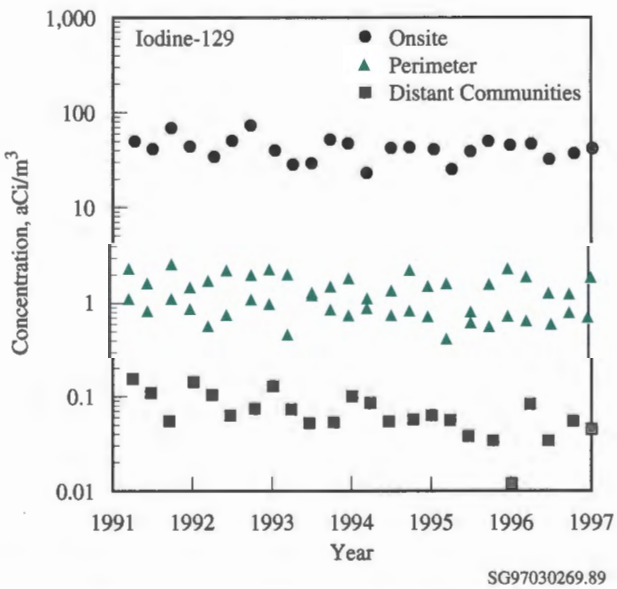

Figure 4.1.4. Concentrations of Iodine-129 in Air, 1991 Through 1996

Plutonium-238 was detected at two locations, one community location and one onsite location, in air samples for 1996 (nominal detection limit of 1 aCi/m^3). The onsite location, 200-West Area (location 11 on Figure 4.1.1), was 0.39 ± 0.38 aCi/m^3. The community location, Tri-City composite sample (locations 32 and 33 on Figure 4.1.1), was at its detection limit of 0.24 aCi/m^3. These plutonium-238 values were well below the nominal detection limit and represents 0.003% of the 30,000-aCi/m^3 derived concentration guide.

The average plutonium-239,240 concentrations detected in onsite and offsite air samples are given in Table 4.1.2 and Figure 4.1.5. The annual average air concentration of plutonium-239,240 at the site perimeter was 0.25 ± 0.20 aCi/m^3, which is 0.001% of the 20,000-aCi/m^3 derived concentration guide. The annual average air concentration was slightly higher for the site perimeter locations compared to the distant locations (0.11 ± 0.11 aCi/m^3); 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 (12 ± 2.5 aCi/m^3) was determined for the 200-East Area composite sample (locations 5, 6 and 7 on Figure 4.1.1). This represents 0.06% of the 20,000-aCi/m^3 derived concentration guide.

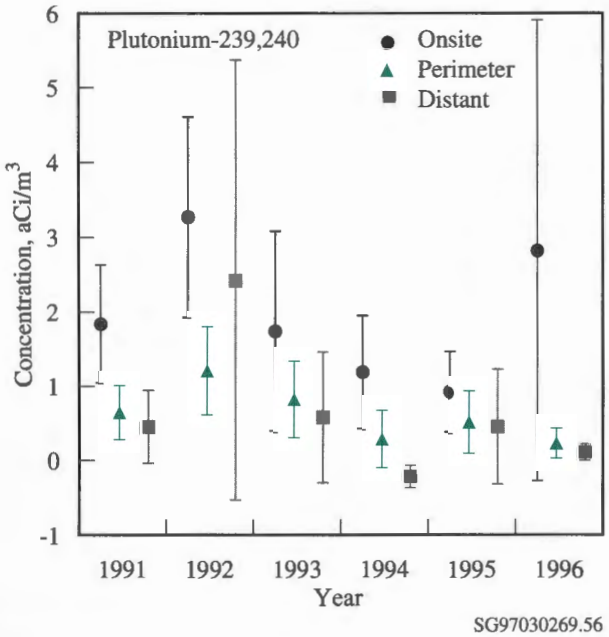

Figure 4.1.5. Annual Average Concentrations (±2 standard error of the mean) of Plutonium-239,240 in Air, 1991 Through 1996

Uranium isotopic concentrations (uranium-234, uranium-235, and uranium-238) in airborne particulate matter in 1996 were similar on the site, at the site perimeter, and at distant communities (see Table 4.1.2 and Figure 4.1.6). The 1996 annual average concentration of uranium-238 for the site perimeter was 25 ± 13 aCi/m^3, which was 0.03% of the 100,000-aCi/m^3 derived concentration guide.

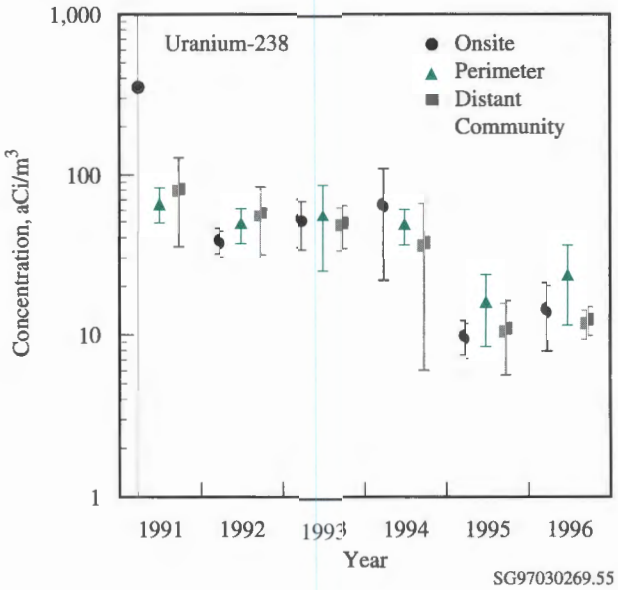

Figure 4.1.6. Annual Average Concentrations (±2 standard error of the mean) of Uranium-238 in Air, 1991 Through 1996

Samples were analyzed quarterly, and at some locations only annually, by gamma-ray spectroscopy. Naturally occurring beryllium-7 and potassium-40 were routinely identified. The potential Hanford-origin gamma-emitting radionuclides of cobalt-60 and cesium-137 associated with airborne particulate matter were monitored by gamma-ray spectroscopy. Results were generally below detectable concentrations both on and off the Hanford Site. Of the 96 samples analyzed by gamma-ray spectroscopy, only 8 of the cobalt-60 and 7 of the cesium-137 samples had concentrations above the detection limits. The cobalt-60 and cesium-137 results for 1996 samples are included in Table 4.1.2. Even the maximum individual measurements for these radionuclides, 750 ± 440 and 710 ± 330 aCi/m^3, and their nominal detection limits of 400 and 370 aCi/m^3, respectively, were less than 0.001% of their derived concentration guide.

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4.2 Surface Water and Sediment Surveillance

G. W. Patton and A. T. Cooper, Jr.

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 irrigation water at the Riverview irrigation canal. Sediment quality surveillance is conducted on the Columbia River and riverbank springs. Tables 4.2.1 and 4.2.2 summarize the sampling locations, types, frequencies, and analyses included in surface-water and sediment surveillance activities during 1996. Sample locations are 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 (1997).

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 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, the Columbia River drains a total area of approximately 70,800 km^2 (27,300 mi^2) en route to the Pacific Ocean. The flow of the river is regulated by 3 dams in Canada and 11 dams in the United States, 7 upstream and 4 downstream of the site. Priest Rapids Dam is nearest upstream and McNary Dam is nearest 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.

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). In 1996, the Columbia River had exceptionally high flow; the annual average flow rate below Priest Rapids Dam was 4,500 m^3/s (160,000 ft^3/s). The peak monthly average flow rate occurred during June (6,700 m^3/s [240,000 ft^3/s]) (Figure 4.2.2). The lowest monthly average flow rate occurred during October (2,800 m^3/s [98,000 ft^3/s]). Daily average flow rates varied from 1,800 to 7,900 m^3/s (63,000 to 280,000 ft^3/s) during 1996. As a result of fluctuations in discharges, the depth of the river varies significantly over time. River stage may change along the Hanford Reach by up to 3 m (10 ft) within a few hours (Dresel et al. 1995). Seasonal changes of approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are only approximately 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 to 1,000 m (980 to 3,300 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 groundwater from past discharges to the ground are known to seep into the river (McCormack and Carlile 1984, Dirkes 1990, DOE 1992a, 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

Table 4.2.1. Surface-Water Surveillance, 1996

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, U[d]
	Particulate (filter)	Q Cont [e]	Gamma scan, Pu[f]
	Soluble (resin)	Q Cont	Gamma scan, ^{129}I, Pu
Vernita Bridge and Richland	Grab (transects)	Q	lo ^{3}H, ^{90}Sr, U
100-F and 300 Areas	Grab (transects)	A	lo ^{3}H, ^{90}Sr, U
100-N Area	Grab (transects)	A	Alpha, beta, lo ^{3}H, ^{90}Sr, U, gamma scan
Old Hanford Townsite	Grab (transects)	A	lo ^{3}H, ^{90}Sr, U
Columbia River - Nonradiological			
Vernita and Richland[g]	Grab	Q	NASQAN, temperature, dissolved oxygen, turbidity, pH, fecal coliforms, suspended solids, dissolved solids, specific conductance, hardness (as $CaCO_3$), P, Cr, N-Kjeldahl, Fe, NH_3, $NO_3 + NO_2$
	Grab (transects)	Q	ICP[h] metals, anions, volatile organics
	Grab (transects)	A	CN, Hg
100-N, 100-F, and Old Hanford Townsite	Grab (transects)	A	ICP metals, anions, volatile organics, Hg
300 Area	Grab (transects)	A	ICP metals, anions, volatile organics
Onsite Ponds			
West Lake	Grab	Q	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U, gamma scan
B Pond	Grab	Q	Alpha, beta, ^{3}H, ^{90}Sr, gamma scan
Fast Flux Test Facility Pond	Grab	Q	Alpha, beta, ^{3}H, gamma scan
Offsite Water			
Riverview Irrigation Canal	Grab	3[i]	Alpha, beta, ^{3}H, ^{90}Sr, U, gamma scan
Riverbank Springs			
100-B, 100-K, 100-N, and 100-H Areas	Grab	A	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U, gamma scan, ICP metals, anions, volatile organics
100-D Area	Grab	A	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, U, gamma scan, ICP metals, anions, volatile organics
Old 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, which includes an electrolytic preconcentration.
(d) U = isotopic uranium.
(e) Q Cont = river water was sampled by continuous flow through a filter and resin column and composited monthly (M) or quarterly (Q) for analysis.
(f) Pu = 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.

Table 4.2.2. Sediment Surveillance, 1996

Location[a]	Frequency	Analyses
River		
McNary Dam: Oregon shore 1/3 from Oregon shore 2/3 from Oregon shore Washington shore	A[b]	Gamma scan, ^{90}Sr, U,[c] Pu,[d] ICP[e] Metals
Priest Rapids Dam: Grant County shore 1/3 from Grant County shore 2/3 from Grant County shore Yakima County shore	A	Gamma scan, ^{90}Sr, U, Pu, ICP Metals
White Bluffs Slough	A	Gamma scan, ^{90}Sr, U, Pu, ICP Metals
100-F Slough	A	Gamma scan, ^{90}Sr, U, Pu, ICP Metals
Hanford Slough	A	Gamma scan, ^{90}Sr, U, Pu, ICP Metals
Richland	A	Gamma scan, ^{90}Sr, U, Pu, ICP Metals
Springs		
100-B Area Spring	A	Gamma scan, ^{90}Sr, U, ICP Metals
100-N Area Spring 8-13	A	Gamma scan, ^{90}Sr, U, ICP Metals
Hanford Spring 28-2	A	Gamma scan, ^{90}Sr, U, ICP Metals
300 Area Spring 42-2	A	Gamma scan, ^{90}Sr, U, ICP Metals
100-K Area Spring	A	Gamma scan, ^{90}Sr, U, ICP Metals
100-F Area Spring	A	Gamma scan, ^{90}Sr, U, ICP Metals

(a) See Figure 4.2.1.
(b) A = annually.
(c) U includes ^{235}U and ^{238}U analyzed by low-energy photon analysis.
(d) Pu = isotopic plutonium.
(e) ICP = inductively coupled plasma analysis method.

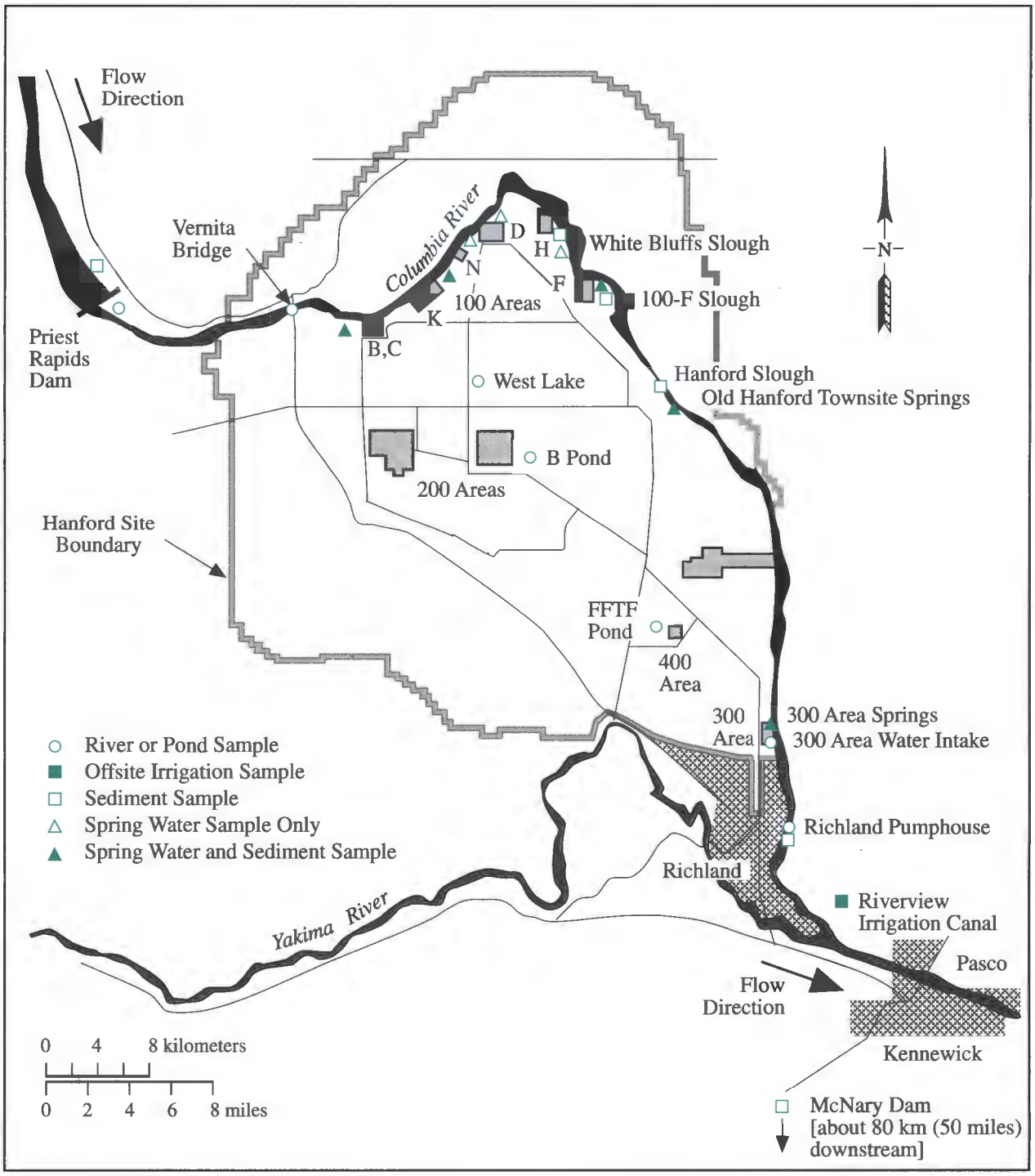

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Figure 4.2.1. Water and Sediment Sampling Locations, 1996

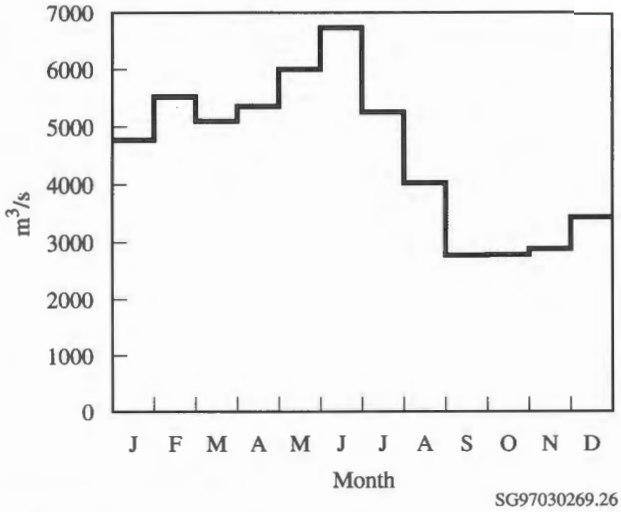


Figure 4.2.2. Mean Monthly Columbia River Flow Rates, 1996

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."

Washington State 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 (WAC 173-201A). 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 of River Water Samples and Analytes of Interest

Samples of Columbia River water were collected throughout 1996 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-F Area, 100-N Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse. Samples were collected upstream from Hanford Site facilities at Priest Rapids Dam and 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 municipal drinking water supply.

The fixed-location monitoring stations at Priest Rapids Dam and 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 (see 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 DOE (1994a).

Analytes of interest in water samples collected from Priest Rapids Dam and Richland Pumphouse fixed-location monitoring stations included total alpha, total beta, selected gamma emitters, tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, uranium-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 (see 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, uranium-235, uranium-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 groundwater underlying the Hanford Site and for 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 (see Appendix C, Table C.2).

Transect sampling was initiated as a result of findings of a special study conducted during 1987 and 1988 (Dirkes 1993). That study concluded that, under certain flow conditions, contaminants entering the river from Hanford are not completely mixed at routine 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 (Section 4.3, "Hanford Site Drinking Water Surveillance") and the Richland Pumphouse. The Vernita Bridge and Richland Pumphouse

transects were sampled quarterly during 1996. Annual transect sampling was conducted at the 100-F Area, 100-N Area, Old Hanford Townsite, and 300 Area sampling locations.

Columbia River transect water samples collected in 1996 were analyzed for both radiological and chemical contaminants (see Table 4.2.1). Metals, anions, and volatile organics, listed in DOE (1994d), were selected for analysis following reviews of existing surface-water and groundwater data, various remedial investigation/feasibility study work plans, and preliminary Hanford Site risk assessments (DOE 1992b, Evans et al. 1992, Dirkes et al. 1993, Blanton et al. 1995b, 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 1996, nonradiological water quality monitoring was also performed by the U.S. Geological Survey in conjunction with the National Stream Quality Accounting Network program. U.S. Geological Survey samples were collected along Columbia River transects quarterly at the Vernita Bridge and the Richland Pumphouse (see Appendix A, Table A.4). 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 Richland Pumphouse during 1996 are reported by Bisping (1997) and summarized in Appendix A (Tables A.1 and A.2). These tables also list the maximum and mean concentrations of select radionuclides observed in Columbia River water in 1996 and during the previous 5 years. All radiological contaminant concentrations measured in Columbia River water in 1996 were less than DOE derived concentration guides (DOE Order 5400.5) and Washington State ambient surface-water quality criteria (WAC 173-201A and 246-290) levels (see Appendix C, Tables C.5 and C.2, respectively). Significant results are discussed and illustrated below, and comparisons to previous years are provided.

Concentrations of radionuclides monitored in Columbia River water were extremely low throughout the year. Radionuclides consistently detected in river water collected from monitoring stations during 1996 at concentrations greater than two times their total propagated analytical uncertainty included tritium, strontium-90, iodine-129, uranium-234, uranium-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 indicators of the general radiological quality of the river and provide an early indication of change. Figures 4.2.3 and 4.2.4 illustrate the average annual total alpha and total beta concentrations, respectively, at Priest Rapids Dam and Richland Pumphouse during the past 6 years. The 1996 average total alpha and total beta concentrations were similar to those observed during recent years. Monthly concentrations measured at the Richland Pumphouse in 1996 were not significantly different (paired sample comparison and two-tailed t-test, 5% significance level) from those measured at Priest Rapids Dam. The average concentrations in Columbia River water at Priest Rapids Dam and Richland Pumphouse in 1996 were less than 5% of their respective Washington State ambient surface-water quality criteria levels of 15 and 50 pCi/L (WAC 246-290).

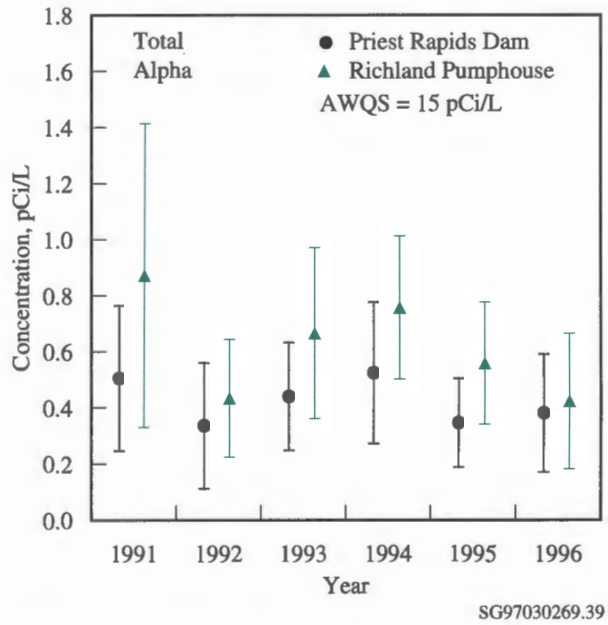


Figure 4.2.3. Annual Average Total Alpha Concentrations in Columbia River Water, 1991 Through 1996 (AWQS = ambient water quality standard)

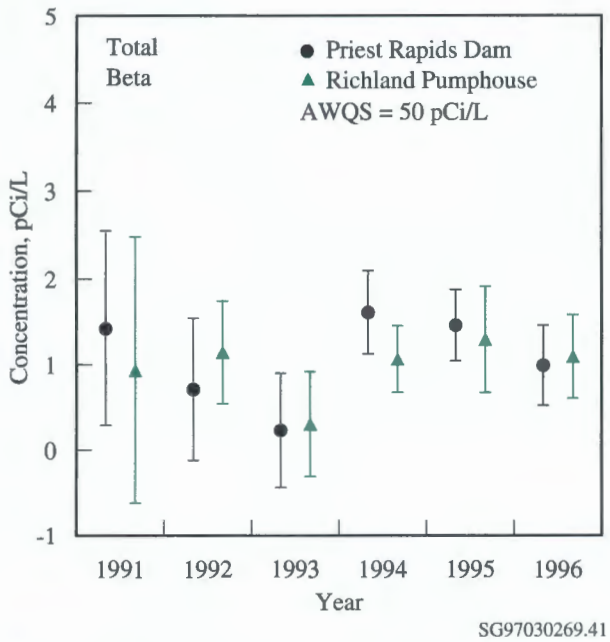


Figure 4.2.4. Annual Average Total Beta Concentrations in Columbia River Water, 1991 Through 1996 (AWQS = ambient water quality standard)

Figure 4.2.5 compares the average annual tritium concentrations at Priest Rapids Dam and Richland Pumphouse from 1991 through 1996. The general decline in tritium concentrations in river water remains evident at both locations. Statistical analysis (paired sample comparison, two-tailed t-test, 5% significance level) indicated that monthly tritium concentrations in river water at the Richland Pumphouse were significantly higher than those at Priest Rapids Dam. However, average tritium concentrations in Columbia River water collected from Priest Rapids Dam and Richland Pumphouse during 1996 were less than 1% of Washington State's ambient surface-water quality criteria level of 20,000 pCi/L (WAC 246-290). Onsite sources of tritium entering the river include groundwater seepage and direct discharge from outfalls located in the 100 Areas (see Section 3.1, "Facility Effluent Monitoring," and Section 4.8, "Groundwater 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 Areas groundwater plume entering the river along the portion of shoreline extending from the Old Hanford Townsite to below the 300 Area, which is relatively close to the Richland Pumphouse sample intake. This plume is not completely mixed within the river at the Richland Pumphouse. Sampling along a transect at the pumphouse during 1996 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.

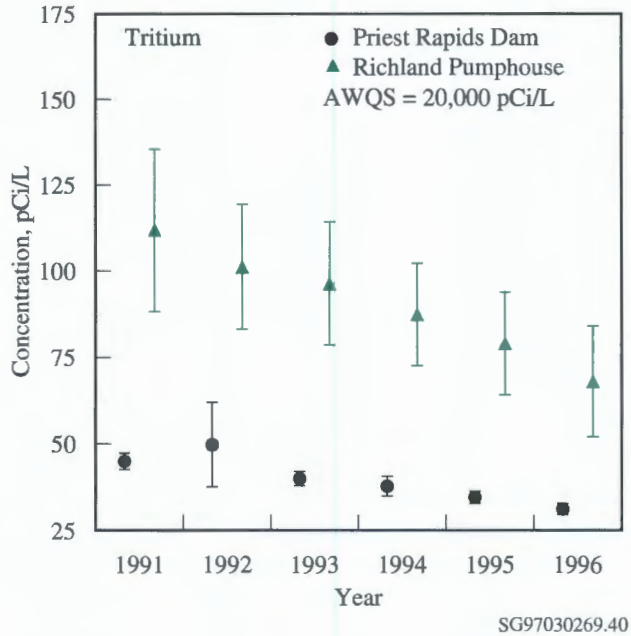


Figure 4.2.5. Annual Average Tritium Concentrations in Columbia River Water, 1991 Through 1996 (AWQS = ambient water quality standard)

The average annual strontium-90 concentrations in Columbia River water collected from Priest Rapids Dam and Richland Pumphouse from 1991 through 1996 are presented in Figure 4.2.6. Concentrations observed in 1996 were similar to those observed previously. Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Areas (Dresel et al. 1995). The highest strontium-90 concentrations in groundwater onsite have been found in the 100-N Area as a result of past discharges to the 100-N Area liquid waste disposal facilities. Despite the Hanford source, the differences between monthly strontium-90 concentrations at Priest Rapids Dam and Richland Pumphouse in 1996 were not significant (paired sample comparison, two-tailed t-test, 5% significance level). Average strontium-90 concentrations in Columbia River water were approximately 1% of the 8-pCi/L ambient surface-water quality criteria level.

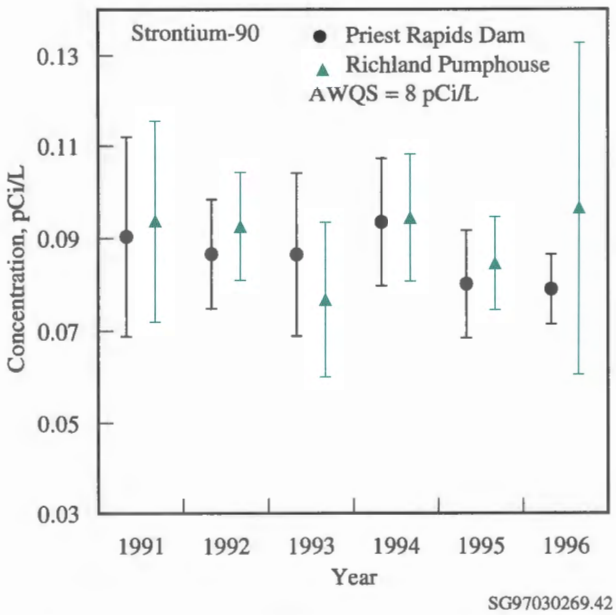


Figure 4.2.6. Annual Average Strontium-90 Concentrations in Columbia River Water, 1991 Through 1996 (AWQS = ambient water quality standard)

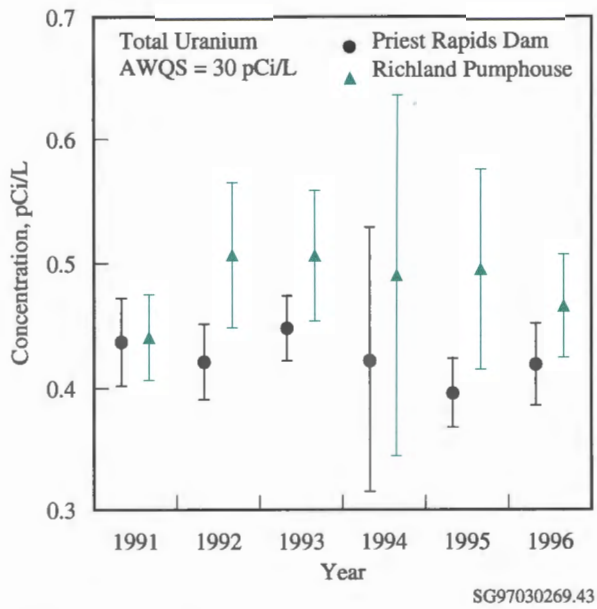


Figure 4.2.7. Annual Average Total Uranium Concentrations in Columbia River Water, 1991 Through 1996 (AWQS = ambient water quality standard)

Average annual total uranium concentrations (i.e., the sum of uranium-234, uranium-235, and uranium-238 concentrations) at Priest Rapids Dam and Richland Pumphouse for 1991 through 1996 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 1996 were similar to those observed during recent years. Monthly total uranium concentrations measured at the Richland Pumphouse in 1996 were not significantly different from those measured at Priest Rapids Dam (paired sample comparison, two-tailed t-test, 5% significance level). Although there is no direct discharge of uranium to the river, uranium is present in the groundwater beneath the 300 Area as a result of past Hanford operations (see Section 4.8, "Groundwater Protection and Monitoring Program") and has been detected at elevated levels in riverbank springs in this area (see "Riverbank Springs Water" subsection). Naturally occurring uranium is also known to enter the river across from Hanford via irrigation return water and groundwater 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 1996 were well below the proposed EPA drinking water standard of 20 µg/L (30 pCi/L; EPA 1996).

The average annual iodine-129 concentrations for Priest Rapids Dam and Richland Pumphouse for 1991 through 1996 are presented in Figure 4.2.8. The large error observed at Priest Rapids Dam in 1994 is attributed to an unusually high third quarter result at that location. Only one quarterly iodine-129 result was available for the Richland Pumphouse during 1995 because of construction activities at the pumphouse. The average concentration of iodine-129 in Columbia River water was extremely low during 1996 (<0.1% of the Washington State ambient surface-water quality criteria [WAC 246-290] level of 1 pCi/L [1 million 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 groundwater along the portion of shoreline downstream of the Old Hanford Townsite (see Section 4.8, "Groundwater Protection and Monitoring Program"). The iodine-129 plume originated in the 200 Areas from past waste disposal practices. Quarterly iodine-129 concentrations in Columbia River water at the Richland Pumphouse were significantly higher than those at Priest Rapids Dam (paired sample comparison, two-tailed t-test, 5% significance level) (Dirkes and Hanf 1995).

During 1996, average plutonium-239,240 concentrations at Priest Rapids Dam and Richland Pumphouse were 42 ± 50 and 58 ± 47 aCi/L, respectively. No ambient surface-water quality criteria levels exist for

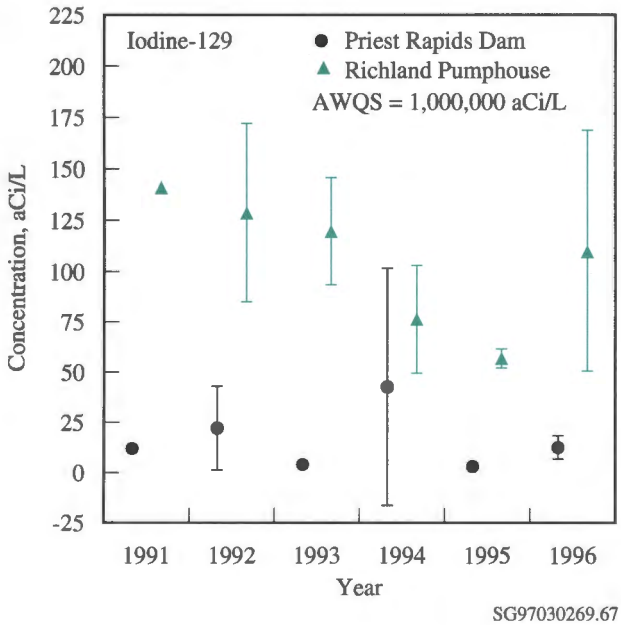


Figure 4.2.8. Annual Average Iodine-129 Concentrations in Columbia River Water, 1991 Through 1996 (AWQS = ambient water quality standard)

plutonium-239,-240; however, if the DOE derived concentration guides (DOE Order 5400.5; see 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 (1.2 million aCi/L) would be the relevant guideline for plutonium-239,-240. As in previous years, there was no significant difference in concentrations at Priest Rapids Dam and Richland Pumphouse (paired sample comparison, t-test, 5% significance level) (Dirkes and Hanf 1995).

Radiological results of samples collected along Columbia River transects established at the Vernita Bridge, 100-F Area, 100-N Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse during 1996 are presented in Appendix A (Table A.4) and Bisping (1997). 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, uranium-234, and uranium-238. All measured concentrations of these radionuclides were less than applicable ambient surface-water quality criteria levels.

Tritium concentrations measured along Columbia River transects during September 1996 are depicted in Figure 4.2.9. The transects are displayed such that the observer's view is upstream. 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 1996 river transect water (see Figure 4.2.9) were detected along the shoreline of the Old Hanford Townsite, where groundwater 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. 1995). Slightly elevated levels of tritium were also evident near the Hanford shoreline at the 100-N Area, 300 Area transect locations, and Richland Pumphouse shoreline. 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 Areas groundwater 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 Richland Pumphouse transect was less than that measured in monthly composited samples from the pumphouse, illustrating the conservative bias of the fixed-location monitoring station.

Strontium-90 concentrations in 1996 transect samples were fairly uniform across the width of the river and varied little between transects (see Appendix A, Table A.3). The mean concentration of strontium-90 found during transect 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 in the river at this location.

Total uranium concentrations (i.e., the sum of uranium-234, uranium-235, and uranium-238 concentrations) in 1996 were elevated along both the Benton and Franklin County shorelines of the 300 Area and Richland Pumphouse transects (see Appendix A, Table A.3). The highest total uranium concentration was measured near the Franklin County shoreline of the Richland Pumphouse transect and likely resulted from groundwater seepage and irrigation return canals on the east side 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.

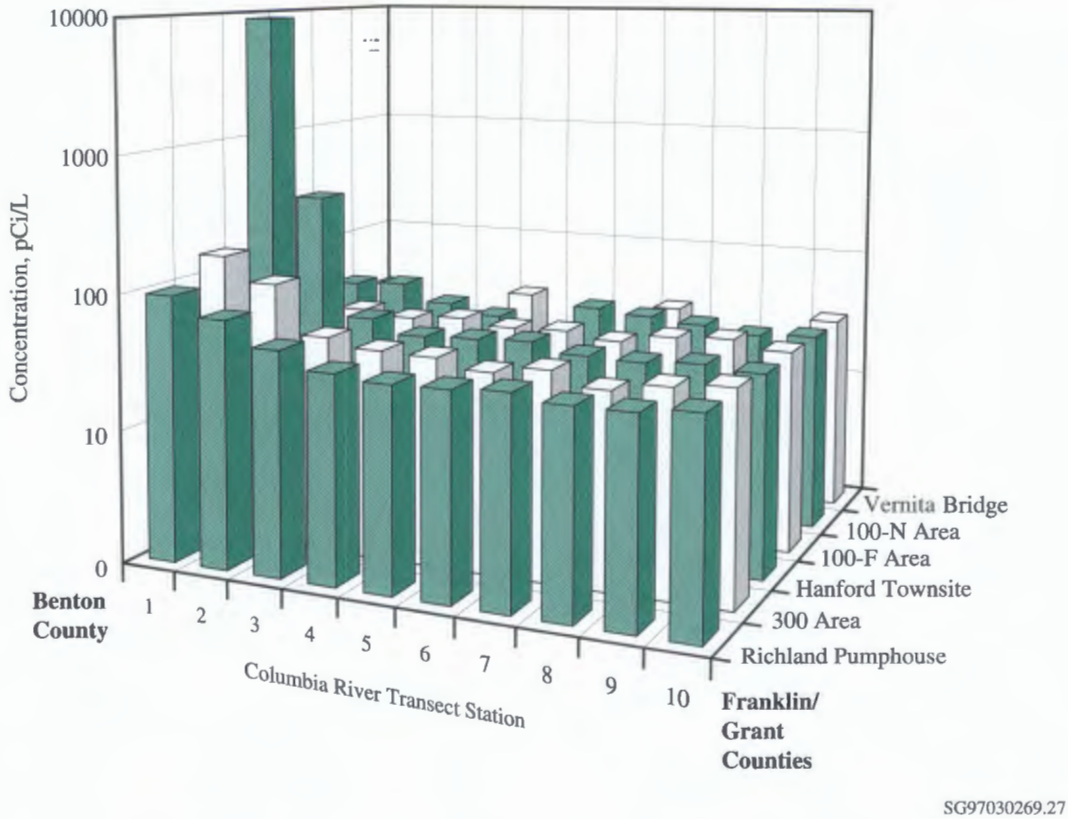


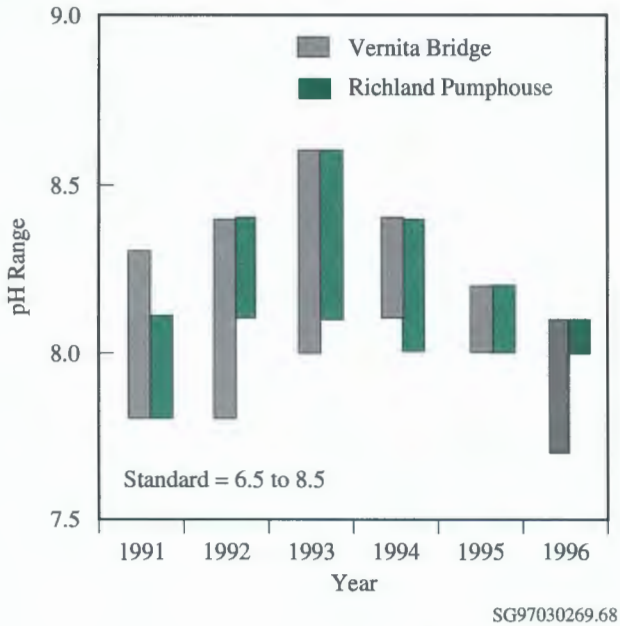
Figure 4.2.9. Mean Tritium Concentrations in Columbia River Transects, 1996

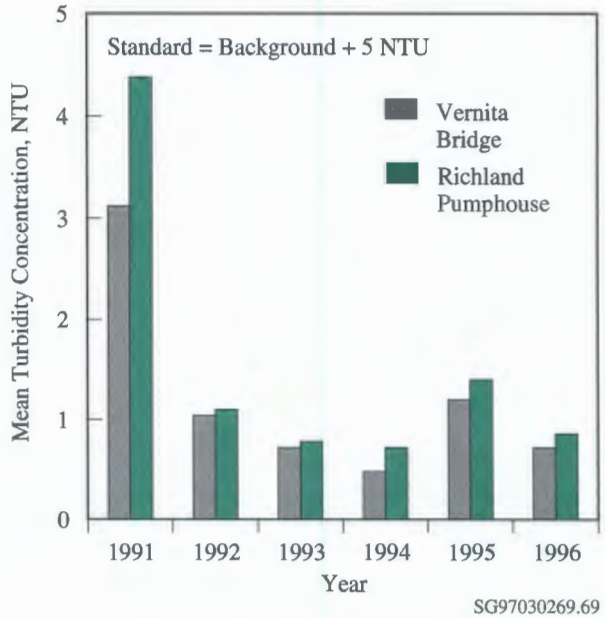
Nonradiological Results for Columbia River Water Samples

Nonradiological water quality data were compiled by the Pacific Northwest National Laboratory and the U.S. Geological Survey during 1996. A number of the parameters measured have no regulatory limits; however, they are useful as indicators of water quality and contaminants of Hanford origin. Potential sources of pollutants not associated with Hanford include irrigation return water and groundwater seepage associated with extensive irrigation north and east of the Columbia River (Dirkes 1990).

Figure 4.2.10 shows the preliminary Vernita Bridge and Richland Pumphouse U.S. Geological Survey results for 1991 through 1996 for several water quality parameters with respect to their applicable standards. The complete list of preliminary results obtained through the U.S. Geological Survey National Stream Quality Accounting Network program is documented in Bisping (1997) and is summarized in Appendix A (Table A.4). Final results are published annually by the U.S. Geological Survey (e.g., Wiggins et al. 1996). The 1996 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 1996, there was no indication of any deterioration of water quality resulting from Hanford operations along the Hanford Reach of the Columbia River (see Appendix C, Table C.1).

Results of nonradiological sampling conducted by Pacific Northwest National Laboratory along transects of the Columbia River in 1996 at the Vernita Bridge, 100-F Area, 100-N Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse are provided by Bisping (1997). The concentrations of volatile organics, metals, and anions observed in river water in 1996 were similar to those observed in the past. Acetone, trichloroethylene, chloroform, and toluene were occasionally detected and was found in Columbia River transect samples. All volatile organic compound concentrations were less than EPA ambient surface-water quality criteria levels (see Appendix C, Table C.3).





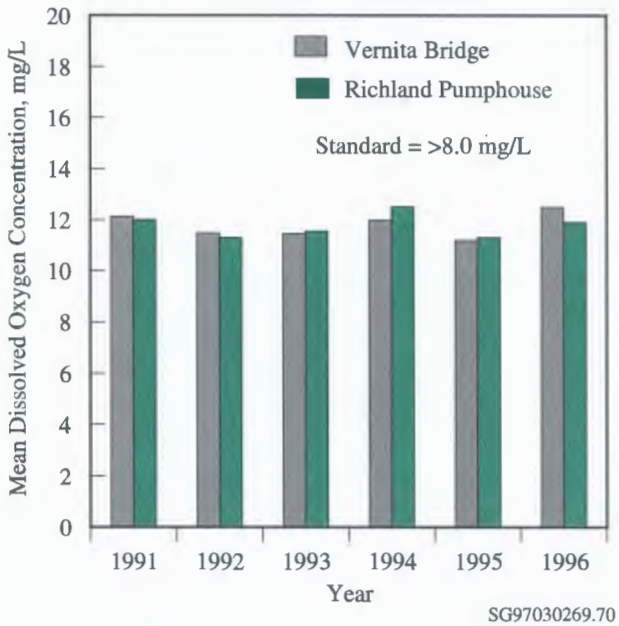


Figure 4.2.10. Preliminary U.S. Geological Survey Columbia River Water Quality Measurements, 1991 Through 1996

Several metals and anions were detected in Columbia River transect samples 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. Aluminum and iron were detected at both Vernita Bridge and Richland Pumphouse, with somewhat higher concentrations of both at the Richland Pumphouse. Arsenic, antimony, beryllium, cadmium, chromium, cobalt, lead, magnesium, manganese, nickel, selenium, silver, strontium, thallium, tin, vanadium, and zinc were only occasionally detected, with similar levels at most locations. Trace levels of mercury (below 0.000001 µg/L) were detected in September 1996 transect samples at Vernita Bridge, 100-F Area, and Richland Pumphouse. Nitrate concentrations were elevated along the Franklin County shoreline of the Old Hanford Townsite, 300 Area, and Richland Pumphouse transects and likely resulted from groundwater seepage associated with extensive irrigation north and east of the Columbia River. Groundwater 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, aluminum, and iron, which had the highest average quarterly concentrations at the Richland Pumphouse, no consistent differences were found between 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 (WAC 246-290; see Appendix C, Table C.3). Criteria for Columbia River water were calculated using a total hardness of 55 mg/L as $CaCO_3$ (calcium carbonate), the limiting value based on U.S. Geological Survey monitoring of Columbia River water near Vernita Bridge and Richland Pumphouse over the past 6 years. The total hardness reported by the U.S. Geological Survey at those locations from 1991 through 1996 ranged from 55 to 77 mg/L as $CaCO_3$. All metal and anion concentrations in river water were less than the Washington State ambient surface-water quality criteria levels for acute toxicity, except for silver and cadmium that exceeded the criteria in a few samples. The chronic toxicity levels for lead and selenium were occasionally exceeded in Columbia River transect samples. All mercury concentrations were below the Washington State chronic toxicity level (WAC 246-290). The chronic toxicity criteria are based on a 4-day average concentration not to be exceeded more than once every 3 years. Transect samples are grab samples; therefore, they are not directly comparable to the standard. Antimony, arsenic, and thallium concentrations occasionally exceeded EPA standards to protect human health for the consumption of water and organisms. However, similar concentrations were found at Vernita Bridge and Richland Pumphouse (see Appendix C, Table C.3). Silver has not been identified as a contaminant of concern from the Hanford Site to the Columbia River (Blanton et al. 1995b, Napier et al. 1995).

Columbia River Sediments

Sediments in the Columbia River contain low concentrations of radionuclides and metals of Hanford origin as well as radionuclides from nuclear weapons testing fallout (Robertson and Fix 1977, Beasley et al. 1981, 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 for 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 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 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 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 (see Section 3.1, "Facility Effluent Monitoring") and via contaminated groundwater seepage (McCormack and Carlile 1984, Dirkes 1990, DOE 1992c, 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 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. 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 (Nelson et al. 1966, Lambert 1967, Richardson and Epstein 1971, Gibbs 1973, Karickhoff et al. 1978, Suzuki et al. 1979, Sinex and Helz 1981, Tada and Suzuki 1982, Mudroch 1983).

Collection of Sediment Samples and Analytes of Interest

During 1996, samples of Columbia River surface sediments (0 to 15-cm [0 to 6-in.] depth) were collected from 6 river locations that are permanently submerged and 5 riverbank spring locations that are periodically inundated (see Figure 4.2.1 and Table 4.2.2). Samples were collected above Priest Rapids Dam (the nearest upstream impoundment) upstream of Hanford facilities 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 these drainages may also contribute to the contaminant load found in McNary Dam sediment. Sediment samples were also collected along the Hanford Reach of the Columbia River from areas close to contaminant discharges (e.g., riverbank springs), from slackwater areas where fine-grained material is known to deposit (e.g., the White Bluffs, 100-F Area, and Hanford sloughs), and from an area 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 on a transect line crossing the Columbia River. 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 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 springwater samples. Sampling methods are discussed in detail in DOE (1994a). All sediment samples were analyzed for gamma emitters (see Appendix E), strontium-90, uranium-235, uranium-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 1996 are reported by Bisping (1997) and summarized in Appendix A (Table A.5). Radionuclides consistently detected in river sediment adjacent and downstream of Hanford during 1996 at concentrations greater than two times their total propagated analytical uncertainty included cobalt-60, strontium-90, cesium-137, europium-155, uranium-238, plutonium-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. Because of variations in the bioavailability of contaminants in various sediments, no state or federal freshwater sediment criteria are available to assess the sediment quality of the Columbia River (EPA 1994).

Radionuclide concentrations reported in river sediment in 1996 were similar to those reported for previous years (see Appendix A, Table A.5). No appreciable differences in isotopic uranium concentrations were noted between locations. Minimum, median, and maximum concentrations of select radionuclides measured in river sediment from 1991 through 1996 are presented in Figure 4.2.11. Sampling areas include stations at Priest Rapids and

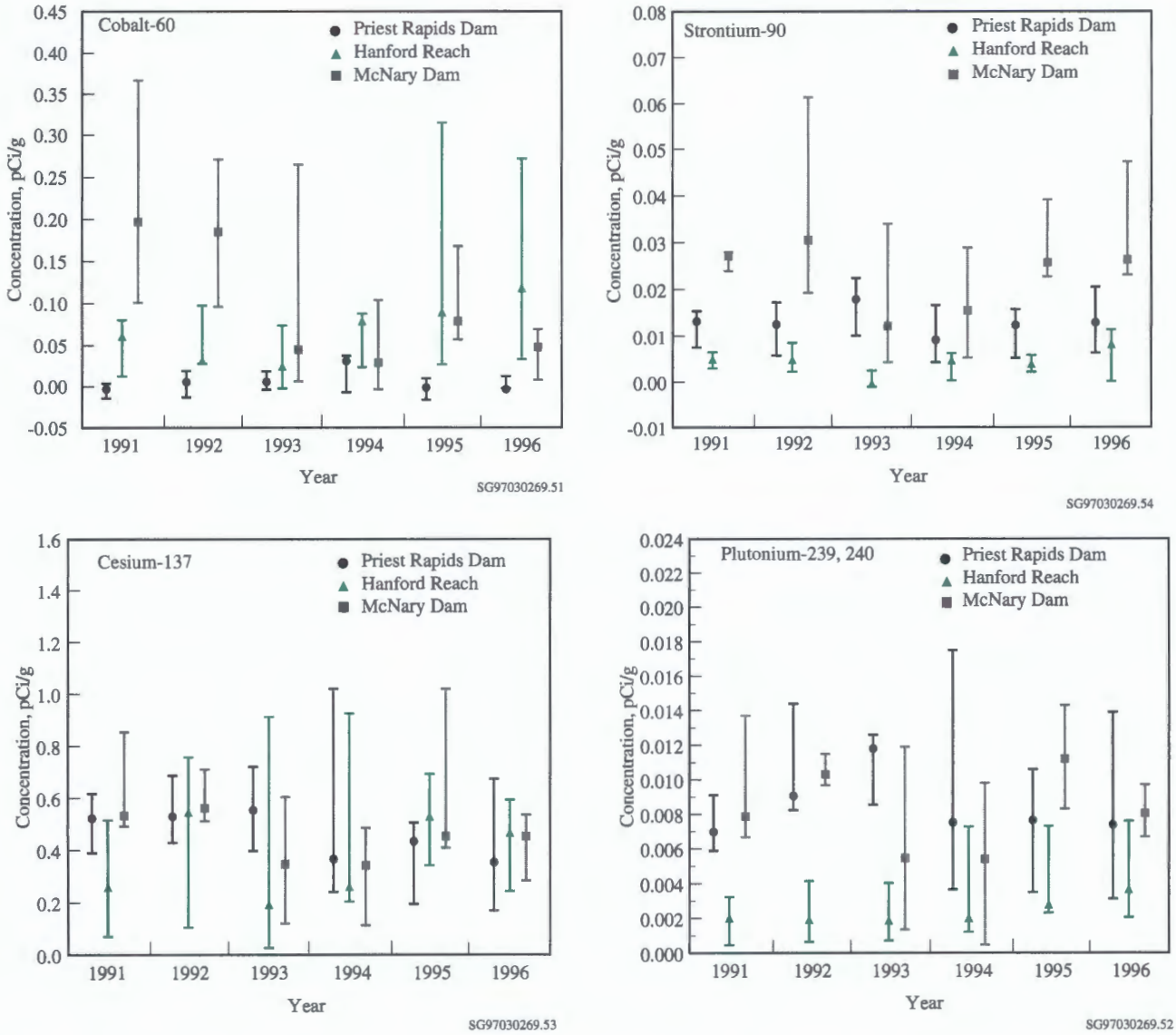


Figure 4.2.11. Minimum, Median, and Maximum Concentrations of Select Radionuclides Measured in Columbia River Sediments, 1991 Through 1996

McNary Dams as well as the Hanford Reach stations: White Bluffs, 100-F Area, Hanford sloughs, and Richland Pumphouse. Strontium-90 is the only radionuclide to exhibit consistently higher median concentrations at McNary Dam from 1991 through 1996. The rank of all other radionuclide concentrations by sampling area varied from year to year. The median concentrations of strontium-90 and plutonium-239,240 were highest in McNary Dam sediment in 1996. The median concentration of cobalt-60 was highest along the Hanford Reach. No other radionuclides measured in 1996 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 riverbank springs in the 100-B, 100-F, 100-K, and 100-N Areas were added in 1995. Sediments at all other riverbank spring sampling locations consisted of predominantly large cobble and were unsuitable for sample collection. Sediment samples were not collected in 1996 at the 100-K Area because of low spring-water flow and specific conductances similar to the Columbia River,

which indicates bank storage of river water. Sediment samples were not collected in 1996 at the 100-N Area because of large cobble at the spring location.

Radiological results for riverbank spring sediment collected in 1996 are presented in Bisping (1997) and are summarized in Appendix A (Table A.5). Results were similar to those observed for previous years, with the exception of total uranium in 300 Area spring sediment that did not show the elevated concentrations reported in 1995. Radionuclide concentrations in riverbank spring sediment were similar to those observed in river sediment in 1996.

Nonradiological Results for Columbia River Sediment Samples

Metal concentrations observed in Columbia River sediment in 1996 are reported by Bisping (1997) and are summarized in Appendix A (Table A.6). Detectable amounts of most metals were found in all Columbia River sediment samples, with the exception of silver. Concentrations of silver were below the detection limit (0.52 mg/kg) for all samples. Overall median concentrations of most metals were similar for most samples, with McNary Dam sediments having slightly higher median concentrations of some metals (Figure 4.2.12). The maximum and highest median concentrations of chromium were found in riverbank spring sediment.

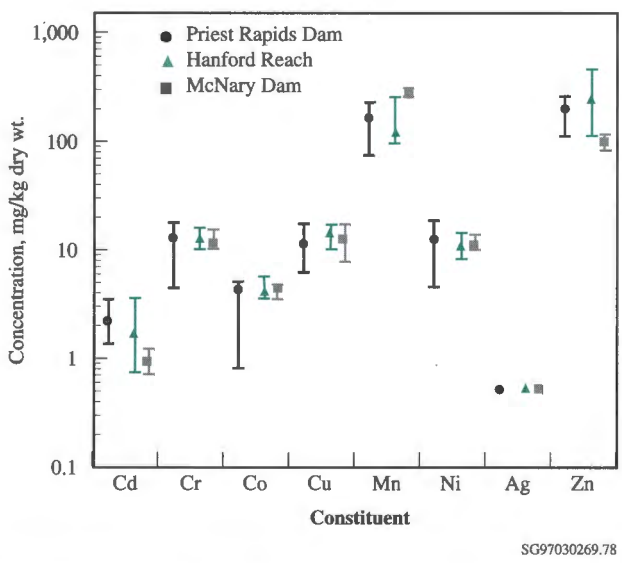


Figure 4.2.12. Minimum, Median, and Maximum Concentrations of Select Metals Measured in Columbia River Sediments, 1996

Riverbank Springs Water

The Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site (Dresel et al. 1995). Groundwater provides a means for transporting Hanford-associated contaminants, which have leached into groundwater from past waste disposal practices, to the Columbia River (McCormack and Carlile 1984, Dirkes 1990, DOE 1992a, Peterson 1992). Contaminated groundwater 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 groundwater being discharged to the river and to assess the potential human and ecological risk associated with the spring water.

The seepage of groundwater into the Columbia River has occurred for many years. Riverbank springs were documented along the Hanford Reach long before Hanford operations began during World War II (Jenkins 1922). McCormack and Carlile (1984) walked the 66-km (41-mi) stretch of Benton County shoreline of the Hanford Reach of the Columbia River in 1983 and identified 115 springs. They reported that the predominant areas of groundwater discharge at that time were in the vicinity of the 100-N Area, Old Hanford Townsite, and 300 Area. The predominance of the 100-N Area may no longer be valid because of 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 also varies with river stage. Dresel et al. (1995) reported that groundwater 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, groundwater discharge zones located above the water level of the river may cease to exist once the level of the groundwater 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 affects the contaminant concentration of the springs. Spring-water discharge immediately following a river stage decline generally consists

of river water or a river-groundwater mix. The percent contribution of groundwater to spring-water discharge is believed to increase over time following a drop in river stage.

Because of the effect of bank storage on groundwater discharge and contaminant concentration, it is difficult to estimate the volume of contaminated groundwater discharged to the Columbia River within the Hanford Reach. The estimated total groundwater 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 flow rate of the Columbia River, which illustrates the tremendous dilution potential offered by the river. Note that not all of the groundwater discharged to the river contains contaminants originating from Hanford Site operations. Riverbank spring studies conducted in 1983 (McCormack and Carlile 1984) and in 1988 (Dirkes 1990) noted that spring discharges had a localized effect on river contaminant concentrations. Both studies reported that the volume of groundwater entering the river at these locations was very small relative to the flow of the river and that the impact of groundwater discharges to the river was minimal.

Riverbank Springs Water Samples and Analytes of Interest

Routine monitoring of select riverbank springs was initiated in 1988 at the 100-N Area, Old Hanford Townsite, and 300 Area. Monitoring was expanded in 1993 to include the 100-B, 100-D, 100-H, and 100-K Areas. The 100-F Area spring was added in 1994. The locations of all riverbank springs sampled in 1996 were identified in Figure 4.2.1. Sample collection methods are described in DOE (1994a). Analytes of interest for samples from riverbank springs were selected based on findings of previous investigations, reviews of contaminant concentrations observed in nearby groundwater monitoring wells, and results of preliminary risk assessments. Sampling is conducted annually during low river flow, typically August through September.

For 1996, high Columbia River flows delayed sample collection until November. Samples were not collected at the 100-K Area because of low riverbank spring flows and specific conductances similar to the Columbia River (i.e., bank storage was apparent). The 100-H Area spring was under water during all sampling attempts in 1996. Samples from riverbank springs collected during 1996 were analyzed for gamma-emitting radionuclides, total alpha, total beta, and tritium. Samples from selected springs were analyzed for strontium-90, technetium-99, uranium-234, uranium-235, and uranium-238. Iodine-129 analysis was included for locations where iodine-129 was known to exist in the groundwater as a result of past Hanford operations. Samples 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 1996. The locations and extent of contaminated discharges were consistent with recent groundwater surveys. Tritium, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, metals (aluminum, arsenic, barium, beryllium, calcium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, sodium, strontium, and zinc), volatile organics (chloroform [100-D and 100-N Areas], tetrahydrofuran and trichloroethylene [100-B Area], and anions (bromide, chloride, fluoride, nitrate, and sulfate) were detected in spring water along the 100 Areas shoreline. Tritium, technetium-99, iodine-129, uranium-234, uranium-235, uranium-238, metals (aluminum, arsenic, barium, beryllium, calcium, cobalt, chromium, copper, iron, lead, magnesium, manganese, potassium, selenium, sodium, strontium, vanadium, and zinc), and anions (bromide, chloride, fluoride, nitrate, and sulfate) were detected in spring water along the portion of shoreline extending from the Old Hanford Townsite to below the 300 Area. The contaminant concentrations in spring water are typically lower than those found in near-shore groundwater wells because of bank storage effects.

The results of radiological and chemical analyses conducted on riverbank spring samples in 1996 are documented by Bisping (1997). Radiological results obtained in 1996 are summarized in Appendix A (Table A.7) and compared to those reported in 1991 through 1995. 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.

(a) Stuart Luttrell, Pacific Northwest National Laboratory, Richland, Washington, January 1995.

Radiological Results for Riverbank Springs Water Samples

All radiological contaminant concentrations measured in riverbank springs in 1996 were less than the DOE derived concentration guides (DOE Order 5400.5, see Appendix C, Table C.5). However, tritium concentrations in the 100-B Area and along the Old Hanford Townsite exceeded the Washington State ambient surface-water quality criteria levels (WAC 246-290, see Appendix C, Table C.1) and were close to these criteria levels at the 100-N Area. There are no ambient surface-water quality criteria levels directly applicable to uranium. However, total uranium concentrations (i.e., the sum of uranium-234, uranium-235, and uranium-238) exceeded the site-specific proposed EPA drinking water standard in the 300 Area (Appendix C, Table C.2) and were close to these levels for the 100-F Area. Total alpha concentrations were elevated at the 100-F and 300 Areas. Total beta concentrations were elevated at the 100-F Area. 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 1991 through 1996 is presented in Table 4.2.3.

Tritium concentrations varied widely with location. The highest concentrations were detected in the Old Hanford Townsite riverbank spring (41,000 ± 3,100 pCi/L), followed by the 100-B Area (24,000 ± 1,800 pCi/L), 100-N Area (17,000 ± 1,300 pCi/L), and 300 Area springs (3,400 ± 360 pCi/L). The Washington State ambient surface-water criteria for tritium is 20,000 pCi/L (WAC 246-290). Tritium concentrations in spring water from the 100-F Area (1,800 ± 240 pCi/L) and 100-D Area (1,000 ± 200 pCi/L) were also elevated compared to the 1996 average Columbia River concentrations at Priest Rapids Dam (31 pCi/L).

Samples from springs in the 100-B, 100-N, Old Hanford Townsite, and 300 Areas were analyzed for technetium-99 in 1996. Historically, the highest concentrations are normally found in the 100-H Area; however, this spring was under water during all 1996 sampling attempts and no sample was obtained. The highest technetium-99 concentration was found in water from the Old Hanford Townsite spring (38 ± 4.5 pCi/L).

Uranium was found in all riverbank spring samples in 1996, and the highest concentration was found for the 300 Area spring (34 ± 2.5 pCi/L) downgradient from the retired process trenches.

Iodine-129 was detected in the Old Hanford Townsite and 300 Area riverbank springs; the highest concentration was found for the Old Hanford Townsite spring (0.086 ± 0.010 pCi/L). This value was elevated compared to the 1996 average concentration measured at Priest Rapids Dam (0.000013 ± 0.0000058 pCi/L) but was well below the surface-water criteria of 1 pCi/L (see Appendix C, Table C.2).

Strontium-90 was analyzed for in samples from the 100-B, 100-D, 100-F, and 100-N Areas for 1996. The highest concentrations were found in the 100-D Area (1.8 ± 0.34 pCi/L). Beta activity paralleled that of strontium-90. Results are consistent with those found in previous years. Before 1993, however, the highest levels of strontium-90 and total beta were found in the 100-N Area (Table 4.2.4). These high concentrations were measured in samples collected from near-shore groundwater wells and not from riverbank springs.

The Near-Facility Environmental Monitoring Program has historically sampled the 100-N Area riverbank seepage from either the 199-N-8T monitoring well, which is located close to the river, or the 199-N-46 monitoring well (caisson), which is slightly inland from well 199-N-8T (see Figure 3.2.4). Well 199-N-8T was also sampled by Pacific Northwest National Laboratory in 1991. In 1992, the Pacific Northwest National Laboratory sample was collected from well 199-N-46. In 1993, 1994, and 1995, Pacific Northwest National Laboratory 100-N Area spring samples were collected from actual groundwater 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 Near-Facility Environmental Monitoring Program.

For 1993 to 1996, there was no visible shoreline seepage present directly adjacent to well 199-N-8T or well 199-N-46 during the sampling period. 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 (see Table 4.2.4). The concentrations of strontium-90 and total beta were much lower in 100-N Area riverbank spring water than in near-shore groundwater. Tritium concentrations in riverbank spring water were similar to

Table 4.2.3. Range of Radiological Data for Columbia Riverbank Springs, 1991 Through 1996

Location	No. of Samples	Concentration, pCi/L						
		Total Alpha	Total Beta	Iodine-129	Strontium-90	Technetium-99	Tritium	Total Uranium
100-B Spring	6	1.1 - 3.5	7.7 - 38	NS[a]	-0.11 - 0.0	8.4 - 25	11,000 - 24,000	1.6 - 3.2
100-K Spring[b]	2	0.61 - 1.6	1.8 - 3.6	NS	-0.031 - 0.1	-0.021 - 0.8	18,000 - 20,000	1.3 - 2.3
100-N Spring 8-13	7	0.043 - 8.9	1.5 - 24,000	NS	-0.01 - 1,100	0.84 - 2.4	4,900 - 31,000	0.24 - 2.5
100-D Spring	6	0.27 - 2.9	2.1 - 21	NS	0.069 - 9.4	-0.24 - 0.07	87 - 13,000	0.28 - 1.9
100-H Spring	4	3.3 - 4.6	39 - 69	NS	12 - 25	44 - 140	690 - 1,200	5.2 - 8.4
100-F Spring	3	2.6 - 41	1.7 - 65	NS	-0.03 - 0.09	-0.03 - 0.0	620 - 1,800	3.4 - 9.2
Hanford Spring 28-2	8	0.82 - 4.9[c]	4.8 - 95	0.044 - 0.22	-5.4 - 0.12	2 - 130	6,300 - 170,000	1.6 - 4.3[d]
300 Area Spring 42-2	8	13 - 110[e]	3.3 - 29	0.0019 - 0.0049	0.014 - 0.2	0.5 - 14[f]	1,300 - 12,000	24 - 130
Ambient Surface-Water Quality Criteria Level		15[g,h]	50[g]	1[i]	8[g]	900[i]	20,000[g]	20[i]

(a) No sample.
(b) Not sampled in 1996.
(c) 5 samples analyzed.
(d) 6 samples analyzed.
(e) 3 samples analyzed.
(f) 7 samples analyzed.
(g) WAC 246-290 and 40 CFR 141.
(h) Ambient surface-water quality criteria level for total alpha excludes uranium.
(i) Proposed standard (EPA 1996).

Table 4.2.4. Select Radionuclide Concentrations in 100-N Riverbank Spring Water, 1991 Through 1996

	Concentration, pCi/L[a]		
Year	^{3}H	Total beta	^{90}Sr
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
1996[d]	17,100 ± 1,340	4.48 ± 1.81	0.0527 ± 0.0479

(a) Concentrations are ±2 total propagated analytical uncertainty.
(b) Samples collected from well 199-N-8T (see Figure 3.2.5).
(c) Sample collected from well 199-N-46 (see Figure 3.2.5).
(d) Sample collected from shoreline spring downstream of well 199-N-8T.

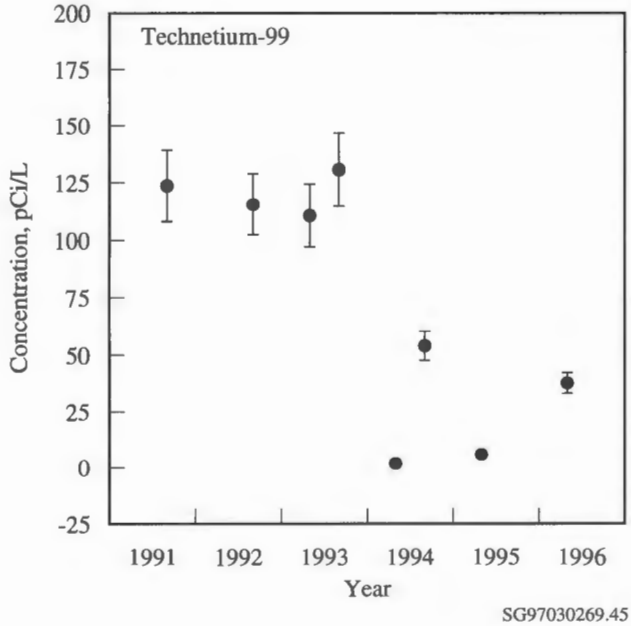
those found in well 199-N-46 (see Table 3.2.5). Tritium and strontium-90 were the only contaminants with measured concentrations greater than two times their total propagated analytical uncertainty at the 100-N Area spring in 1996. Tritium and strontium-90 concentrations were 86% and 0.66% of their ambient surface-water quality criteria levels, respectively (see Appendix C, Table C.3).

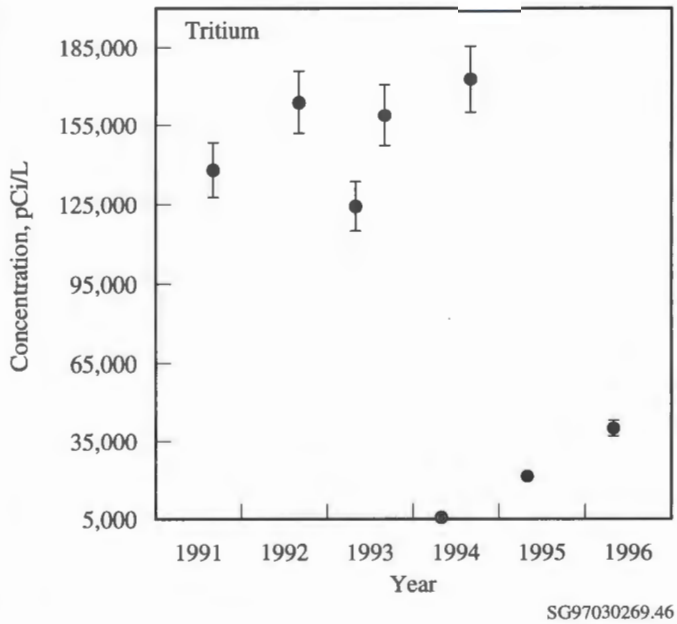
Concentrations of select radionuclides in riverbank spring water near the Old Hanford Townsite from 1991 through 1996 are provided in Figure 4.2.13. Total beta and technetium-99 concentrations in 1996 were similar to those observed in 1994 and 1995 and slightly lower than those observed prior to 1994. The 1996 tritium concentration was similar to 1994 and 1995 results but well below values reported from 1991 through 1993. Annual fluctuations in these tritium concentrations may reflect the influence of bank storage during the sampling period. Technetium-99 and total uranium concentrations were also detected in Old Hanford Townsite spring water in 1996 at 4.2% and 12% of their respective ambient surface-water quality criteria levels and the proposed EPA drinking water standard for uranium (see Appendix C, Table C.3). The iodine-129 concentration measured in the Old Hanford Townsite riverbank spring water for 1996 was 8.6% of the ambient surface-water quality standard (see Appendix C, Table C.3).

Figure 4.2.14 depicts the concentrations of select radionuclides in the 300 Area riverbank spring from 1991 through 1996. Results in 1996 were similar to those observed previously, except that tritium concentrations were lower in 1996. 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 groundwater in the springs and minimized the bank-storage effect. The elevated tritium concentrations measured in the 300 Area riverbank spring are indicators of the contaminated groundwater plume emanating from the 200 Areas (Dresel et al. 1995). Technetium-99 and iodine-129 are also contained in the 200 Areas contaminated groundwater plume. Tritium, technetium-99, and iodine-129 concentrations in 300 Area riverbank spring water in 1996 were 17%, 0.14%, and 0.22% of their respective ambient surface-water quality criteria levels (see Appendix C, Table C.3). The highest total uranium concentrations in riverbank spring water from 1991 through 1996 were found in the 300 Area riverbank springs, with the 1996 concentration 250% times higher than the proposed site-specific EPA drinking water standard (13.4 pCi/L; see Appendix C, Table C.2). 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 1991 through 1996 parallel that of uranium and are likely associated with its presence. Strontium-90 was not analyzed for in 300 Area riverbank spring water in 1996.

Nonradiological Results for Riverbank Springs Water Samples

The range of concentrations of selected chemical compounds measured in riverbank spring water in 1993 through 1996 were presented in Table 4.2.5. With the exceptions of 1996 sample results for 100-F and 300 Area springs, nonradiological results in 1996 were similar to those reported previously. Samples from the 100-F Area springs, and to a lesser extent the 300 Area springs, had elevated concentrations of most metals and anions. The 100-F Area riverbank spring-water sample was collected below a steep bluff in the 100-F Area slough, where the spring water percolates through a deep layer of fine sediments. High suspended particulate loading in the 100-F





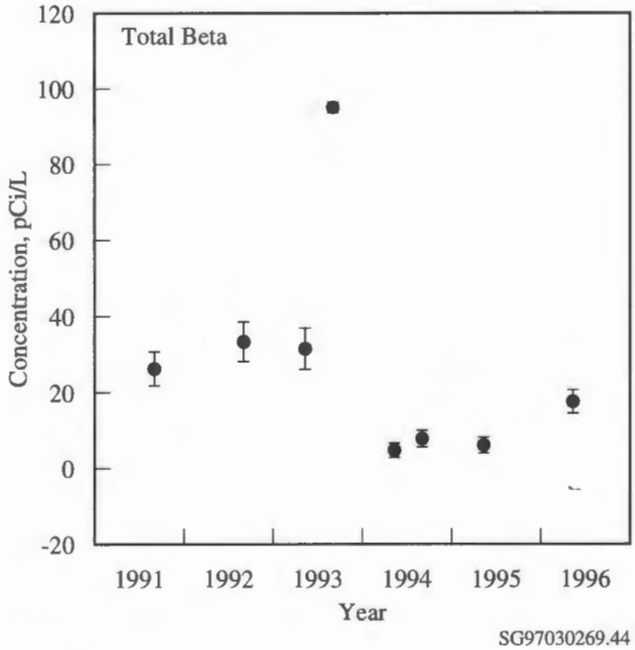


Figure 4.2.13. Concentrations (average ±2 total propagated analytical uncertainty) of Constituents of Interest in Riverbank Spring Near the Old Hanford Townsite, 1991 Through 1996. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

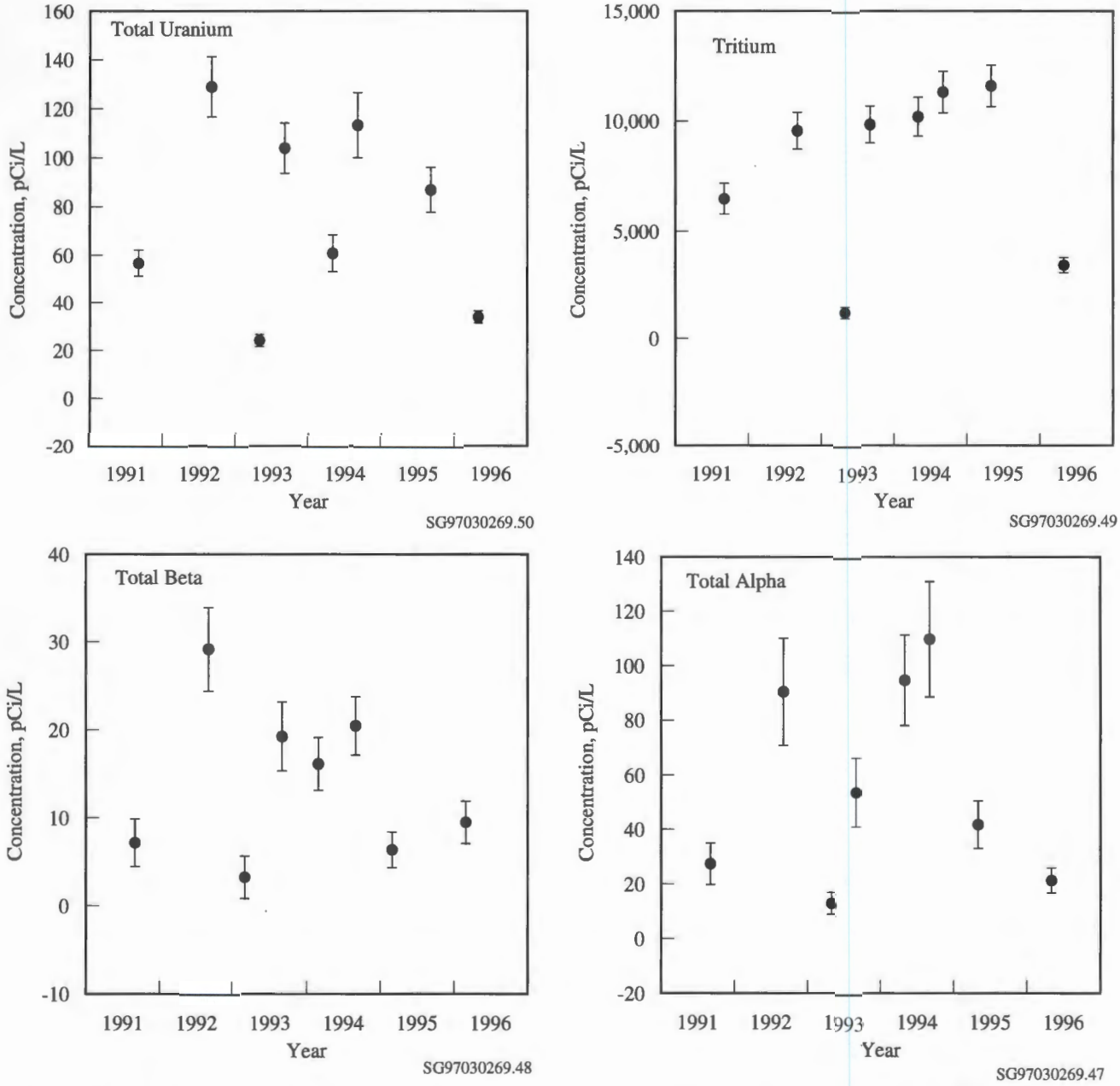


Figure 4.2.14. Concentrations (results ±2 total propagated analytical uncertainty) of Constituents of Interest in the 300 Area Riverbank Spring, 1991 Through 1996. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

Table 4.2.5. Concentration Ranges of Select Nonradiological Compounds in Columbia Riverbank Springs, 1993 Through 1996

	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	Old Hanford Townsite	300 Area
No. of Samples		4	1[a]	3	5	3[a]	3	4	3
Metals									
Aluminum		34 - 610	4,800	ND[b] - 9,400	66 - 180	27 - 88	41 - 20,000	67 - 940	140 - 3,100
Barium		55 - 64	120	32 - 140	34 - 80	27 - 48	41 - 270	43 - 54	95 - 120
Cadmium	[c]	ND - 0.72	2.0	ND	ND	ND	ND - 4.8	ND	ND
Chromium	[c]	21 - 25	66	ND - 45	ND - 400	18 - 55	6.0 - 99	ND - 2.5	ND - 6.4
Copper	[c]	ND	37	ND - 30	ND - 6.4	ND - 4.7	ND - 85	ND - 5.4	ND - 14
Iron		25 - 860	9,300	60 - 12,000	93 - 250	52 - 180	18 - 21,000	100 - 1,600	190 - 4,700
Manganese		1.9 - 22	330	3.2 - 680	6.6 - 27	7.6 - 11	3.1 - 470	7.1 - 82	5.8 - 220
Nickel	[c]	ND - 8.1	ND	ND - 25	ND - 26	ND	ND - 31	ND - 22	ND
Vanadium		ND - 11	33	6.6 - 42	ND - 5.3	ND - 3.6	ND - 59	ND - 19	ND - 4
Zinc	[c]	ND - 45	410	3.8 - 460	7.3 - 18	7 - 15	7.3 - 910	5.4 - 32	9.6 - 100
Anions									
Nitrate		7,600 - 11,000	15,000	3,800 - 15,000	1,000 - 46,000	27,000 - 47,000	20,000 - 33,000	5,000 - 40,000	6,600 - 23,000
Volatile Organics									
Chloroform	5.7	ND - 0.44 (5)[d]	ND - 0.79 (3)	0.75 - 3 (5)	ND - 4.1 (6)	3.7 - 14 (4)	ND	ND (5)	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	0.52 - 1.0 (4)	7.4 - 9.5 (3)	ND (4)	ND (5)	ND (4)	ND	ND (4)	ND

(a) No samples were collected in 1996.
(b) ND indicates result was less than the minimum detection level.
(c) Ambient surface-water quality criteria level is hardness-dependent (WAC 173-201A-040; see Appendix C, Table C.3).
(d) Number in parentheses indicates number of samples used to calculate the range, if different from above.

and 300 Areas spring-water samples may be the cause of the elevated nonradiological results because these samples are collected unfiltered. Chromium concentrations were highest in the 100-D and 100-F Areas springs. Nitrate concentrations are highest in the 100-D Area and Old Hanford Townsite springs. Concentrations of volatile organic compounds were similar to previous years, with most below detection levels. Chloroform (100-B and 100-D Areas), trichloroethylene (100-B Area), and tetrahydrofuran (100-B Area) were the only volatile organic compounds detected in 1996. Hanford groundwater monitoring results for 1996 indicate similar levels of nonradiological contaminant concentrations in shoreline areas (Dresel et al. 1995).

Washington State ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; see Appendix C, Table C.3). Criteria for 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 calculations provided the most limiting surface-water quality criteria. The riverbank spring-water sampling protocol used did not lend itself to a direct comparison of most metal concentrations in riverbank springs to ambient surface-water acute and chronic toxicity levels because of different time frames (DOE 1994a). 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 (WAC 173-201 A-040). Riverbank spring samples are grab samples. Metal concentrations measured in riverbank springs from the Hanford shoreline in 1996 were below Washington State ambient surface-water acute toxicity levels (WAC 173-201A-040), with the following exceptions. Concentrations of copper in spring water were above acute toxicity levels in the 100-F and 300 Areas. Copper was not detected in other samples; however, the detection limit was above the chronic toxicity level. Cadmium was above the acute toxicity standard in 100-F Area spring water and similar to the chronic toxicity standard in the 100-B Area spring water. Chromium concentrations in spring water exceeded the chronic toxicity standard for the 100-B, 100-D, and 100-F Areas. Zinc concentrations were above the chronic toxicity standard in the 100-F and 300 Areas. Selenium concentration was above the chronic toxicity standard at the 100-F Area. The minimum detectable concentrations of silver exceeded their chronic and acute toxicity standards in 1996.

Riverbank spring-water samples were analyzed for chromium(IV) (i.e., chromium ion in the 6+ oxidation state) using an electroanalytical technique. Chromium(IV) concentrations were 67 to 70 µg/L in 100-D Area spring water, 32 to 34 µg/L in 100-F Area spring water, 20 µg/L in 100-B Area spring water, 5.2 to 5.3 µg/L in 100-N Area spring water, 1.2 to 1.4 µg/L in the Old Hanford Townsite spring water, and 0.6 to 0.9 µg/L in 300 Area spring water. The Washington State acute toxicity values for chromium (see Appendix C, Table C.3) were exceeded in the 100-B, 100-D, and 100-F Areas spring-water samples. Chromium concentrations in all other riverbank spring-water samples were below the Washington State chronic toxicity values.

The concentrations of all volatile organic compounds measured in riverbank spring water collected from the Hanford shoreline in 1996 were below Washington State ambient surface-water quality criteria levels. Because of low riverbank spring flow or evidence of bank storage, no sample was collected for volatile organics at the 100-K Area spring, where in previous years the concentration of trichloroethylene exceeded the EPA standard to protect human health.

Onsite Pond Water

Three onsite ponds (see Figure 4.2.1), located near operational areas, were sampled periodically during 1996. 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 (Gephart et al. 1976). West Lake has not received direct effluent discharges from site facilities, but is influenced by the changing water table at the Hanford Site.

The site management and integration contractor is responsible for monitoring effluents discharged to the ponds and for operational surveillance of the ponds. Although

the ponds are inaccessible to the public and did not constitute a direct offsite environmental impact during 1996, they were accessible to migratory waterfowl, thus creating a potential biological pathway for the dispersion of contaminants (see Section 4.5, "Fish and Wildlife Surveillance"). Periodic sampling of the ponds also provided an independent check on effluent control and monitoring systems.

Collection of Pond Water Samples and Analytes of Interest

In 1996, grab samples were collected quarterly from B Pond, 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. West Lake samples were also analyzed for strontium-90, technetium-99, uranium-234, uranium-235, and uranium-238. Constituents were chosen for analysis based on their known presence in local groundwater and in effluents discharged to the ponds and their potential to contribute to the overall radiation dose delivered to the public.

Radiological Results for Pond Water Samples

Analytical results from pond samples collected during 1996 are given by Bisping (1997). With the exceptions of uranium-234 and uranium-238 in July and October samples from West Lake, radionuclide concentrations in onsite pond water were less than the DOE derived concentration guides (see Appendix C, Table C.5). Average annual total beta concentrations exceeded the ambient surface-water quality criteria level in West Lake. The average concentrations of all other radionuclides were below ambient surface-water quality criteria levels (see Appendix C, Table C.2).

Annual concentrations of selected radionuclides in B Pond for the years 1991 through 1996 are shown in Figure 4.2.15. B Pond comprises a series of four ponds: 216-B-3 (main pond) and the 216-B-3A, -3B, and -3C expansion ponds. Before October 1994, B Pond samples were collected from 216-B-3. However, 216-B-3 and -3A were decommissioned in 1994, and 216-B-3B was never active, though it did receive one accidental discharge. B Pond samples are currently collected from 216-B-3C. Contaminant concentrations found in samples collected from 216-B-3C in 1996 are similar to those found previously in 216-B-3. Average total alpha, total beta, tritium, strontium-90, and cesium-137 concentrations in 1996 were 17%, 18%, 0.42%, 4.1%, and 5.0% 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 the Fast Flux Test Facility Pond from 1991 through 1996. Median concentrations of both constituents have remained stable in recent years. However, the tritium concentration in the July 1995 sample was 16,400 pCi/L, which is much higher than that observed previously. 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 a portion of 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 July 1995 because the primary source of water to the pond is 400 Area sanitary water. Average total beta and tritium concentrations in Fast Flux Test Facility Pond water during 1996 were 23% and 25% of their respective ambient surface-water quality criteria levels. The concentrations of all other measured contaminants in this pond water were greater than two times their respective total propagated analytical uncertainties in less than 33% of samples collected.

The annual concentrations of selected radionuclides from 1991 through 1996 in West Lake are shown in Figure 4.2.17. Radionuclide concentrations in West Lake during 1996 were similar to those observed in the past. Total alpha and total beta concentrations in West Lake continued to be higher than levels found in the other onsite ponds. These elevated levels are believed to result from high concentrations of naturally occurring uranium (Speer et al. 1976, Poston et al. 1991). 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 the relatively large concentration of suspended sediment in the samples is causing the elevated results. Similar total uranium concentrations were reported by Poston et al. (1991) for West Lake samples that contained high concentrations of suspended sediment. Declines in groundwater levels beneath the 200 Areas have been recorded since the decommissioning

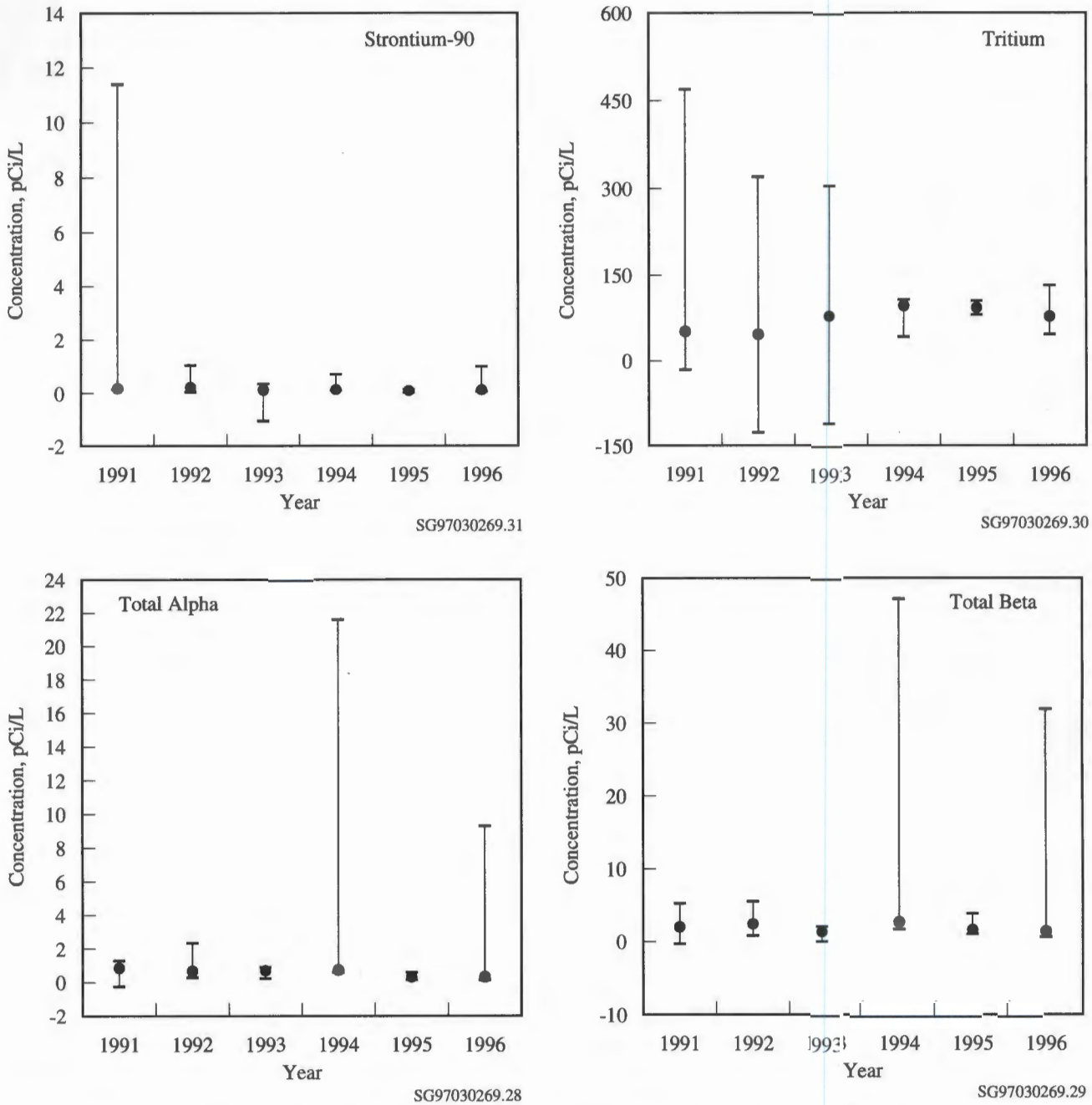
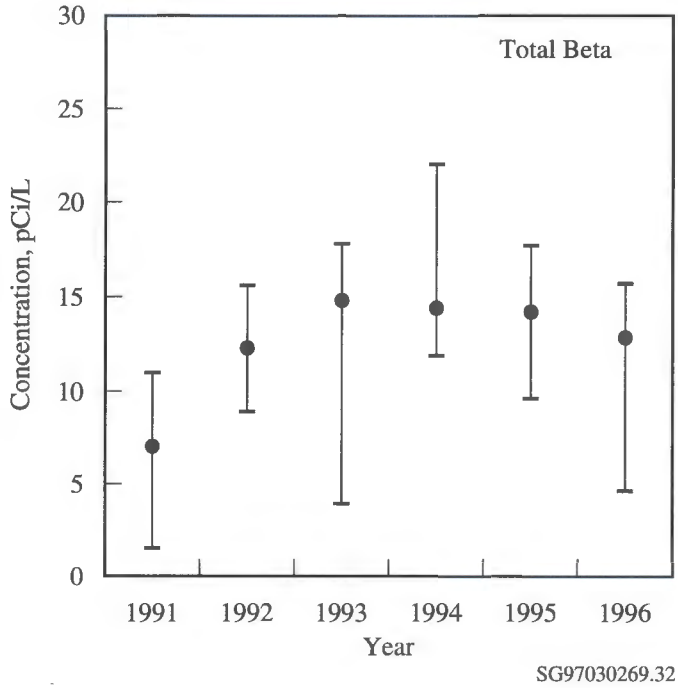


Figure 4.2.15. Minimum, Median, and Maximum Concentrations of Select Radionuclides in B Pond, 1991 Through 1996



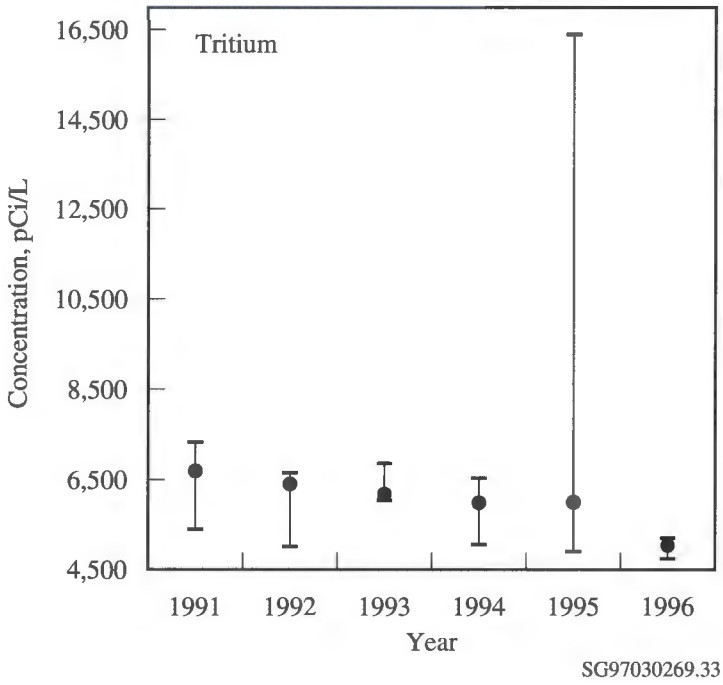


Figure 4.2.16. Minimum, Median, and Maximum Total Beta and Tritium Concentrations in the Fast Flux Test Facility Pond, 1991 Through 1996

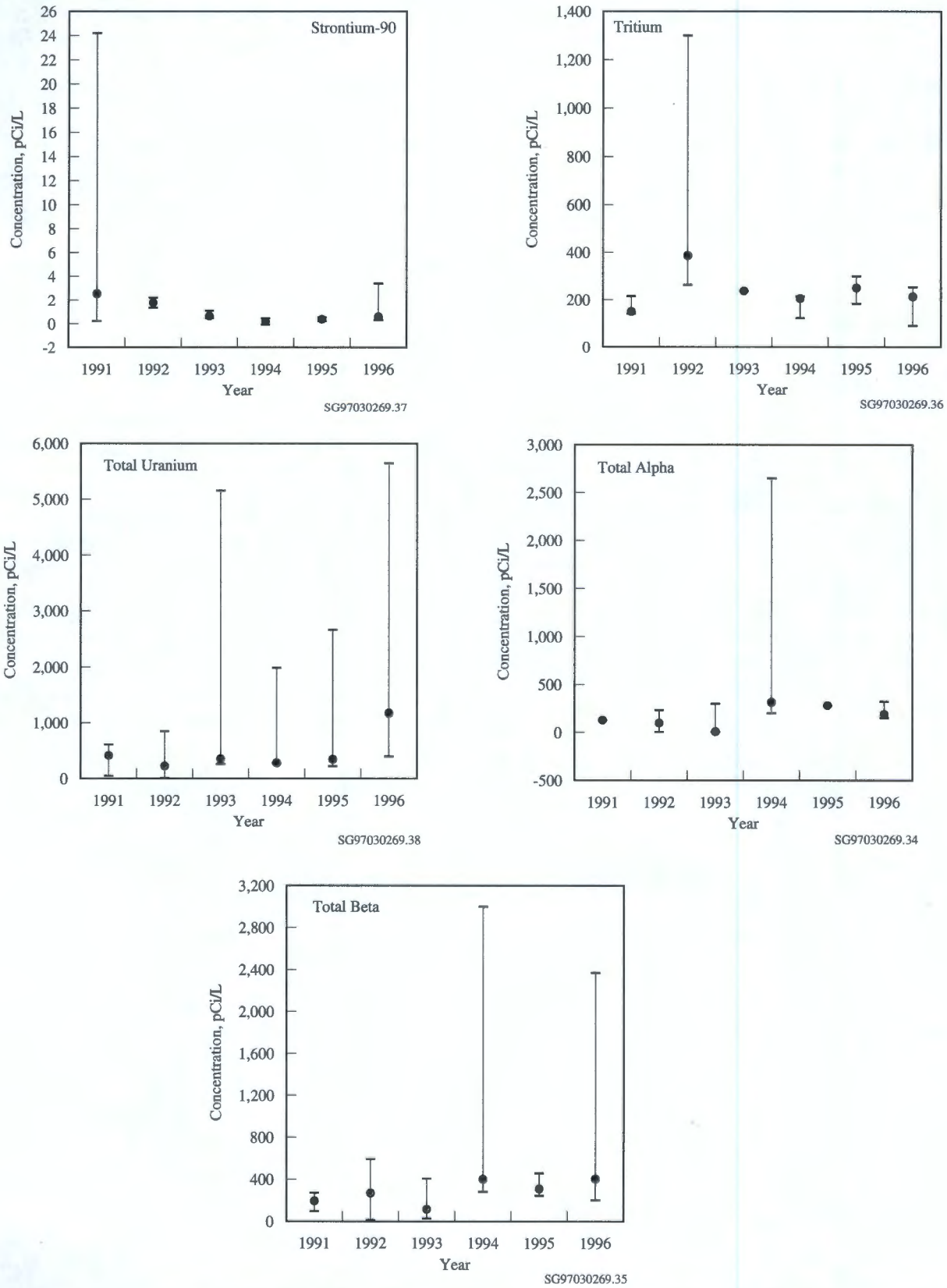


Figure 4.2.17. Minimum, Median, and Maximum Concentrations of Select Radionuclides in West Lake, 1991 Through 1996

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. Average concentrations of tritium, strontium-90, and technetium-99 in West Lake in 1996 were 0.96%, 18%, and 6.2%, respectively, of ambient surface-water quality criteria levels and were reflective of local groundwater concentrations. The concentrations of all other measured radionuclides were rarely higher than two times their associated total propagated analytical uncertainties.

Offsite Water

During 1996, Pacific Northwest National Laboratory staff collected and provided to the Washington State Department of Health water samples from five water supplies that utilized groundwater directly east of and across the Columbia River from the Hanford Site. Pacific Northwest National Laboratory did not analyze these samples for contaminants. Water samples were also collected from an irrigation canal downstream from Hanford that receives water pumped from the Columbia River, and these samples were analyzed by Pacific Northwest National Laboratory. 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 (Section 5.0, "Potential Radiation Doses from 1996 Hanford Operations").

Collection, Analysis, and Radiological Results for Riverview Irrigation Canal Water

Water in the Riverview irrigation canal was sampled three times in 1996 during the irrigation season. Unfiltered samples of the canal water were analyzed for gamma emitters, strontium-90, total alpha, total beta, tritium, uranium-234, uranium-235, and uranium-238. Results are presented by Bisping (1997). In 1996, radionuclide concentrations measured in Riverview irrigation canal water were found to be at the same levels observed in the Columbia River. All radionuclide concentrations were below the 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 1996 ranged from 0.071 ± 0.039 to 0.13 ± 0.047 pCi/L and were similar to those reported for the Columbia River at Priest Rapids Dam and Richland Pumphouse (see "Columbia River Water" subsection).

4.3 Hanford Site Drinking Water Surveillance

R. W. Hanf

The primary purpose of the Hanford Site drinking water surveillance program is to verify the quality of the site's drinking water. This is achieved by routinely collecting and analyzing drinking water samples and comparing the data with established drinking water standards and guidelines (WAC 246-290 and 40 CFR 141; see Appendix C, Tables C.2 and C.5). In 1996, radiological surveillance of drinking water on the site was conducted for DynCorp Tri-Cities Services, Inc. primarily by Pacific Northwest National Laboratory. However, Westinghouse Hanford Company (from January through September 1996) and DE&S Hanford, Inc. (from October through December 1996) each collected radiological data for one system as noted below. Chemical and microbiological surveillance was conducted by DynCorp Tri-Cities Services, Inc. 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 in an annual Hanford sanitary water quality surveillance report (Thurman 1994, 1995). DynCorp Tri-Cities Services, Inc. is not producing a 1996 drinking water surveillance report due in part to continuing reductions in federal funding. Therefore, the 1996 radiological data for Hanford Site drinking water are summarized here, and the individual results are reported in Bisping (1997). Nonradiological data will not be published at this time. WAC 246-290 requires that all drinking water analytical results be reported to the state of Washington. Nonradiological results have been reported to the state by DynCorp Tri-Cities Services, Inc. throughout the year; radiological results are provided to the state and to site contractors in this report and in Bisping (1997).

Radiological Monitoring of Hanford Site Drinking Water Systems

Drinking water is supplied to the site through contractor-operated water systems. Nine of these systems use water from the Columbia River and consist of pumping stations and/or treatment and distribution facilities. Three systems use groundwater from beneath the site (Table 4.3.1). Most of the systems are operated by DynCorp Tri-Cities Services, Inc. However, DE&S Hanford, Inc., Bechtel Hanford, Inc., and B&W Hanford Company also each operate one system, though water for the Bechtel system is supplied by a pumping station operated by DynCorp. The city of Richland provides drinking water to the 700, 1100, and Richland North Areas of the site and serves as a backup supplier for the 300 Area. This water, however, is not monitored through the site drinking water surveillance program and is not discussed here. 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 can be found in Appendix A (Table A.2).

In 1996, radionuclide concentrations were monitored at the locations shown in Figure 4.3.1, which represent the principal sources of water for the site drinking water systems. The 100-B Area 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 Areas Fire Station), with the 100-D Area pumphouse available as an emergency backup. Water for the 100-K Area was supplied by the 100-K Area pumphouse. The Yakima Barricade, Patrol Training Academy, and the 400 Area (Fast Flux Test Facility) obtained water from groundwater wells.

The 400 Area continued to use well 499-S1-8J (P-16) for drinking water, with well 499-S0-7 (P-15) serving as the emergency supply for most of the year. Well 499-S0-7 was used only once when well 499-S1-8J was shut down for maintenance from August 1 to 6, 1996.

A review of tritium data for all three 400 Area drinking water wells resulted in a reclassification of wells 499-S0-7 and 499-S0-8 late in 1996. Well 499-S0-7 was designated as the dire emergency well, and well 499-S0-8 became the emergency well. Tritium levels in well 499-S0-8

Table 4.3.1. Hanford Site Drinking Water Systems

System Name/ Number	Source of Supply	Notes
100-D/001761	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 183-D. Operated by DynCorp Tri-Cities Services, Inc.
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 Pumphouse	Filtered and chlorinated at 183-K. Operated by DE&S Hanford, Inc.
100-N/418532	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 183-N. Operated by Bechtel Hanford, Inc.
200-E/41866V	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 283-E. Operated by DynCorp Tri-Cities Services, Inc.
200-W/001004	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 283-W. Operated by DynCorp Tri-Cities Services, Inc.
251 Bldg/001782 (Electrical Switching)	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 251 Building. Operated by DynCorp Tri-Cities Services, Inc.
609 Bldg/001806 (100 Areas Fire Station)	Columbia River via 181-B or D Raw Water Export	Filtered and chlorinated at 609 Building. Operated by DynCorp Tri-Cities Services, Inc.
Yakima Barricade/ 001848	Well 699-49-100C	No treatment provided. Operated by DynCorp Tri-Cities Services, Inc.
Patrol Training Academy/00183Q	Well 699-S28-E0	Chlorination only. Operated by DynCorp Tri-Cities Services, Inc.
400 Area/419470	Wells 499-S1-8J, 499-S0-7, and 499-S0-8	Supplied from 499-S1-8J (P-16); 499-S0-8 (P-14) is the emergency supply, 499-S0-7 (P-15) is the dire emergency supply. Chlorination only. Operated by B&W Hanford Company.
300 Area/418408	Columbia River via 312 Pumphouse or City of Richland	Filtered and chlorinated at 315 Building. Operated by DynCorp Tri-Cities Services, Inc.

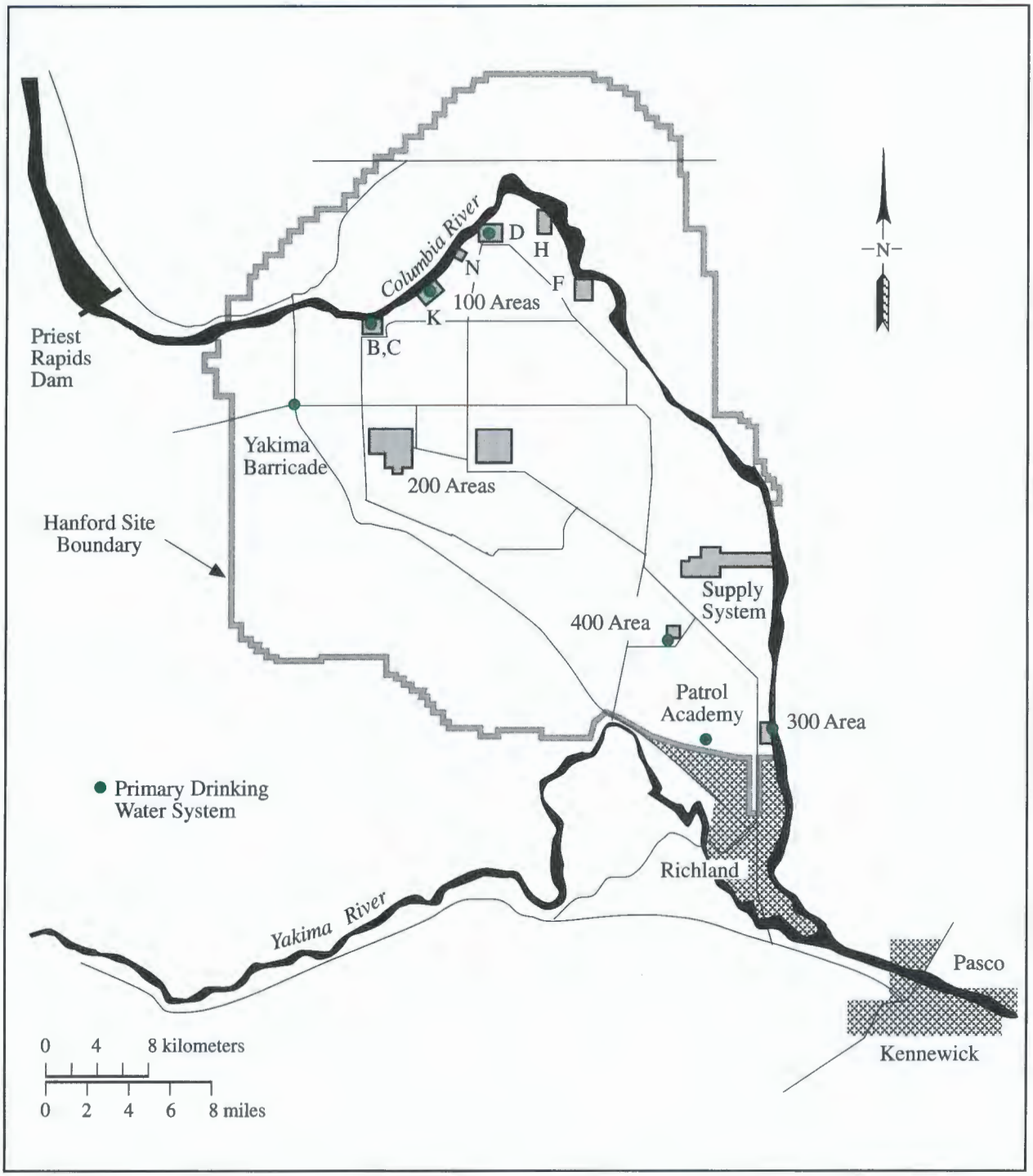


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Figure 4.3.1. Hanford Site Primary Drinking Water Systems

decreased dramatically in 1992 (Figure 4.3.2) and are currently lower than levels in well 499-S0-7 (Table 4.3.2). Well 499-S0-8 was used once when the primary supply well (499-S1-8J) was shut down for repair between December 30, 1996 and January 6, 1997. All three wells remain operational to maintain fire suppression capabilities within the 400 Area.

Radiological monitoring of well water from the Fitzner/Eberhardt Arid Lands Ecology Reserve was discontinued in 1996. Bottled drinking water has been used at this location in recent years because of elevated levels of naturally occurring fluoride in the well water.

Collection of Drinking Water Samples and Analytes of Interest

Samples for radiological analysis were collected according to a schedule established at the beginning of the calendar year (Bisping 1996). 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 annually for iodine-129 analysis and quarterly for other analyses. Samples from most locations were grab samples of treated water collected at the tap. The 300 Area samples were cumulative raw river-water samples that were collected at the water supply pumphouse before any water treatment. Tap-water samples collected from the 100-B Area in May and the 400 Area in May and October 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's environmental radiation program annual report for 1996.

All 1996 drinking water samples were analyzed for total alpha, total beta, tritium or low-level tritium, and strontium-90. Additionally, samples from the 300 Area were analyzed for uranium, and concentrations of plutonium and americium were monitored in water from the 100-K Area. The 100-K Area samples were also analyzed by gamma spectrometry. One sample from the 400 Area was analyzed for iodine-129. Alpha and beta measurements provided a general indication of radioactive contamination. Gamma spectrometry was used to detect numerous specific radionuclides (see Appendix E). Sensitive radiochemical analyses were used to determine the concentrations of specific analytes.

Radiological Results for Hanford Site Drinking Water

The Hanford Site was in compliance with Washington State and EPA annual average radiological drinking water standards in 1996, and results were similar to those observed in recent years (Thurman 1995, Dirkes and Hanf 1996). Results for radiological monitoring of Hanford Site drinking water during 1996 are summarized in Table 4.3.3. Concentrations of total alpha, total beta, tritium, strontium-90, and uranium 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 Washington State and 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/yr. 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 concentration for each of total beta, total alpha, tritium, and strontium-90 are less than 50, 15, 20,000, and 8 pCi/L, respectively (see Appendix C, Table C.2).

Iodine-129 was measured in one sample of 400 Area drinking water collected in July. The result (0.01095 ± 0.00092 pCi/L) was well below the 1.0-pCi/L drinking water standards that would result in an annual dose equivalent of 4 millirem. Concentrations of plutonium, americium, uranium, and radionuclides measured by gamma spectrometry (Bisping 1997) were all below drinking water standards.

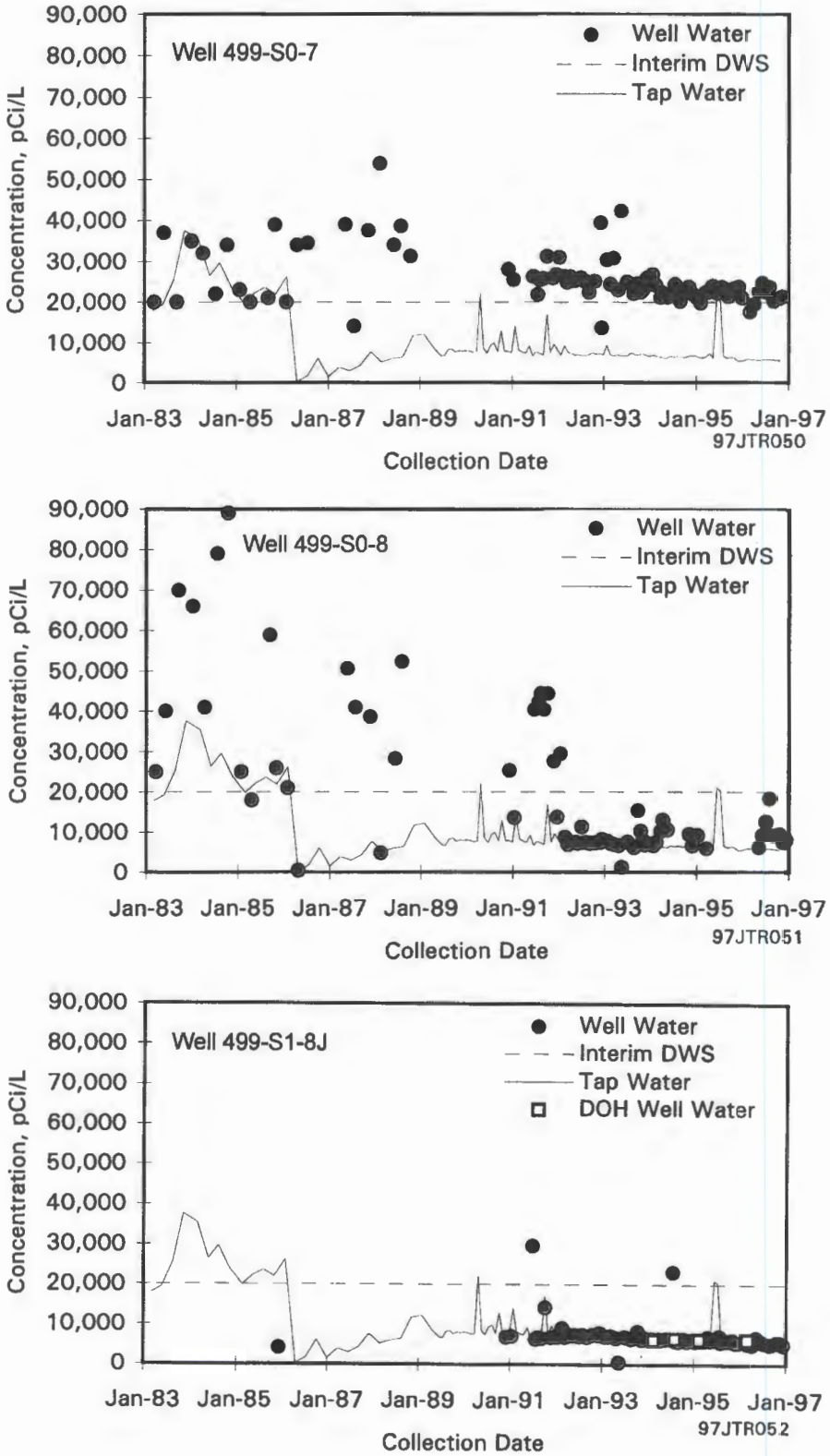

Figure 4.3.2. Comparison of Tritium Trends in 400 Area Drinking Water System (DOH = Washington State Department of Health, DWS = Drinking Water Standard

Table 4.3.2. Tritium Concentrations in 400 Area Drinking Water Wells, 1996

Well Number	Sampling Date, 1996	Concentration, pCi/L
499-S1-8J (P-16)	January 4	5,543.3
	March 5	5,231.0
	April 10	4,962.5
	May 14	6,824.7
	June 12	6,003.4
	July 8	5,557.3
	August 26	5,067.9
	September 6	5,130.2
499-S0-7 (P-15)	January 14	20,997
	March 5	17,561
	April 10	19,535
	May 14	22,616
	June 12	24,844
	July 8	22,485
	August 5	23,858
	September 6	20,316
499-S0-8 (P-14)	May 14	6,060.4
	June 12	9,177.5
	July 8	12,502
	August 5	18,447
	September 6	9,100.9

Table 4.3.3. Radiological Contaminants in Hanford Drinking Water Systems, 1996 Annual Average Concentrations[a]

System	No. of Samples	Total Alpha, pCi/L	Total Beta, pCi/L	Tritium, pCi/L	Strontium-90, pCi/L	U-Total, pCi/L
100-B Area	4	0.12 ± 0.21	1.23 ± 1.11	86.13 ± 35.52[b]	0.10 ± 0.02	NM[c]
100-D Area	4	0.20 ± 0.15	0.97 ± 0.90	82.07 ± 53.77	0.08 ± 0.03	NM
100-K Area[d]	4	0.16 ± 0.13[e]	0.59 ± 0.96	57.20 ± 21.24[e]	0.002 ± 0.1	NM
300 Area	4	0.68 ± 0.48	1.99 ± 1.36	133.78 ± 76.58[b]	0.13 ± 0.08	0.77 ± 0.31
Yakima Barricade	4	1.80 ± 1.23	5.78 ± 1.12	-4.22 ± 34.09	0.02 ± 0.03	NM
400 Area	4	-0.005 ± 0.19	5.68 ± 1.82	5,692 ± 188	0.20 ± 0.38	NM
Patrol Academy	4	0.80 ± 0.44	3.76 ± 0.58	-0.75 ± 64.00	0.001 ± 0.009	NM
Standards[f]		15	50	20,000	8	

(a) Average value ±2 standard error of the calculated mean.
(b) Low-level tritium.
(c) NM = Not measured.
(d) Reported by DE&S Hanford, Inc.
(e) Computed using a questionable result obtained for first quarter sample.
(f) See Appendix C (Table C.2).

4.4 Food and Farm Product Surveillance

T. M. Poston

Foodstuffs, including milk, vegetables, fruits, and wine, were collected in 1996 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 at the site perimeter and at locations somewhat distant from the site to provide information on background radioactivity.

The food and farm product sampling design addresses the potential influence of Hanford Site releases in two ways: 1) by comparing results from several downwind locations to those from generally upwind or distant locations and 2) by comparing results from locations irrigated with Columbia River water withdrawn downstream from Hanford to results from locations irrigated with water from other sources. In 1996, the food and farm product sampling schedule was modified by establishing a 2- or 3-year rotation for certain farm products. Additionally, analyses for specific radionuclides that historically have not been detected in a food or farm product were discontinued. These changes were adopted because of the site's mission emphasis on cleanup. Specific details of the revised food and farm product sampling design, including sampling locations and radionuclides analyzed, are reported in DOE (1994a) and Bisping (1996) 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. Additionally, milk was analyzed for iodine-129, and wine was analyzed for tritium. Radionuclide concentrations in most samples were less than the limits of detection. Results for fruits and vegetables are reported in picocuries per gram wet weight. Results for tritium in wine are reported in picocuries per liter of liquid distilled from wine. Most tritium is found as water, and very little tritium is organically bound to other constituents present in food products.

Tritium and iodine-129 are released to the atmosphere from site facilities and to the Columbia River via shoreline springs. Strontium-90 is released to the Columbia River through shoreline springs. Cesium-137 is present in atmospheric fallout from weapons testing and is found in site radiological waste.

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 uncertainty (2-sigma). The value from a group of samples is used as an estimate of the lower level of detection for that analyte and particular food product. The total propagated analytical uncertainty 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 within the range of the uncertainty 95% of the time. Counting and propagated errors not given in this report may be found in Bisping (1997).

Collection of Milk Samples and Analytes of Interest

Composite samples of raw, whole milk were collected from three East Wahluke Area and three Sagemoor Area dairy farms near the site perimeter in the prevailingly downwind direction (see Figure 4.4.1). Milk samples were also collected from a Sunnyside Area dairy to indicate background radionuclide concentrations at a generally upwind location.

Milk was analyzed for strontium-90, iodine-129, 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. Gamma and strontium-90 analyses were conducted quarterly, and iodine-129 analyses were conducted on two semiannual composite samples.

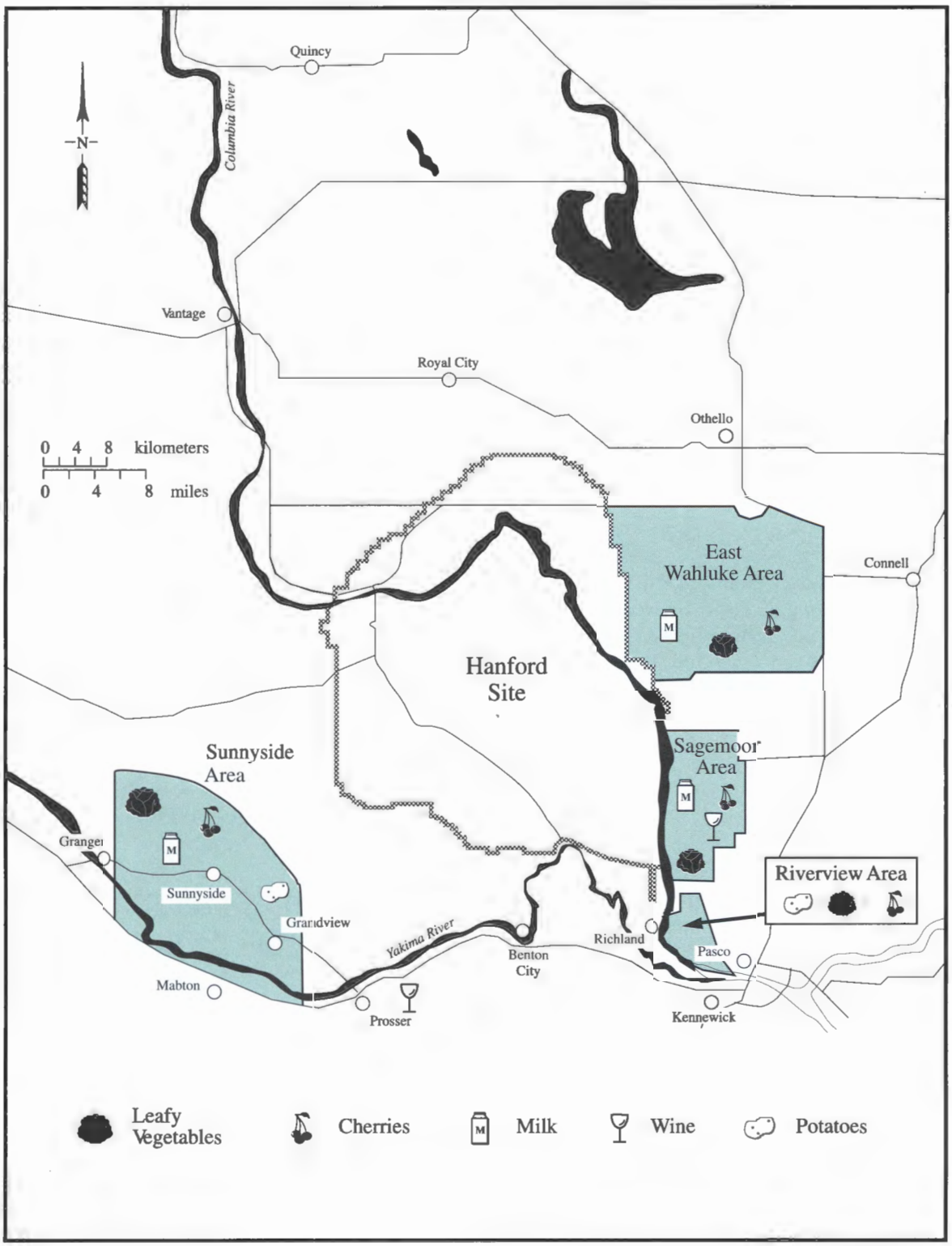

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Figure 4.4.1. Food and Farm Product Sampling Locations, 1996

Table 4.4.1. Numbers of Locations, Sampling Frequencies, and Analyses Performed for Routinely Sampled Food and Farm Products, 1996[a]

Product	Number of Locations		Sampling Frequency[b]	Number of Locations Analyzed			
	Upwind	Downwind		^{3}H	Gamma	^{90}Sr	^{129}I
Milk	1	2	Q or SA	0	3	3	3
Vegetables	1	3	A	0	4	4	0
Fruit	1	3	A	0	4	4	0
Wine	2	2	A	4	4	0	0

(a) Products may include multiple varieties for each category. Not all analytes were assayed at all locations or for each variety of product.
(b) Q = quarterly, SA = semiannually, A = annually.

One factor influencing concentrations of radionuclides in milk is the source of food for the dairy cows. Dairy cows may be fed food grown outside of their sampling locations. Generally, levels of fallout radioactivity in environmental media correlate positively with the amount of precipitation that an area receives. The agricultural areas around the site are arid and historically have received less weapons-testing atmospheric fallout than some distant locations. Consequently, background levels of radioactivity in hay or alfalfa grown in some distant locations and purchased by local dairies may contribute more radioactivity to milk than background levels in feed grown locally. Alternatively, it is possible that alfalfa fed to dairy cows in Sunnyside could have been grown in Sagemoor. Fallout radionuclides in feed may be a significant source of radioactivity in animal products; however, observed levels in milk are usually near levels considered to be background.

Radiological Results for Milk Samples

Strontium-90 was measured in 4 of 12 (33%) milk samples analyzed in 1996, with no apparent differences between upwind and downwind locations. Concentrations of strontium-90 remain near the nominal detection limit (0.7 pCi/L) and are relatively constant over the past 6 years (Figure 4.4.2). The maximum observed concentration of strontium-90 in milk in 1996 was 1.3 ± 0.62 pCi/L. While there is no strontium-90 standard for milk, the drinking water standard (based on a 2-L/d consumption) is 8 pCi/L (40 CFR 141). The maximum milk consumption rate for estimating dose is approximately 0.75 L/d (see Appendix D, Table D.2).

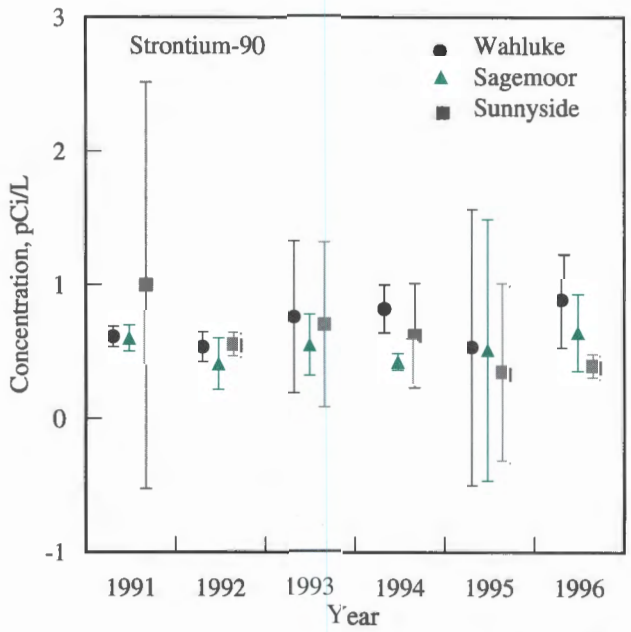

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Figure 4.4.2. Mean (±2 standard error of the mean) Strontium-90 Concentrations in Milk, 1991 Through 1996. As a result of figure scale, some uncertainties are concealed by point symbol.

Iodine-129 was identified by high-resolution mass spectrometry in six 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 and 1996. Iodine-129 contributes less than 1% of the dose to the maximally exposed individual through the consumption of dairy products (Section 5.0, "Potential Radiation Doses from 1996 Hanford Operations"). The maximum observed concentration of iodine-129 in milk in 1996 was 0.0005 ± 0.0001 pCi/L in a sample collected from the Sagemoor Area. While there is no iodine-129 standard for milk, the federal drinking water standard is 1 pCi/L (EPA 1976).

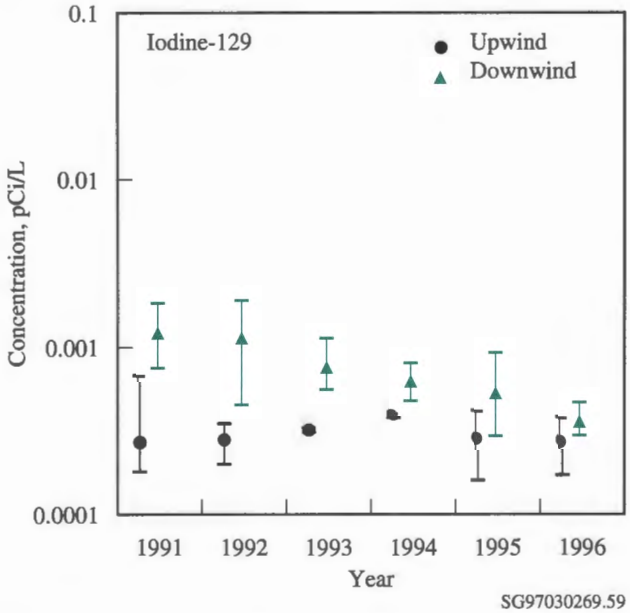

Figure 4.4.3. Mean, Maximum, and Minimum Iodine-129 Concentrations in Milk, 1991 Through 1996. As a result of figure scale, some uncertainties are concealed by the point symbol.

None of the 12 milk samples collected and analyzed in 1996 contained detectable concentrations of cesium-137 (<2.6 pCi/L). While there is no cesium-137 standard for milk, the drinking water standard is 200 pCi/L (EPA 1976). Additionally, no other manmade gamma emitters were detectable in milk (Bisping 1997).

Collection of Vegetable Samples and Analytes of Interest

Samples of leafy vegetables (i.e., cabbage, broccoli, beet tops, or turnip greens) and potatoes were obtained during the summer from gardens and farms located within selected sampling areas (see Figure 4.4.1). Samples were collected from the Riverview Area to assess potential contamination to crops from irrigation water from the Columbia River. Irrigation water for the Riverview Area 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, exposure to potentially contaminated irrigation water withdrawn from the Columbia River downstream of the Hanford Site. All vegetable samples were analyzed for gamma-emitting radionuclides and strontium-90.

Radiological Results for Vegetable Samples

Many of the analytical results for vegetables were below nominal detection limits for specific radionuclides. Strontium-90 was detected in leafy vegetable samples collected from the Riverview and East Wahluke Areas in 1996 (Bisping 1997) but was below detection (0.005 pCi/g) in samples from the Sunnyside and Sagemoor Areas. Measurements of gamma emitters in vegetable samples were all less than their respective detection limits and are consistent with results in recent years.

Collection of Fruit Samples and Analytes of Interest

Cherries were collected during harvest from the areas shown in Figure 4.4.1. The edible portions were analyzed for gamma emitters and strontium-90.

Radiological Results for Fruit Samples

Measurable levels of manmade radioactivity were not detected in cherries in 1996. These results are consistent with measurements in grapes, apples, and melons over recent years (Bisping and Woodruff 1991, 1992, 1993,

Bisping 1994, 1995). Nominal levels of detection were 0.02 pCi/g wet weight for cesium-137 and 0.004 pCi/g wet weight for strontium-90.

Collection of Wine Samples and Analytes of Interest

Locally produced red and white wines (1996 vintage grapes) were analyzed for tritium and gamma-emitting radionuclides. The wines were made from grapes grown at individual vineyards downwind of the site and at an upwind location in the lower Yakima Valley. Two samples each of red and white wines were obtained and analyzed from each upwind and downwind location.

Radiological Results for Wine Samples

Gamma spectroscopy of wine samples did not indicate the presence of cesium-137 in any of the samples. The nominal detection limit for cesium-137 in wine is approximately 3 pCi/L.

Prior to 1996, tritium concentrations in wine samples were determined by distilling the wine and analyzing the distillate with a liquid scintillation counter. The distillation procedure resulted in some samples containing alcohol, and alcohol can affect the accuracy of the scintillation counter results. In 1996, an electrolytic enrichment method was employed to improve the accuracy of the analysis. The electrolytic method also lowered the tritium detection limit from 300 to 10 pCi/L. Consequently, with the exception of 1993, tritium concentrations reported for 1996 wine samples are significantly lower than tritium concentrations reported in wine samples collected in previous years (Dirkes and Hanf 1995, 1996). In 1993, several wine samples were shipped to Lawrence Livermore National Laboratory for analysis by a special mass spectrometry technique that measured the amount of helium in the wine. Tritium decays to helium, and the amount of helium (at equilibrium) can be used to accurately assay the amount of tritium in the sample. The detection limit for this technique was similar to the detection limit for the electrolytic distillation method. Results for these samples were also lower than results previously obtained using the old distillation method but were similar to those obtained in 1996 using the electrolytic distillation method (Figure 4.4.4). Therefore, comparisons between 1996 data and data from all other years except 1993 are not practicable.

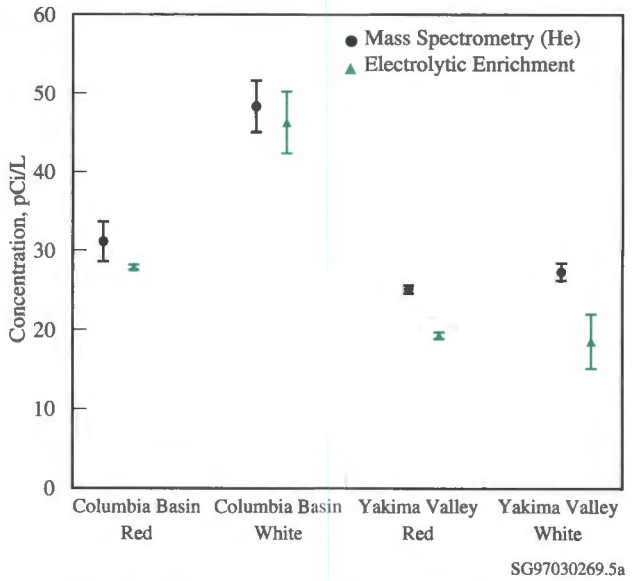

Figure 4.4.4. Comparison of Tritium Concentrations in Wine Samples Collected in 1993 and 1996. As a result of figure scale, some uncertainties are concealed by the point symbol.

Concentrations in 1996 wine samples ranged from 15.1 to 50.2 pCi/L of distillate. Differences in locations may reflect differences in irrigation water. Deep groundwater may not contain tritium while surface-water concentrations may range from 30 to 80 pCi/L (see Section 4.2). While there is no tritium standard for wine, the drinking water standard (40 CFR 141) is 20,000 pCi/L. This standard is based on the daily consumption of 2 L of water and the daily consumption of wine is much less than 2 L.

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4.5 Fish and Wildlife Surveillance

T. M. Poston

Contaminants in fish and wildlife species that inhabit the Columbia River and Hanford Site are monitored for several reasons. Wildlife have access to areas of the site containing radioactive or chemical 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 contaminants in wildlife may indicate that wildlife are entering contaminated areas (e.g., burrowing in waste burial grounds) or that materials are moving out of contaminated areas (e.g., through blowing dust or food-chain transport). Consequently, samples are collected at various locations annually, generally during the hunting or fishing seasons (Figure 4.5.1). More detailed rationale for the selection of specific species sampled in 1996 can be found in DOE (1994a).

Results from background samples are compared to results from Hanford samples to identify differences. Routine background sampling is conducted approximately 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 1996, background contaminant concentrations were measured in bass and carp from the Priest Rapids reservoir near Mattawa, Washington. The Washington State Department of Health provided background deer samples collected near Vail, Washington (near Centralia approximately 240 km [150 mi] west of Hanford).

As a result of changing site operations, fish and wildlife sampling frequencies were modified significantly in 1995. Species that had been collected annually were placed on a rotating schedule so that surveillance of all key species would be accomplished over a 3-year period. Factors supporting these changes included the elimination of many radiological source terms onsite and a decrease in environmental concentrations of radionuclides of interest. Additionally, several radionuclides that were monitored in the past had not been detected in recent wildlife samples because they were no longer present in the environment in sufficient amounts to accumulate in wildlife or they did not accumulate in fish or wildlife tissues of interest.

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 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. Strontium-90 has a long biological half-life in hard tissue. Hard-tissue concentrations may profile an organism's lifetime exposure 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 (<2%) (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. Having a relatively short biological half-life, cesium-137 is an indicator of more recent exposure to radioactive materials, and is also a major constituent of historical fallout.

Fish and wildlife samples were analyzed by gamma spectrometry to detect a number of gamma emitters (see Appendix E). However, gamma spectrometry results for most radionuclides are not discussed here because concentrations were too low to measure or measured concentrations were considered artifacts of low background counts. Low background counts occur at random intervals during sample counting and can produce occasional spurious false-positive results.

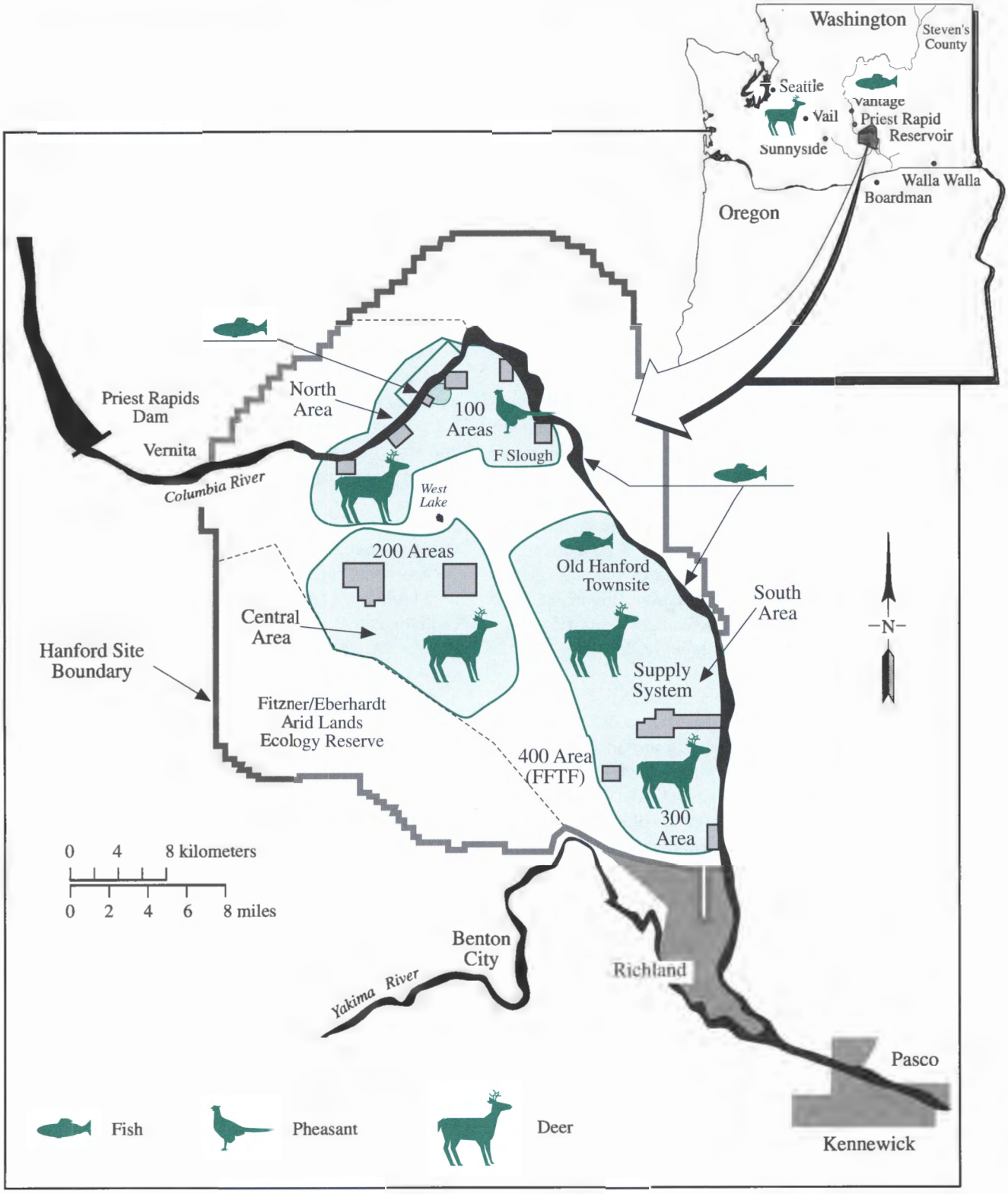

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Figure 4.5.1. Fish and Wildlife Sampling Locations, 1996

Table 4.5.1. Locations, Species, and Contaminants Sampled for Fish and Wildlife, 1996

Medium	Number of Species	Offsite Locations	Onsite Locations	Contaminants Sampled/Number of Locations	
				Gamma	^{90}Sr
Fish (Bass, Carp)	2	1[a]	2	3	3
Pheasant	1	0	1	1	1
Mule deer	1	1[b]	3	4	4

(a) Background samples collected from Priest Rapids reservoir.
(b) Background sample (white-tailed deer) collected by Washington State Department of Health from Vail, Washington.

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 (1997).

Great blue heron and deer were also sampled in support of graduate student studies in 1996. Liver samples were analyzed by inductively coupled plasma-mass spectrometry for several trace metals. Heron and deer sampled for metals analysis were collected from the riparian areas along the Columbia River on the site.

Collection of Fish Samples and Analytes of Interest

In 1996, carp were collected from the 100-N to 100-D Areas of the Columbia River. Five bass were collected from the 100-F Slough and one bass was collected from the Hanford Slough. Attempts to electrofish for carp near the 300 Area were unsuccessful. Background samples of carp were collected in 1990 from the Columbia River at Vantage and again from Priest Rapids reservoir in 1996. Background bass were also collected from a pond near Sunnyside, Washington in 1991 and from Priest Rapids reservoir in 1996.

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. Fillets and the eviscerated remains (offal) were analyzed. Results for all 1996 samples are given by Bisping (1997).

Radiological Results for Fish Samples

Bass

Muscle. In 1996, muscle samples were analyzed with gamma spectrometry for cesium-137 and other gamma-emitting radionuclides (see Appendix E). Cesium-137 was found at the detection level of 0.02 pCi/g in the bass fillet collected from the Hanford Slough. Cesium-137 was not detected in the samples from 100-F Slough or Priest Rapids reservoir (Table 4.5.2).

Offal. Strontium-90 was found in all bass offal samples analyzed in 1996. There was no apparent difference between offal samples collected at the 100-F Slough and the Hanford Slough nor have concentrations changed much over the past 5 years (see Table 4.5.2). Concentrations of strontium-90 in offal were slightly elevated in the 100-F Slough and Hanford Slough samples compared to background samples collected at Sunnyside in 1991 and at Priest Rapids reservoir in 1996.

Carp

Muscle. Cesium-137 was not detected in carp fillets collected in 1996 (Table 4.5.3). Moreover, cesium-137

Table 4.5.2. Concentrations of Select Radionuclides in Bass, 1996 Values Compared to Values from the Previous 5 Years

Location	1996 Maximum,[a] pCi/g wet wt.	1996 Mean,[b] pCi/g wet wt.	1996 No. Less Than Detection[c]	1991-1995 Maximum,[a] pCi/g wet wt.	1991-1995 Mean,[b] pCi/g wet wt.	1991-1995 No. Less Than Detection[c]
Cesium-137 in Muscle						
100-F Slough	0.02 ± 0.01	0.01 ± 0.01	5 of 5	0.05 ± 0.03	0.03 ± 0.01	5 of 10
Hanford Slough	0.02 ± 0.01	NA[d]	0 of 1	NS[c]	NS	
Sunnyside	NS	NS		0.09 ± 0.09	0.01 ± 0.01	20 of 20
Priest Rapids Reservoir	0.01 ± 0.04	0.00 ± 0.01	2 of 2	NS	NS	
Strontium-90 in Offal						
100-F Slough	0.027 ± 0.008	0.023 ± 0.003	0 of 5	0.03 ± 0.008	0.021 ± 0.005	0 of 10
Hanford Slough	0.023 ± 0.014	NA	0 of 1	NS	NS	
Sunnyside	NS	NS		0.03 ± 0.009	0.007 ± 0.002	8 of 20
Priest Rapids Reservoir	0.018 ± 0.010	0.018 ± 0.000	0 of 2	NS	NS	

(a) Maximum is pCi/g ± total propagated analytical uncertainty (2-sigma).
(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) NA = Not applicable, n = 1.
(e) NS = No sample.

Table 4.5.3. Concentrations of Select Radionuclides in Carp, 1996 Values Compared to Values from the Previous 5 Years

Location	1996 Maximum,[a] pCi/g wet wt.	1996 Mean,[b] pCi/g wet wt.	1996 No. Less Than Detection[c]	1991-1995 Maximum,[a] pCi/g wet wt.	1991-1995 Mean,[b] pCi/g wet wt.	1991-1995 No. Less Than Detection[c]
Cesium-137 in Muscle						
100-N to 100-D	0.01 ± 0.01	0.01 ± 0.01	2 of 2	0.06 ± 0.02	0.01 ± 0.01	12 of 13
300 Area	NS[d]	NS		0.02 ± 0.02	0.01 ± 0.00	16 of 20
Priest Rapids Reservoir	0.01 ± 0.0[e]	0.00 ± 0.01	2 of 2	NS	NS	
Vantage	NS	NS		0.02 ± 0.01	0.01 ± 0.00	15 of 20
Strontium-90 in Offal						
100-N to 100-D	0.038 ± 0.009	0.027 ± 0.022	0 of 2	0.26 ± 0.051	0.055 ± 0.042	0 of 11
300 Area	NS	NS		0.15 ± 0.035	0.034 ± 0.014	1 of 20
Priest Rapids Reservoir	0.035 ± 0.008	0.033 ± 0.005	0 of 2	NS	NS	
Vantage	NS	NS		0.11 ± 0.024	0.076 ± 0.012	0 of 20

(a) Maximum is pCi/g ± total propagated analytical uncertainty (2-sigma).
(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) NS = No sample.
(e) This result is actually less than detection; uncertainty was rounded down to 0.0.

was not detected in approximately 85% of the carp fillet samples collected from the Hanford Reach from 1991 through 1995.

Offal. Strontium-90 was measured in all carp offal samples collected in 1996. Concentrations were low (<0.038 ± 0.009 pCi/g, wet wt.) and comparable to results obtained from 1991 through 1995 (see Table 4.5.3). There was no apparent difference between concentrations of strontium-90 in Hanford Reach carp and background carp collected in 1996.

Wildlife Sampling

Wildlife sampled in 1996 for radioactive constituents included deer and pheasants. Results from all 1996 samples are summarized in Bisping (1997).

Collection of Deer Samples and Analytes of Interest

Ongoing studies of site mule deer indicate that populations residing along the river can be divided into two distinct categories (Tiller et al. 1995): 1) the population that inhabits land around the retired reactors in the 100 Areas is designated the north population and 2) the population that resides from the Old Hanford Townsite south to the 300 Area is designated the south population. By default, deer collected around the 200 Areas, away from the river, constitute a third grouping named the central population (see Figure 4.5.1).

Radionuclide concentrations in animals collected onsite in 1996 were compared to concentrations in deer collected distant from the site from 1991 through 1995 near Boardman, Oregon and in Stevens County, Washington. Additionally, a white-tailed deer was cosampled for background concentrations with the Washington State Department of Health in 1996 at Vail, Washington. The Stevens County deer samples were donated to the program. These comparisons are useful in evaluating Hanford's impact to deer because the distant sampling areas in Stevens County and Vail get more rainfall containing atmospheric fallout than Hanford; therefore, background concentrations of cesium-137 and strontium-90 are usually higher (Poston and Cooper 1994). This difference was not noted in deer collected from Boardman because the climate and precipitation there are similar to Hanford.

Radiological Results for Deer Samples

Muscle. Cesium-137 was not detected in the 13 deer muscle samples collected and analyzed in 1996 (Table 4.5.4). These results are consistent with trends observed in Hanford deer muscle samples analyzed in recent years (Poston and Cooper 1994). The cesium-137 concentration in Hanford deer muscle was less than background concentrations measured in the deer samples collected from 1991 through 1995 from Stevens County and, in 1996, from Vail.

Bone. Strontium-90 was detected in all deer bone samples analyzed in 1996. The maximum concentration was 1.6 ± 0.30 pCi/g in a deer sampled from the North Area. Generally, strontium-90 concentrations were higher in deer collected from the North Area when compared to the South or Central Areas. These 1996 results are consistent with prior observations (Poston and Cooper 1994). Boardman deer bone samples had a maximum strontium-90 concentration of 0.13 ± 0.04 pCi/g, which was lower than the concentrations in the deer bone samples from Vail and Stevens County but comparable to results from Hanford deer samples analyzed over the past several years (see Table 4.5.4). The apparently higher concentrations of strontium-90 in onsite deer bone from the North Area may indicate some prior exposure to localized low-level contamination onsite.

Collection of Pheasant Samples and Analytes of Interest

Two pheasants where collected from the 100-D to 100-F Areas in the fall of 1996. Radionuclide concentrations in these samples were compared to background concentrations in pheasants collected in the lower Yakima Valley near Sunnyside, Washington in 1994.

Muscle. Cesium-137 was not detected in pheasant muscle samples collected in 1996, but was detected in approximately 75% of the pheasants collected onsite since 1991 (Table 4.5.5).

Bone. Strontium-90 was measured in pheasant bones in both samples collected onsite in 1996. The mean concentration (0.07 ± 0.005 pCi/g, wet wt.) was similar to strontium-90 levels observed in site pheasants over the preceding 5 years and exceeded concentrations observed in background samples collected from 1991 through 1995 by a factor of two.

Table 4.5.4. Concentrations of Select Radionuclides in Deer, 1996 Values Compared to Values from the Previous 5 Years

Location	1996 Maximum,[a] pCi/g wet wt.	1996 Mean,[b] pCi/g wet wt.	1996 No. Less Than Detection[c]	1991-1995 Maximum,[a] pCi/g wet wt.	1991-1995 Mean,[b] pCi/g wet wt.	1991-1995 No. Less Than Detection[c]
Cesium-137 in Muscle						
North Area	0.02 ± 0.02	0.01 ± 0.01	7 of 7	0.02 ± 0.01	0.00 ± 0.00	13 of 14
South Area	0.49 ± 0.11	0.42 ± 0.051	5 of 5	0.01 ± 0.005	0.00 ± 0.00	16 of 16
Central Area	-0.003 ± 0.01	NA[d]	1 of 1	0.4 ± 0.05	0.07 ± 0.12	3 of 6
Stevens Co., WA	NS[e]	NS		0.5 ± 0.06	0.31 ± 0.26	0 of 3
Boardman, OR	NS	NS		0.03 ± 0.03	0.01 ± 0.01	3 of 4
Vail, WA	0.12 ± 0.03	NA	0 of 1	NS	NS	
Strontium-90 in Bone						
North Area	1.6 ± 0.30	0.63 ± 0.41	0 of 6	21 ± 10	3.6 ± 3.6	0 of 11
South Area	0.49 ± 0.11	0.42 ± 0.051	0 of 4	0.22 ± 0.11	0.11 ± 0.11	2 of 4
Central Area	0.14 ± 0.054	NA	0 of 1	3.3 ± 0.64	1.1 ± 1.5	1 of 4
Stevens Co., WA	NS	NS		2.1 ± 0.41	1.1 ± 1.0	0 of 3
Boardman, OR	NS	NS		0.13 ± 0.041	0.11 ± 0.015	0 of 4
Vail, WA	0.94 ± 0.20	NA	0 of 1	NS	NS	

(a) Maximum is pCi/g ± total propagated analytical uncertainty (2-sigma).
(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) NA = Not applicable, n = 1.
(e) NS = No sample.

Table 4.5.5. Concentrations of Select Radionuclides in Pheasant, 1996 Values Compared to Values from the Previous 5 Years

Location	1996 Maximum,[a] pCi/g wet wt.	1996 Mean,[b] pCi/g wet wt.	1996 No. Less Than Detection[c]	1991-1995 Maximum,[a] pCi/g wet wt.	1991-1995 Mean,[b] pCi/g wet wt.	1991-1995 No. Less Than Detection[c]
Cesium-137 in Muscle						
100-D to 100-F	0.00 ± 0.01	0.00 ± 0.00	2 of 2	0.17 ± 0.03	0.02 ± 0.01	19 of 26
100-N Area	NS[d]	NS		-0.01 ± 0.01	-0.02 ± 0.00	2 of 2
Yakima Valley	NS	NS		0.16 ± 0.14	0.02 ± 0.03	10 of 10
Strontium-90 in Bone						
100-D to 100-F	0.08 ± 0.06	0.07 ± 0.005	0 of 2	0.21 ± 0.11	0.077 ± 0.023	7 of 19
100-N Area	NS	NS		0.080 ± 0.048	0.072 ± 0.014	0 of 2
Yakima Valley	NS	NS		0.055 ± 0.037	0.032 ± 0.010	6 of 10

(a) Maximum is pCi/g ± total propagated analytical uncertainty (2-sigma).
(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) NS = No sample.

Nonradiological Results for Deer and Great Blue Heron Samples

Deer and great blue heron samples were also collected in 1996 for trace metal analyses. These analyses were conducted in support of efforts to evaluate metals concentrations in the Hanford environs and the potential risk these metals pose to site biota. Generally, analyses focused on liver tissue because this organ provides a better indicator of metals exposure than muscle or other tissues. Data on metal concentrations in site biota will assist in efforts to evaluate the relative risk from metal contaminants in the environment.

Metals Analysis in Hanford Site Wildlife

Liver samples were collected from 12 nonfledged juvenile herons residing in the Hanford Reach as part of a graduate student study. Chromium, copper, mercury, selenium, and zinc were consistently measured in heron liver samples collected in 1996. Nickel was detected in two-thirds of the heron samples collected. These concentrations can be compared to concentrations in pigeon samples analyzed in 1995 (Table 4.5.6). Most concentrations were similar, except for cadmium and lead that were not detected in heron liver samples but were found in pigeon liver samples. These differences may be indicative of the different behavior, dietary sources, and physiology of the two birds. Herons are predatory birds feeding on aquatic life and pigeons feed on grain.

Deer liver samples collected at Hanford were compared with liver samples collected from near Boardman, Oregon. Boardman has a similar climate compared to Hanford, but it is also the site of a coal-fired power plant that could raise the levels of metals in the environment. With the exception of copper, metals that were detected in deer livers from animals collected onsite were generally higher than concentrations observed in Boardman deer in 1994 (Table 4.5.7).

Table 4.5.6. Comparison of Metal Concentrations in Liver Samples of Pigeons and Herons

Tissue/Sampling Location	No. of Samples	Mean,[a] µg/g, dry weight			
		Cadmium	Chromium	Copper	Lead
Pigeon (1995 data)					
300 Area (January)	5	0.68 ± 0.22	0.49 ± 0.07	8.45 ± 1.03	0.11 ± 0.02
300 Area (August)	5	0.59 ± 0.74	0.81 ± 0.12	17 ± 4.62	0.69 ± 0.53
Seattle	8	4.3 ± 2.4	0.81 ± 0.22	17.6 ± 4.95	1.75 ± 1.19
Walla Walla	7	1.4 ± 0.38	0.72 ± 0.11	10.8 ± 1.33	0.17 ± 0.12
Heron (1996 data)	12	ND[b]	0.49 ± 0.044	59.2 ± 28.6	ND
		Zinc	Selenium	Nickel	Mercury
Pigeon (1995 data)					
300 Area (January)	5	59.5 ± 10.8	NR[c]	ND	NR
300 Area (August)	5	175 ± 94.9	NR	ND	NR
Seattle	8	123 ± 60	NR	ND	NR
Walla Walla	7	78.1 ± 19.4	NR	ND	NR
Heron (1996 data)	12	236 ± 63.4	5.76 ± 0.698	0.49 ± 0.28	2.2 ± 0.7

(a) Result is ±2 standard error of the mean.
(b) Not detected.
(c) Not reported.

Table 4.5.7. Comparison of Metal Concentrations in Deer Liver Samples Collected from the Hanford Site in 1996 and Boardman, Oregon in 1994

	Hanford Site, 1996			Boardman, Oregon, 1994		
Metal	Maximum, µg/g	Mean,[a] µg/g	No. Less Than Detection	Maximum, µg/g	Mean,[a] µg/g	No. Less Than Detection
Cadmium	1.75	0.787 ± 0.51	0 of 5	0.39	0.34 ± 0.087	0 of 4
Chromium	0.445	0.386 ± 0.049	0 of 5	0.11	0.08 ± 0.021	3 of 4
Copper	125	56.0 ± 36.4	0 of 5	161	144 ± 17.8	0 of 4
Iron	698	498 ± 171	0 of 5			NA[b]
Mercury	0.045	0.0103 ± 0.017	3 of 5	0.016	0.014 ± 0.0024	0 of 4
Nickel	0.99	0.44 ± 0.33	1 of 5	<0.056[c]		4 of 4
Zinc	183	148 ± 20.5	0 of 5	155	133 ± 20.7	0 of 4
Silver	<0.20[c]		5 of 5	0.182	0.143 ± 0.029	0 of 4

(a) Mean result is ±2 standard error of the mean.
(b) Not available.
(c) Detection limit.

4.6 Soil and Vegetation Surveillance

T. M. Poston, G. W. Patton, and K. R. Price

Soil and vegetation surveillance provides information on atmospheric deposition of radioactive materials in uncultivated areas, long-term trends, and baseline environmental radionuclide concentrations in undisturbed locations (DOE 1994a). Accordingly, concentrations of radionuclides in soil and natural vegetation provide a baseline against which unplanned releases can be compared.

Soil and natural vegetation have been collected on and around the Hanford Site for more than 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. There are several additional 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 detectable. Moreover, radionuclide releases from Hanford in recent years have been small; therefore, baseline radionuclide concentrations have not changed appreciably. Because only natural or manmade radionuclides with relatively long half-lives are found in soil and vegetation samples, annual sitewide environmental surveillance sampling of soil and vegetation can be less frequent. As a result, no soil or natural vegetation surveillance samples were collected for the sitewide surveillance program in 1996. Future sampling of soil and natural vegetation will be conducted on an as-needed basis in support of site cleanup activities and facility operations.

Other soil and vegetation sampling conducted by the management and operations contractor (January through September 1996) and the management and integration contractor (October through December 1996) occurred near active facility release points and waste sites on the site. Results are discussed in Section 3.2, "Near-Facility Environmental Monitoring."

In 1996, two special investigations were conducted that addressed contaminants in soil. These included a special investigation of potential polychlorinated biphenyl contamination on onsite roads and a review of historical and current soil sampling locations and analytical methods. Results of these investigations are summarized below.

Road Contamination

Surface crust and soil samples from two unimproved and generally unused roads on the Hanford Site, which had been treated during past site operations with oil for dust suppression, were analyzed for potential polychlorinated biphenyl contamination (Figure 4.6.1). Each of the roads had an intact crust of oil/tar on top of the underlying soil surface. Control samples were collected at an untreated soil site near the Prosser Barricade air sampling station.

Several samples were collected at each location. These included portions of the oil/tar surface crust, the soil immediately beneath the surface crust (0 to 3 cm below the crust), and a deeper soil sample (12 to 20 cm below the surface crust). Samples were collected at two locations on each road. The samples were extracted with methylene chloride using a roller technique, cleaned using column chromatography and high-pressure liquid chromatography, and analyzed by capillary gas chromatography using electron capture detection. The samples were analyzed for polychlorinated biphenyls as the following technical mixtures: Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260.

Concentrations of Aroclor mixtures at all locations were less than the following detection limits: 42 µg/kg dry weight for surface crust and 2.1 µg/kg dry weight for soil. These concentrations are below the EPA's preliminary remediation goals for polychlorinated biphenyls in residential soil (66 µg/kg) and well below the preliminary remediation goal in industrial soil (340 µg/kg) (Smucker 1995).

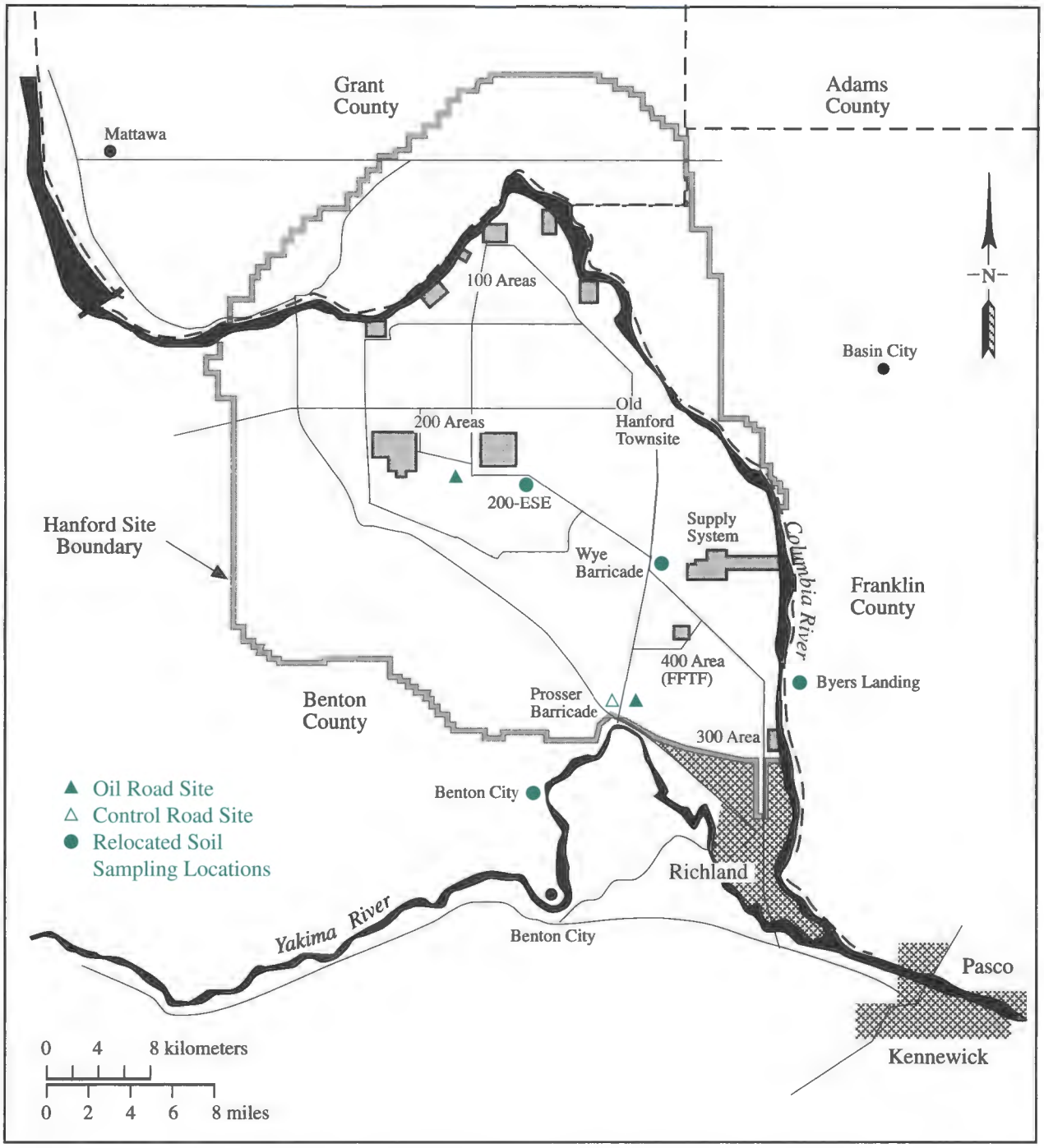

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Figure 4.6.1. Relocated Soil Sampling and Road Sampling Locations

Historical and Current Soil Sampling

In response to interest in past releases of radionuclides, a review of archived monitoring and surveillance records for soil sampling was conducted. This review documented changes in soil sampling locations, procedures, and methods used for the analysis of radiological contaminants over the past 26 years of soil surveillance. Four stations have been relocated since 1971. The Wye Barricade location was relocated across the road from the original site in the late 1980s. The Byers Landing location was moved approximately 0.16 km (0.1 mi) east of the original site also in the late 1980s. The 200-ESE location was moved approximately 3.6 km (2.25 mi) closer to the Plutonium-Uranium Extraction Plant stack in 1976 or 1977. The Benton City location was apparently relocated in the mid-1970s to a position several kilometers (miles) closer to the southern boundary of the site. The current positions of these four sampling locations are shown in Figure 4.6.1. Additionally, the current state of these sampling locations was evaluated, vegetation cover and disturbance was documented, and global positioning coordinates established for recently active sampling locations. This information will provide useful guidance when soil sampling is conducted in the future.

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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, power, research, waste management, and consumer products containing nuclear materials. Environmental radiation fields may be influenced by the presence of radionuclides deposited as fallout from 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 (National Council on Radiation Protection 1987).

The interaction of radiation with matter results in energy being deposited in matter. This is why your hand feels warm when exposed to a light source (e.g., flame, light bulb, sun, etc.). 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: 1 Gy is equivalent to 100 rad (American Society for Testing and Materials 1993).

One device for measuring radiation absorbed dose is the thermoluminescent dosimeter. 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 (U.S. Department of Health, Education and Welfare 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.

$$D\ (\text{rad}) \approx X\ (\text{R}) * 1.0$$
$$H\ (\text{rem}) \approx D * N * Q$$

To convert to SI units of grey and sievert, divide rad and rem by 100, respectively.

Environmental external radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters. External radiation and surface contamination surveys at these locations were also performed with portable radiation survey instruments at locations on and around Hanford. This section describes how external radiation was measured, how surveys were performed, and gives the results of these measurements and surveys.

External Radiation Measurements

In 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 approximately 1 m (3.3 ft) above the ground at 24 locations onsite (Figure 4.7.1), four around the site perimeter, in eight nearby and two distant communities (Figure 4.7.2), and 28 locations 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. Quarterly dose equivalent rates (mrem/d) at each location were converted to annual

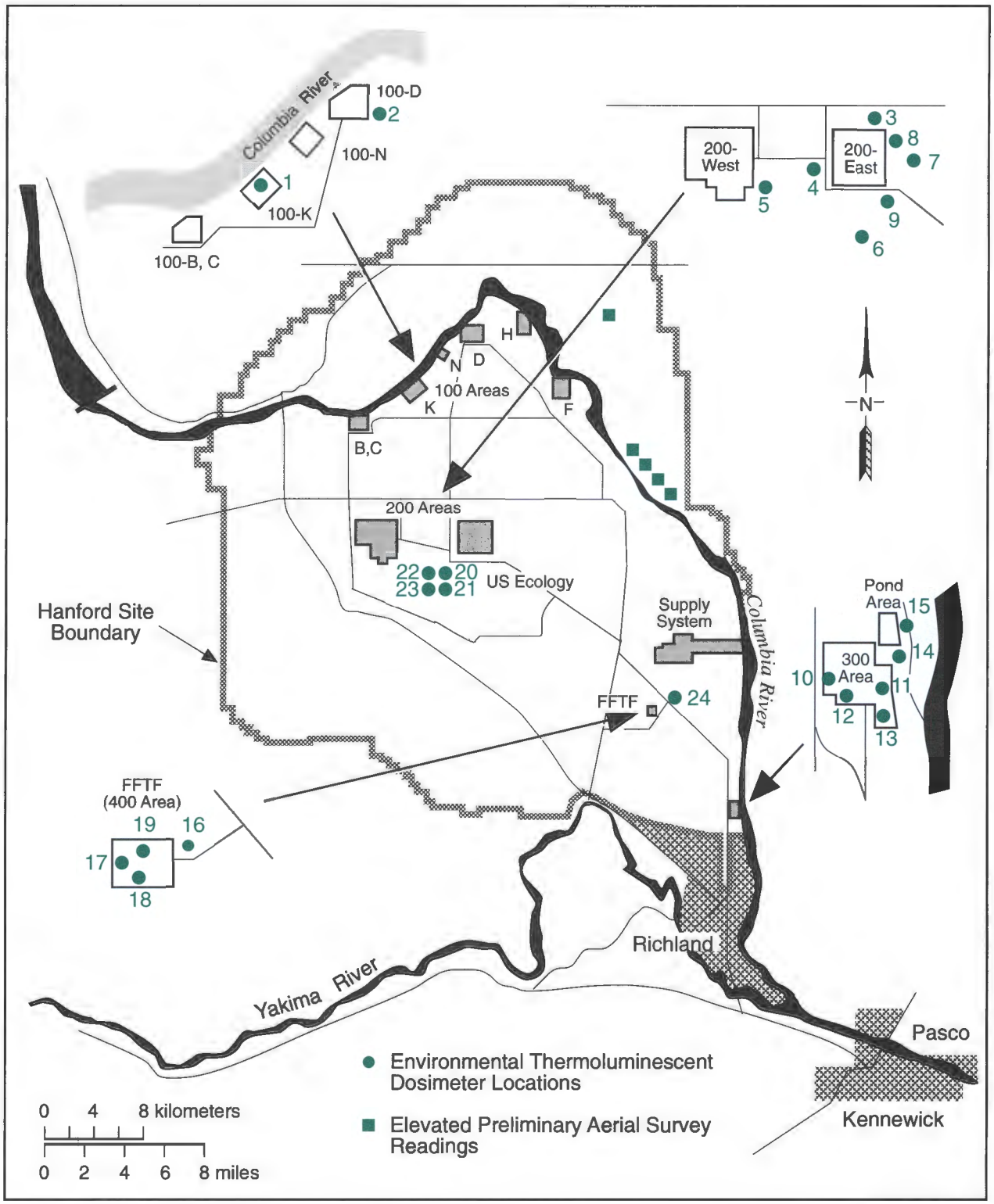

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Figure 4.7.1. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 1996

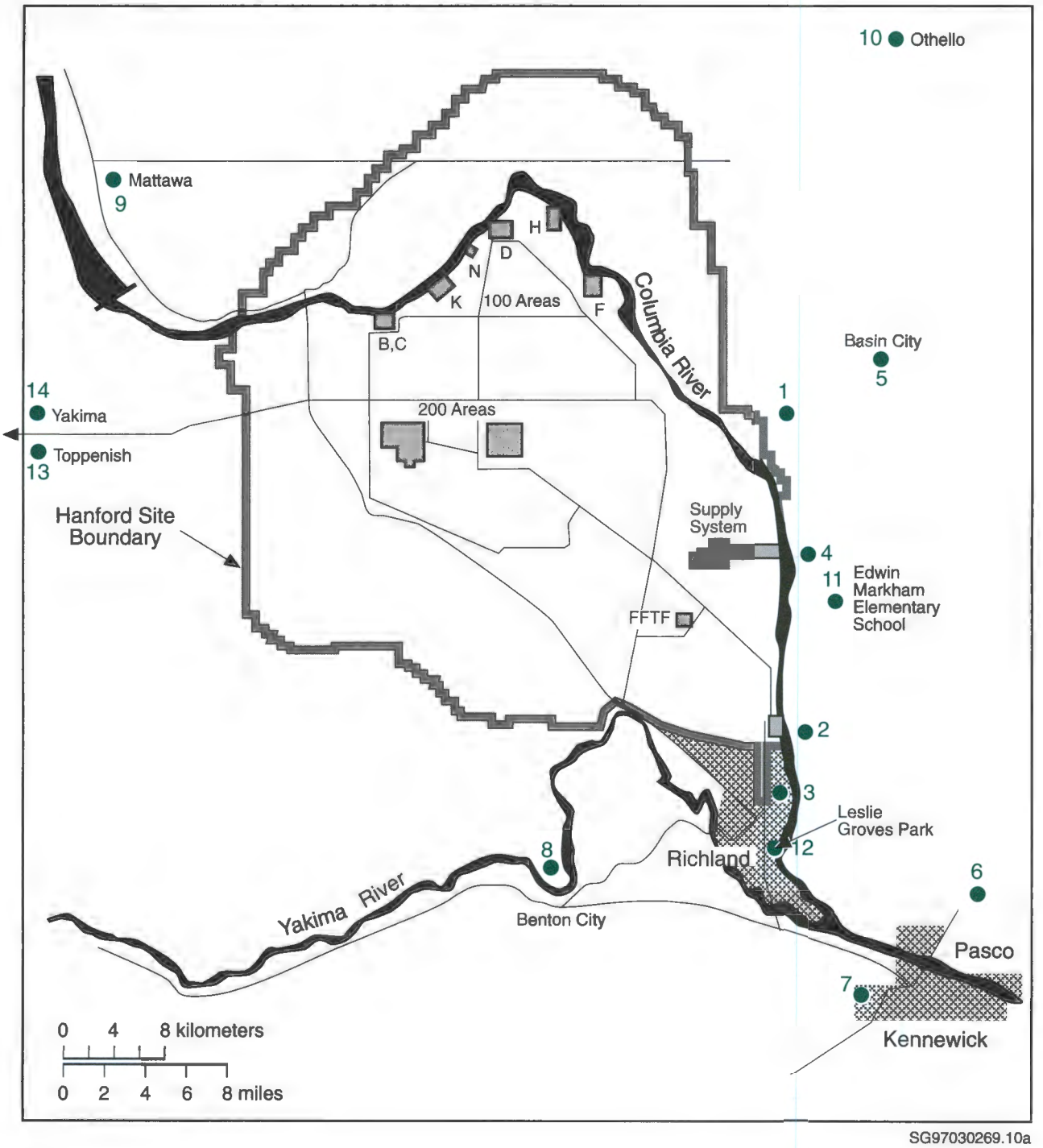

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Figure 4.7.2. Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 1996

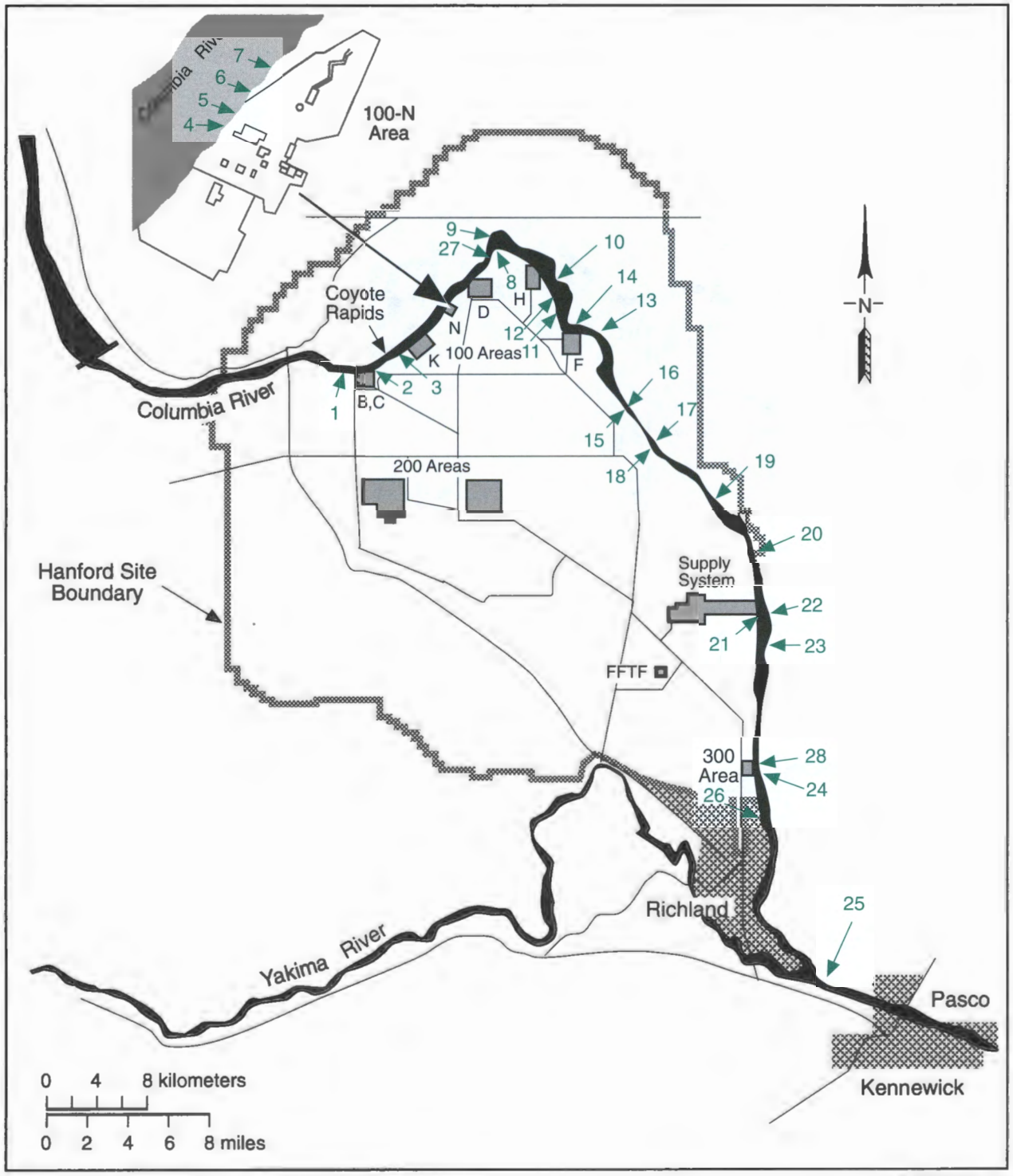

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Figure 4.7.3. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Reach of the Columbia River, 1996

dose equivalent rates (mrem/yr) by averaging the quarterly dose rates and multiplying by 365 d/yr. The two TLD-200 chips are included to determine doses in the event of a radiological emergency.

All community and most of the onsite and perimeter locations are collocated with air monitoring stations. The onsite and perimeter 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. The two background stations in Yakima and Toppenish were chosen because they are generally upwind and distant from the site.

Twenty-eight thermoluminescent dosimeter locations are established along the Columbia River shoreline (see Figure 4.7.3), from upstream of the 100-B Area to just downstream of Bateman Island at the mouth of the Yakima River. The general public has access to most of this shoreline.

External Radiation Results

Thermoluminescent dosimeter exposures have been converted to dose equivalent rates by the process described above. Table 4.7.1 shows maximum and mean dose rates for perimeter and offsite locations measured in 1996 and the previous 5 years. 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 location classification and the mean dose rate (±2 standard error of the mean) for each class. The mean dose rates were computed by averaging the annual means for each location within a location classification. Locations were classified (or grouped) based on their distance from the site.

In 1996, the annual average perimeter external radiation dose rate was 88 ± 10 mrem/yr (see Table 4.7.1), while in 1995, the average was 86 ± 8 mrem/yr. The mean background external radiation dose rate (in distant communities in 1996) was 71 ± 1 mrem/yr, compared to the 1995 perimeter average of 72 ± 8 mrem/yr (Dirkes and Hanf 1996) and a 5-year perimeter average of 99 ± 4 mrem. Simple, two-tailed t-tests were unable to show a significant difference between 1995 and 1996 data, $p = 0.52$ and $p = 0.89$, respectively. The small variation in exposure rates may be partially attributed to changes in natural background radiation that can occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15% to 25% [National Council on Radiation Protection 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 station locations. These changes include, but are not limited to, the discontinuation of thermoluminescent dosimeter locations or the changing of a location to avoid continual vandalism. Figure 4.7.4 graphically displays a comparison between, and trends

Table 4.7.1. Dose Rates Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations, 1996 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1996		1991-1995		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Perimeter	1 - 4	97 ± 5	88 ± 10	27	121 ± 17	99 ± 4
Community	5 - 12	89 ± 3	79 ± 3	40	106 ± 16	89 ± 3
Distant	13 - 14	72 ± 3	71 ± 1	12	100 ± 11	85 ± 6

(a) ±2 standard error of the mean.
(b) All station locations are shown in Figure 4.7.2.
(c) Maximum annual average dose rate (±2 standard error of the mean) for all stations within a given location.
(d) Means ±2 standard error of the mean computed by averaging annual means for each station within each location.

Table 4.7.2. Dose Rates Measured by Thermoluminescent Dosimeters Along the Hanford Reach of the Columbia River, 1996 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1996		1991-1995		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Typical shoreline	1 - 24	95 ± 3	82 ± 3	118	167 ± 159	106 ± 3
100-N Shoreline[e]	25 - 28	173 ± 5	129 ± 30	19	355 ± 143	221 ± 27
All shoreline	1 - 28	173 ± 5	89 ± 7	137	355 ± 143	123 ± 8

(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 does 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. Dose Rates Measured by Thermoluminescent Dosimeters on the Hanford Site, 1996 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1996		1991-1995		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
100 Areas	1 - 2	88 ± 5	80 ± 16	14	115 ± 21[e]	96 ± 7
200 Areas	3 - 9	92 ± 1	86 ± 4	39	121 ± 10	98 ± 3
300 Area	10 - 15	85 ± 4	81 ± 2	30	110 ± 18	94 ± 3
400 Area	16 - 19	85 ± 2	82 ± 2	20	111 ± 18	96 ± 4
600 Area	20 - 25	138 ± 5	97 ± 21	30	183 ± 16	109 ± 10
Combined Onsite	1 - 25	138 ± 5	86 ± 5	134	183 ± 16	100 ± 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.
(e) Only one quarter of data for this maximum; error term is two times the analytical counting error.

of, onsite, perimeter, and distant thermoluminescent dosimeter locations during 1991 through 1996.

Locations of the thermoluminescent dosimeters positioned along the Columbia River shoreline were shown in Figure 4.7.3, and Table 4.7.2 showed the measured dose rates for shoreline locations. Dose rates were highest near the 100-N Area shoreline, approximately 1.5 times the 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 (Sula 1980). The maximum reading from the 100-N Area shoreline was 176 mrem/yr for both the third and fourth quarters at the station located at the 100-N Area springs. The general public does not have legal access to the 100-N Area shoreline but does have access to the adjacent Columbia

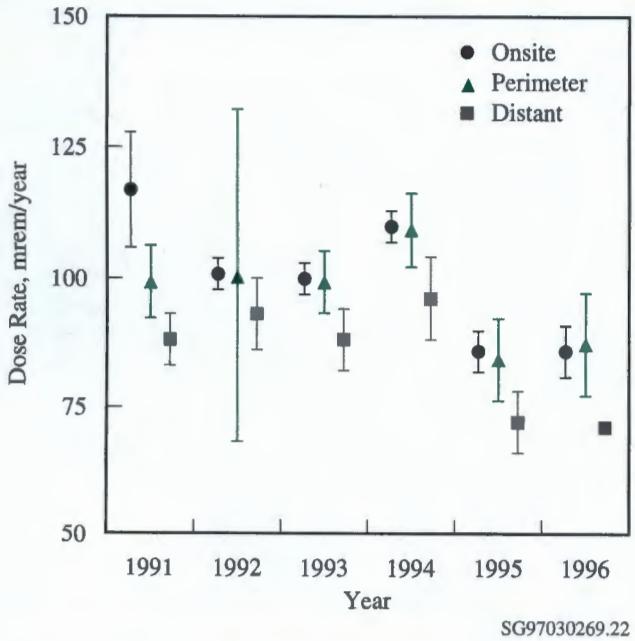

Figure 4.7.4. Annual Average Dose Rates (±2 standard error of the mean), 1991 Through 1996

River. The dose implications associated with this access are discussed in Section 5.0, "Potential Radiation Doses from 1996 Hanford Operations."

Table 4.7.3 summarized the results of 1996 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 1996, 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 8 to 20 µrem/h. As a point of comparison, 20 µrem/h equates to 175 mrem/yr, which correlates well with the maximum quarterly dose rate measured by the thermoluminescent dosimeters. Survey information is not included in the 1996 data volume (Bisping 1997), but is maintained in the Surface Environmental Surveillance Project files at Pacific Northwest National Laboratory and can be provided on written request.

Franklin County Elevated Gamma Measurements

EG&G Energy Measurements, Inc. performed an aerial radiological survey of the Hanford Site in March 1996. Preliminary results of this survey indicated elevated (up to 10 µR/h above background) exposure levels in Franklin County across the Columbia River from the Old Hanford Townsite. The elevated exposure levels were tentatively attributed to europium and cobalt isotopes. These preliminary data were of interest because elevated radiation levels had not been identified at these locations in previous aerial surveys (EG&G Energy Measurements, Inc. 1975, 1982, 1990). Five locations across the Columbia River, north of Ringold, were identified as having elevated exposure rates (see Figure 4.7.1).

A qualitative evaluation of radionuclides present at each of these locations was conducted with a portable gamma spectrometer. At each location, the primary radionuclides contributing to the exposure levels were associated with the natural uranium-238 or thorium-232 decay series. Other radionuclides not in the above-mentioned decay series but also identified in each spectra collected and, hence, contributing to the exposure rates were potassium-40, also a natural radionuclide, and cesium-137, a radionuclide present in worldwide fallout.

Radionuclides contributing to the elevated exposure rates noted in the aerial survey have been identified as naturally occurring gamma emitters in the thorium-232 or uranium-238 decay series, potassium-40 and cesium-137. The tentative identification of europium and cobalt was in error. This conclusion is in agreement with previous investigations by Rathbun (1989).

Gamma Radiation Measurements

During 1996, gamma radiation levels in air were continuously monitored at four community-operated air monitoring stations (Section 6.4, "Community-Operated Environmental Surveillance Program"). These stations were located in Leslie Groves Park in Richland, at Edwin Markham Elementary School in north Franklin County, at Basin City Elementary School in Basin City, and at

Heritage College in Toppenish (see Figure 4.1.1). Measurements were collected to determine ambient gamma radiation levels near and downwind of the site and upwind and distant from the 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.

Measurements at the Basin City and Edwin Markham schools were obtained using Reuter-Stokes Model S-1001-EM19 pressurized ionization chambers connected to Reuter-Stokes RSS-112 Radiation Monitoring Systems. Data were collected every 5 seconds, and an average reading was calculated and recorded on an electronic data card every 30 minutes. Data cards were exchanged monthly. Readings at the Leslie Groves Park and Heritage College stations were collected every 10 seconds with a Reuter-Stokes Model RSS-121 pressurized ionization chamber, and an average reading was recorded every hour by a flat panel computer system located at the station. Data were obtained monthly from the computer via modem. Data were not collected at every station every month because of problems with recording instruments and electrical service. The number of data collected at each station each month are provided in Table 4.7.4.

Table 4.7.4. Average Exposure Rates Measured by Pressurized Ionization Chambers at Four 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]	Heritage College[d]
Month				
January	8.7 ± 0.5 (745)	8.3 ± 0.6 (1,414)	8.7 ± 0.8 (1,360)	[f]
February	8.6 ± 0.5 (557)	8.3 ± 0.4 (1,233)	8.6 ± 0.6 (1,441)	[f]
March	ND[g]	8.4 ± 0.4 (1,452)	8.7 ± 0.5 (1,344)	[f]
April	ND	8.3 ± 0.3 (1,589)	9.4 ± 40.1 (1,822)	[f]
May	8.4 ± 0.3 (719)	8.2 ± 0.2 (1,439)	ND	7.8 ± 0.2 (623)
June	8.3 ± 0.4 (718)	8.2 ± 0.3 (1,336)	ND	7.8 ± 0.2 (394)
July	8.3 ± 0.4 (573)	8.2 ± 0.3 (1,419)	ND	7.8 ± 0.3 (467)
August	8.3 ± 0.5 (741)	8.2 ± 0.3 (1,567)	ND	ND
September	8.4 ± 0.4 (720)	8.2 ± 0.3 (1,440)	ND	7.9 ± 0.4 (664)
October	8.6 ± 0.5 (547)	ND	ND	ND
November	8.7 ± 0.6 (588)	ND	ND	7.8 ± 1.1 (698)
December	8.6 ± 0.6 (550)	8.1 ± 1.0 (1,273)	8.7 ± 1.0 (912)	7.2 ± 0.7 (744)

(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) Station under construction, not yet operational.
(g) ND = No data collected; equipment or power problems.

The measurements recorded at Basin City, Edwin Markham, and Leslie Groves Park during the year were similar and at background levels. Data collected at Edwin Markham during the first half of April included some variable readings associated with an equipment problem. The readings recorded at Heritage College were also within normal limits but were, on average, slightly lower than readings measured near Hanford.

Monthly average exposure rates ranged from 7.2 μR/h at Heritage College in December to 9.4 μR/h at Edwin Markham in April (a suspect reading because of subsequent equipment problems). Average monthly readings at the stations near Hanford were consistently between 8.2 and 8.7 μR/h and readings at Heritage College ranged between 7.2 and 7.8 μR/h. These dose rates were consistent with dose rates measured by the thermoluminescent dosimeters at these locations (Table 4.7.5).

Table 4.7.5. Quarterly Exposure Rates Measured by Thermoluminescent Dosimeters at Four Offsite Locations

	Exposure Rate, μR/h[a]			
Sampling Locations[b]	Leslie Groves Park	Basin City	Edwin Markham	Heritage College
Quarter Ending				
March	9.2 ± 0.04	8.7 ± 0.00	9.1 ± 0.46	8.5 ± 0.13
June	9.0 ± 0.33	9.0 ± 0.71	8.8 ± 0.04	8.2 ± 0.21
September	9.0 ± 0.13	8.9 ± 0.08	8.3 ± 0.21	8.2 ± 0.46
December	8.9 ± 0.08	8.7 ± 0.04	8.5 ± 0.17	7.8 ± 0.08

(a) ±2 standard deviations of the exposure rate.
(b) Sampling locations are illustrated in Figure 4.1.1.

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4.8 Groundwater Protection and Monitoring Program

P. D. Thorne and P. E. Dresel

The strategy for protecting groundwater at the Hanford Site is presented in the *Hanford Site Ground-Water Protection Management Plan* (DOE 1995k). Two key elements of this strategy are to 1) protect the unconfined aquifer from further contamination and 2) monitor the extent of groundwater contamination. The groundwater monitoring program at the Hanford Site documents groundwater quality to meet the needs of these elements. The monitoring program is designed to detect new contaminant plumes and to document the distribution and movement of existing groundwater contamination. Monitoring provides the historical baseline for evaluating current and future risk from exposure to groundwater contamination and for deciding on remedial options. Because the geology and hydrology of the Hanford Site control the movement of contaminants in groundwater, hydrogeologic studies are an integral part of the monitoring program.

The effort to protect groundwater quality at the Hanford Site is being implemented through programs to minimize wastes being discharged to the soil column and through site remediation activities. The Tri-Party Agreement (Ecology et al. 1989) provides a framework for remediation of the Hanford Site, including groundwater, over a 40-year period. A summary of accomplishments in waste minimization and site remediation is presented in Section 2.0, "Environmental Compliance Summary."

DOE 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 and diverted to the 200 Areas Treated Effluent Disposal Facility. In addition, process condensate from the 242-A Evaporator is treated at the 200 Areas Effluent Treatment Facility and then discharged to a state-approved facility, also called the Effluent Treatment Facility north of the 200-West Area. The location of these facilities is shown in Figures 1.0.3 and 4.8.1. They are discussed in detail in Section 2.3, "Accomplishments and Issues." Disposal of liquids to soil has been significantly reduced during the last several years. For example, in 1987, over 23 billion L (6 billion gal) of liquid effluents were discharged to the soil. This was reduced to approximately 4.9 billion L (1.3 billion gal) in 1995 and less than 1 billion L (290 million gal) in 1996. The locations and status of Phase I effluent streams are shown in Figure 4.8.1. Approximately 90% of the discharged volume goes to B Pond and approximately 9% goes to the 200 Areas Treated Effluent Disposal Facility.

Groundwater is used for drinking water and other purposes at a few locations on the Hanford Site. DE&S Hanford, Inc. and Pacific Northwest National Laboratory monitor drinking water supplies at the point of use. Results of the radiological monitoring conducted by Pacific Northwest National Laboratory are summarized in Section 4.3, "Hanford Site Drinking Water Surveillance." The locations of wells completed in the unconfined aquifer that are used for water supplies are shown in Figure 4.8.2.

Geologic Setting

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).

The Columbia River basalts were formed from lava that periodically erupted from volcanic fissures starting approximately 17 million years ago and continuing until approximately 8.5 million years ago. The regional river system eroded the basalt and deposited sediments across the basalt surfaces between eruptions. Zones between the

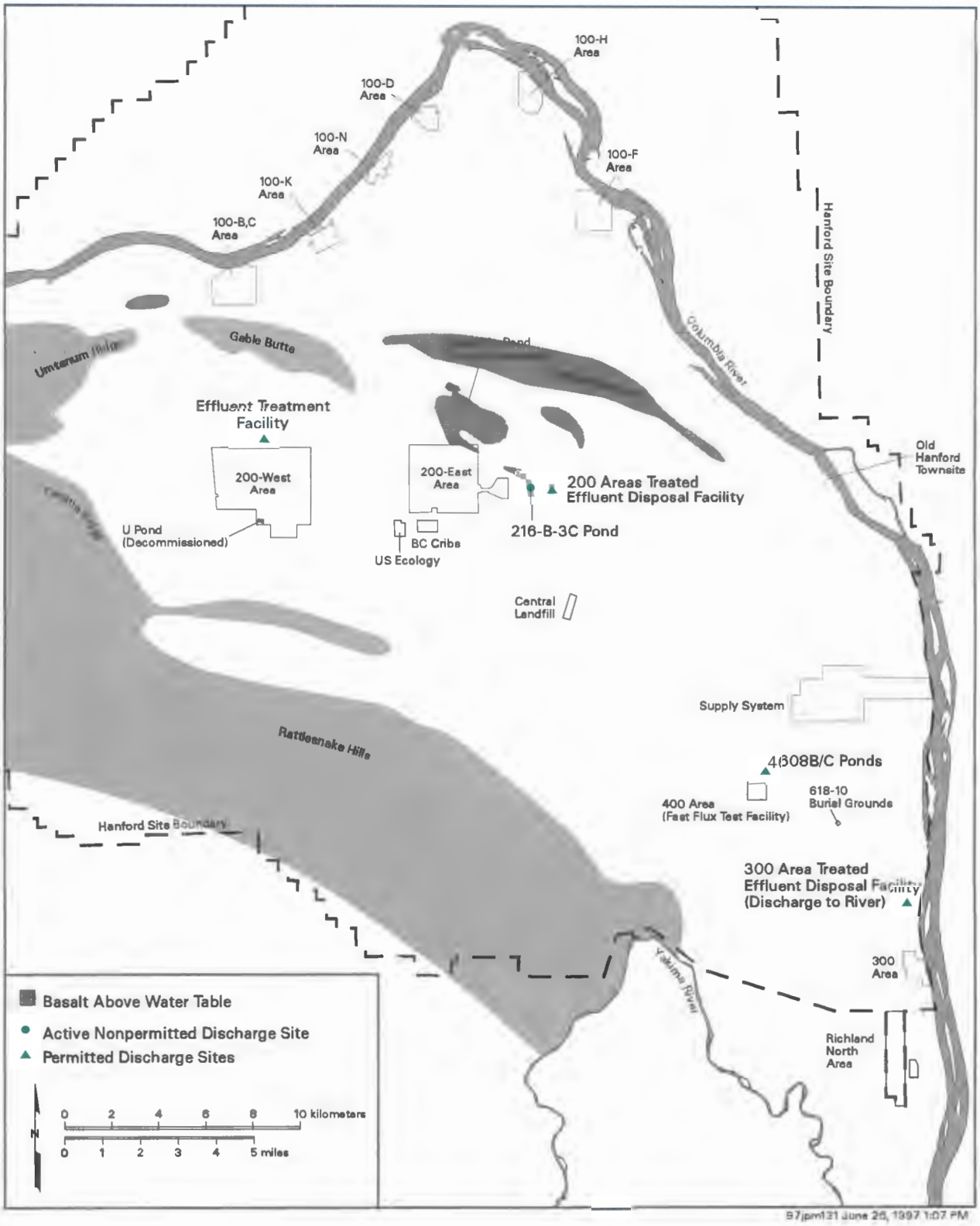

Figure 4.8.1. Disposal Facilities for the Major Liquid Waste Streams at the Hanford Site

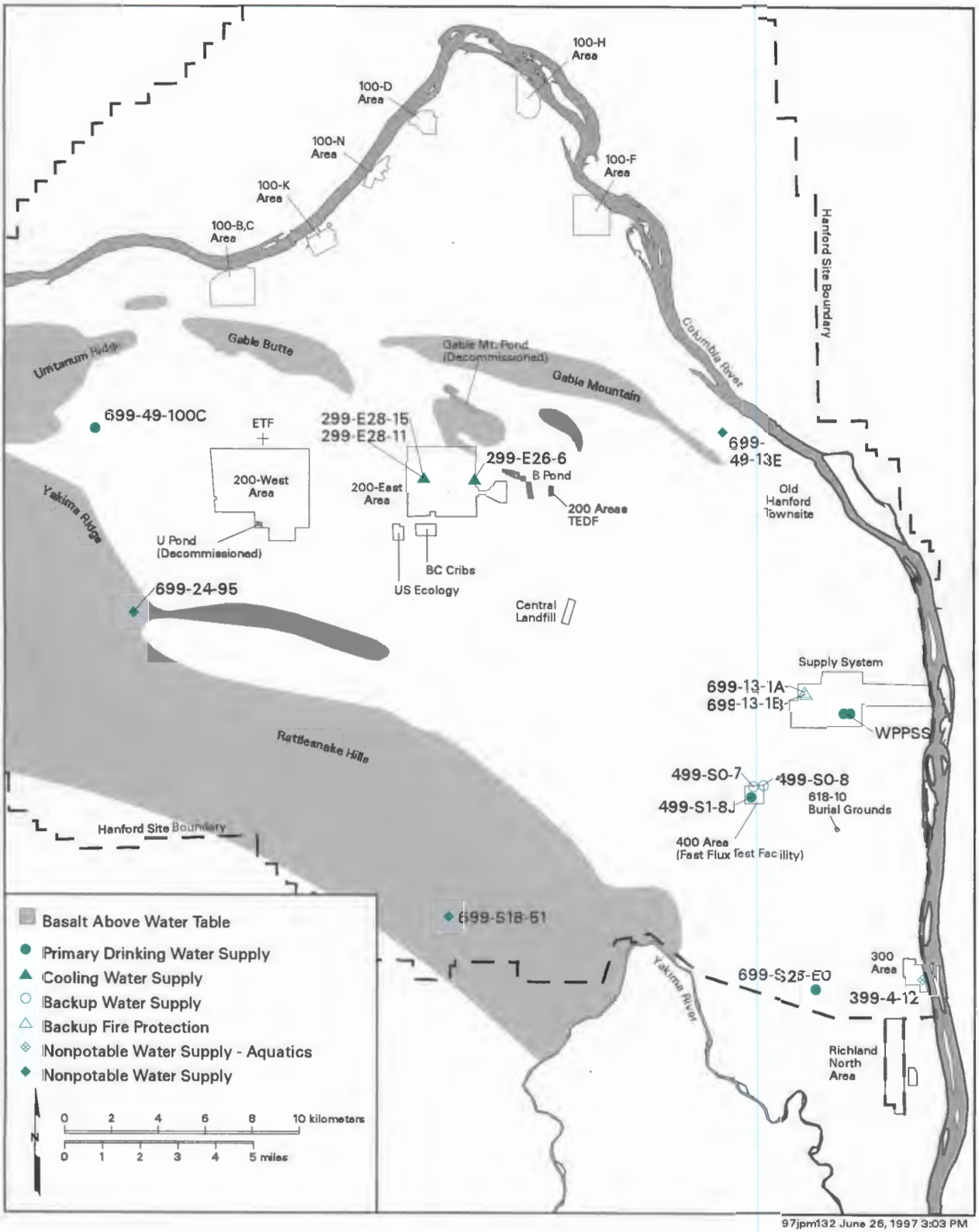

Figure 4.8.2. Water-Supply Wells in the Unconfined Aquifer at the Hanford Site

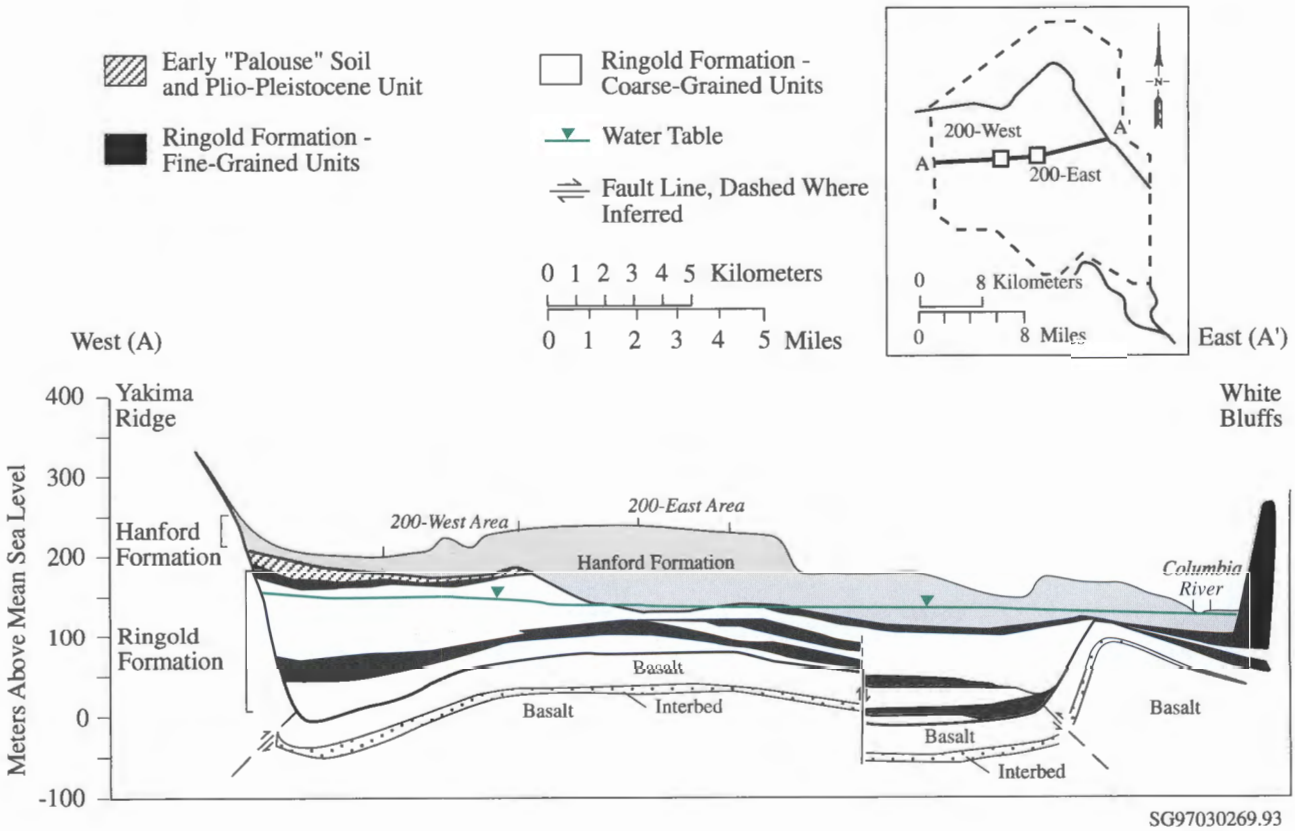

Figure 4.8.3. Geologic Cross Section of the Hanford Site

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. Approximately 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 (feet) of recent stream or windblown deposits.

More detailed information on the geology of the Pasco Basin can be found in DOE (1988), Connelly et al. (1992a, 1992b), Reidel et al. (1992), Lindsey (1995), and Hartman and Dresel (1997).

Groundwater Hydrology

Both confined and unconfined aquifers are present beneath the Hanford Site. An aquifer is a water-saturated geologic interval or unit that has a high permeability, meaning it can transmit significant quantities of water. A confined aquifer is bounded above and below by low-permeability materials that restrict the vertical movement of water.

The confining layers may be dense rock such as the central parts of basalt flows, silt, clay, or well-cemented sediments. Areally extensive confined aquifers at the Hanford Site are found primarily within interflows and interbeds of the Columbia River basalts. These are referred to as basalt-confined aquifers. Locally confined aquifers are also found below the clays and silts of the Ringold Formation.

An unconfined aquifer, or water-table aquifer, is overlain by unsaturated sediments. The upper surface of the saturated zone in an unconfined aquifer, which is called the water table, rises and falls in response to changes in the volume of water stored in the aquifer. In general, the unconfined aquifer at Hanford is located in the Hanford and Ringold Formations. In some areas, the water table 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 and zones of natural cementation form low-permeability zones within the Ringold Formation.

The unconfined aquifer forms the uppermost groundwater zone and has been directly impacted by waste-water disposal at the Hanford Site. The unconfined aquifer discharges primarily into the Columbia River, and is the most thoroughly monitored aquifer beneath the site. The Rattlesnake Ridge interbed is the uppermost, basalt-confined aquifer within the Pasco Basin and the Hanford Site. This aquifer and other 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 (Newcomb et al. 1972, Graham et al. 1984, Reidel et al. 1992). Additional information on the basalt-confined aquifer system can be found in Spane and Vermeul (1994) and Spane and Webber (1995).

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 uplifted basalt ridges (Figure 4.8.4). Depth from the ground surface to the water table ranges from <0.3 m (1 ft) near the Columbia River to >106 m (348 ft) in the center of the site. The unconfined aquifer is bounded below by either the basalt surface or, in places, by 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 groundwater where they rise above the water table (Gephart et al. 1979).

The water-table elevation contours shown in Figure 4.8.5 indicate the direction of groundwater flow and the magnitude of the hydraulic gradient in the unconfined aquifer. Groundwater 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 groundwater flow is greater. However, because sediments with low permeabilities inhibit groundwater flow and produce steeper gradients, a high gradient does not necessarily mean high groundwater 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 and the aquifer is entirely within the less-permeable Ringold sediments. Figure 4.8.6 shows the generalized distribution of transmissivity as determined from aquifer pumping tests and groundwater flow model calibration. Additional information on aquifer hydraulic properties at Hanford is presented in DOE (1988) and Thorne and Newcomer (1992).

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 Yakima River, where it flows along the southern boundary of the Hanford Site, also recharges the unconfined aquifer. 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. Groundwater discharges to the surface north of the 200-East Area form West Lake, a small water body formed in a closed depression. The size of West Lake fluctuates in response to changes in the water-table elevation, which is influenced by waste-water discharge practices. Recharge from infiltration of precipitation is highly variable on the Hanford Site both spatially and from year to year. The rate of natural recharge depends primarily on soil texture, vegetation, and climate (Gee et al. 1992,

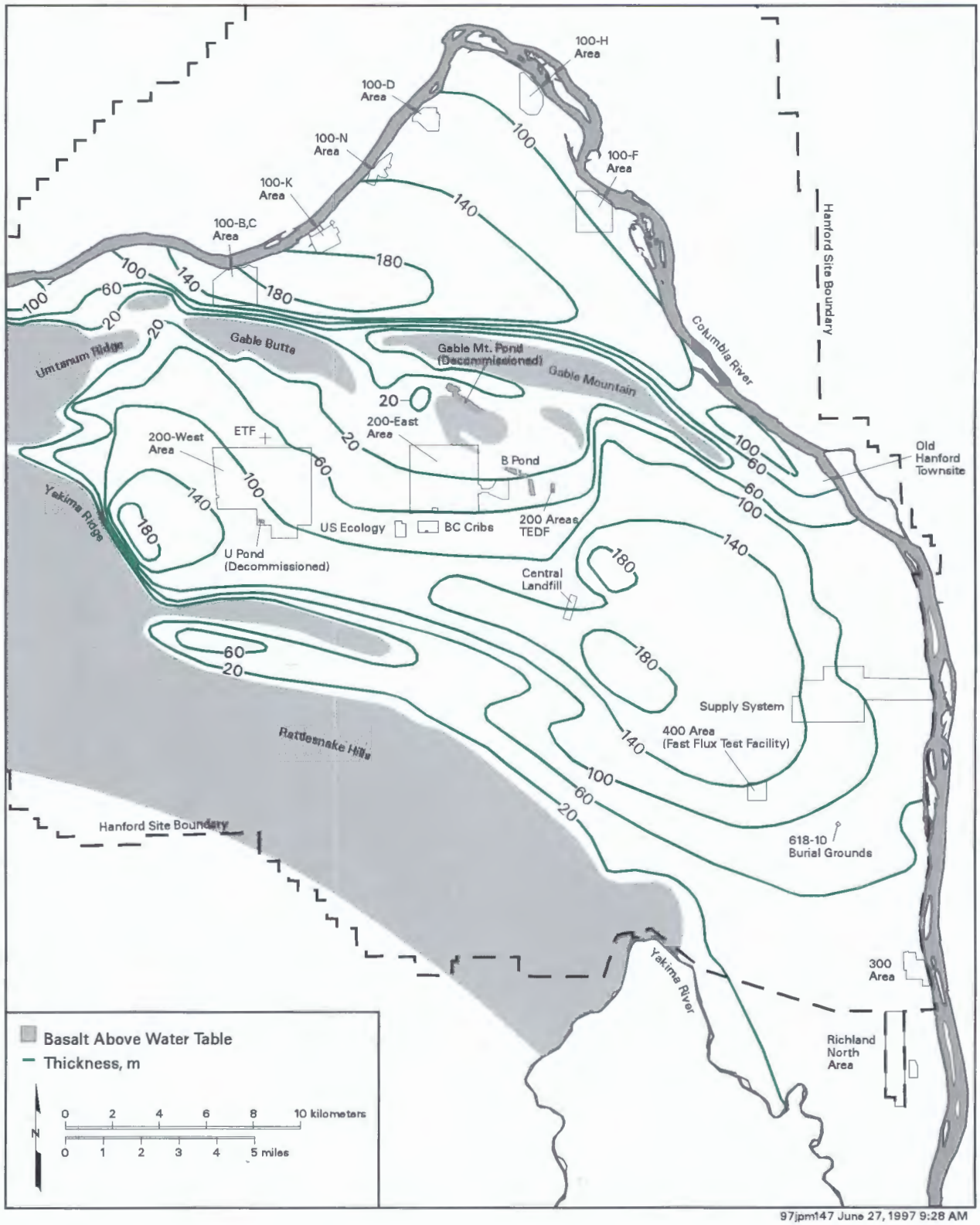

Figure 4.8.4. Saturated Thickness of the Unconfined Aquifer at the Hanford Site

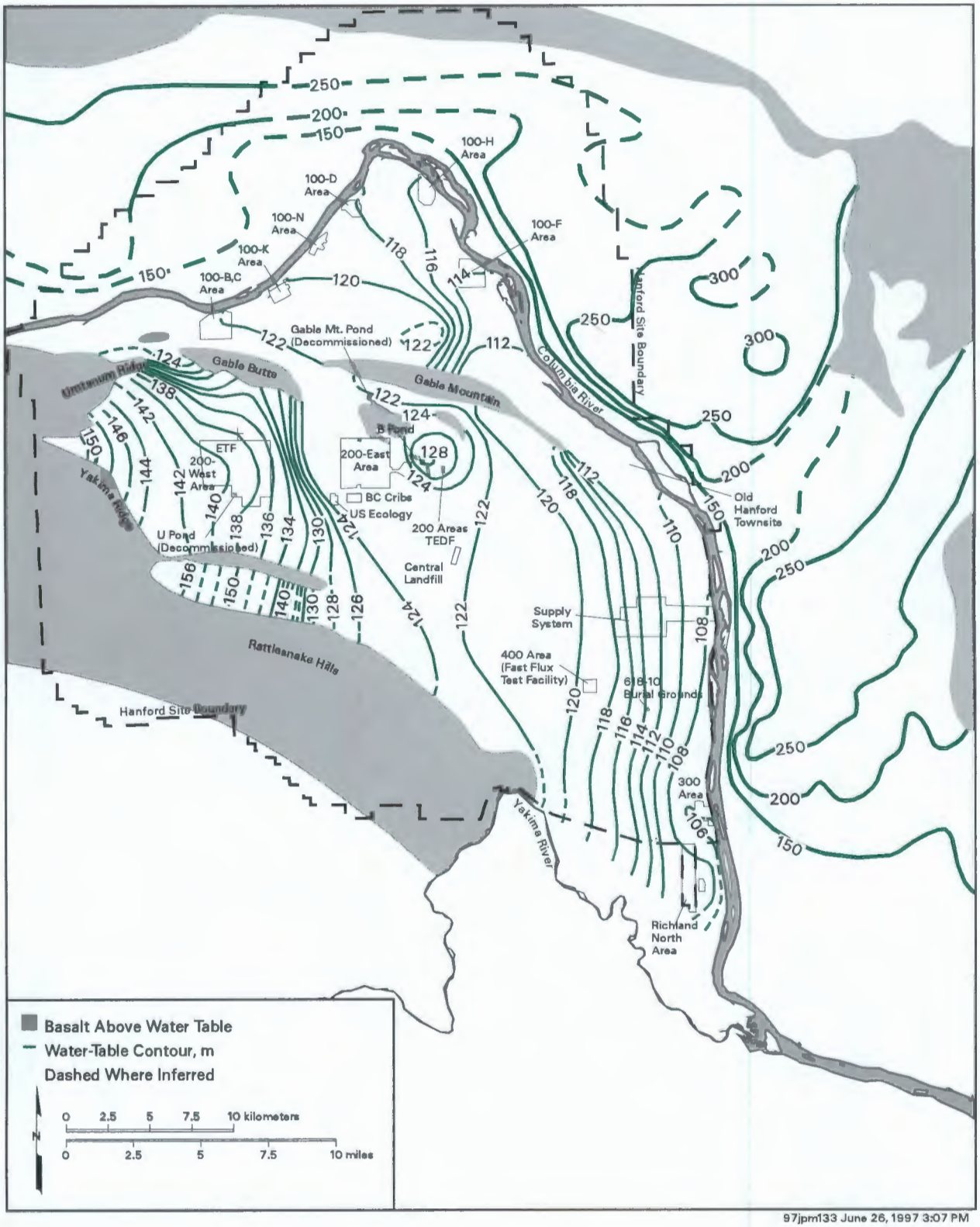

Figure 4.8.5. Water-Table Elevations for the Unconfined Aquifer at the Hanford Site and in Adjacent Areas East and North of the Columbia River, June 1996

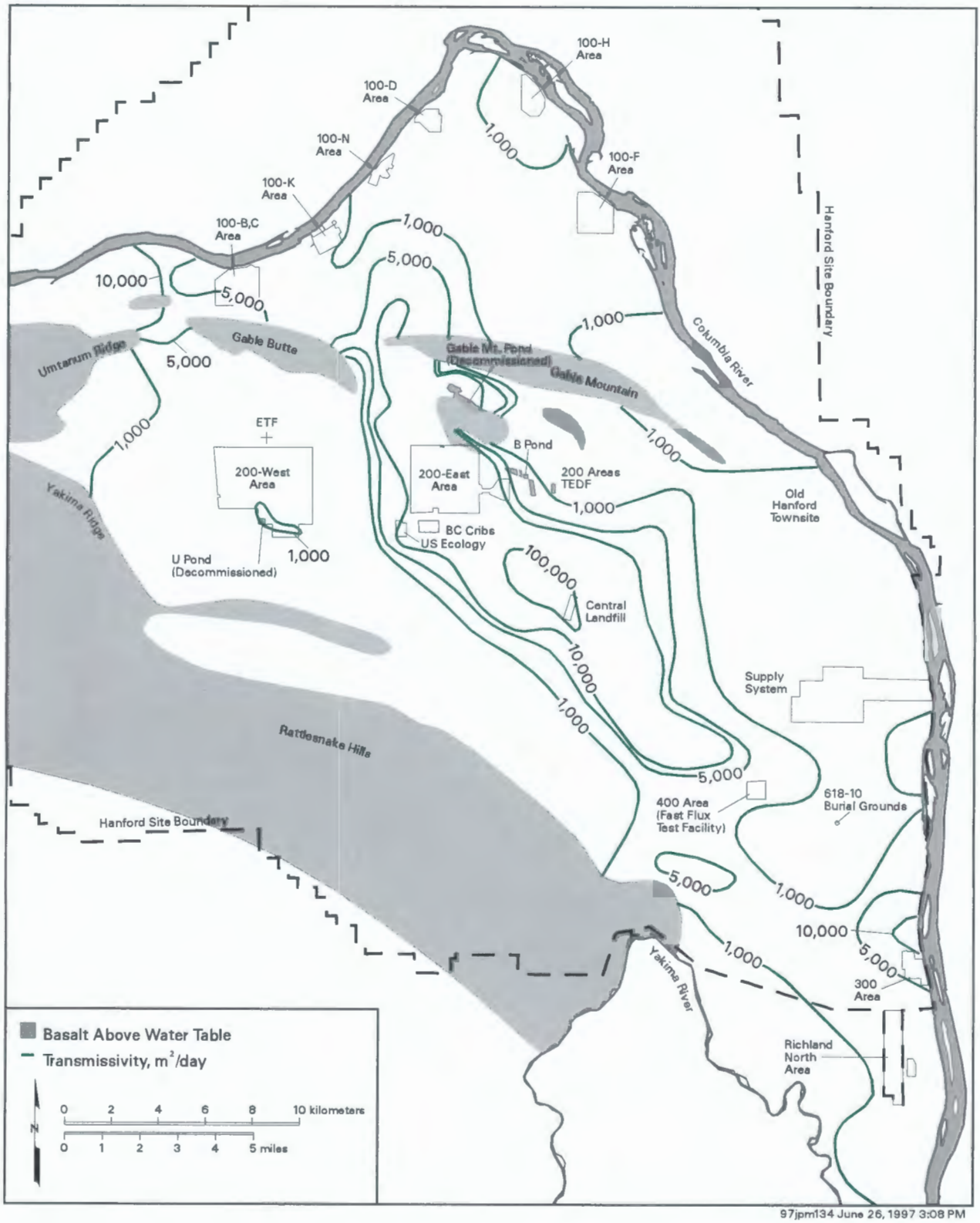

Figure 4.8.6. Distribution of Transmissivity of the Unconfined Aquifer at the Hanford Site

Fayer and Walters 1995), and ranges from near zero, where fine-grained soils and deep-rooted vegetation are present, to >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 groundwater mounds. Figure 4.8.7 shows the change in water-table elevations between 1944 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 1996 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 groundwater 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 (164 to 492 ft) higher than the water-table elevation on the Hanford Site.

Two major groundwater mounds formed in the vicinity of the 200-East and 200-West 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 by a maximum of approximately 9 m (29 ft) before 1990 (Newcomer 1990) and has decreased slightly over the last 5 years because of reduced discharge. These mounds have altered the unconfined aquifer's natural flow pattern, which is generally from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east and north. Water levels in the unconfined aquifer have continually changed as a result of variations in the volume and location of waste-water discharge. Consequently, the movement of groundwater and its associated constituents has also changed with time. Groundwater mounding has also occurred in some of the 100 and 300 Areas. Groundwater mounding in these areas is not as great as in the 200 Areas because of lower discharge volumes.

In the 100 and 300 Areas and other locations near the Columbia River, groundwater levels are influenced by river stage. Water levels in the Columbia River fluctuate on annual and daily cycles. The river level is primarily 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 than the river water actually travels (up to 1.6 km [1 mi] in places).

Contaminant Transport

The history of contaminant releases and the physical and chemical principles of mass transport control the distribution of radionuclides and chemicals in groundwater. Processes that control the movement of these contaminants at the Hanford Site are discussed below.

Most of the groundwater contamination at Hanford resulted from discharge of waste water from reactor operations, reactor fuel fabrication, and processing of spent reactor fuel. Table 4.8.1 lists the major contaminants found in each area and the type of operation that generated them. 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 waste water from fuel reprocessing were discharged. Other contamination sources in the 200 Areas include plutonium purification waste and decontamination waste. The plutonium purification process resulted in the discharge of large amounts of chemicals in a liquid organic chemical form in addition to aqueous solutions. In particular, carbon tetrachloride was discharged in the 200-West Area in a nonaqueous liquid form. This organic liquid, once in contact with groundwater, slowly dissolves and produces groundwater contaminant plumes. The presence of nonaqueous liquid has a major impact on the site's groundwater remediation strategy because the organic liquid in the subsurface represents a continuing source of groundwater contamination but is very difficult to clean up. Groundwater contamination in the 300 Area resulted mainly from discharge of fuel fabrication wastes. Historically, the discharge of large volumes of water during site operations had a major impact on groundwater flow

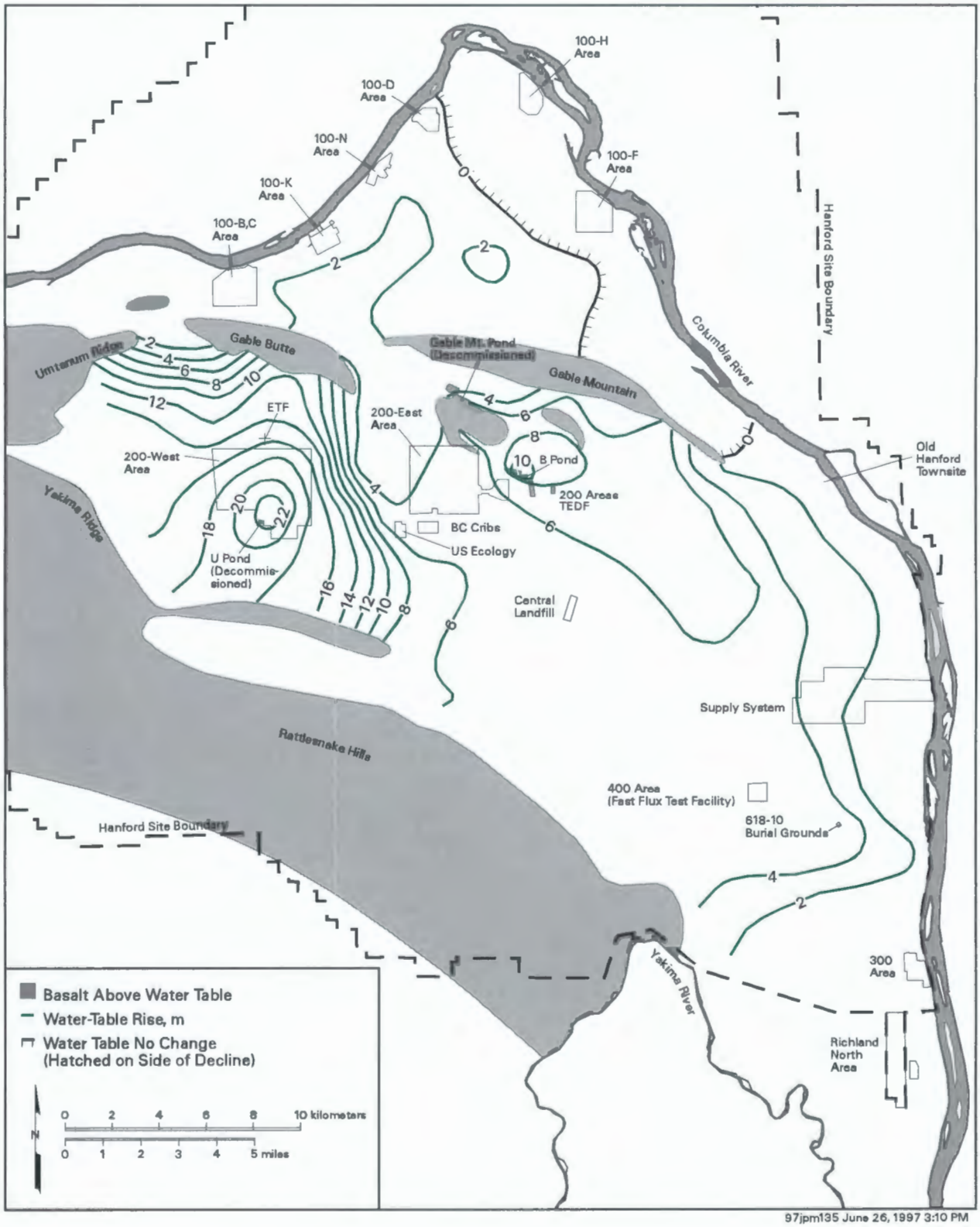

Figure 4.8.7. Change in Water-Table Elevations Between 1944 and 1979

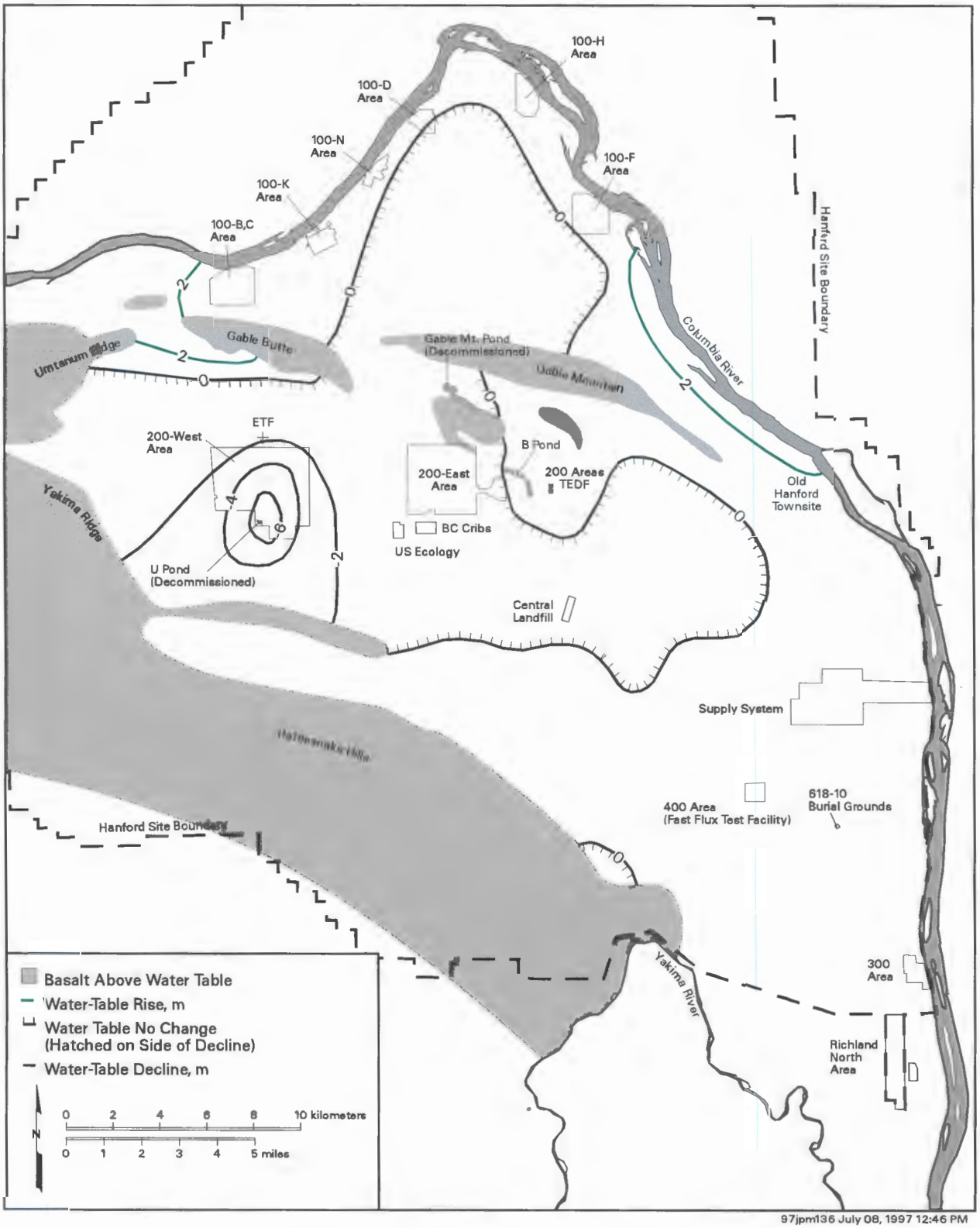

Figure 4.8.8. Change in Water-Table Elevations Between 1979 and 1996

Table 4.8.1. Major Chemical and Radiological Groundwater Contaminants and Their Link to Site Operations

Facilities Type	Areas	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

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 move through the soil column and, in some cases, enter the groundwater. 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 strontium-90, cesium-137, and plutonium-239,240. However, these processes may be affected by the chemical characteristics of the waste such as high ionic strength, acidity, or presence of chemical complexants. Other radionuclides such as technetium-99, iodine-129, and tritium and chemicals 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 contaminants reach the water table, their concentrations are reduced by dilution with groundwater in the aquifer. As these constituents move with the groundwater, radionuclide and chemical concentrations are reduced further by adsorption and spreading (dispersion). Radionuclide concentrations are also reduced by radioactive decay.

Outside the source areas (i.e., liquid disposal sites) at the Hanford Site there is typically little or no downward gradient (driving force or head), so contamination tends to remain in the upper part of the aquifer. Where large volumes of water are discharged, there may be a significant vertical hydraulic gradient that tends to move contaminants downward in the aquifer. Layers of low-permeability silt and clay within the unconfined aquifer also limit the vertical movement of contaminants. Flow in the unconfined aquifer is generally toward the Columbia River, which acts as a drainage area for the groundwater flow system at Hanford. Contamination that reaches the river is further diluted by river water.

Groundwater Modeling

Numerical modeling of groundwater flow and contaminant transport at the Hanford Site is performed for several different purposes. The Groundwater Monitoring Project uses models to predict future groundwater flow conditions and to assess the potential impacts of contaminants migrating from the Hanford Site through the groundwater pathway. Models have also been used by the Environmental Restoration Contractor to provide a basis for prioritizing and optimizing environmental restoration activities. These are complex, large-scale models capable of simulating sitewide groundwater flow and contaminant transport. Simpler, smaller-scale models were used by the Environmental Restoration Contractor to support the design of site-specific groundwater remediation projects. A brief description of these modeling efforts is provided in this section. Additional details and results are presented in Hartman and Dresel (1997).

During the past several years, a three-dimensional flow and transport model has been under development by the Groundwater Monitoring Project to improve the simulation of groundwater flow and contaminant transport within the unconfined aquifer system. The model is based on the Coupled Fluid, Energy, and Solute Transport (CFEST) code (Gupta et al. 1987). The model includes nine layers above the top of basalt to represent the major hydrogeologic units within the unconfined aquifer system. Information on the initial development of the three-dimensional model is available in Wurstner et al. (1995). The first transport simulations using this new model were performed during 1996 and supported the state discharge

permitting effort for the startup of the new Effluent Treatment Facility. The model was applied to predict the migration of tritium from this facility, which is located north of the 200-West Area. The model was also used to predict the future movement of existing tritium and iodine-129 plumes originating in the southeastern part of the 200-East Area. Preliminary modeling results are presented in Hartman and Dresel (1997).

A separate modeling effort, with the objective of prioritizing and optimizing environmental restoration activities, was completed during 1996 by the Environmental Restoration Contractor. This modeling effort was initiated approximately 5 years ago to support development of the Hanford Sitewide Groundwater Remediation Strategy, which is required by the Tri-Party Agreement. Migration patterns of eight radionuclide and chemical contaminant plumes over the next 200 years were simulated using a two-layer model based on the Variably Saturated Analysis Model in 3 Dimensions with Preconditioned Conjugate Gradient Matrix Solvers (VAM3DCG) code (developed by HydroGeoLogic, Inc., Herndon, Virginia).

The Environmental Restoration Contractor also applied models based on the Micro-FEM© code (Hemker-vanElburg, Amsterdam, The Netherlands) and the FLOWPATH code (developed by Waterloo Hydrogeologic Software, Waterloo, Ontario) to design pump-and-treat operations in the 100 and 200-West Areas. These models were used to support the design of the operations and to assess performance under operating conditions. The models were also used to describe the capture and injection zones for the extraction and injection wells, respectively, and to estimate the area affected by the pump-and-treat operations at different times.

Groundwater Monitoring

Groundwater monitoring at the Hanford Site is an integral part of the *Hanford Site Ground-Water Protection Management Plan* (DOE 1995k). This plan integrates monitoring at active waste disposal facilities to comply with monitoring requirements of the Resource Conservation and Recovery Act and Washington State regulations, as well as requirements for operational monitoring around reactor and chemical processing facilities, and environmental surveillance monitoring. Pacific Northwest National Laboratory manages these monitoring efforts through the Groundwater Monitoring Project. This project is responsible for assessing the distribution and movement of existing groundwater contamination, identifying potential and emerging groundwater contamination problems, and integrating the various groundwater projects to minimize redundancy. Information on contaminant distribution and transport are integrated into a sitewide evaluation of groundwater quality, which is documented in an annual groundwater monitoring report (Hartman and Dresel 1997). Groundwater monitoring is also carried out during cleanup investigations under the Comprehensive Environmental Response, Compensation, and Liability Act as described in the five-year plan (DOE 1992d). These investigations are managed by the Environmental Restoration Contractor.

Groundwater Sampling and Analytes of Interest

Groundwater samples were collected from approximately 800 wells for all monitoring programs during 1996. The locations of sampled wells are shown in Figures 4.8.9 and 4.8.10. Well names are indicated only for wells in the 600 Area that are specifically discussed in the text. Because of the density of unconfined aquifer wells in the operational areas, well names in these areas are shown on detailed maps in the following sections. Figure 4.8.11 shows the locations of facilities where groundwater monitoring was conducted to comply with the Resource Conservation and Recovery Act (Hartman and Dresel 1997). 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.

The monitoring frequency for the wells is selected based on regulatory requirements, proximity to waste sources, and characteristics of the groundwater flow system at the sample location. Of the wells sampled, approximately 270 were sampled once, 280 twice, 100 three times, 90 four times, and 60 more frequently during the year.

Each monitoring program has access to groundwater data collected by other programs through a common database, the Hanford Environmental Information System. This database currently contains approximately 1.4 million groundwater monitoring result records. After the data are verified and/or validated, they are made available to federal and state regulators for retrieval.

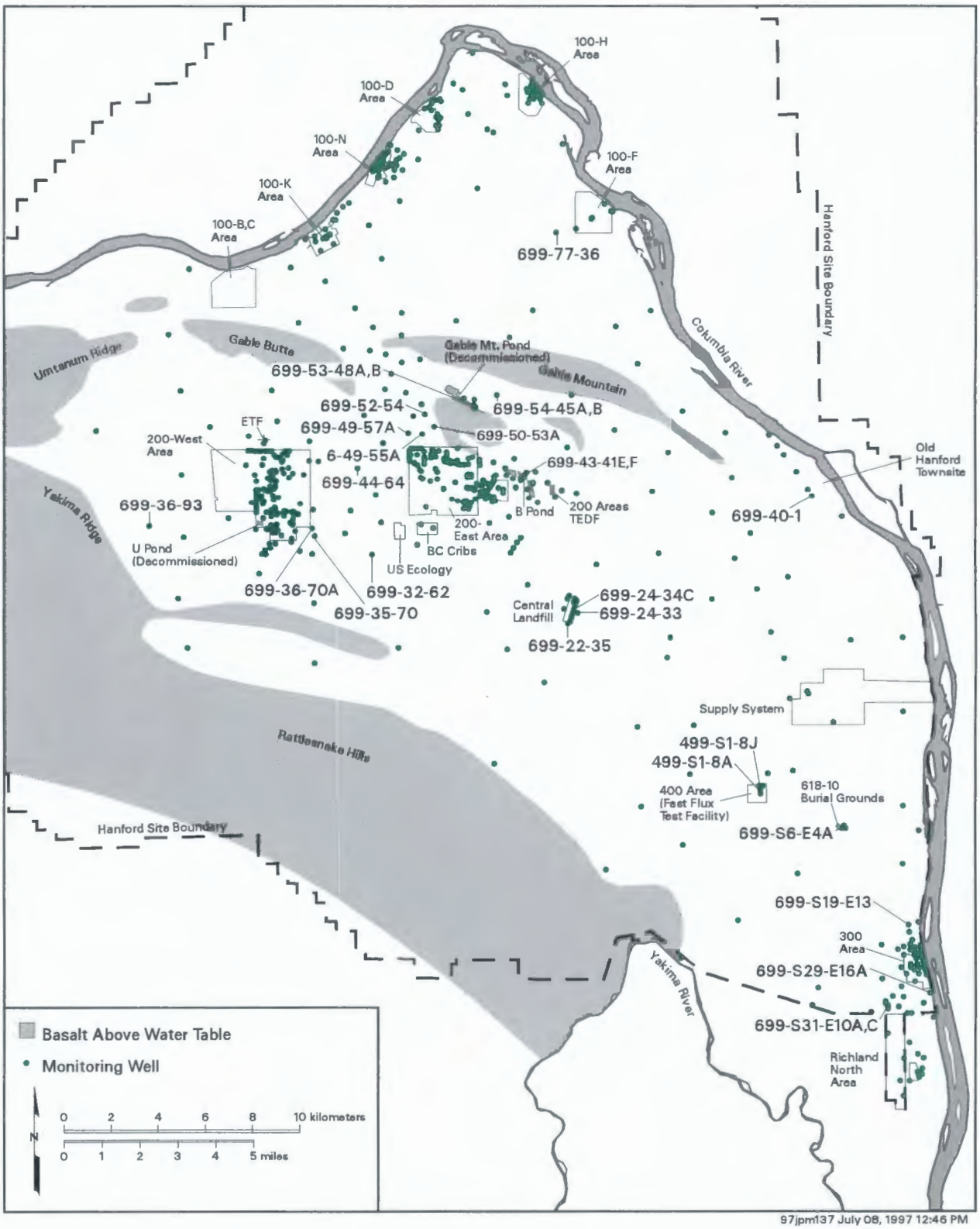

Figure 4.8.9. Hanford Site Unconfined Aquifer Monitoring Well Locations, 1996

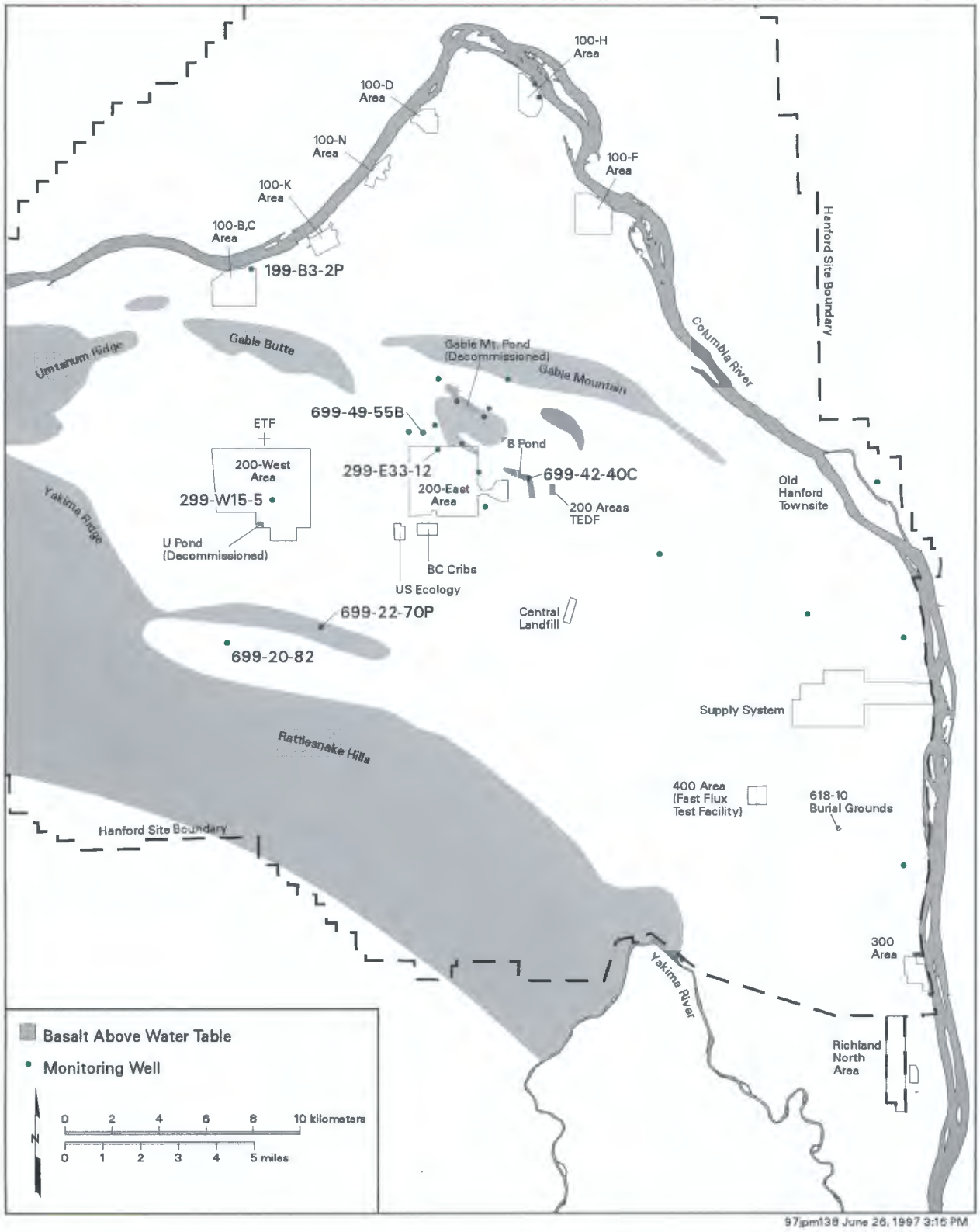

Figure 4.8.10. Hanford Site Confined Aquifer Monitoring Well Locations, 1996

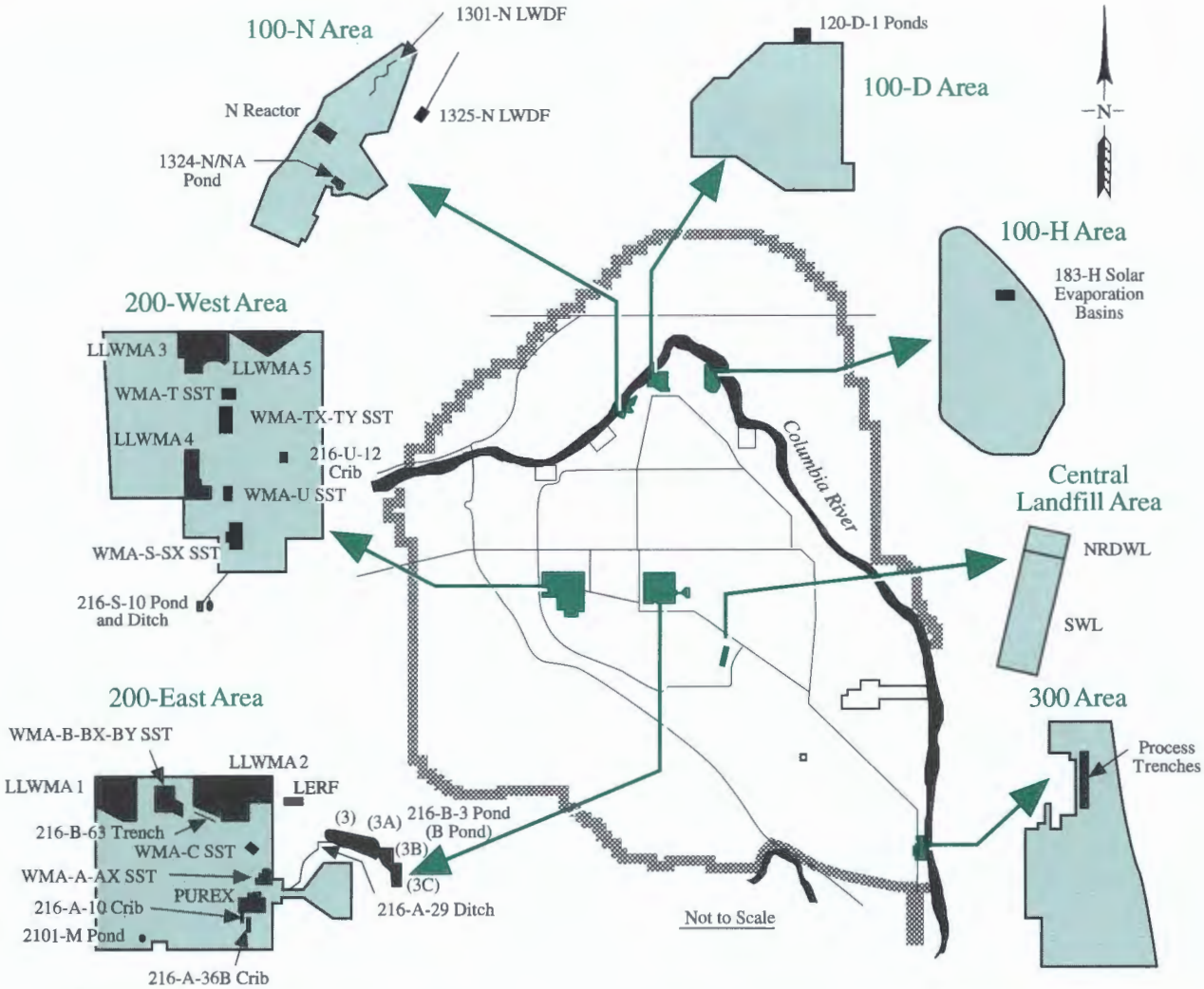

Figure 4.8.11. Locations of Resource Conservation and Recovery Act Groundwater Monitoring Projects on the Hanford Site

Most groundwater 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, though some wells are sampled with bailers or air-lift systems.

Table 4.8.2. Explanation of the Hanford Site Well Naming System

Example Well Name	Area
199-	**100 Areas**
199-B3-47	100-B,C 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 Areas**
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.

Samples were collected for all programs following documented sampling procedures (Westinghouse Hanford Company 1991a, Pacific Northwest Laboratory 1993) based on EPA guidelines (EPA 1986a). Analytical techniques used are listed in DOE (1994a), Dresel et al. (1995), and Comprehensive Environmental Response, Compensation, and Liability Act work plans. The radionuclides and chemicals analyzed are listed in Table 4.8.3. Of the parameters listed in Table 4.8.3, several were not measured during 1996 because sufficient characterization had been obtained by past analyses.

Most groundwater samples collected onsite in 1996 were analyzed for tritium. Selected samples were analyzed for other radionuclides. Sample results for radionuclides are generally presented in picocuries per liter (pCi/L). However, the results for total uranium, which is usually measured by laser fluorescence, are given in micrograms per liter (µg/L). The results for analyses of individual uranium isotopes are reported in picocuries per liter.

Nitrate analyses were performed on many samples collected during 1996 because of the extensive areas with elevated nitrate concentrations originating from onsite and offsite sources. However, nitrate concentrations were below the EPA drinking water standard (40 CFR 141) for most of the affected area. Selected monitoring wells were used for additional chemical surveillance. The results of previous chemical analyses and the proximity to known active and inactive chemical disposal sites were considered in choosing wells for sampling for chemical contaminants.

Data Interpretation

Each analysis of a groundwater sample provides information on the composition of groundwater 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.

Groundwater 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 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 that indicates the review has occurred and the datum may be suspect.

Table 4.8.3. Radionuclides and Chemicals Analyzed for in Groundwater

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
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

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 that is reported with the analytical result. Generally, a sample result less than the counting error indicates 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 Groundwater Monitoring Project and other programs participate in interlaboratory comparisons in which many laboratories analyze blind samples prepared by the EPA (Section 7.0, "Quality Assurance").

In 1996, double-blind samples for specific constituents were analyzed as part of the Groundwater Monitoring Project (Section 7.0, "Quality Assurance," discusses double-blind results). Several wells were also cosampled with the Washington State Department of Health for comparison. Results of the comparison sampling are available from the Washington State Department of Health.

The chemical composition of groundwater may fluctuate from differences in the contaminant source, recharge, or the groundwater 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 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 groundwater 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, groundwater flow, site geology, and other available information are factored into their preparation.

Groundwater Monitoring Results

The following sections summarize the distribution of radioactive and chemical contaminants detected in Hanford Site groundwater during 1996. These discussions are followed by a summary of groundwater monitoring results for Resource Conservation and Recovery Act sites. More detailed information on groundwater monitoring, including listings of analysis results for each monitoring well in electronic format, is available in *Hanford Site Groundwater Monitoring for Fiscal Year 1996* (Hartman and Dresel 1997). However, because the annual groundwater report covers the fiscal year, it does not include results from the last three months of 1996.

One way to assess the impact of radionuclides and chemicals in groundwater is to compare the concentrations to EPA's drinking water standards and DOE's derived concentration guides (40 CFR 141 and WAC 246-290; see 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 the physiological factors such as the buildup of the isotope in particular organs. Drinking water standards are more restrictive than derived concentration guides. This is because the standards are based on an annual dose to the affected organ of 4 mrem/yr, while the guides are based on an effective dose equivalent of 100 mrem/yr (see Appendix C, Tables C.2 and C.5). In addition, the standards use older factors for calculating the concentrations that would produce a 4-mrem/yr dose than are used in calculating the guides. Thus, the values used below for standards are not always in agreement with the guides. The guides are available only for radionuclides. Primary and secondary drinking water standards are given for some chemical constituents; secondary standards are based on aesthetic rather than health considerations.

Radiological Monitoring Results for the Unconfined Aquifer

The radionuclides analyzed for in Hanford Site groundwater were listed in Table 4.8.3. The distribution of tritium, iodine-129, strontium-90, technetium-99, uranium, cobalt-60, cesium-137, plutonium, and antimony-125 are discussed in the following sections. Iodine-131, ruthenium-103, and ruthenium-106 are also analyzed for but have relatively short half-lives. These radionuclides have not been observed in concentrations above the drinking water standards and have rarely been detected since soon after the shutdown of N Reactor and the Plutonium-Uranium Extraction Plant. 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 individually. Several other radionuclides are associated with wastes from Hanford operations. Because of their very low concentrations in groundwater, they are not discussed in this section.

Tritium

Tritium was present in many historical waste streams at Hanford and is highly mobile, essentially moving at the same velocity as the groundwater. As a result, the extent of groundwater contamination from site operations is generally reflected by tritium distribution. Tritium is the radionuclide most frequently monitored at the Hanford Site for this reason. Tritium is present in irradiated nuclear fuel and was released in process condensates associated with decladding and dissolution of the fuel. Tritium was

also manufactured as part of the Hanford mission by irradiating targets containing lithium in several reactors from 1949 to 1952 (DOE 1992c, Gerber 1993). In the late 1960s, tritium production took place in N Reactor (Gerber 1992). Figure 4.8.12 shows the 1996 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,C, 100-D, 100-F, 100-K, and 100-N Areas.

One sample from the 100-B,C Area (well 199-B5-2) contained a maximum of 27,000 pCi/L of tritium during 1996, slightly above the drinking water standard. Although this well has shown an increasing trend in tritium concentration, the maximum 1996 value was the same as that observed during 1995, and upgradient wells 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 during 1996 was 37,800 pCi/L in monitoring well 199-D2-6.

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) in 1995. This well was not analyzed for tritium in 1996, and no other wells in this area showed a concentration higher than the standard.

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 576,000 pCi/L reported in 1996. Previously, in April and May 1993, this well contained tritium in excess of the 2,000,000-pCi/L derived concentration guide. The tritium trend for well 199-K-30 is shown in Figure 4.8.13 and has been declining since mid-1995. The probable 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 carbon-14, strontium-90, and antimony-125 suggests that the primary source of tritium is not leakage of the K-East Reactor fuel storage basin. However, basin leakage is implicated in contamination found in well 199-K-27, located just north of the K-East Reactor. Tritium concentrations in monitoring well 199-K-27 continue to decline but remained well above the drinking water standard (maximum of 66,000 pCi/L) in 1996. Well 199-K-106A was installed in 1994 adjacent to a french drain near the K-West Reactor. Samples from this well revealed high tritium concentrations from basin leakage or from a related sump overflow discharge system leading to the french drain. The maximum concentration of tritium detected in well 199-K-106A in 1996 was 499,000 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 the 1301-N and 1325-N Liquid Waste Disposal Facilities. The maximum tritium level reported in the 100-N Area in 1996 was 61,900 pCi/L in well 199-N-76, located between the 1301-N Liquid Waste Disposal Facility and the Columbia River.

Tritium in the 200, 400, and 600 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 derived concentration guide were detected in only one well (299-E17-9) in 1996 in the 200-East Area. The maximum tritium level detected in this well, which monitors the 216-A-36B Crib, was 2,940,000 pCi/L. This was the highest tritium concentration detected in any well onsite. The tritium concentration in this well is 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 derived concentration guide in 1993 and remained below the guide in 1996. Tritium concentrations are generally decreasing in wells near the Plutonium-Uranium Extraction Plant cribs.

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 1996, Hartman and Dresel 1997). Separate tritium pulses associated with the two episodes of Plutonium-Uranium Extraction Plant operations can be distinguished in the plume. High tritium concentrations east of the 200-East Area near the Columbia River result from 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 second plume is clearly observable in well 699-24-33 (Figure 4.8.15), which shows arrival of the plume in early 1987. Tritium concentrations from the first plume were much higher than from the second. Concentrations of tritium detected in 1996 in this plume

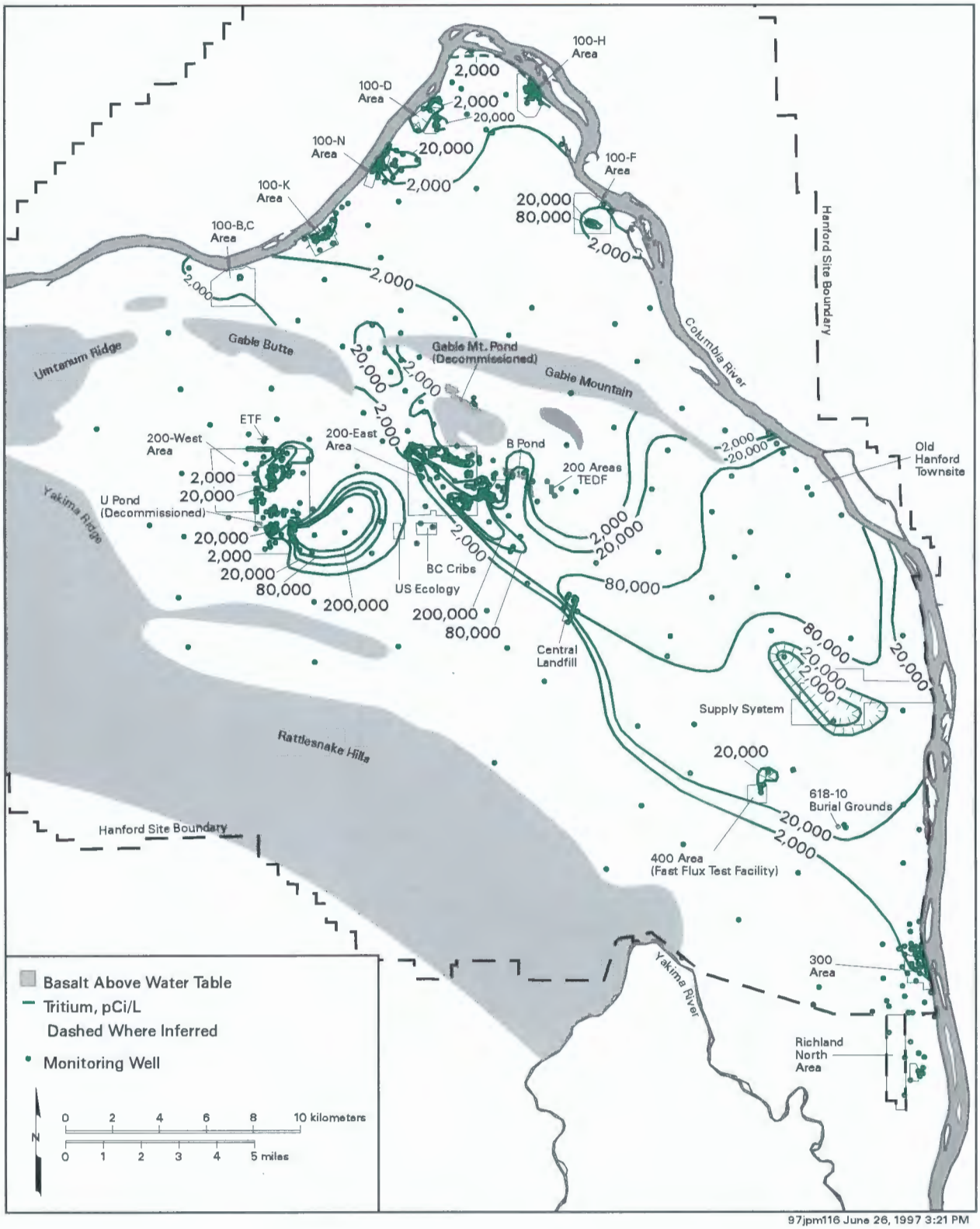

Figure 4.8.12. Distribution of Tritium in the Unconfined Aquifer, 1996

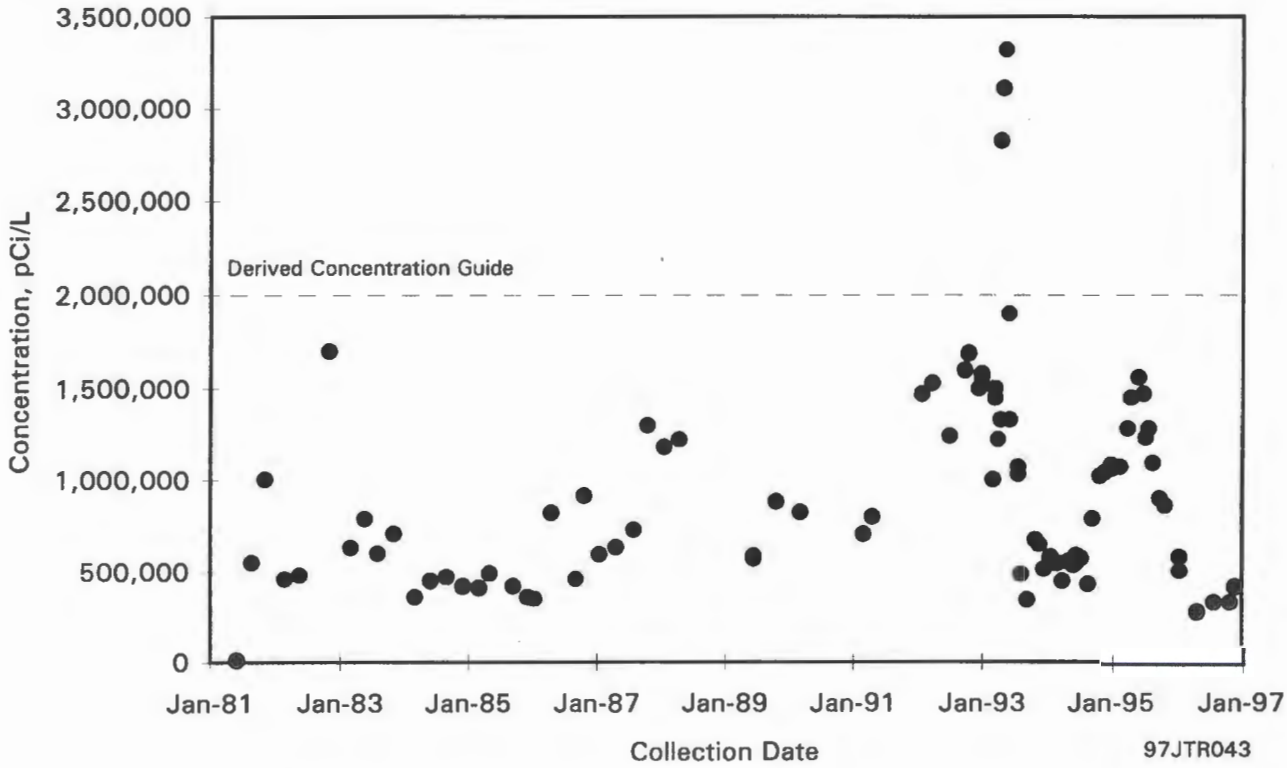

Figure 4.8.13. Tritium Concentrations in Well 199-K-30, 1981 Through 1996

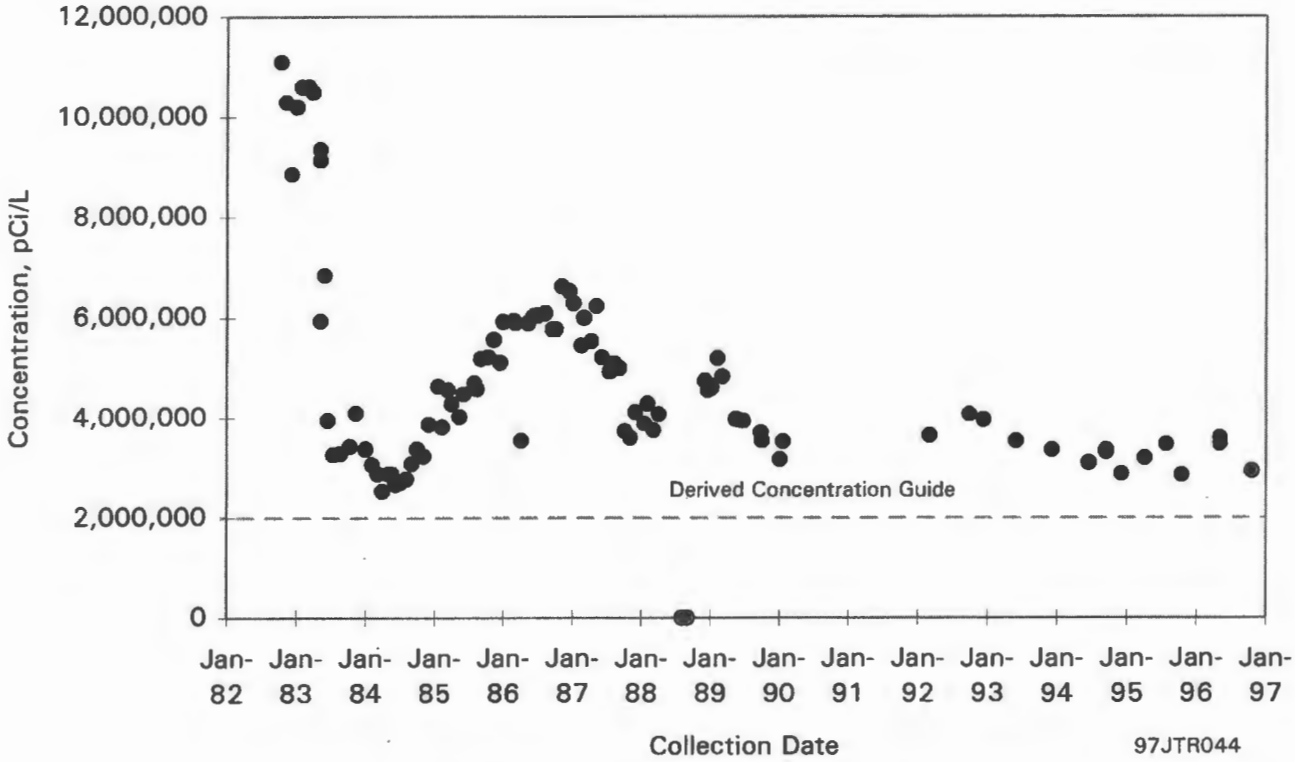

Figure 4.8.14. Tritium Concentrations in Well 299-E17-9, 1982 Through 1996

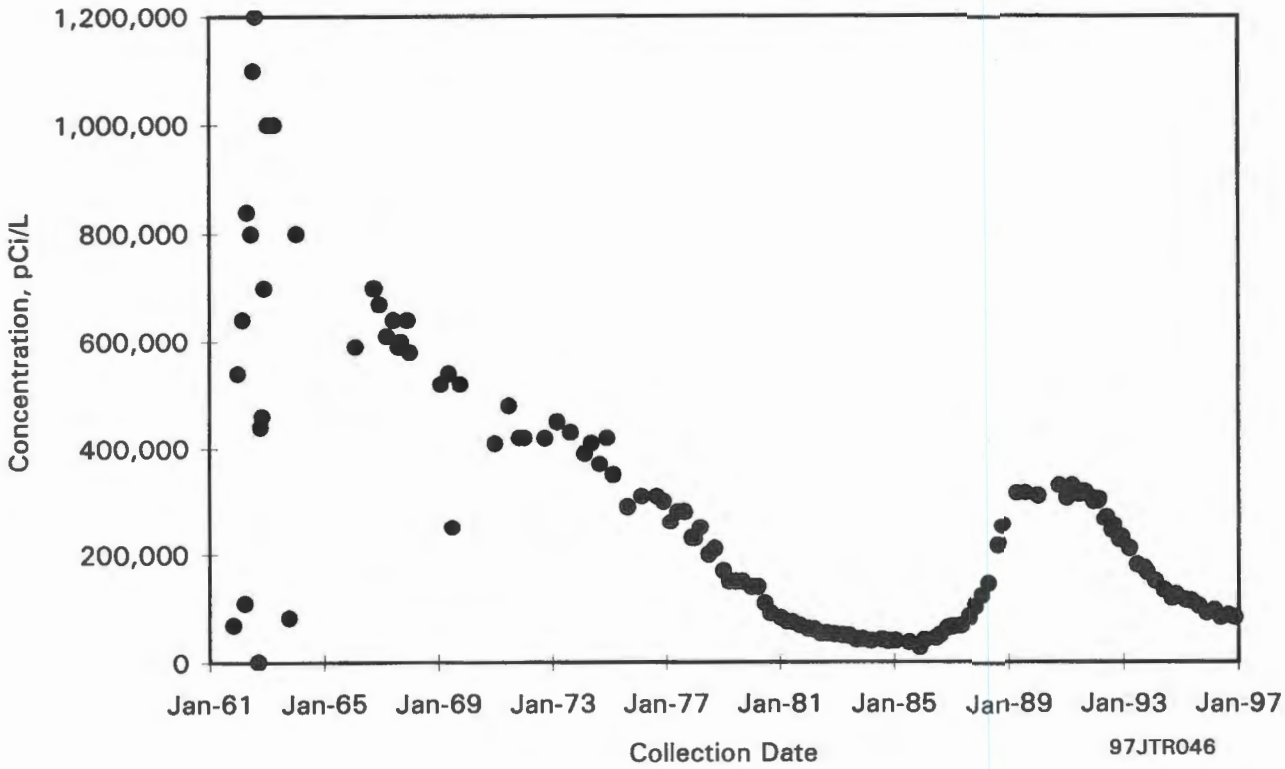

Figure 4.8.15. Tritium Concentrations in Well 699-24-33, 1961 Through 1996

were generally lower than in previous years as a result of dissipation and radioactive decay. Thus, the area of contaminated groundwater downgradient of the Plutonium-Uranium Extraction Plant, with tritium concentrations above 200,000 pCi/L in 1996, 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 (Figure 4.8.16) of the tritium concentrations in well 699-40-1, 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 tritium plume has been monitored since the 1960s and provides information on the extent of groundwater contamination over time. Figure 4.8.17 shows the distribution 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 among 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. This well, which has shown an increase in tritium since 1985, decreased from 13,300 pCi/L in November 1995 to a maximum 1996 value of 11,700 pCi/L. The tritium plume extends into the 300 Area, where concentrations in some wells (e.g., well 399-1-18A) are greater than half the drinking water standard. Figure 4.8.19 shows a trend plot for well 399-1-17A, which has also displayed elevated levels of tritium. The increase in tritium at this well resulted from the termination of discharge to the 300 Area process trenches, which allowed the regional tritium plume to migrate to this well. A single sample from well 699-S29-E16A, located south of the 300 Area, showed a tritium concentration of 2,030 pCi/L in 1996, up from 65 pCi/L in 1995. The cause of this apparent increase is unknown and will be evaluated after verification by subsequent sampling. Laboratory error is suspected. The tritium plume is not expected to impact the

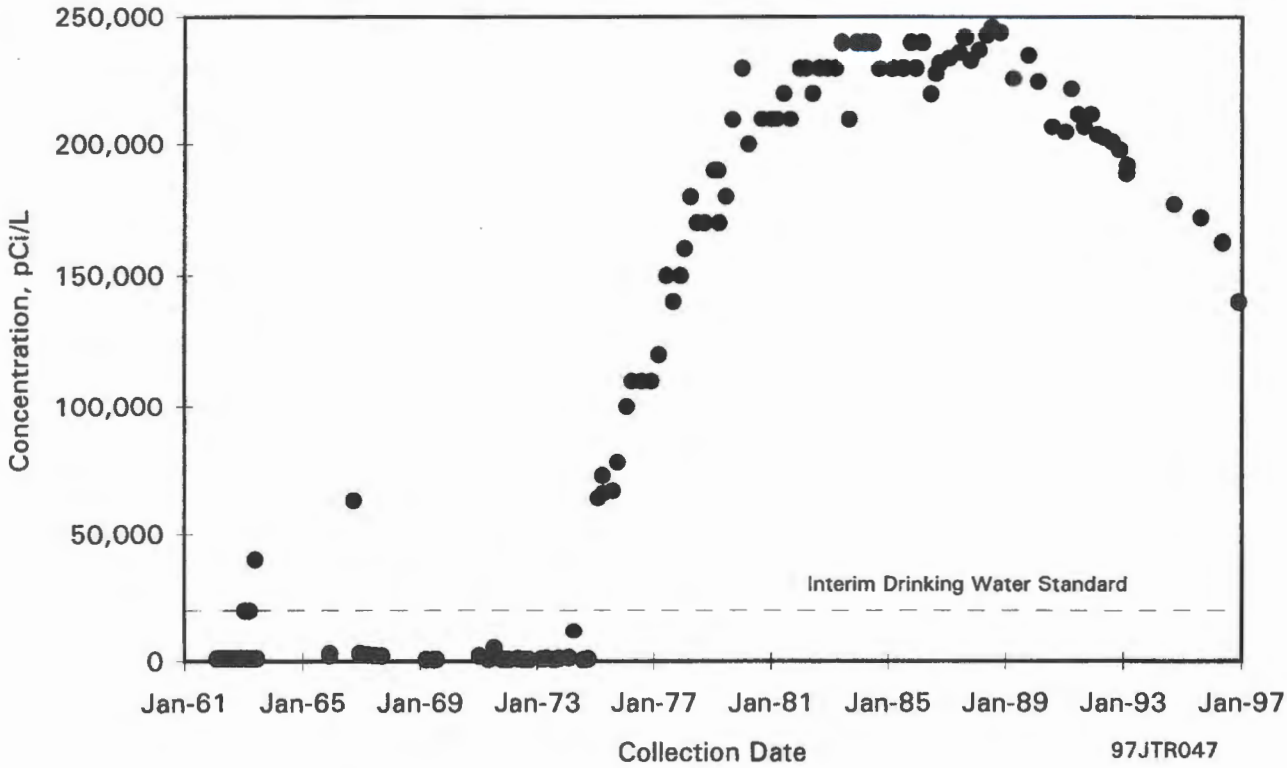

Figure 4.8.16. Tritium Concentrations in Well 699-40-1, 1962 Through 1996

north Richland well field because of the influence on groundwater flow from the Yakima River and recharge from infiltration ponds at the well field (Figure 4.8.20). The Yakima River is at a higher elevation and recharges the groundwater in this area (Newcomer et al. 1991). As a result, groundwater flows from west to east (see Figure 4.8.20), minimizing the southward movement of the contaminant plume. Recharge ponds at the north Richland well field are supplied with Columbia River water, which infiltrates to the groundwater. The amount of recharge water exceeds the amount pumped at the well field by a factor of approximately 2:1, resulting in groundwater flow away from the well field. This further ensures that tritium-contaminated groundwater will not reach the well field. Ongoing monitoring is performed 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 groundwater 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 near B Pond, which produces a spreading area of essentially uncontaminated water. The mound under B Pond is expected to dissipate as flow is diverted to the 200 Areas Treated Effluent Disposal Facility. A new mound will presumably form farther east, under this facility, as long as it is used for disposal of site effluent.

The tritium plume that originated in the 200-East Area extends under the 400 Area. The maximum concentration observed in this area during 1996 was 38,000 pCi/L at well 499-S1-8A. The primary water supply well for the 400 Area (499-S1-8J) is completed in the lower part of the aquifer and had a maximum tritium concentration of 6,800 pCi/L during 1996. Concentrations at wells used for backup water supply were near or slightly above the 20,000-pCi/L drinking water standard. Additional information on the 400 Area water supply is provided in Section 4.3, "Hanford Site Drinking Water Surveillance."

Tritium is also found at levels above the drinking water standard in the northwestern part of the 200-East Area.

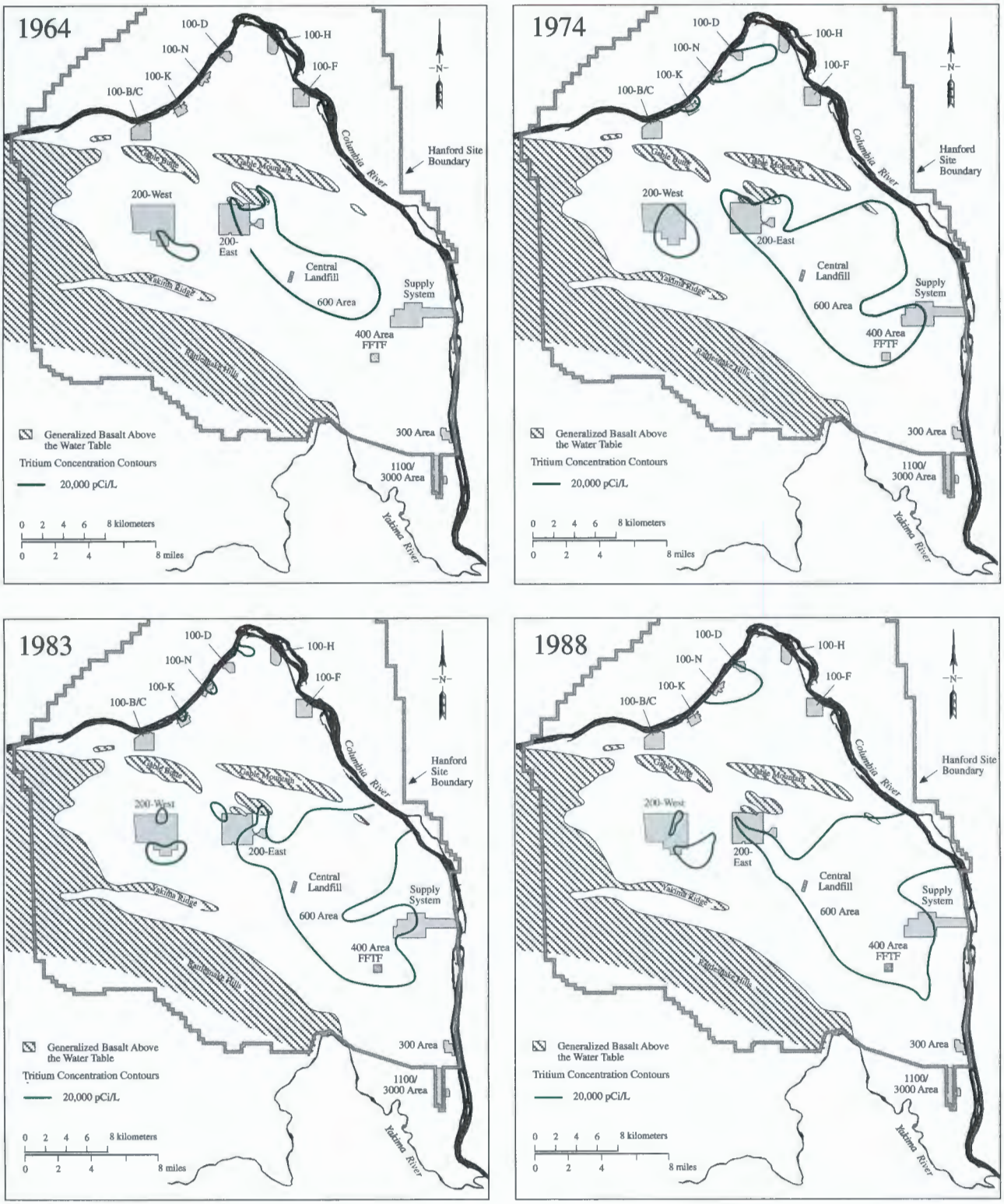

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Figure 4.8.17. Historical Tritium Concentrations on the Hanford Site

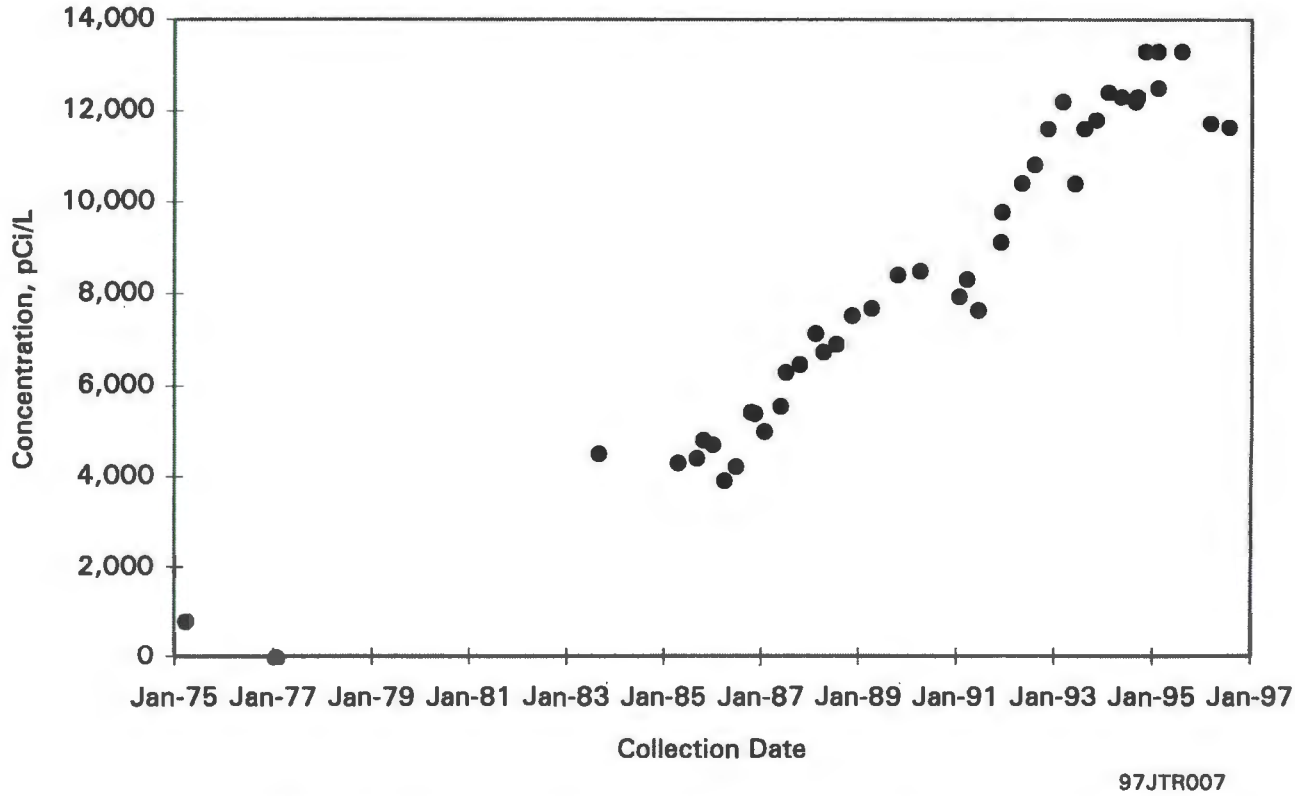

Figure 4.8.18. Tritium Concentrations in Well 699-S19-E13, 1975 Through 1996

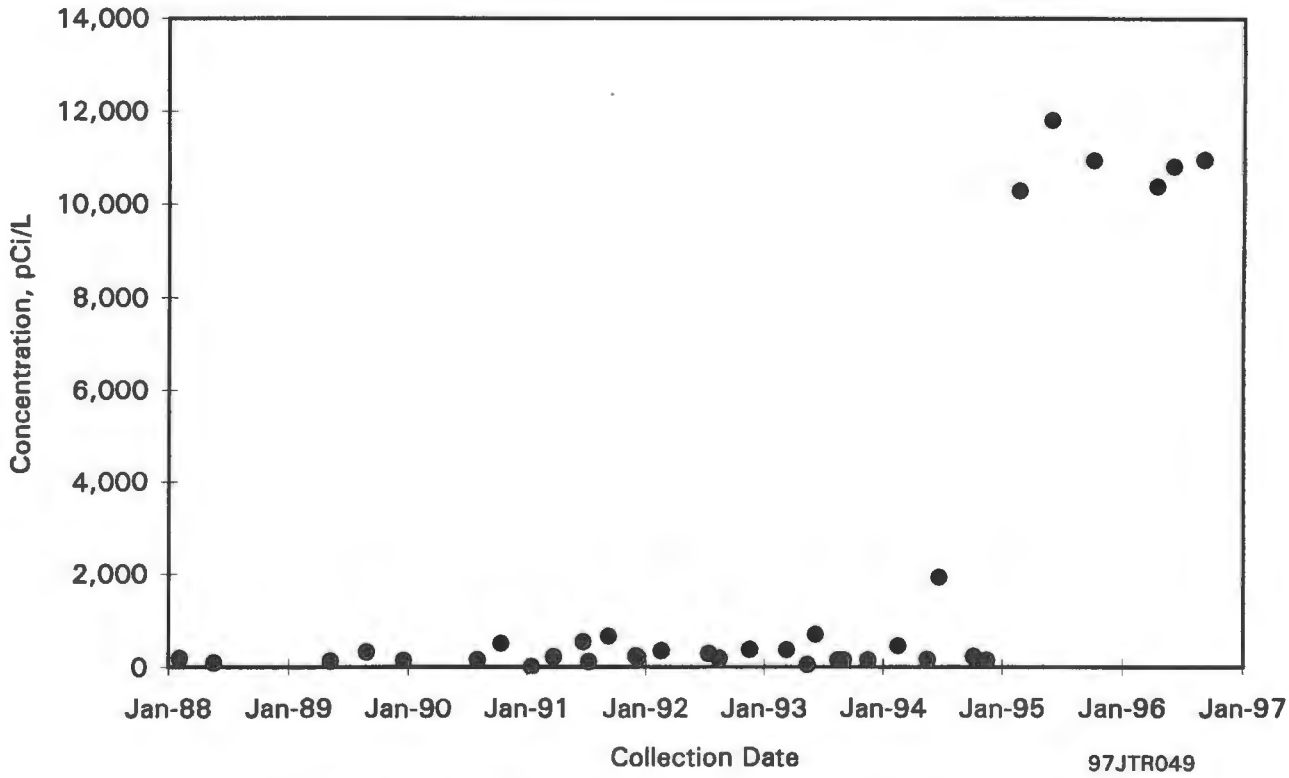

Figure 4.8.19. Tritium Concentrations in Well 399-1-17A, 1986 Through 1996

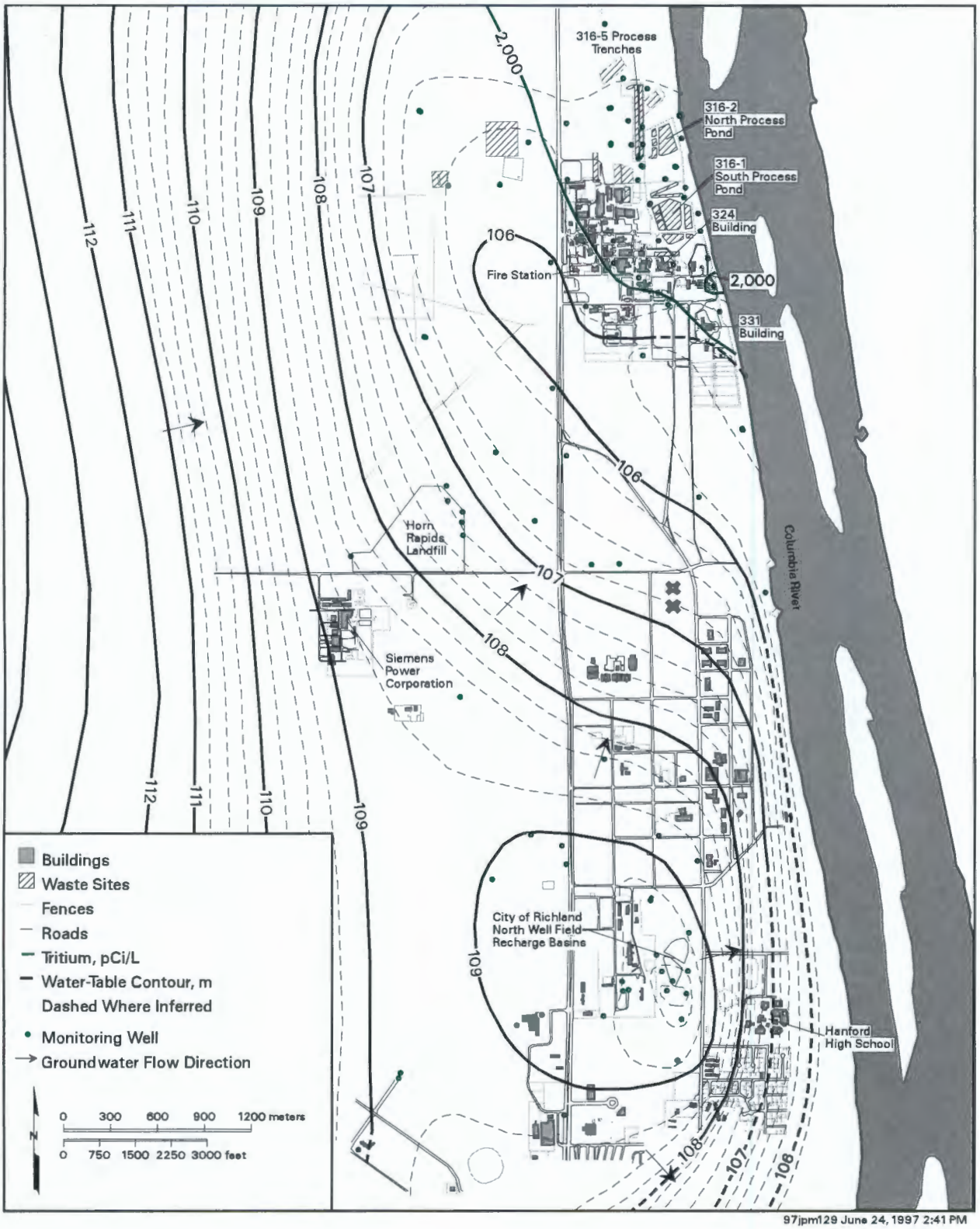

Figure 4.8.20. Tritium Distribution and Groundwater Flow Near the 300 Area, 1996

This plume appears to extend to the north through the gap between Gable Mountain and Gable Butte, indicating a divide in groundwater 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 derived concentration guide during 1996. Samples from the well in the 200-West Area with the highest tritium concentrations (well 299-W22-9) contained a maximum of 1,290,000 pCi/L of tritium. The declining concentrations in this well are shown in Figure 4.8.21. The movement of groundwater in the 200-West Area is slow because Ringold Formation sediments have low permeability. Movement 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 TX-TY single-shell high-level waste tanks (see 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.

Iodine-129

The presence of iodine-129 in groundwater 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 yr). The relatively low fission yield for production of iodine-129 combined with its long half-life limits its specific activity in Hanford wastes. Iodine-129 may be released as a vapor during fuel dissolution and other elevated-temperature processes and, thus, may be associated with process condensate wastes. At Hanford, the main contributor of iodine-129 to groundwater has been liquid discharges to cribs in the 200 Areas. Iodine-129 has essentially the same high mobility in groundwater as tritium and nitrate. The highest concentrations observed

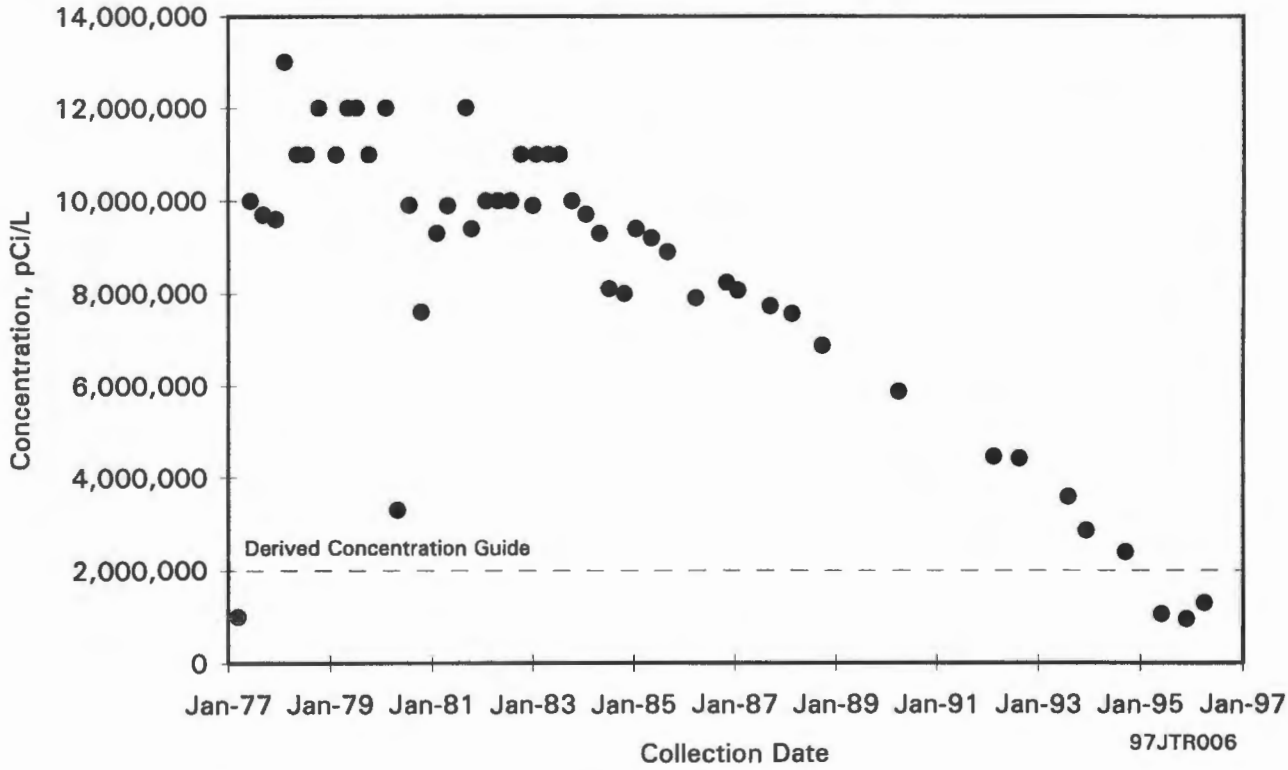

Figure 4.8.21. Tritium Concentrations in Well 299-W22-9, 1977 Through 1996

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 500-pCi/L derived concentration guide in 1996.

The highest iodine-129 concentrations in the 200-East Area are in the northwest near the BY Cribs and in the southeast near the Plutonium-Uranium Extraction Plant. The maximum concentration of iodine-129 detected in 1996 in the 200-East Area was 13.6 pCi/L in well 299-E17-14. This well is located south of the Plutonium-Uranium Extraction Plant near the 216-A-36B 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 contamination 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 (see 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 groundwater at levels above the drinking water standard in the northwestern 200-East Area near the BY Cribs and the B-BX-BY single-shell high-level waste tanks. This plume extends northwest into the gap between Gable Mountain and Gable Butte.

The highest iodine-129 concentration observed in 1996 in Hanford groundwater was 56.9 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, though there appears to be a contribution from cribs to the north near U Plant. A second iodine-129 plume originates near the T single-shell tank farm and nearby disposal facilities and extends northeast toward T Plant, coincident with the technetium-99 and tritium plumes in this area.

Strontium-90

Strontium-90 was produced as a high-yield fission product and was present in waste streams associated with fuel reprocessing. Reactor operations also resulted in the release of some strontium-90 associated with fuel element breaches. Strontium-90 mobility in Hanford groundwater is reduced by adsorption onto sediment particles. Because this adsorption is much weaker than for cobalt-60, cesium-137, 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 groundwater concentrations of strontium-90 decrease as a result of natural processes or remediation activities, the sorbed strontium-90 will desorb and remobilize. This limits the options for groundwater remediation.

Concentrations of strontium-90 greater than the 8-pCi/L drinking water standard were found in one or more wells in each of the following areas: 100-B, 100-D, 100-F, 100-H, 100-K, 100-N, 200, and 600 Areas. Concentrations of strontium-90 were greater than the 1,000-pCi/L 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 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 the 100-B Area in 1996 was 33.5 pCi/L at 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 B Reactor and liquid overflow trenches near the Columbia River (DOE 1993b). The extent of strontium-90 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 near D Reactor. The maximum concentration in 1996 was 25.7 pCi/L, down from 38.7 in 1995. This is the only well in the 100-D Area with strontium-90 concentrations greater than the drinking water standard.

Groundwater within a small part of the 100-F Area has strontium-90 concentrations greater than the drinking water standard. The maximum concentration detected in 1996 was 282 pCi/L in monitoring well 199-F5-3. This is more than twice the concentration of 136 pCi/L measured at this well in 1995. 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 1996 was 39 pCi/L at monitoring well 199-H4-63. This is slightly higher than the maximum level detected in 1995.

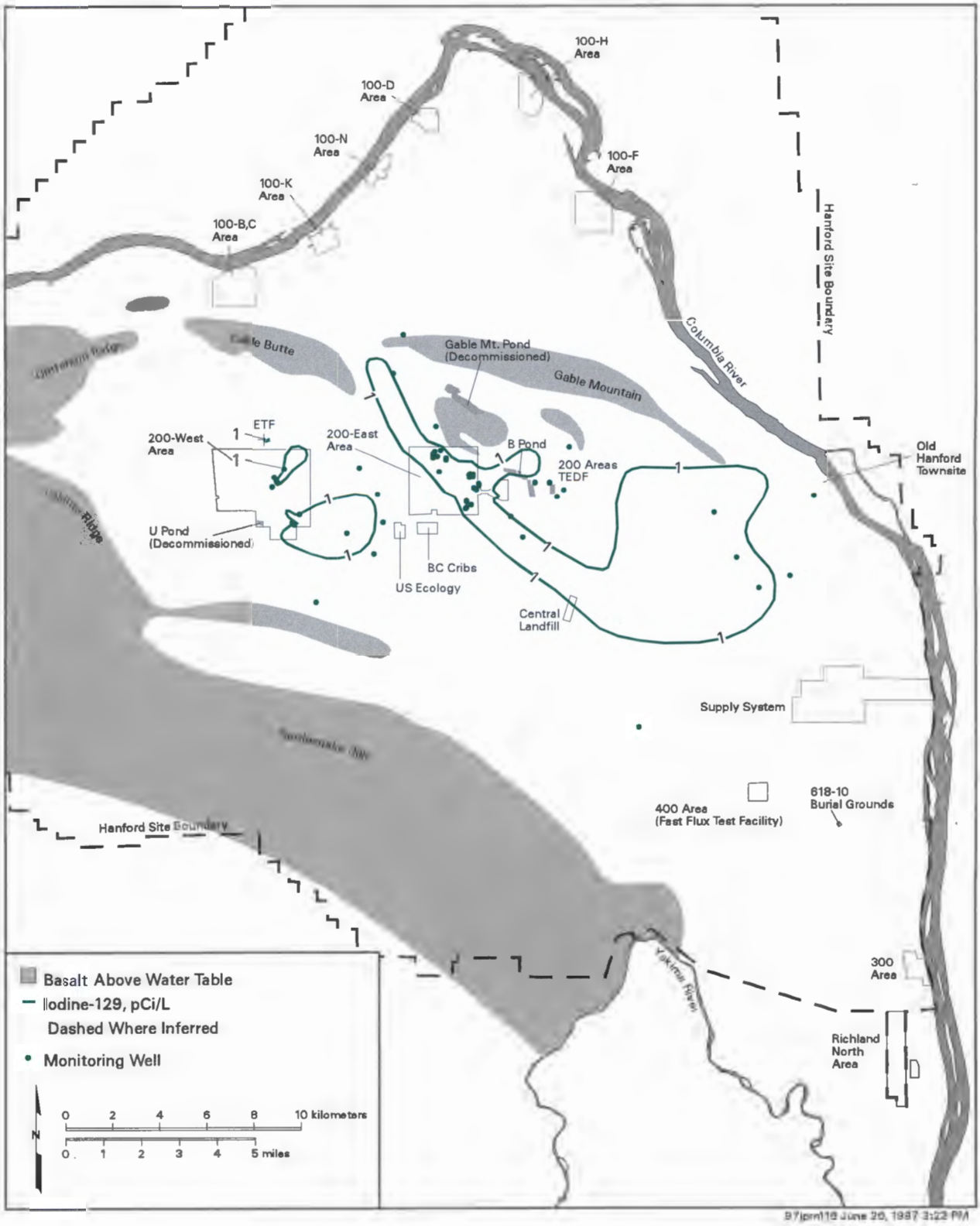

Figure 4.8.22. Distribution of Iodine-129 in the Unconfined Aquifer, 1996

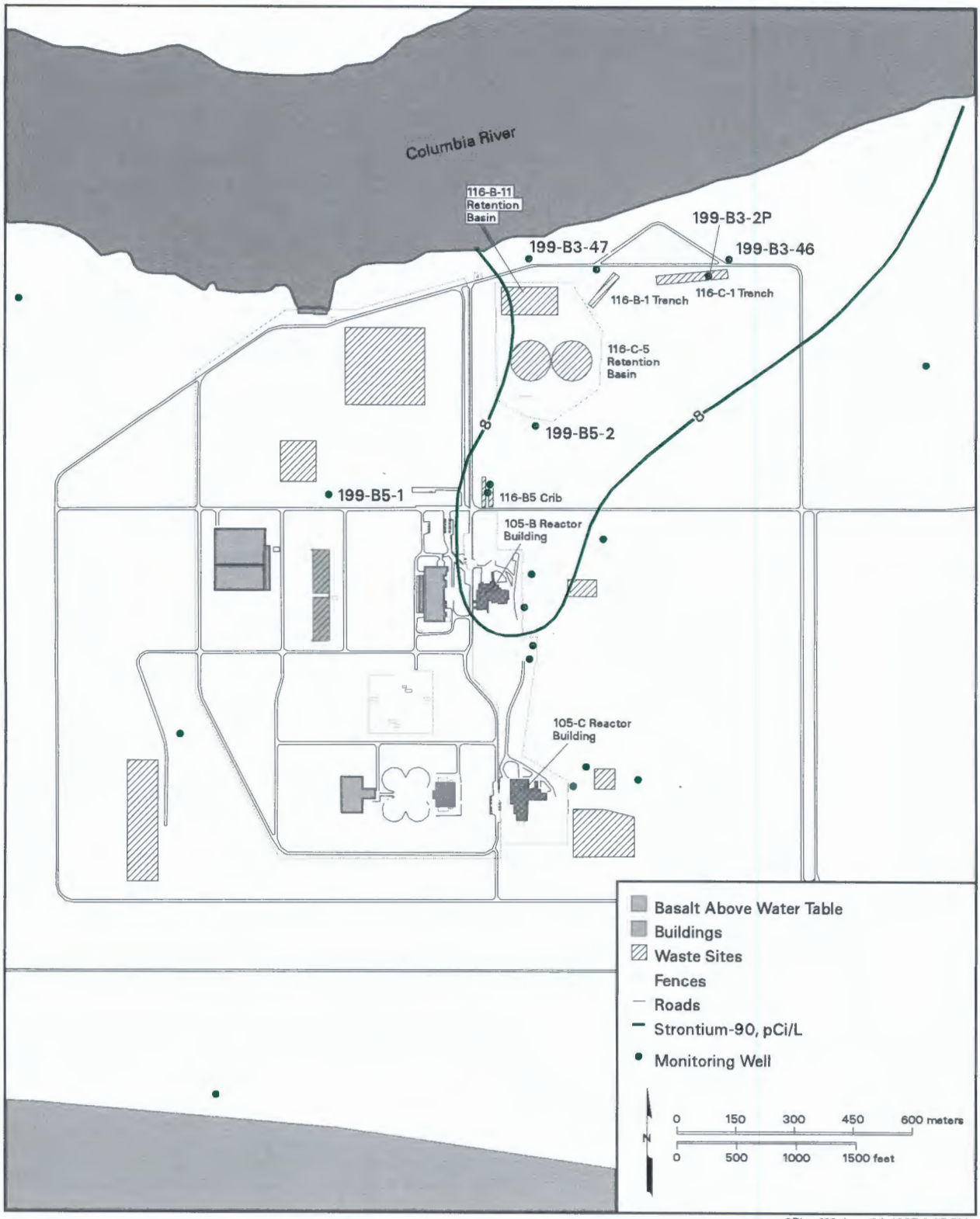

Figure 4.8.23. Concentrations of Strontium-90 in the Unconfined Aquifer in the 100-B Area, 1996

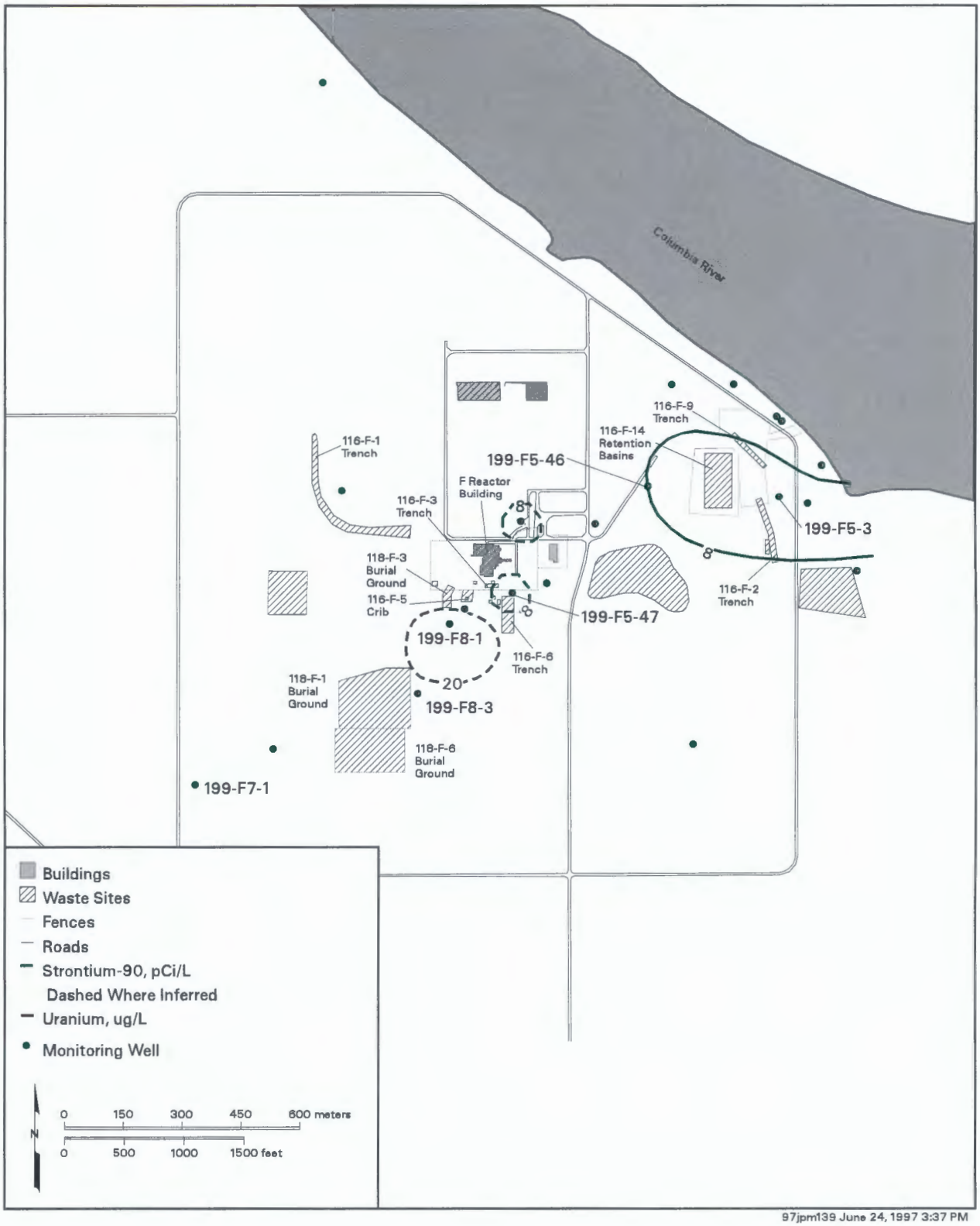

Figure 4.8.24. Concentrations of Strontium-90 and Uranium in the Unconfined Aquifer in the 100-F Area, 1996

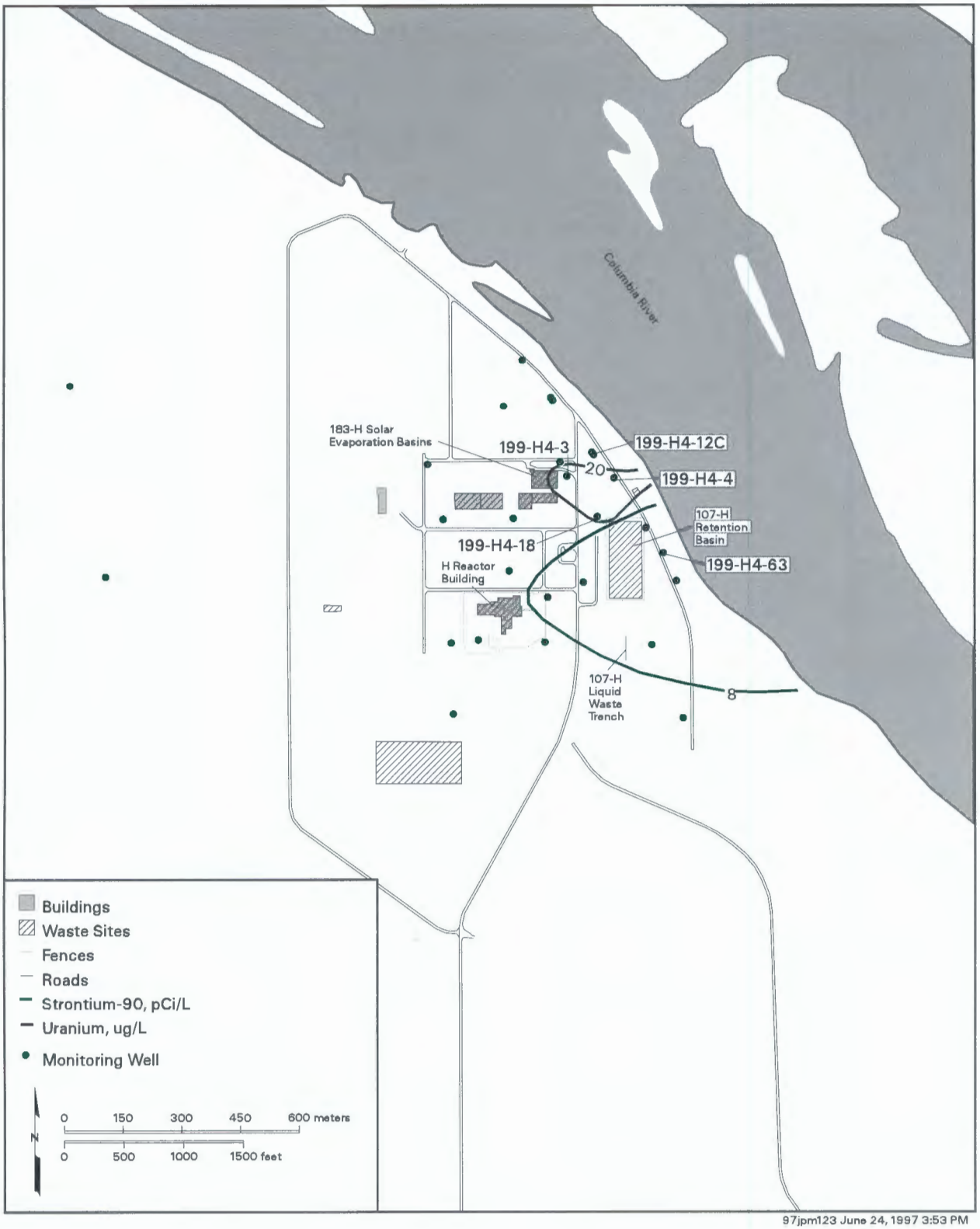

Figure 4.8.25. Concentrations of Strontium-90 and Uranium in the Unconfined Aquifer in the 100-H Area, 1996

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 1996 was over 8,000 pCi/L measured in September at well 199-K-109A. The concentration at this well had reached 6,000 pCi/L in April, then dropped significantly after repair of a leaking water supply line located within 5 m (16.4 ft) of the well. A trend plot of strontium-90 in well 199-K-109A is also shown in Figure 4.8.26. It was thought that strontium-90 contamination in the soil column might have been transported to the water table by the water from the leak. However, the reason for the increase in concentration during September is not yet understood. In October, the concentration dropped to 3,200 pCi/L. The derived concentration guide for strontium-90 is 1,000 pCi/L. Strontium-90 is also found near the K-West Reactor, and an extensive plume continues to be found near the liquid waste trench.

Strontium-90 was detected at concentrations greater than the derived concentration guide in the 100-N Area in 1996. The maximum level detected was 19,100 pCi/L at well 199-N-99A in May 1996. However, the average concentration throughout the year was 8,300 pCi/L at this well, compared to 11,600 pCi/L at well 199-N-67. Both wells are located between the 1301-N Liquid Waste Disposal Facility and the Columbia River. As shown in Figure 4.8.26, strontium-90 concentrations at well 199-N-67 increased and then decreased during 1996. Higher than normal river stages during the year may have caused the water table to rise into contaminated sediments, releasing strontium-90 to the aquifer.

The distribution of strontium-90 in the 100-N Area is shown in Figure 4.8.26. The movement of the strontium-90 plume northward in the 1980s is illustrated by the trend data from well 199-N-14. Strontium-90 discharges to the Columbia River in the 100-N Area through springs along the shoreline. Section 4.2, "Surface Water and Sediment Surveillance" and Section 3.2, "Near-Facility Environmental Monitoring," give the results of spring-water sampling. Remediation of strontium-90 in the 100-N Area by the 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 5,800 pCi/L in well 299-E28-23 near the 216-B-5 injection well. Strontium-90 was also found at 80 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 1996 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 1996 in this vicinity was 15.7 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 concentrations of 71.3 pCi/L at well 299-W22-1 and 26.8 pCi/L at well 299-W22-10, located in the southern part of the 200-West Area. These wells were not sampled during 1996, and no concentrations over the drinking water standard were measured in the other sampled wells.

Strontium-90 in the 600 Area. The maximum concentration of strontium-90 detected in the 600 Area was 1,500 pCi/L at well 699-53-48B, which is in the former Gable Mountain Pond area (see Figure 4.8.27). This is the first time in several years that a value greater than the 1,000-pCi/L derived concentration guide has been detected in this area. A trend plot is shown in Figure 4.8.28. 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 groundwater, 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.

Technetium-99

Technetium-99 is produced as a fission byproduct and is present in waste streams associated with fuel reprocessing. Reactor operations may also result in the release of some technetium-99 associated with fuel element breaches. Under the chemical conditions that exist in Hanford groundwater, technetium-99 is normally present in solution as anions that sorb poorly to sediments. Therefore, technetium-99 is very mobile in Hanford Site groundwater.

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 groundwater. The

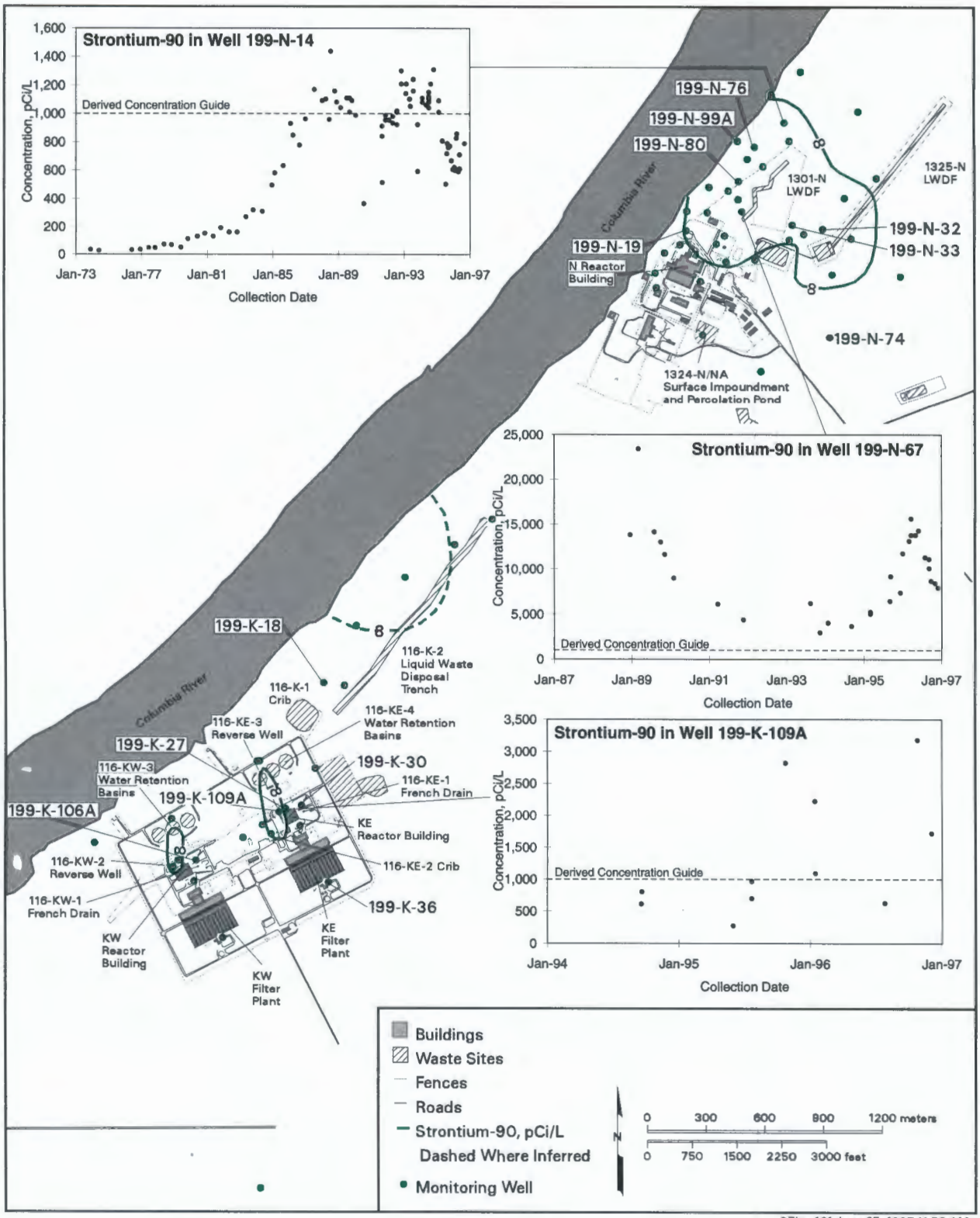

Figure 4.8.26. Concentrations of Strontium-90 in the Unconfined Aquifer in the 100-K and 100-N Areas, 1996, and Concentration Trends in Select Wells

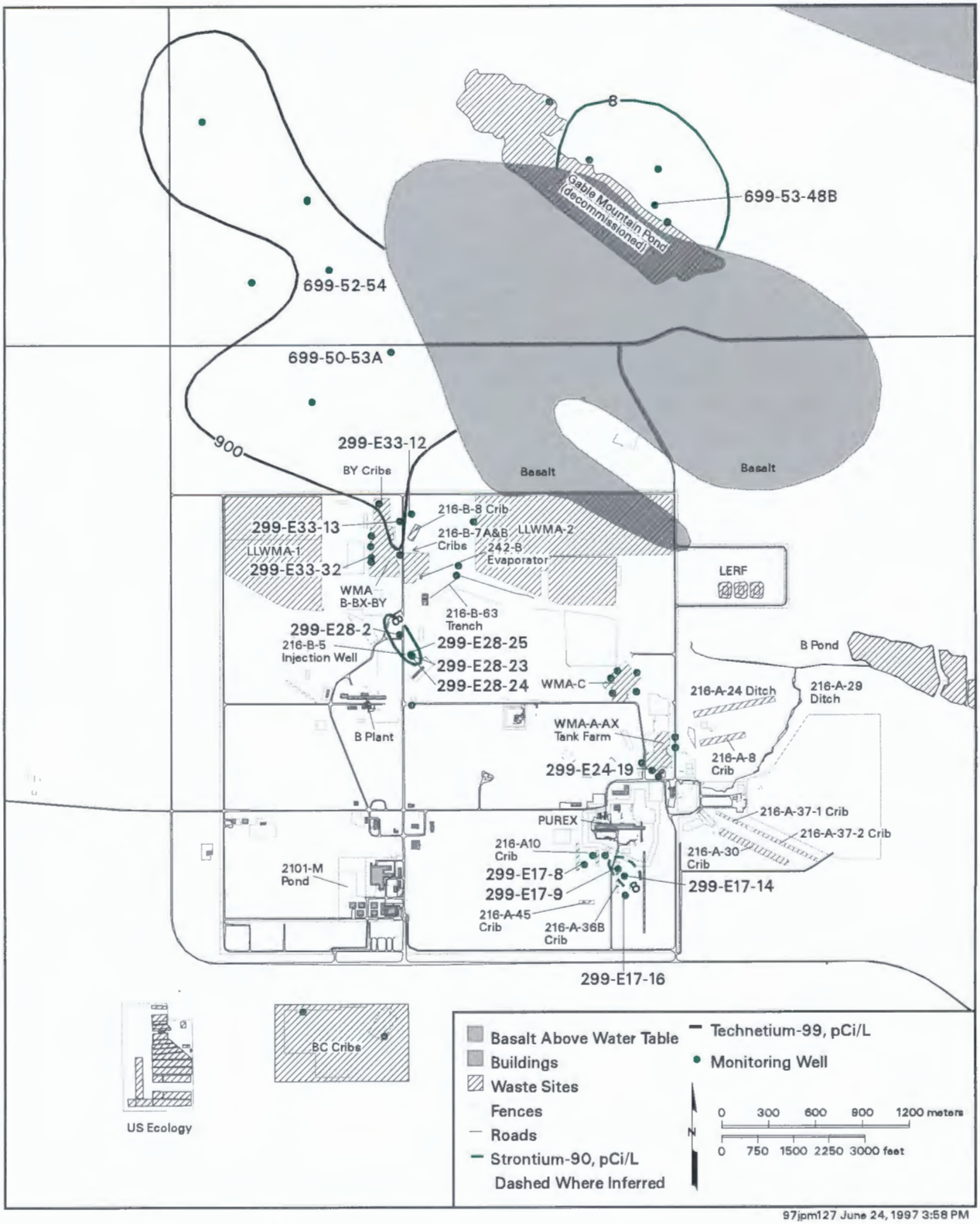

Figure 4.8.27. Concentrations of Strontium-90 and Technetium-99 in the Unconfined Aquifer Near the 200-East Area, 1996

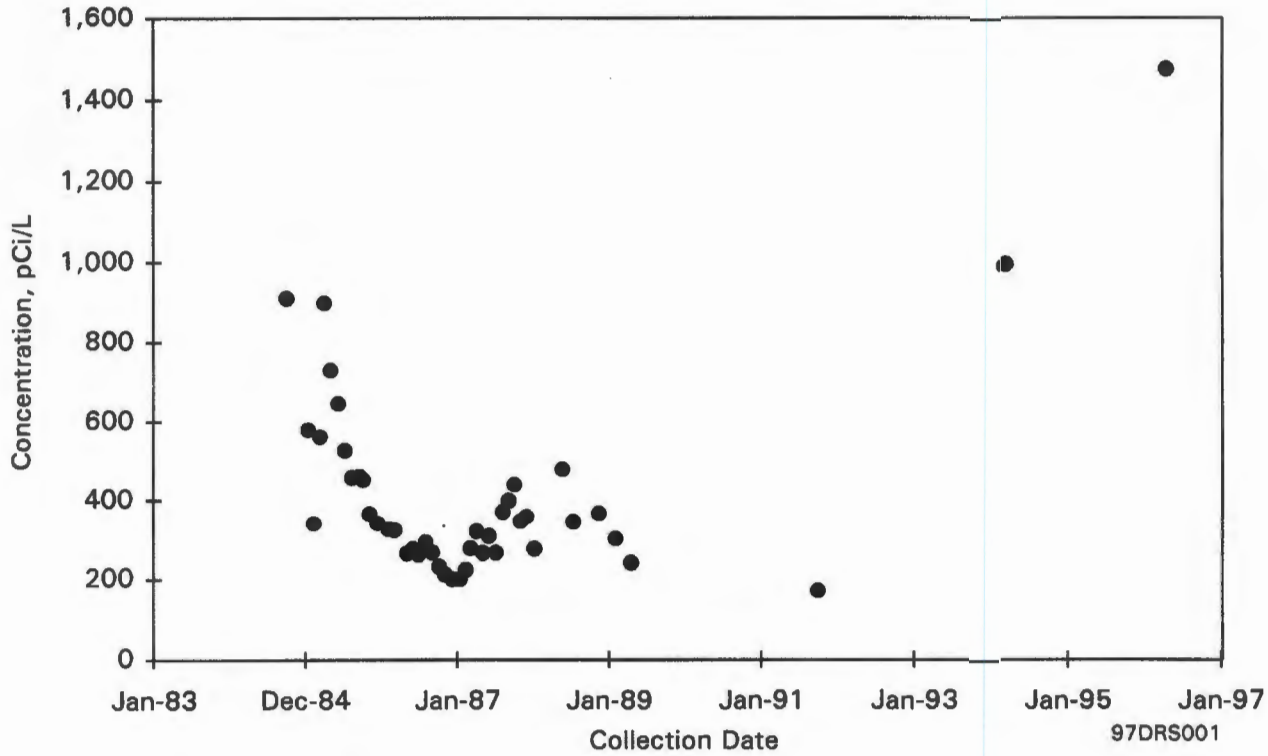

Figure 4.8.28. Strontium-90 Concentrations in Well 699-53-48B, 1984 Through 1996

maximum concentration of technetium-99 detected in this area in 1996 was 5,140 pCi/L at well 199-H4-3. Technetium-99 was also detected above the drinking water standard at wells 199-H4-4 and 199-H4-18.

Groundwater 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 (see 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 1996 was 2,900 pCi/L at well 699-52-54. A concentration of 9,910 pCi/L was observed at well 699-50-53A during 1995. This well, however, was not sampled in 1996 because it was being used for a groundwater treatment study. The technetium-99 trend for well 699-52-54 shows the progress of this plume as it migrates north (Figure 4.8.29).

Technetium-99 is also detected at levels greater than the drinking water standard in the 200-West Area and the adjacent 600 Area (Figure 4.8.30). 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 1996 was in well 299-W19-30, which had a maximum concentration of 29,300 pCi/L. This plume extends into the 600 Area toward the 200-East Area. The part of this plume with the highest concentration is currently undergoing remediation by the pump-and-treat method.

Several smaller areas with technetium-99 concentrations greater than the drinking water standard were also found in the 200-West Area. One well near the T-TX-TY Tank Farms contained technetium-99 at levels above the drinking water standard. Technetium-99 concentrations in this well declined sharply in 1996. However, as shown in Figure 4.8.31, technetium-99 levels increased sharply in well 299-W11-27 near the T Tank Farm. The maximum concentration detected in this well was 21,500 pCi/L, and the source of this increased technetium-99 is being assessed.

The southernmost plume in the 200-West Area originates near the S-SX Tank Farms and nearby disposal facilities. During 1996, all samples were below the drinking water standard. Leakage from the SX single-shell tanks is being investigated as a potential source of the technetium-99 in this vicinity.

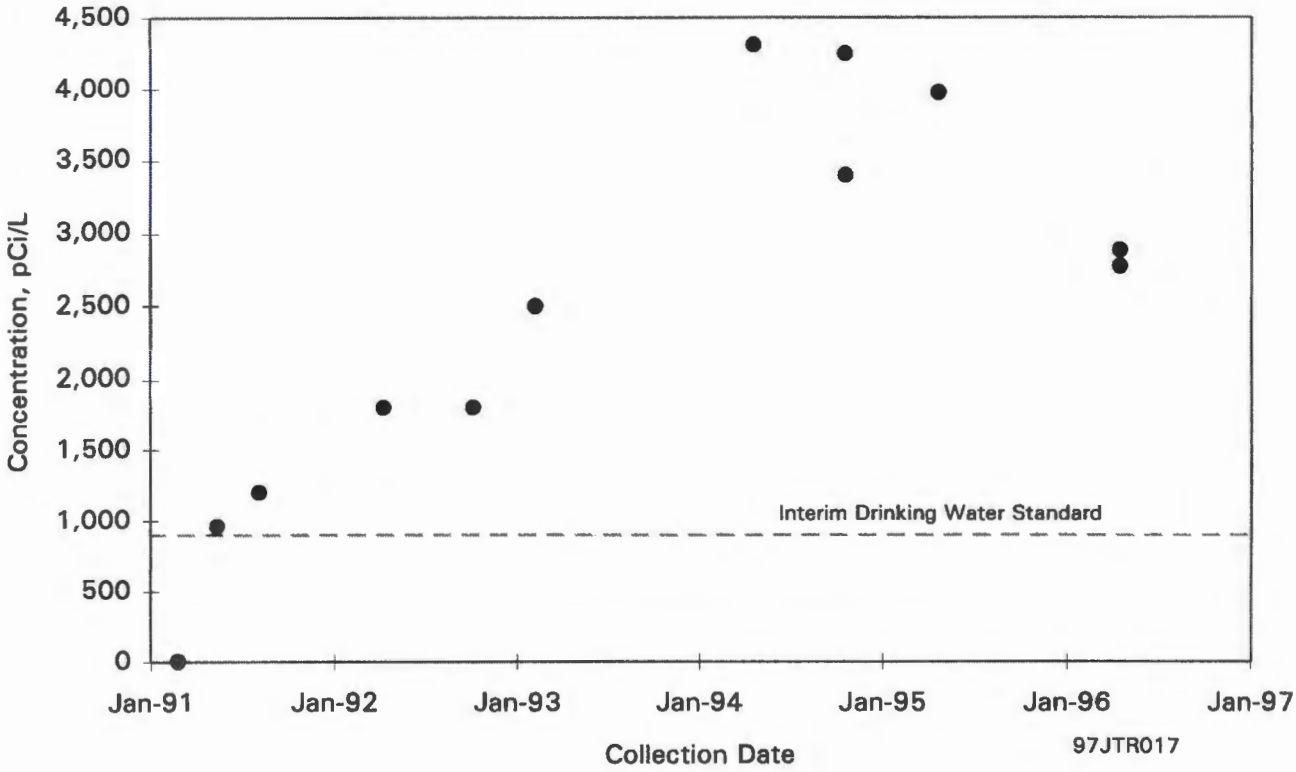

Figure 4.8.29. Technetium-99 Concentrations in Well 699-52-54, 1991 Through 1996

Uranium

There are numerous possible sources of uranium released to the groundwater at the Hanford Site, including fuel fabrication, fuel reprocessing, 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 groundwater, largely by forming dissolved carbonate species. Uranium mobility is thus dependent on both oxidation state and pH. Uranium is observed to migrate in Hanford groundwater but is retarded relative to more-mobile species such as technetium-99 and tritium. The EPA's proposed drinking water standard is 20 µg/L for uranium.

Uranium has been detected at concentrations greater than the proposed drinking water standard in the 100-F, 100-H, 200, 300, and 600 Areas. The highest concentrations detected at Hanford in 1996 were in the 200-West Area near U Plant.

Uranium in the 100 Areas. In 1996, uranium was detected at concentrations greater than the proposed drinking water standard near F Reactor in the 100-F Area (see Figure 4.8.24). The maximum concentration detected was 27.7 µg/L in well 199-F8-1.

Uranium was detected at levels higher than the proposed drinking water standard in two wells in the 100-H Area (see Figure 4.8.25). The maximum concentration detected in 1996 was 358 µg/L in well 199-H4-3. Uranium concentrations in this well fluctuate widely. The average concentration measured at this well in 1996 was 167 µg/L. Past leakage from the 183-H Solar Evaporation Basins is considered to be the source of the 100-H Area uranium contamination. These basins were demolished during 1996.

Uranium in the 200 Areas. A few wells in the 200-East Area contained uranium at concentrations greater than the proposed drinking water standard. The highest concentration detected was 128 µg/L at well 299-E33-13, located on the northern edge of the 200-East Area. Uranium concentrations in this well have increased greatly in the last several years but the source of the contamination is unclear.

The highest uranium concentrations in Hanford groundwater occurred near U Plant in the 200-West Area, at

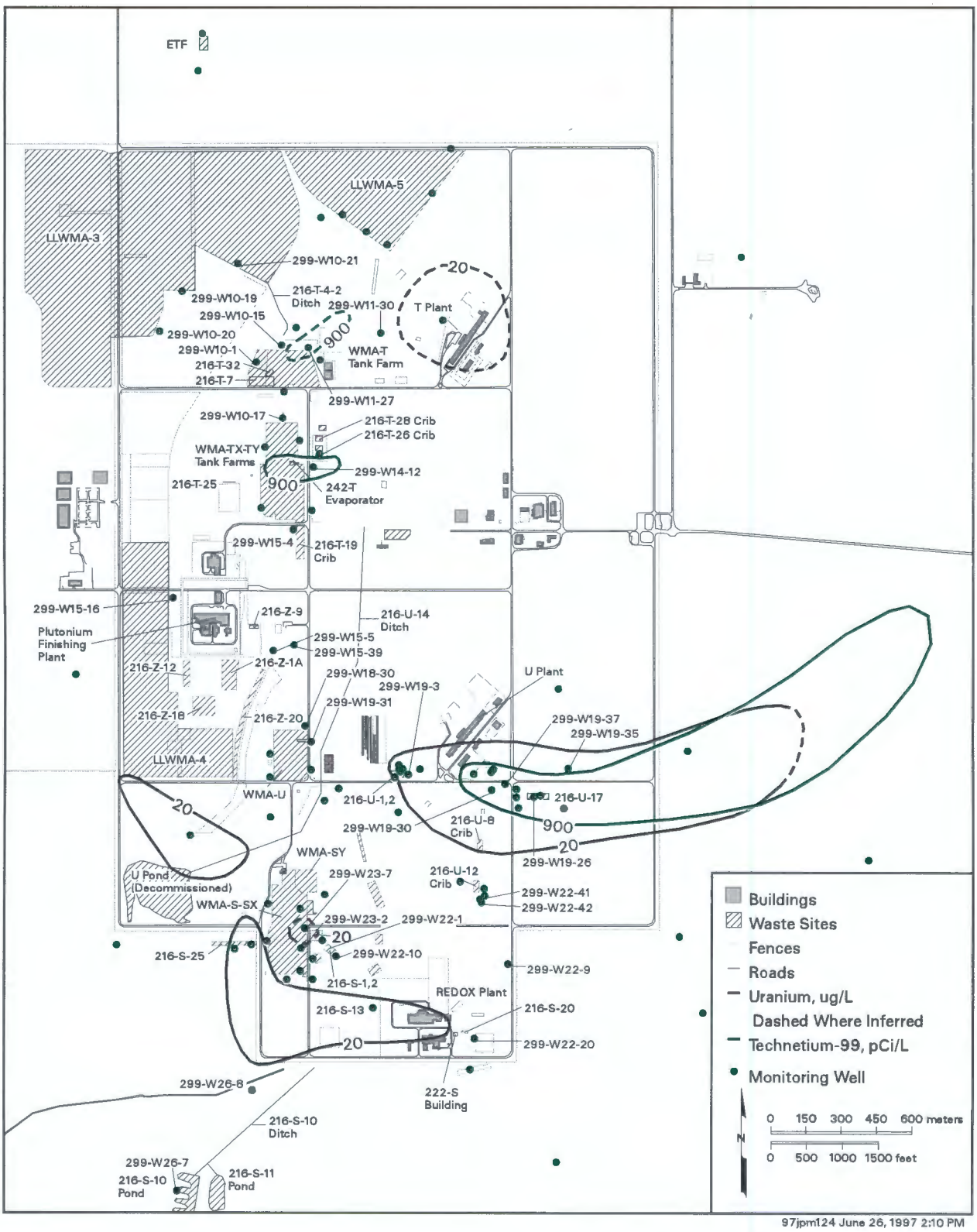

Figure 4.8.30. Concentrations of Technetium-99 and Uranium in the Unconfined Aquifer in the 200-West Area, 1996

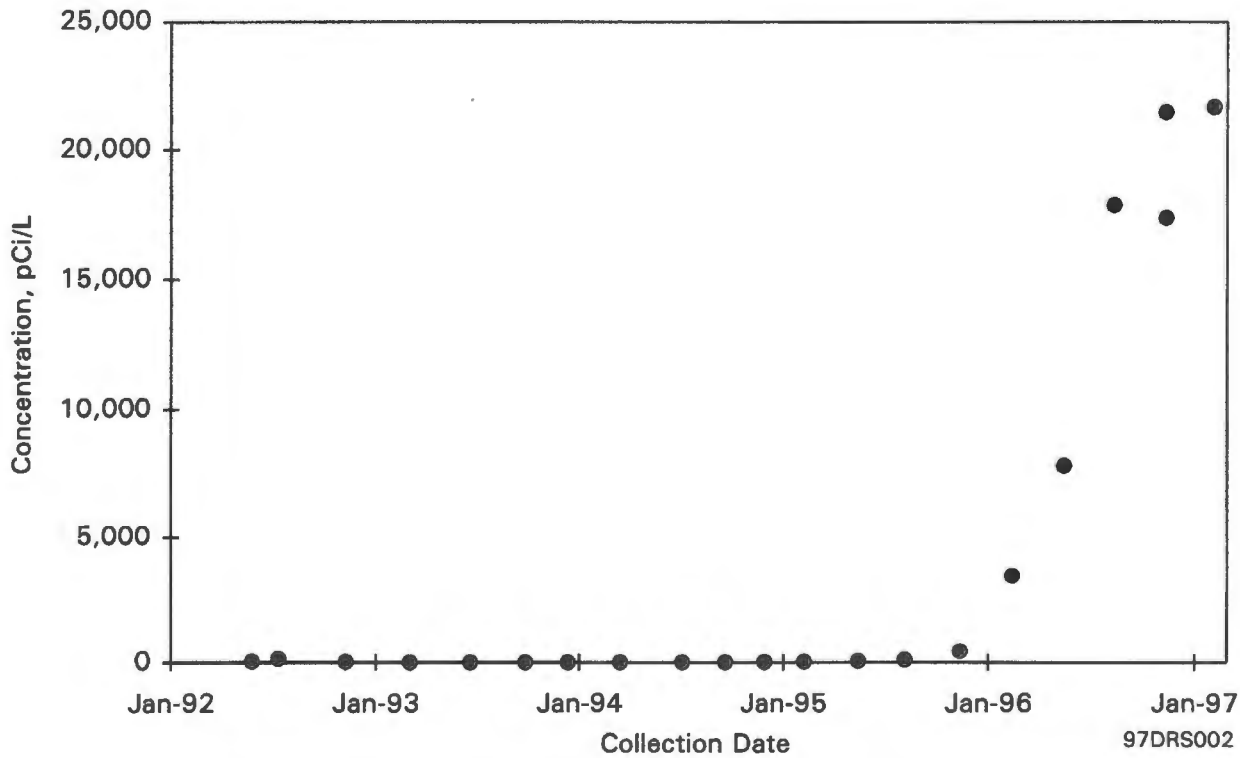

Figure 4.8.31. Technetium-99 Concentrations in Well 299-W11-27, 1992 Through 1996

wells adjacent to the inactive 216-U-1, 216-U-2, and 216-U-17 Cribs (see Figure 4.8.30). The maximum uranium detected in this area in 1996 was 3,790 µg/L at well 299-W19-37, a new well installed to monitor groundwater remediation activities. Uranium concentrations in this area have been decreasing over the last 5 years following remediation activities with the 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 4.8.32. The uranium levels in this well continue to decrease slowly but remain greater than the proposed drinking water standard. This uranium plume extends east into the 600 Area along with the technetium-99 plume discussed above. Other areas within the 200-West Area with uranium contamination are also shown in Figure 4.8.30, 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 Area. A plume of uranium contamination exists in the unconfined aquifer beneath the 300 Area in the vicinity of uranium fuel fabrication facilities and inactive sites known to have received uranium waste. The plume extends downgradient from inactive liquid waste disposal facilities to the Columbia River (Figure 4.8.33). 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 4.8.33. The maximum concentration of uranium detected in the 300 Area in 1996 was 300 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, though discharge to the trenches was much lower than before the expedited response action and ceased completely in 1995. Uranium levels in well 399-1-17A 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.

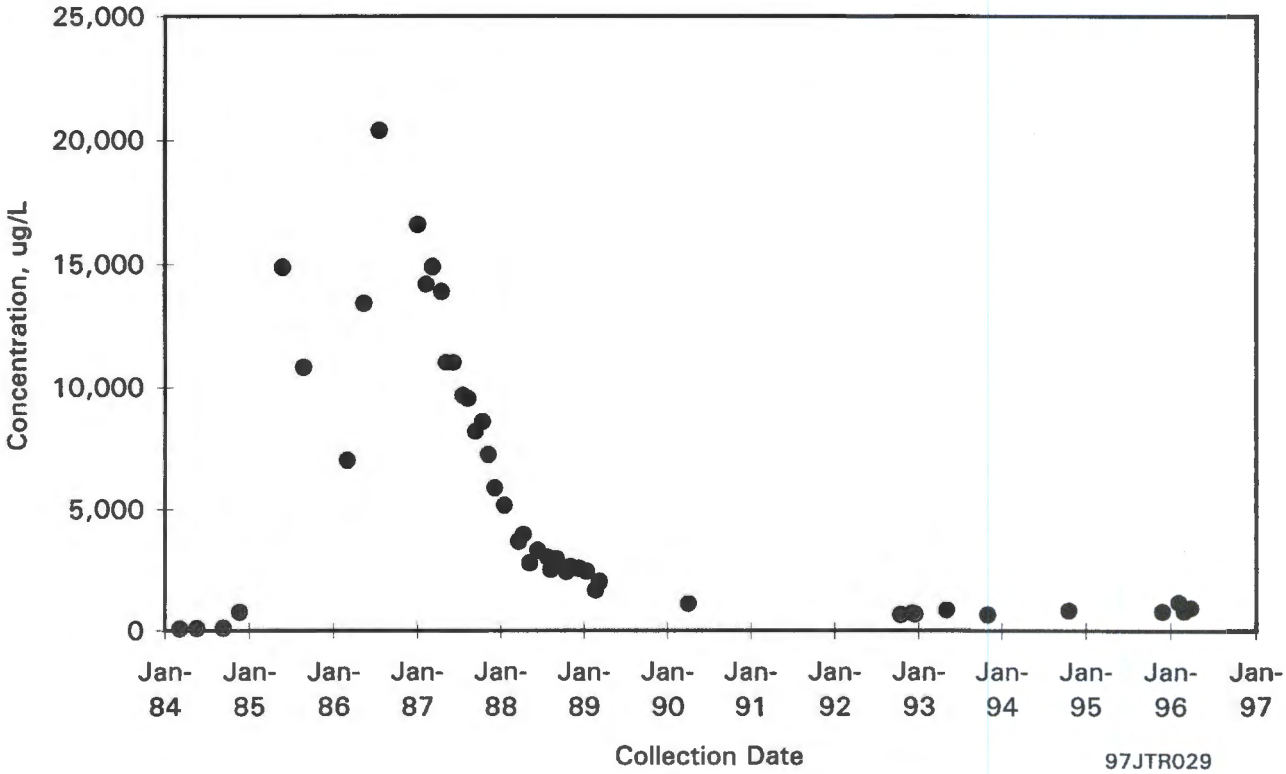

Figure 4.8.32. Uranium Concentrations in Well 299-W19-3, 1984 Through 1996

A trend plot showing the uranium concentrations in well 399-1-17A is shown in Figure 4.8.34.

Uranium in the 600 Area. The measured uranium concentration in well 699-S6-E4A, which is located southeast of the 400 Area, dropped from 768 µg/L in 1995 to 108 µg/L in 1996, following renovation of the well. The contamination at this well is attributed to the nearby 316-4 Crib (Hartman and Dresel 1997). The 618-10 burial grounds are also located near this well.

Cobalt-60

Cobalt-60 is a neutron activation product typically associated with wastes generated by reactor effluent. Cobalt-60 is normally present as a divalent transition metal cation and, as such, tends to be highly immobile in groundwater. However, complexing agents may mobilize it. The derived concentration guide for cobalt-60 is 5,000 pCi/L.

The maximum concentration of cobalt-60 detected in 100-N Area wells during 1996 was 648 pCi/L in an unfiltered sample from well 199-N-32. A filtered sample taken at the same time from the same well resulted in a concentration of 5.5 pCi/L. The difference in these results indicates that the bulk of cobalt-60 in the unfiltered sample was adsorbed on particles suspended in the water rather than in solution.

A cobalt-60 plume is found north of the 200-East Area in the same area as the technetium-99 contamination associated with the BY Cribs. Apparently, cobalt in this plume is mobilized by reaction with cyanide or ferrocyanide in the waste stream, forming a dissolved cobalt species. During 1995, cobalt-60 was detected in this area at levels above the 100-pCi/L drinking water standard, with a maximum concentration of 166 pCi/L detected at well 699-50-53A (Dirkes and Hanf 1996). However, this well was not analyzed for cobalt-60 in 1996.

Cobalt-60 was detected at well 299-E17-16, near the Plutonium-Uranium Extraction Plant, in June 1994 at a concentration of 40.1 pCi/L. This well has consistently shown detectable but low levels of cobalt-60. However, samples from this well were not analyzed for cobalt-60 in 1995 or 1996.

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 1996 samples. The

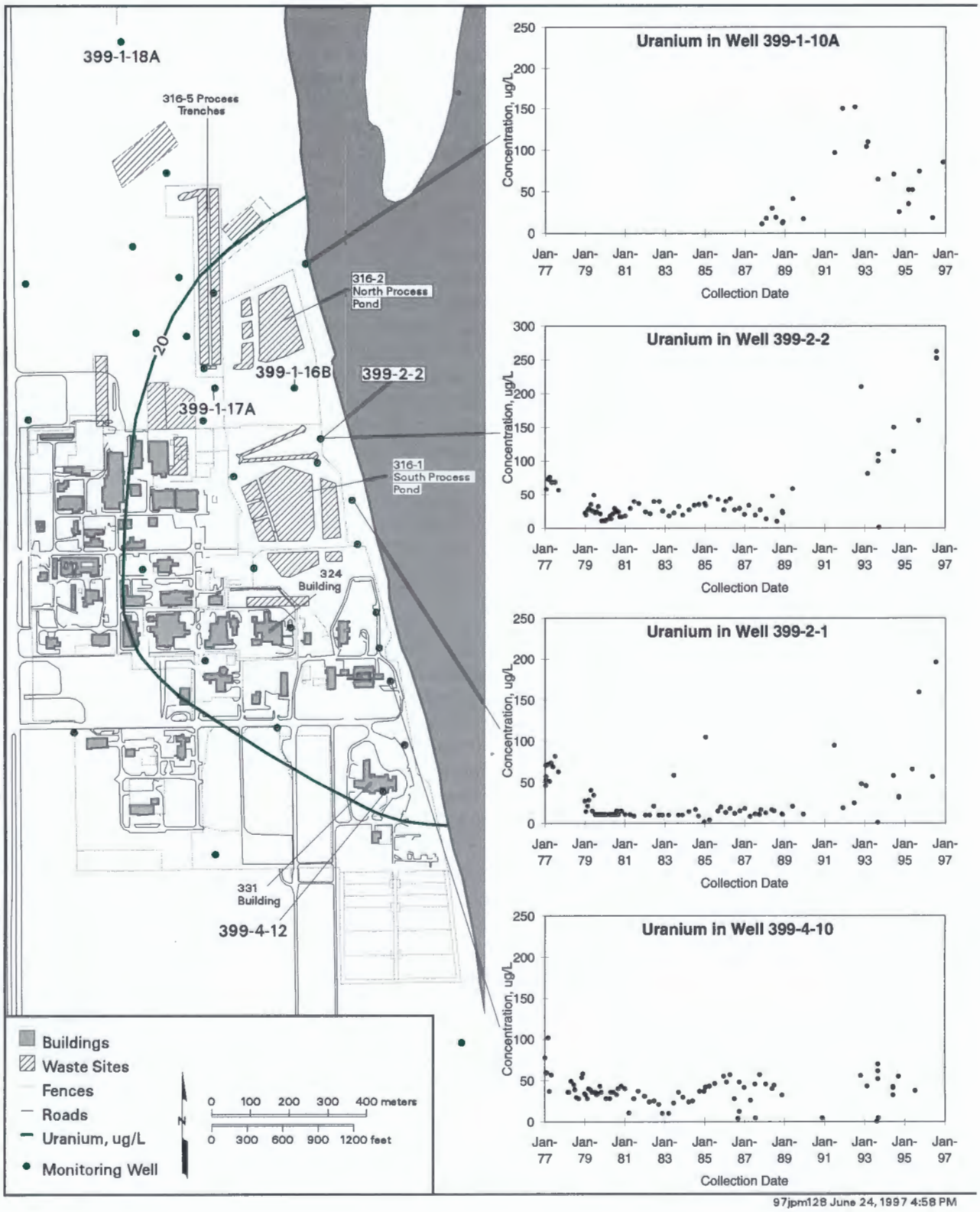

Figure 4.8.33. Uranium Concentrations in the Unconfined Aquifer in the 300 Area, 1996, and Concentration Trends for Select Wells

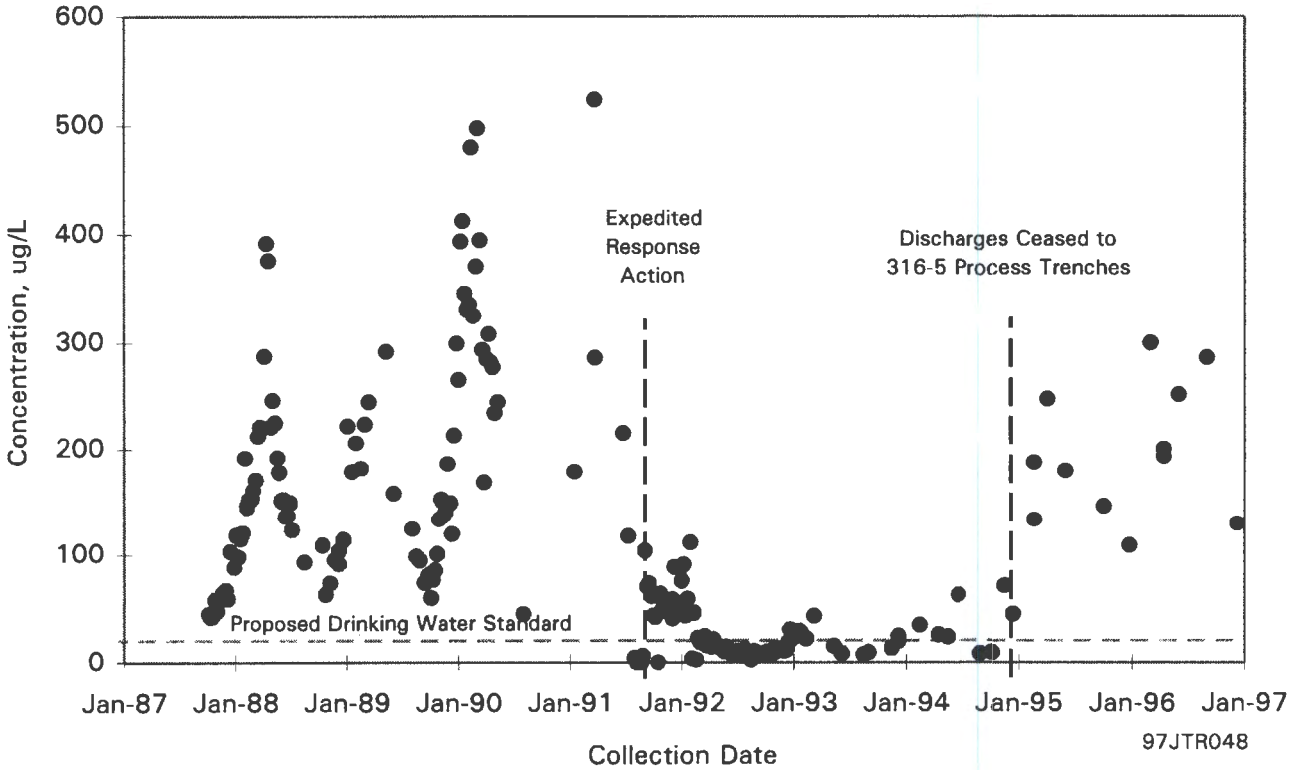

Figure 4.8.34. Uranium Concentrations in Well 399-1-17A, 1987 Through 1996

highest value reported in this well was 4.5 pCi/L, down from 17.2 pCi/L in 1995. This well is located to the east of the TX-TY Tank Farms. It is not known if the presence of cobalt-60 in the groundwater results from tank leaks or discharge to nearby cribs. The levels of cobalt-60 are well below regulatory standards, and 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 strongly sorbed on soil and, thus, is very immobile in Hanford groundwater. The drinking water standard for cesium-137 is 200 pCi/L; the 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 1996 concentration of cesium-137 in well 299-E28-25 was 114 pCi/L. Well 299-E28-23 was not sampled in 1996; however, the 1995 concentration was 1,470 pCi/L. Cesium-137 appears to be restricted to the immediate vicinity of the injection well by its extremely low mobility in groundwater.

In the 200-West Area, a sample from well 299-W23-7 contained 18 pCi/L of cesium-137 in 1996. This well is located in the S-SX Tank Farms area and was sampled to confirm the presence of cesium-137 in groundwater at this location.

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 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. Alternatively, if the derived concentration guide, which is based on a 100-mrem dose standard, is converted to the 4-mrem dose equivalent used for the drinking water standard, 1.2 pCi/L would be the relevant guideline.

Groundwater sampled during 1996 at 200-East Area wells located near the 216-B-5 Injection Well ranged up to 81 pCi/L of plutonium-239,240 at well 299-E28-25. A concentration of 51 pCi/L was measured at well 299-E28-24 in 1996. This value is similar to that measured in 1995. Plutonium-238 was also detected at wells 299-E28-24 and 299-E28-25 in 1996, but at considerably lower levels of 0.257 and 0.569 pCi/L, respectively. 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 previously detected in a sample from well 299-E28-2, which is approximately 150 m (490 ft) from the 216-B-5 Injection Well. The 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 reprocessing. Reactor operations may also result in the release of some antimony-125 associated with fuel element breaches. Antimony-125 tends to migrate in Hanford groundwater with low retardation, but generally has not been observed in recent years because of its relatively short half-life (2.7 yr). The drinking water standard for antimony-125 is 300 pCi/L.

Antimony-125 was detected at 52 pCi/L in an unfiltered sample from well 199-N-33 in the 100-N Area during 1996. However, the concentration measured in a filtered sample from the same well was 6.5 pCi/L, indicating that the antimony was adsorbed on particles suspended in the water sample. Levels below the drinking water standard have also been historically detected in the 100-B and 100-K Areas. A maximum concentration of 12.8 pCi/L was measured at well 199-K-109A, down from 44.8 pCi/L at this well in 1995. No samples from the 100-B Area were analyzed for this radionuclide in 1996. During 1995, antimony-125 was 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. However, this well was not analyzed for antimony-125 in 1996.

Chemical Monitoring Results for the Unconfined Aquifer

In recent years, chemical analyses performed by various monitoring programs at the Hanford Site have identified nine hazardous chemicals in groundwater at significant concentrations. These are nitrate, cyanide, fluoride, chromium, carbon tetrachloride, chloroform, trichloroethylene, tetrachloroethylene, and cis-1,2-dichloroethylene.

A number of parameters such as pH, specific conductance, total carbon, total organic carbon, and total organic halogens are used as indicators of contamination. These are mainly discussed in the section, "Resource Conservation and Recovery Act Summary." Other chemicals and parameters listed in Table 4.8.3 are indicators of the natural chemical composition of groundwater and are usually not contaminants from operations at the Hanford Site. These include alkalinity, aluminum, calcium, iron, magnesium, manganese, potassium, silica, and sodium. Chloride and sulfate naturally occur in groundwater and can also be introduced as contaminants from site operations. 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. Therefore, they will not be discussed in detail. The analytical technique used to determine the concentration of metals in groundwater 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 presents additional information on the nine chemical constituents occurring in groundwater at concentrations greater than existing or proposed drinking water standards (40 CFR 141 and EPA 1996; see Appendix C).

Nitrate

Many groundwater samples collected in 1996 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, though 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 4.8.35; 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.

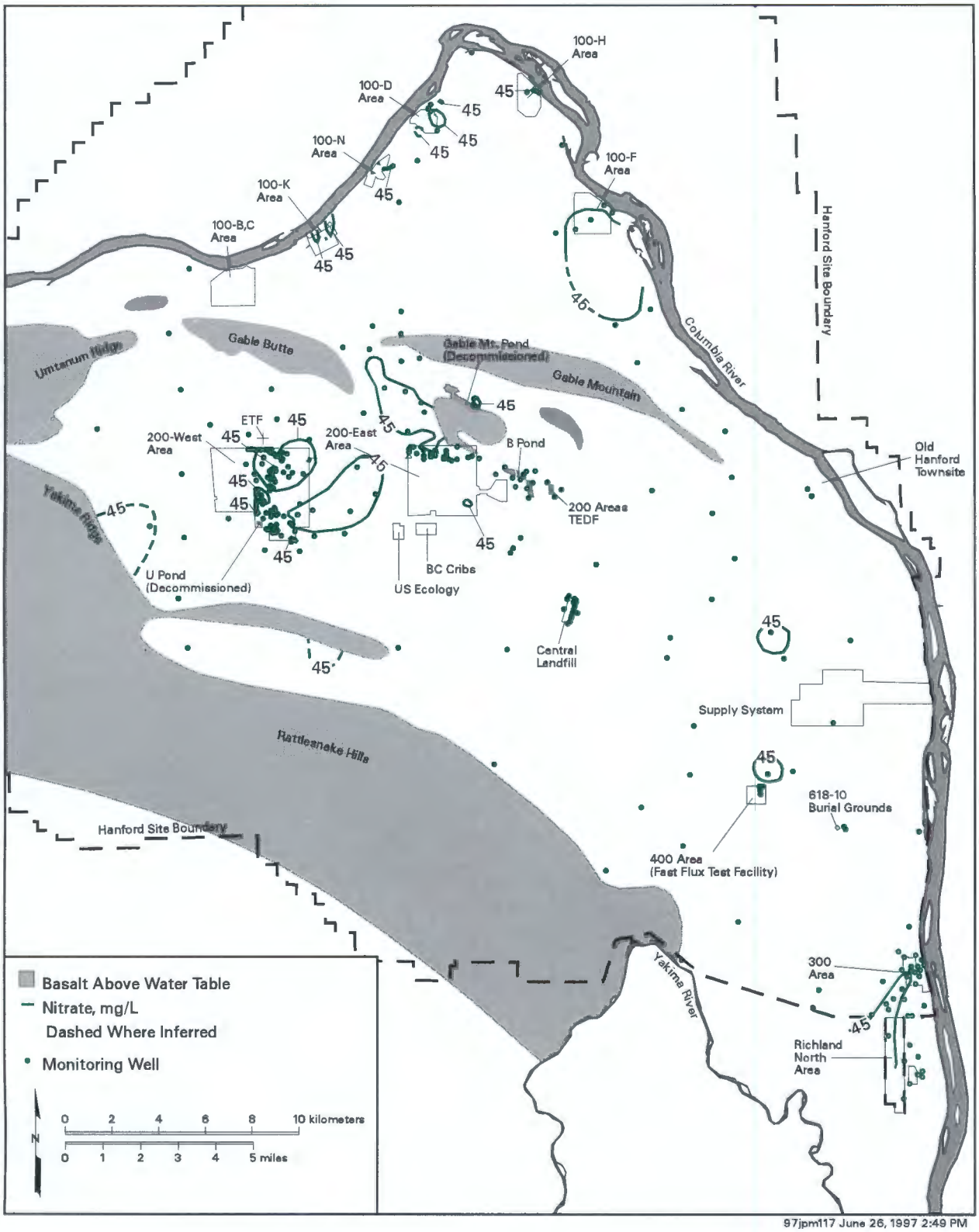

Figure 4.8.35. Distribution of Nitrate in the Unconfined Aquifer, 1996

Most nitrate analyses performed onsite in recent years have been performed using the ion chromatography method. However, a colorometric method also has been used. The colorometric results appear prone to erratic errors, and these results are 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 45-mg/L drinking water standard in parts of the 100-D Area. The highest nitrate value found in the 100-D Area in 1996 was 119 mg/L in well 199-D8-3, located in the northern part of the area near the Columbia River.

The 100-F Area contains nitrate in groundwater 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 an unknown source upgradient. The maximum nitrate detected in the 100-F Area in 1996 was 100 mg/L in well 199-F5-47, located in the central part of the 100-F Area.

Nitrate in the 100-H Area is restricted to a small area downgradient of the former 183-H Solar Evaporation Basins. The maximum concentration of nitrate detected in this area in 1996 was 1,300 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 Reactors. The maximum concentration detected in 1996 was 98 mg/L in a sample from well 199-K-18.

Minor nitrate contamination is found in parts of the 100-N Area. The maximum detected in a 1996 sample was 220 mg/L in well 199-N-19, located between the 1301-N Liquid Waste Disposal Facility and the Columbia River.

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 137 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 4.8.35, nitrate is only found at levels above the drinking water standard in a few restricted places in the 200-East Area. 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 699-49-57A at 95 mg/L in 1996. Nitrate is also found in a few wells near the former Gable Mountain Pond, north of the 200-East Area. The highest measured concentration in this area was 320 mg/L at well 699-53-48A.

Nitrate in the 200-West Area. Nitrate concentrations greater than the drinking water standard were widespread in groundwater 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 1996 was 1,100 mg/L (well 299-W19-26). Well 299-W19-30, which showed a concentration of 1,400 mg/L in 1995, was not sampled during 1996. 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, west of U Plant. 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 continued to decrease, with concentrations in several of the wells dropping to less than the drinking water standard.

Several wells in the northern 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 1996 ranged up to 1,100 mg/L in well 299-W10-1. The area with groundwater 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. There is no known source of nitrate in that area associated with site operations, and the groundwater 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. The concentration at this well in 1996 was 48 mg/L.

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 manufacturing 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 groundwater in the area north of the Columbia River.

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. Procedures used to analyze for cyanide 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 groundwater is present as free cyanide and the rest may be present as ferrocyanide (Evans et al. 1989a, 1989b). 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. No samples collected in 1996 contained cyanide at levels above the drinking water standard. Well 699-52-54 had the highest concentration, with 140 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 by cyanide or ferrocyanide. The complexed chemical species is more soluble and more mobile in groundwater.

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 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 (24 µg/L in 1996).

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 rather than health considerations. Fluoride was detected at levels greater than the primary drinking water standard at a few wells near T Plant in the 200-West Area in 1996. Well 299-W10-15 showed a maximum fluoride concentration of 7.8 mg/L, and well 299-W15-4 had a maximum concentration of 4.8 mg/L. 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. Thus, hexavalent chromium is freely mobile in the groundwater. The federal drinking water standard for chromium is 100 µg/L, and the state standard is 50 µg/L.

Both filtered and unfiltered samples were collected for analyses of chromium and other metals from several 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 that are fine enough to pass through the filter. Drinking water standards are based on unfiltered concentrations; however, differences in well construction and pumping practices 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 groundwater contamination levels for chromium because 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 groundwater from wells in each of the 100 Areas. Chromium concentrations in filtered samples collected from the 100-B,C Area in October 1995 were above the state drinking water standard in well 199-B5-1, which showed a maximum concentration of 88.6 µg/L. No wells in this area were analyzed for chromium during 1996.

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 groundwater. The maximum chromium concentration from filtered samples in the 100-D Area in 1996 was 727 µg/L in well 199-D5-14. The chromium distribution in the 100-D Area is shown in Figure 4.8.36.

Relatively few chromium analyses are available from the 100-F Area for 1996. However, several wells were sampled during the last few months of 1995. The highest concentration was 153 µg/L detected at well 199-F5-46 in November 1995. This was 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 (see Figure 4.8.36). 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 1996 was 240 µg/L in well 199-H4-3. Chromium is also found at levels above the drinking water standard in deeper parts of the unconfined aquifer in the 100-H Area. For example, samples from well 199-H4-12C contained up to 277 µg/L chromium in filtered samples in 1996. Potential chromium sources in the 100-H Area include disposal of sodium dichromate near the H 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, which is probably the 100-D Area. Effluent releases at the 100-D Area during operations produced groundwater mounding, which altered flow conditions. This caused the spreading of chromium contamination into the 600 Area.

Chromium is found in both filtered and unfiltered samples from the 100-K Area at levels greater than the drinking water standards (Figure 4.8.37). The maximum concentration in 1996 was 2,710 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 116-K-2 Liquid Waste Disposal Trench and the K-West Reactor.

At the 100-N Area, only two wells sampled in 1996 contained filtered chromium at concentrations greater than the drinking water standards. Well 199-N-33 had a maximum concentration in filtered samples of 430 µg/L. Well 199-N-80 had a maximum concentration of 178 µg/L. Well 199-N-80 is completed in the deeper part of the unconfined aquifer and suggests that the chromium distribution at depth is different from that near the water table.

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 1996 was 140 µg/L. This well is located on the southern boundary of the A-AX single-shell high-level waste tank farms. Chromium concentrations in this well have decreased from a peak in late 1992 (Figure 4.8.38) and were down from the 410 µg/L measured in 1995. 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

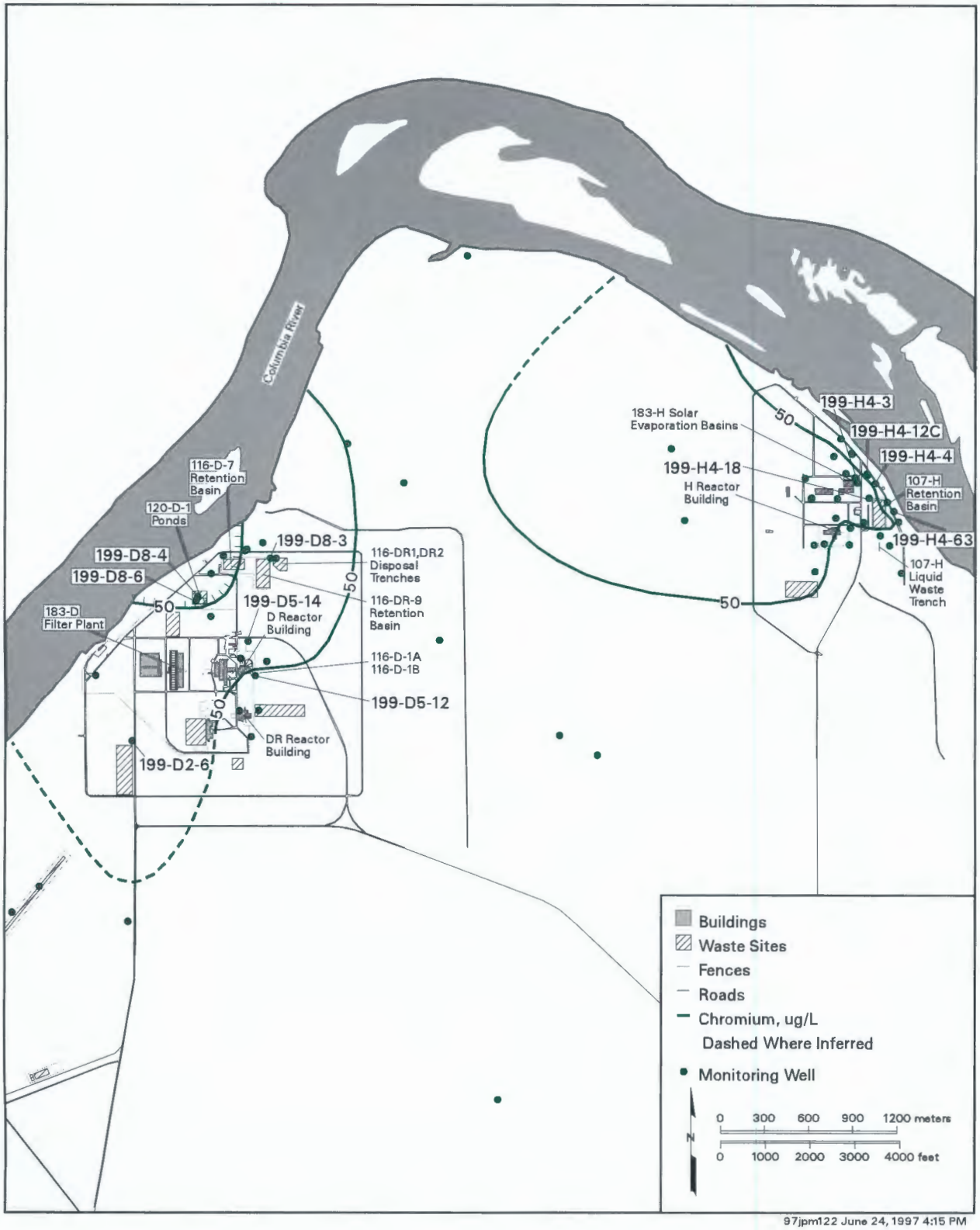

Figure 4.8.36. Distribution of Filtered Chromium in the 100-D and 100-H Areas, 1996

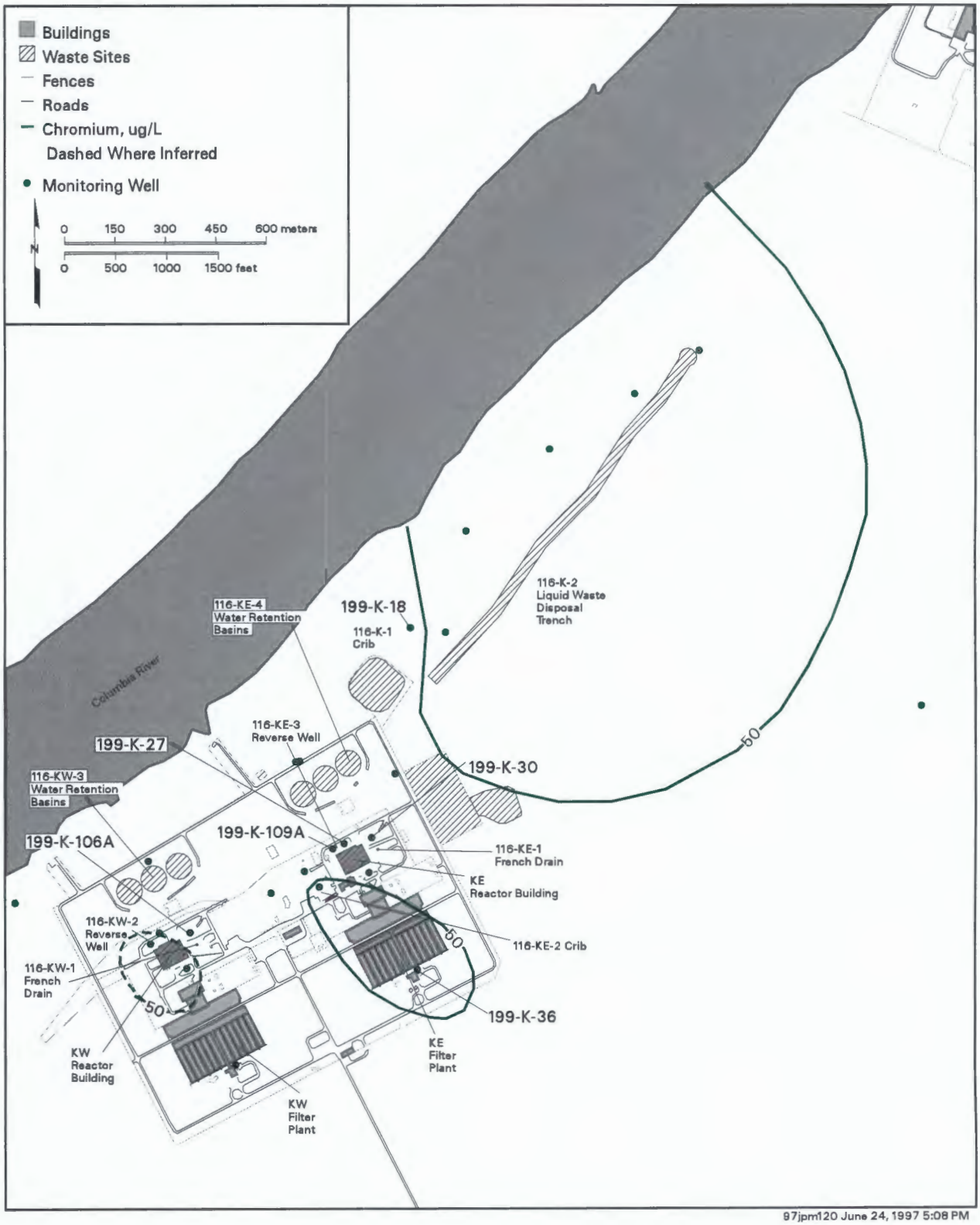

Figure 4.8.37. Distribution of Filtered Chromium in the 100-K Area, 1996

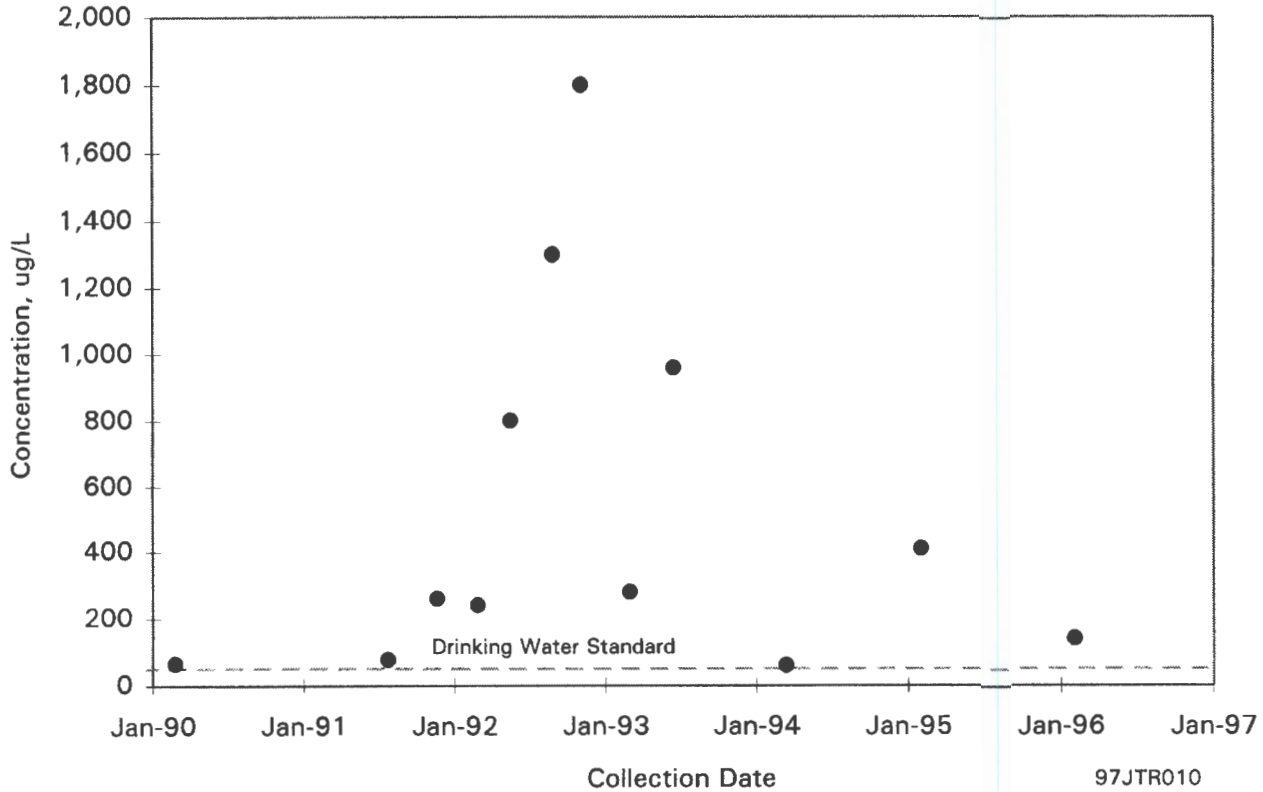

Figure 4.8.38. Filtered Chromium Concentrations in Well 299-E24-19, 1990 Through 1996

to be erratic as the result of variable amounts of particulate matter being present in the sample. Release from the A-AX Tank Farms is a potential source of this chromium contamination.

Chromium contamination has been found at several locations in the 200-West Area and is detected in both filtered and unfiltered samples, though the filtered concentrations tend to be lower. The highest filtered chromium concentration observed in the 200-West Area in 1996 was 590 µg/L at well 299-W11-27, which is located north of the T single-shell tank farm, near facilities that received liquid discharge from T Plant operations.

Chromium in the 300 Area. Chromium is occasionally 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 and are affected by the stainless-steel well construction purging procedures, time between samples, and other factors that do not reflect groundwater 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, located downgradient of the southern part of the 200-West Area, contained chromium at levels above the drinking water standards. The maximum concentration detected in filtered samples in this area during 1996 was 227 µg/L at well 699-32-62. The extent of chromium contamination in this area is poorly defined, and the source has not been determined.

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 while machining

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 groundwater. Mobilization above the water table can also occur through vapor transport. The drinking water standard for carbon tetrachloride is 5 µg/L.

The carbon tetrachloride distribution in the 200-West Area groundwater (Figure 4.8.39) has changed slowly since the presence of the contaminant plume was first noted in 1987. Figure 4.8.39 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. The maximum concentration of carbon tetrachloride detected in the 200-West Area in 1996 was 5,170 µg/L in well 299-W15-16. Concentrations in the central part of the carbon tetrachloride plume have declined in recent years. The trend plot (Figure 4.8.40) 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 5,170 µg/L during 1995 and 1996. The carbon tetrachloride in the most contaminated part of the groundwater plume is being remediated by the pump-and-treat method; vadose zone contamination is removed by vapor extraction.

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 groundwater flow since decommissioning U Pond may be influencing 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. Therefore, lateral expansion of the carbon tetrachloride plume is expected to continue.

In addition to carbon tetrachloride, significant amounts of chloroform were found in 200-West Area groundwater. 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 1996 was 250 µg/L in well 299-W15-39, 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, which is a commonly used organic solvent, has a drinking water standard of 5 µg/L. In 1996, trichloroethylene was detected at levels greater than the drinking water standard in wells in the 100-F, 100-K, 200-West, and 300 Areas and parts of the 600 Area.

Trichloroethylene in the 100 Areas. Trichloroethylene was detected in 1996 at levels less than the drinking water standard in a few 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 1996 was 10 µg/L in a sample for well 199-F7-1. In addition, trichloroethylene was found at 19 µg/L in well 699-77-36, west of the 100-F Area, indicating a potential source upgradient.

Two wells sampled in 1996 in the 100-K Area contained trichloroethylene at levels above the drinking water standard. The maximum concentration was 27 µg/L in monitoring well 199-K-106A, which is located near the K-West Reactor.

Trichloroethylene in the 200 Areas. Trichloroethylene was detected at levels greater than the drinking water standard in the 200-West Area in several areas in 1996 (Figure 4.8.41). 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 26 µg/L were detected in 1996 in this plume at well 299-W11-30. The second area of trichloroethylene contamination near U Plant showed a maximum concentration of 15 µg/L at well 299-W19-35 in 1996. 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 11 µg/L in a sample from well 299-W22-20 near the Reduction-Oxidation Plant.

Trichloroethylene in the 300 Area. Trichloroethylene was detected during 1996 at several wells throughout the 300 Area at concentrations below the drinking water standard. The maximum concentration was 3.0 µg/L at well 399-4-12, which is used as a nonpotable water supply for aquatics research (see Figure 4.8.2).

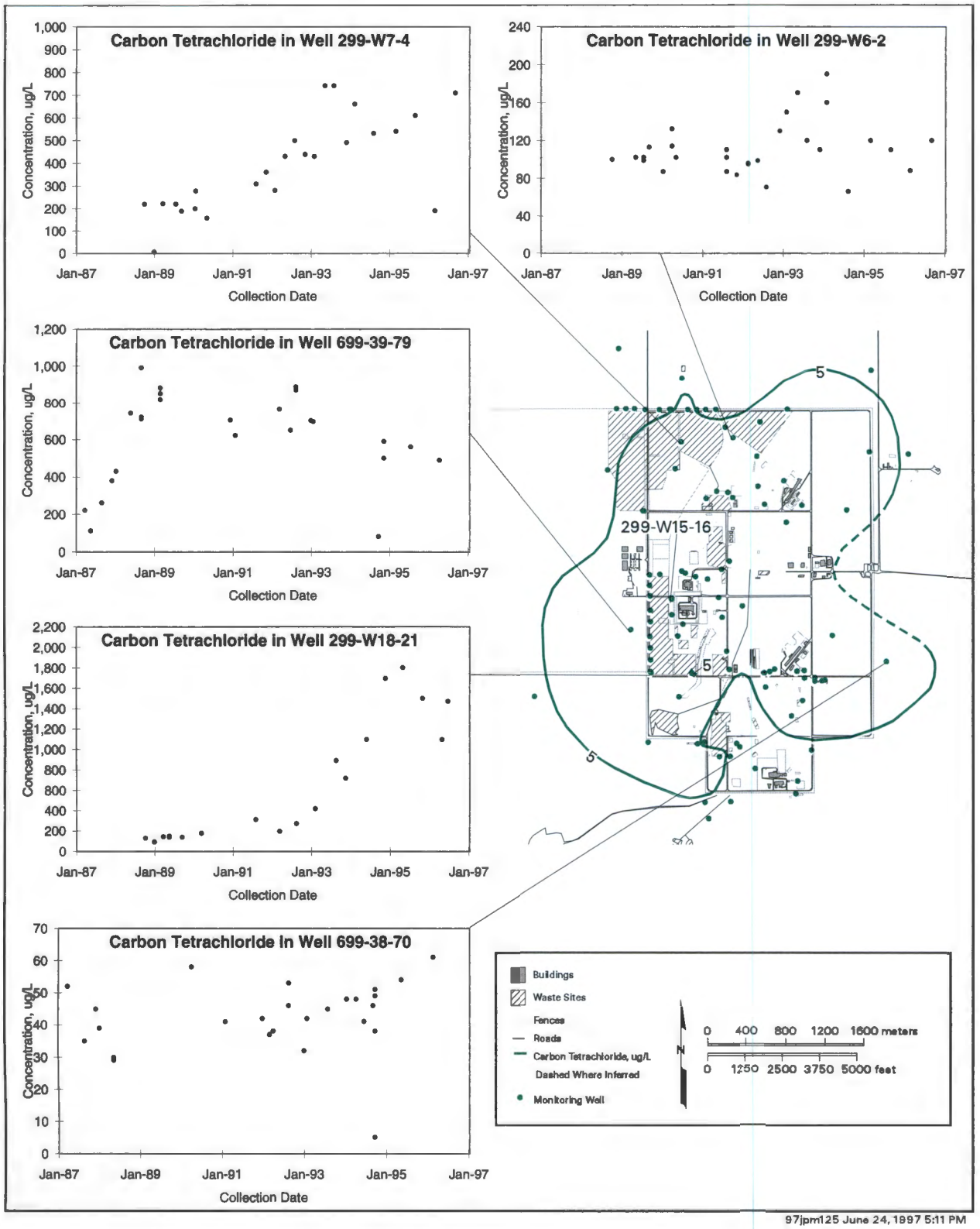

Figure 4.8.39. Distribution of Carbon Tetrachloride in the Unconfined Aquifer in the 200-West Area, 1996, and Concentration Trends for Several Wells Within the 200-West Area

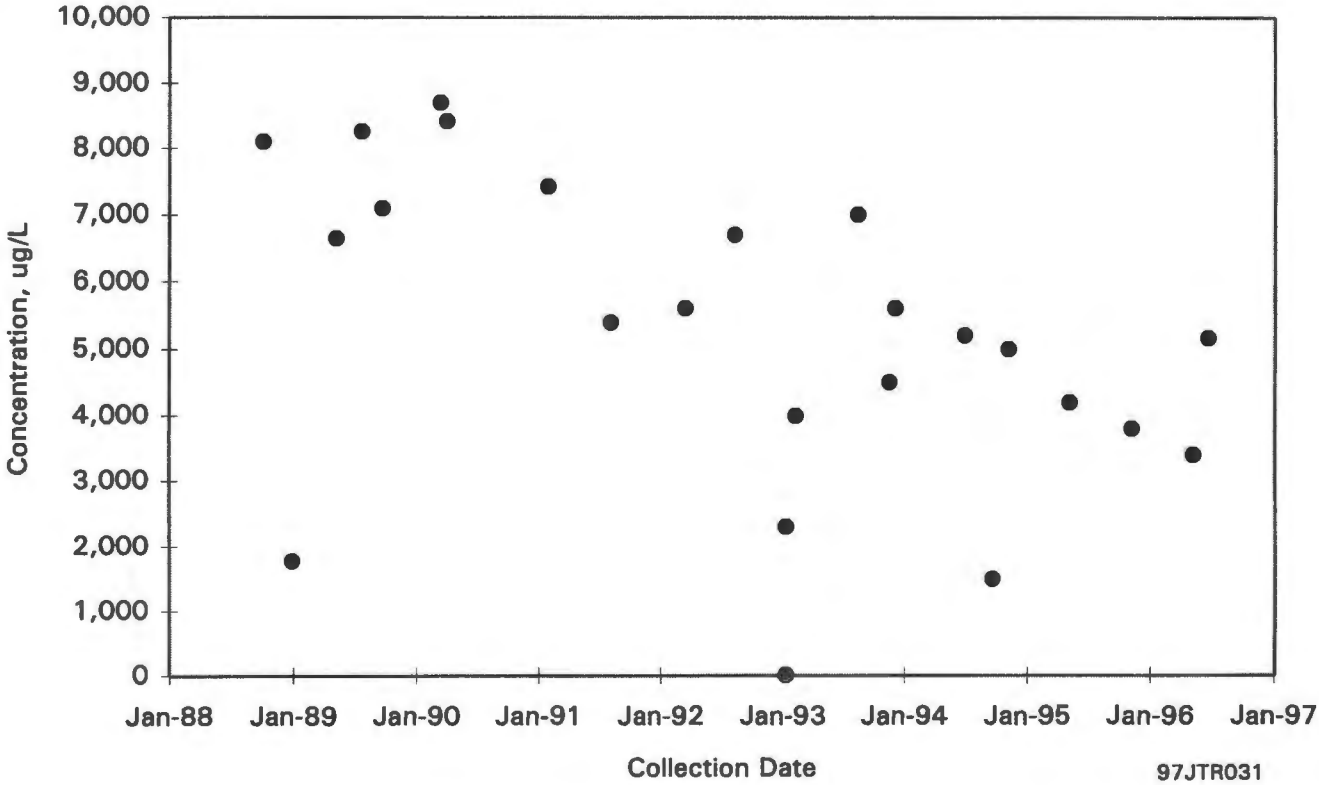

Figure 4.8.40. Carbon Tetrachloride Concentrations in Well 299-W15-16, 1988 Through 1996

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. The maximum concentration observed in 1996 was 1.5 µg/L at well 699-23-35. Solid Waste Landfill wells showed 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.

Trichloroethylene was 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 toward the 300 Area that appears to have an origin off the Hanford Site (Figure 4.8.42). Trend plots shown in Figure 4.8.42 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 1996 was 14 µg/L at wells 699-S31-E10A and 699-S31-E10C.

Tetrachloroethylene

Tetrachloroethylene, also referred to as perchloroethylene, was detected at levels below the 5-µg/L drinking water standard in several areas of the site during 1996. These included 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 also contained concentrations of tetrachloroethylene below the drinking water standard. The maximum tetrachloroethylene concentration detected at the Solid Waste Landfill was 3.1 µg/L at well 699-24-34C. Tetrachloroethylene exceeded the drinking water standard in wells near the Solid Waste Landfill before 1994. Tetrachloroethylene is commonly used as a degreasing solvent.

cis-1,2-Dichloroethylene

Concentrations of cis-1,2-dichloroethylene are increasing in well 399-1-16B. This well is completed in the deeper part of the unconfined aquifer in the 300 Area and is the only well onsite where this constituent is found at levels

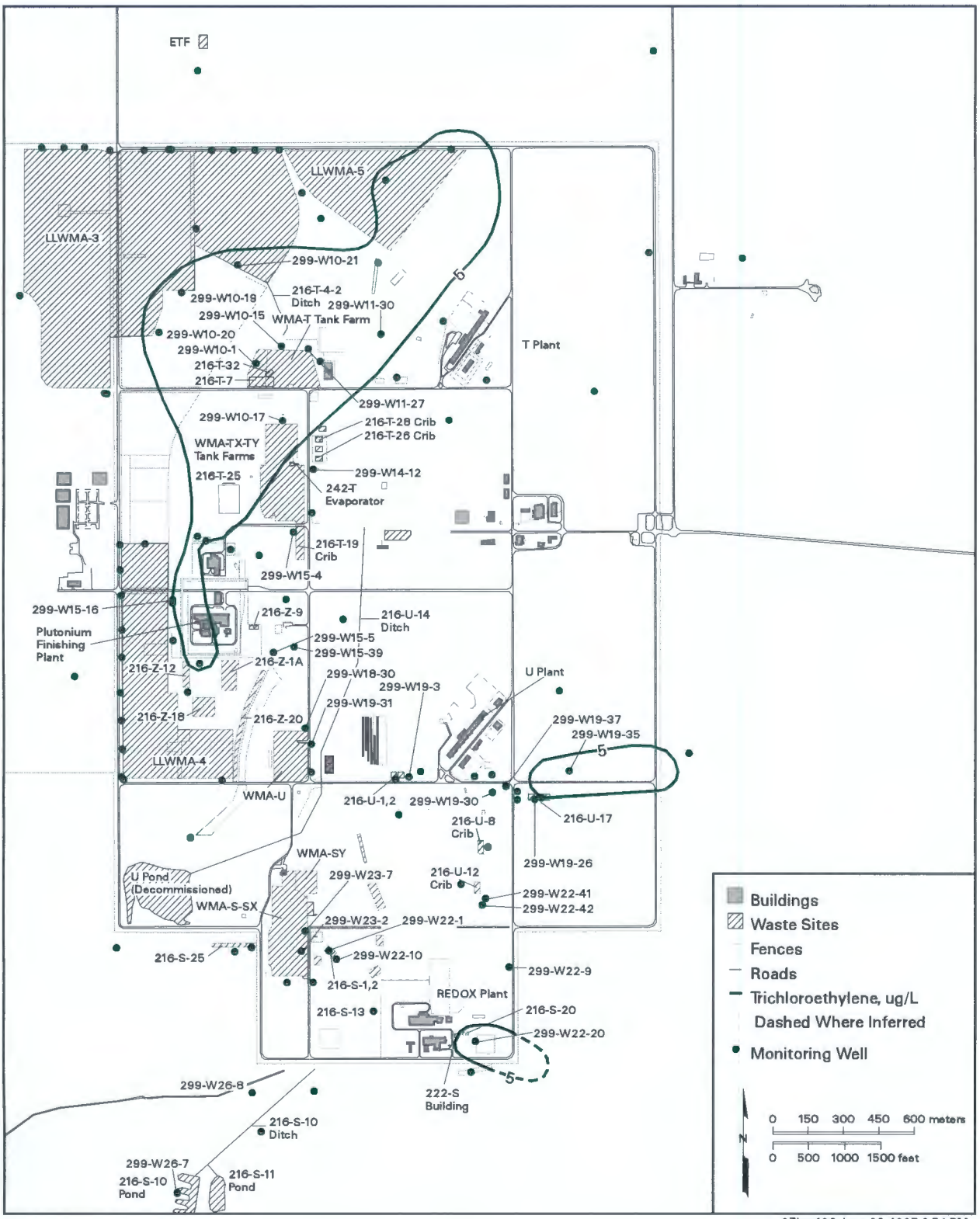

Figure 4.8.41. Distribution of Trichloroethylene in the Unconfined Aquifer in the 200-West Area, 1996

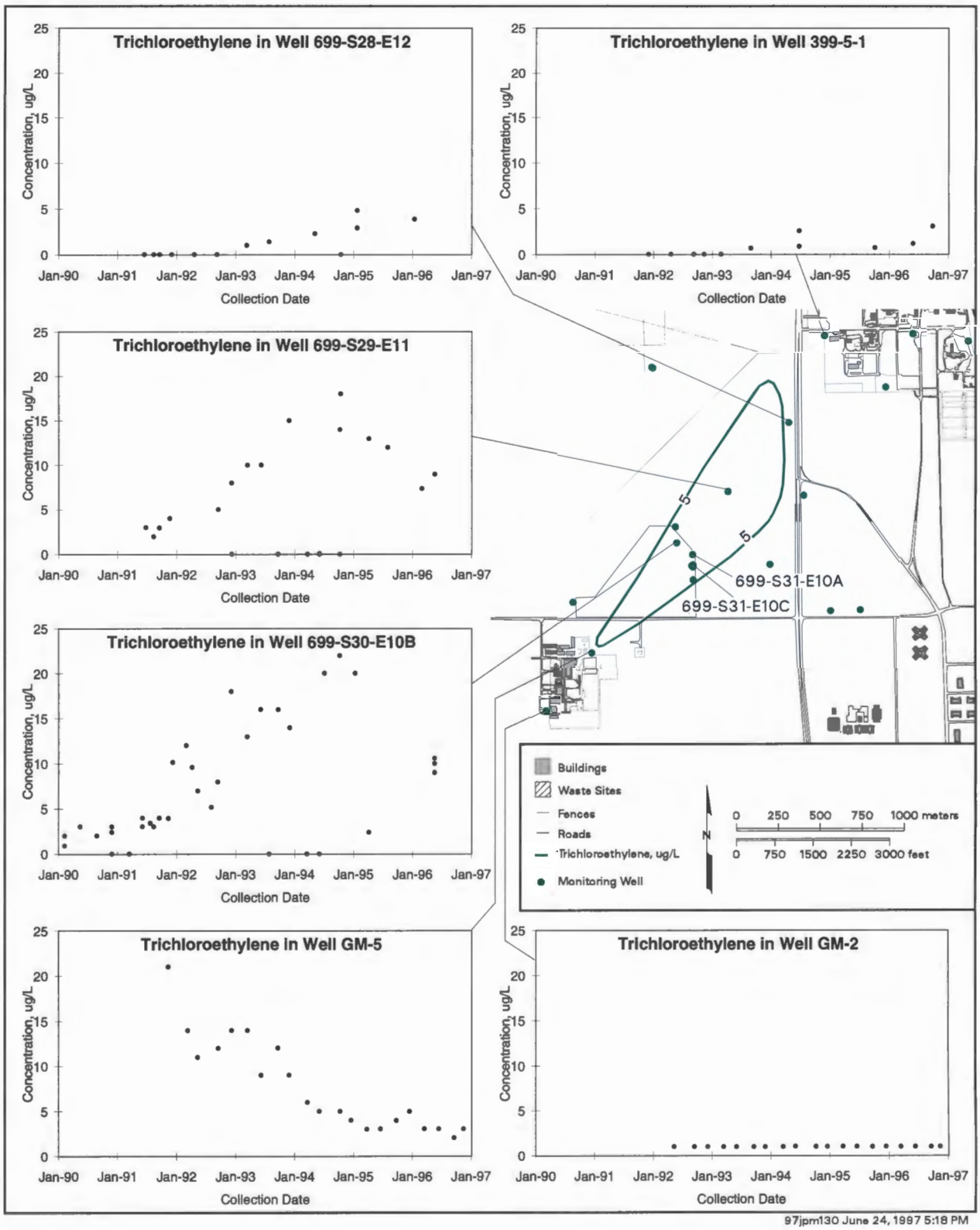

Figure 4.8.42. Distribution of Trichloroethylene in the Vicinity of the Horn Rapids Landfill and Richland North Area, 1996, and Concentration Trends for Select Wells

above the 70-µg/L drinking water standard. In 1996, 140 µg/L of cis-1,2-dichloroethylene were detected in well 399-1-16B. cis-1,2-dichloroethylene is a biodegradation product of trichloroethylene.

Radiological and Chemical Monitoring Results for the Basalt-Confined Aquifer

Aquifers confined below the uppermost basalt layers show much less impact from Hanford Site contamination than the unconfined aquifer system within the overlying sediments. The minor contamination found in the basalt-confined aquifers may be attributed to several factors. These factors include 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 groundwater 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 extents of tritium and other detected contaminants in the uppermost confined aquifer are shown in Figure 4.8.43.

Intercommunication between the unconfined and basalt-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.

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 groundwater mounding associated with waste disposal. Groundwater 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.

Results of the 1995 sampling and analyses of groundwater from the upper basalt-confined aquifer indicated only a few areas of concern that warranted continued annual monitoring. Consequently, the number of wells sampled during 1996 was reduced to those with groundwater contamination or those downgradient from areas with historical indications of contamination. Prominent analytical results and trends arising from 1996 sampling are discussed below. The locations of wells used for monitoring confined aquifer groundwater chemistry were given in Figure 4.8.10.

Well 199-B3-2P, in the 100-B Area, is currently completed within the confined aquifer but was open to both the confined and unconfined aquifers between 1953 and 1970. This well likely provided a conduit for downward migration of contamination from the unconfined aquifer. The 7.0-pCi/L concentration for strontium-90 measured at this well in 1996 was up from 3.9 pCi/L in 1995. The drinking water standard for strontium-90 is 8 pCi/L. The extent of contamination in the confined aquifer near well 199-B3-2P is unknown.

Contamination has also 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 unconfined and confined aquifers (Graham et al. 1984). During 1996, a technetium-99 concentration of 1,280 pCi/L was detected at well 299-E33-12, which is above the 900-pCi/L drinking water standard. Cobalt-60 was detected during 1995 at 154 pCi/L in the confined aquifer at well 699-49-55B, located north of the 200-East Area. This well was not analyzed for cobalt-60 in 1996. The cobalt-60 contamination at this well may be related to the use of neighboring well 699-49-55A, which is completed in the unconfined aquifer, for injection of water from a pump-and-treat test for groundwater remediation in 1994.

Well 699-42-40C monitors the confined aquifer adjacent to B Pond. Tritium at this well reached a high of 8,320 pCi/L in 1993, the concentration declined until 1995, then began rising again. In 1996, the tritium concentration was 8,284 pCi/L, still well below the

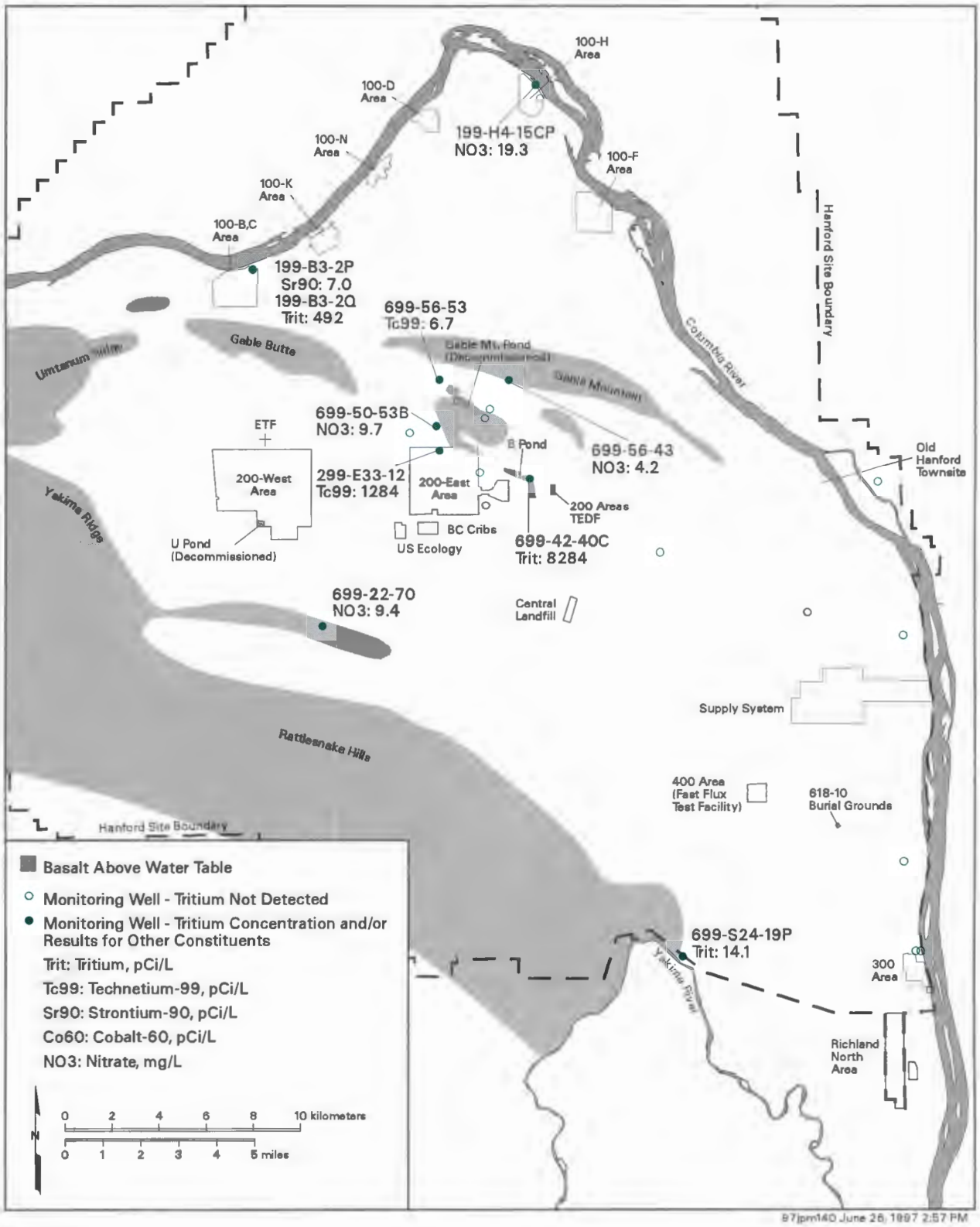

Figure 4.8.43. Tritium and Other Contaminants Detected in Confined Aquifer Wells, 1996

20,000-pCi/L drinking water standard. The iodine-129 result for 1996 was 0.36 pCi/L, the highest since monitoring began in 1988 but still less than the 1-pCi/L drinking water standard.

Well 299-W15-5 in the 200-West Area is completed in both the unconfined and confined aquifers, where groundwater 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-confined aquifer 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 from well 699-22-70 contained up to 9.0 mg/L of nitrate in 1996, well below the 45-mg/L drinking water standard. In past years, samples from well 699-20-82 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 and is not believed to originate from sources on the Hanford Site.

Resource Conservation and Recovery Act Summary

More than 60 treatment, storage, and disposal units are recognized under the Hanford Facility Resource Conservation and Recovery Act permit. Of these, 26 required groundwater monitoring during 1996. Locations of these groundwater monitoring sites were given in Figure 4.8.11. This section provides a summary of groundwater monitoring activities and results for these sites. Additional information on Resource Conservation and Recovery Act groundwater monitoring, including complete listings of radioactive and chemical constituents measured in monitoring wells from October 1995 through September 1996, is available in Hartman and Dresel (1997). Any significant changes in Resource Conservation and Recovery Act groundwater monitoring results that occurred from October through December 1996 are noted below.

Resource Conservation and Recovery Act groundwater monitoring is conducted under one of three phases: 1) indicator parameter/detection, 2) groundwater quality assessment/compliance, or 3) corrective action. Initially, a detection program is developed to monitor the impact of facility operations on groundwater. During the indicator parameter/detection phase, groundwater parameters established for the particular site are measured in wells upgradient and downgradient from the site. Statistical tests are applied to the monitoring results to calculate "critical mean" values for each monitoring parameter. These values represent the background water quality for the site. Subsequent monitoring data are compared to the critical mean values to determine if there has been a statistically significant increase in the concentrations of key indicator parameters or dangerous waste constituents in the groundwater. The statistical methods used to calculate critical means and compare with monitoring data are described in Hartman and Dresel (1997). If a statistically significant difference is observed, then a groundwater quality assessment/compliance phase of monitoring and investigation is initiated. During this phase, groundwater monitoring is designed to determine if groundwater protection standards have been exceeded. If the source of the contaminants is determined to be the treatment, storage, and disposal unit, and concentrations exceed maximum contaminant levels defined in the monitoring plan or permit, then the Washington State Department of Ecology may require corrective action to reduce the contaminant hazards to the public and environment. Groundwater monitoring during the corrective action phase is designed to assess the effectiveness of the corrective action. Table 2.2.2 listed the phase pertaining to each of the Resource Conservation and Recovery Act groundwater monitoring projects at the end of 1996.

100 Areas Facilities

1301-N Liquid Waste Disposal Facility. The 1301-N facility was the primary liquid waste disposal site for N Reactor from 1963 until 1985. Discharges were primarily radioactive fission and activation products. Minor amounts of dangerous waste and other constituents may also have been discharged, including ammonium hydroxide, cadmium, diethylthiourea, hydrazine, lead, morpholine, phosphoric acid, and sodium dichromate. 1301-N consists of a concrete basin with an unlined, zigzagging extension trench, covered with concrete panels.

The indicator parameters of specific conductance, pH, total organic carbon, and total organic halogen measured in downgradient wells remained below the critical mean values at 1301-N during 1996.

1325-N Liquid Waste Disposal Facility. The 1325-N facility was constructed in 1983 and also received

effluent from N Reactor. In 1985, discharge to 1301-N ceased, and all effluent was sent to 1325-N. All discharge to 1325-N ceased in late 1991. The facility consists of a concrete basin with an unlined extension trench, covered with concrete panels.

The indicator parameters of specific conductance, pH, total organic carbon, and total organic halogen in downgradient wells remained below the critical mean values at 1325-N during 1996. Specific conductance in the upgradient well (199-N-74) was elevated in the past, possibly because of the upgradient influence of the 1324-NA Pond. Groundwater at 1325-N and at 1301-N is also analyzed for other constituents that were discharged to these facilities. These include cadmium, chromium, lead, nitrate, and phosphate. Cadmium, lead, and phosphate (in filtered samples) were not detected in 1301-N or 1325-N groundwater in significant concentrations. Nitrate is sporadically detected, but the sources are uncertain.

1324-N and 1324-NA Ponds. The 1324-N Pond was a treatment facility that was in service from May 1986 to November 1988. This facility is a double-lined pond that was used to neutralize high- and low-pH waste from a demineralization plant. 1324-NA is unlined and was used to treat waste from August 1977 to May 1986 and to dispose treated waste from May 1986 to August 1990. The effluent to both facilities contained sulfuric acid and sodium hydroxide, whose pH was occasionally high or low enough to be classified as a dangerous waste.

Specific conductance measured in 1996 in wells downgradient from 1324-N and 1324-NA was higher than the background critical mean value. The increase in this indicator parameter was expected because 1324-NA introduced nondangerous constituents (e.g., sodium and sulfate) to groundwater. Downgradient measurements of pH, total organic carbon, and total organic halogen were below critical mean values in 1996. It was determined that no additional groundwater assessment was warranted for this site.

120-D-1 Ponds. The 120-D-1 Ponds were constructed in 1977 for disposal of nonradioactive effluent derived from operating facilities in the 100-D,DR Area. This facility is located in the former 188-D Ash Disposal Basin and includes settling and percolation ponds separated by a dike. Effluent to the ponds originated from two sources: the 183-D Filter Plant and the 189-D Building engineering testing laboratories. Some past discharges contained hydrochloric acid, sodium hydroxide, and sulfuric acid. Before 1986, the effluent may have had a >12.5 or <2.0 pH and, thus, may have been dangerous waste. There was also a potential for up to 2.3 kg of mercury to have been discharged to the ponds. Effluent discharge ceased in 1994. Between 1986 and 1994, the effluent included chlorine and flocculating agents such as aluminum sulfate. Contaminated soils were removed from the 120-D-1 Ponds in 1996.

At the 120-D-1 Ponds site, samples from wells 199-D8-4 and 199-D8-6 exceeded the critical mean value for pH in February 1996, and verification sampling was conducted in March 1996. Results for well 199-D8-4 were below the critical mean but results for well 199-D8-6 were confirmed to be greater than the critical mean. The Washington State Department of Ecology was promptly notified of the exceedance as required by 40 CFR 265.93(d)(1) and a report describing the results of a groundwater quality assessment at the ponds was prepared and submitted in April 1996 (Hartman 1996a). The report concluded that the elevated pH originated from coal ash under the ponds and not from the ponds themselves. Therefore, the site remains in indicator parameter monitoring.

183-H Solar Evaporation Basins. The 183-H facility, which is now demolished, consisted of four separate concrete basins surrounded by an earthen berm. Between 1973 and 1985, the basins were used to store liquid waste, primarily from nuclear fuel fabrication activities conducted in the 300 Area. Volume reduction occurred by solar evaporation. The waste was predominantly acid etch solution that had been neutralized with sodium hydroxide before being discharged into the basins. The solutions included chromic, hydrofluoric, nitric, and sulfuric acids and also contained various metallic and radioactive constituents.

Groundwater in the vicinity of the 183-H basins is characterized by elevated levels of chromium, nitrate, sodium, sulfate, technetium-99, and uranium. All of these constituents were present in waste discharged to the basins when they were in use. The Resource Conservation and Recovery Act groundwater monitoring plan for these basins (Hartman and Chou 1995) identifies four contaminants of concern (waste indicators) for statistical evaluations under WAC 173-303-645(10): chromium, nitrate, technetium-99, and uranium. The concentrations of the waste indicators typically are highest in well 199-H4-3, located immediately downgradient of the basins. Although the concentrations decreased several orders of magnitude in this well since the basins ceased operation, they remained above drinking water standards for most of the past year.

In 1986, the Washington State Department of Ecology issued a compliance order that placed the 183-H basins into interim-status assessment monitoring. The basins were incorporated into the Hanford Site Resource Conservation and Recovery Act permit in September 1994 and became subject to final-status monitoring.

Results of the September through December 1995 sampling event indicated that concentration limits for chromium, nitrate, technetium-99, and uranium were exceeded in one or more downgradient wells. Confirmation sampling was conducted in the spring of 1996. Some of the samples confirmed the presence of contamination at levels above regulatory limits. The Washington State Department of Ecology was notified of the exceedances, which normally initiates a corrective action program. The 183-H basins are part of the 100-HR-1 and 100-HR-3 Operable Units, so corrective action was deferred and will be completed under the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act. In the interim, Resource Conservation and Recovery Act monitoring will continue under the current program.

The 183-H basins monitoring program is adequate under current flow conditions. However, a planned pump-and-treat system will extract groundwater from five wells around the basins, including two of the Resource Conservation and Recovery Act wells. The adequacy of the monitoring network will be evaluated in the coming year.

200 Areas Single-Shell Tank Farms

Single-shell tanks are located in the A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U Tank Farms and have been designated as Resource Conservation and Recovery Act facilities. The single-shell tanks store a mixture of dangerous chemical and radioactive wastes generated by reprocessing fuel irradiated in Hanford reactors. The single-shell tanks received mixtures of organic and inorganic liquids containing radionuclides, solvents, and metals that were originally discharged to the tanks as alkaline slurries. Subsequent waste management operations have mixed waste streams from different processes. In many tanks, wastes have been concentrated by removing water vapor.

A-AX Tank Farms. Critical mean values of the indicator parameters specific conductance, pH, total organic carbon, and total organic halogen were not exceeded during 1996. For iodine-129, all wells show concentration values above the drinking water standard because of a plume extending through this area from other sources. Tritium levels have been historically greater in one upgradient well versus downgradient wells at these tank farms.

B-BX-BY Tank Farms. The indicator parameter of specific conductance has been increasing in downgradient wells since monitoring began in 1990 and exceeded the critical mean value in well 299-E33-32 in February 1996 and in subsequent verification sampling. The rise in specific conductance appears to be related to an increase in nitrate and chloride. Several other downgradient wells have displayed trends of increasing nitrate and chloride with corresponding increases in specific conductance since 1992. There were no exceedances of critical means for the indicator parameters pH, total organic carbon, or total organic halogen during 1996. Iodine-129 levels in the groundwater at the B-BX-BY Tank Farms were above the drinking water standard because of a plume extending through this area from other sources.

C Tank Farm. Critical mean values of the indicator parameters specific conductance, pH, total organic carbon, and total organic halogen were not exceeded during 1996. For iodine-129, all wells showed concentrations above the drinking water standard because of a plume extending through this area from other sources.

S-SX Tank Farms. As discussed in Section 3.3, "Vadose Zone Characterization and Monitoring," spectral gamma logging in the vadose zone at the S-SX Tank Farms in 1996 indicated the presence of cesium-137 at depths ranging from 18 to 37 m (59 to 121 ft). Because the logging results indicated a possible faster-than-expected migration of cesium-137 from known tank leaks and because of elevated concentrations of technetium-99 in groundwater beneath the SX Tank Farm, which may also have resulted from tank leaks, a groundwater quality assessment phase groundwater monitoring program was initiated and an assessment groundwater monitoring plan (Caggiano 1996) was prepared and submitted to the Washington State Department of Ecology. Results for indicator parameters at the S-SX Tank Farms are discussed below:

pH. Field pH measurements for all wells ranged from 7.9 to 8.1, with the upgradient and downgradient wells exhibiting the same range. The critical mean values of 6.68 and 9.18 were not exceeded.

Specific Conductance. If values from the initial four quarters for both upgradient wells 299-W23-13 and 299-W23-14 are used, then the critical mean for specific

conductance was not exceeded. However, using only the southernmost upgradient well (299-W23-14) results in a lower critical mean that was exceeded in three downgradient wells during 1996. The cause of elevated specific conductance is being addressed by the assessment groundwater monitoring plan (Caggiano 1996).

Total Organic Carbon. Reported values for total organic carbon did not exceed the critical mean value.

Total Organic Halogen. Concentrations of total organic halogen exceeded the critical mean value at both upgradient and downgradient wells at the S-SX Tank Farms. The increasing total organic halogen concentrations are attributed to the southward and eastward migration of the carbon tetrachloride plume resulting from historical discharge activities at the Plutonium Finishing Plant. Because increasing concentrations are seen in upgradient wells, the increased halogen is not suspected to be from the S-SX Tank Farms.

Technetium-99 and Total Beta. As late as 1994, technetium-99 was found above the interim drinking water standard in a plume extending southeasterly from the vicinity of the S-SX Tank Farms. Since that time, measured concentrations have declined to less than the interim drinking water standard for all samples from this plume. The highest technetium-99 concentrations are found near the eastern half of the S-SX Tank Farms and near the 216-S-1 and 216-S-2 Cribs. The technetium-99 plume extends to the southeast, and can be detected beyond the 200-West Area boundary. Technetium-99 was generally not measured in groundwater samples before approximately 1986. However, measurements of total beta radiation correlate with the concentration of technetium-99 because it is a beta-emitting radionuclide. Total beta measurements indicate that peak technetium-99 concentrations in the vicinity of the S-SX Tank Farms probably occurred during the late 1980s at well 299-W23-2, which is just east of the tank farms (Hartman and Dresel 1997).

This technetium-99 plume was previously thought to be from discharge to nearby cribs. However, an examination of the ratios of technetium-to-uranium concentration provided evidence that tank waste liquids may be the source. A large area under the eastern portion of the S-SX Tank Farms is underlain by groundwater with technetium-99-to-uranium ratios that are >50. These relatively high ratios indicate that the tanks may be the source because the ratio of technetium-99-to-uranium concentration in tank waste liquids is generally high (>300) and the ratio in waste disposed to cribs is generally low (<0.1). In addition, the area with high technetium-99-to-uranium ratios tended to have relatively high technetium-99 concentrations and low tritium concentrations. Tritium is removed from the tank waste by evaporation. Condensate from this evaporation process is disposed in the adjacent cribs, thus enriching the discharge to the cribs with tritium (Hartman and Dresel 1997). The source of technetium-99 is being further evaluated under the assessment groundwater monitoring plan for the S-SX Tank Farms (Caggiano 1996).

Cesium-137. One sample collected in 1994 from well 299-W23-7, located on the eastern edge of the S-SX Tank Farms, contained 22 pCi/L of cesium-137. The same well showed a cesium-137 concentration of 18 pCi/L in 1996. These values are well below the 200-pCi/L drinking water standard. However, no cesium-137 was expected in the groundwater at this location. Although cesium-137 is known to have been released from tank leaks, it was not expected to be found at water-table depth, approximately 50 m (162 ft) below the bottom of the waste tanks, because its movement through the soil column is slowed by chemical sorption processes. Cesium-137 may have migrated to the water table through the well bore or well annulus at this location. However, because spectral-gamma logging within the vadose zone at the S-SX Tank Farms indicated a possible faster-than-expected migration of cesium-137 from known tank leaks, the presence of cesium-137 at well 299-W23-7 is being investigated as part of the S-SX Tank Farms' assessment monitoring program.

T and TX-TY Tank Farms. In November 1992, the critical mean for field specific conductance was exceeded in downgradient wells 299-10-15 (at the T Tank Farm) and 299-W10-17 and 299-W14-12 (at the TX-TY Tank Farms). Verification sampling placed these two sites into the groundwater quality assessment phase of monitoring. Quarterly sampling along with historic trends and waste management data identified calcium, chloride, magnesium, and nitrate as the primary constituents contributing to the elevated specific conductance. Elevated nitrate is widespread in the groundwater in the northern part of the 200-West Area (see Figure 4.8.35) because of the discharge of large amounts of nitrate to nearby trenches and cribs in the mid-1950s. The current assessment study of the T and TX-TY Tank Farms is attempting to differentiate contamination emanating from nearby trenches and cribs from that which may have leaked from waste tanks.

A number of other constituents exceeded regulatory limits in the vicinity of these tank farms. These include carbon tetrachloride, filtered chromium, filtered iron, fluoride, iodine-129, nickel, nitrate, technetium-99, and tritium. Some of these contaminants follow the same historical trend as nitrate, indicating a source more extensive than these tank farms. At the T Tank Farm, well 299-W11-27 showed large increases in several chemical species, including specific conductance, nitrate, technetium-99, and tritium that diverge from trends in nearby wells.

Tritium. A tritium plume that covers much of the northern half of the 200-West Area has its highest concentrations near the TX-TY Tank Farms and associated cribs (see Figure 4.8.12). The maximum average annual tritium detected in this plume in 1996 was 120,000 pCi/L in well 299-W15-4. The plume extends northeast, beyond the 200-West Area boundary. An area north of the T Tank Farm consistently shows tritium at levels much lower than the surroundings. The reason for this is unclear but may be related to discharge of relatively clean water to the 216-T-4 Ditch (Alexander et al. 1995). Concentrations of tritium and other constituents are increasing rapidly at well 299-W11-27 in the southern portion of this less-contaminated zone. The tritium concentration increased from approximately 1,200 to 12,000 pCi/L at this well during 1996.

Technetium-99. The area of the technetium-99 plume above the interim 900-pCi/L drinking water standard is restricted to the immediate vicinity of the TX-TY Tank Farms and the northeastern corner of the T Tank Farm. The maximum average annual technetium-99 detected near the TX-TY Tank Farms in 1996 was 1,200 pCi/L at well 299-W14-12. The technetium-99 concentration at this well, like the tritium concentration discussed above, declined in 1996. At the T Tank Farm, technetium-99 increased sharply at well 299-W11-27 to 19,500 pCi/L (see Figure 4.8.31). Total beta concentrations also showed a corresponding increase. No similar increases were seen at upgradient or other downgradient wells for this tank farm. These data are being evaluated as possible evidence of groundwater contamination from past T Tank Farm leaks.

Iodine-129. The extent of iodine-129 at concentrations above the interim 1.0-pCi/L drinking water standard in the T Plant area coincides with the tritium and technetium-99 plumes (see Figure 4.8.22). The maximum concentration of iodine-129 detected in this vicinity during 1996 was 6.8 pCi/L in well 299-W14-12. The iodine-129 concentration in this well declined in a manner similar to that of tritium and technetium-99. Iodine-129 was not measured in well 299-W11-27 during 1996.

Uranium. Few analyses for uranium were performed in the vicinity of T Plant in 1996 because most wells showed insignificant levels in previous monitoring. Wells monitored near the single-shell tanks for Resource Conservation and Recovery Act compliance were sampled for total alpha measurements, which would show an increase if uranium contamination appeared.

Nitrate. Much of the northern part of the 200-West Area continued to contain nitrate at concentrations in excess of the 45-mg/L drinking water standard (see Figure 4.8.35). During 1996, nitrate ranged up to 1,100 mg/L in well 299-W10-1, which is located west of the T Tank Farm near the 216-T-7 and 216-T-32 Cribs. A large quantity of nitrate was discharged in this area during the 1940s and 1950s. Nitrate was also found at elevated levels farther south near the TX-TY Tank Farms. The area of low nitrate north of the T Tank Farm corresponds to the area of low concentration of other constituents discussed above. The nitrate concentration at well 299-W11-27 increased from approximately 27 to 230 mg/L during 1996, which coincided with the increases in tritium and technetium-99 at this well.

Chromium. Chromium contamination continues to be found above the 50-mg/L state drinking water standard and the 100-mg/L federal drinking water standard in the T Plant area. Chromium was above the drinking water standard in filtered samples from the area north and west of the T Tank Farm, where the maximum average annual concentration detected in 1996 was 306 mg/L at well 299-W11-27. Chromium concentrations decreased to less than 100 mg/L at this well during 1996 and did not follow the same increasing trend as nitrate, technetium-99, and tritium. Chromium was also above the drinking water standard in well 299-W14-12, located east of the TX-TY Tank Farms, though at lower levels than in 1995.

U Tank Farm. This single-shell tank farm is currently under a detection-level monitoring program. There were several critical mean exceedances for contamination indicator parameters pH and total organic halogen during the year. However, given the changes in groundwater flow directions and resultant uncertainty in upgradient-downgradient distinctions, the meaning of the exceedances is somewhat uncertain.

pH. The field pH upper critical mean value of 8.59 was exceeded in well 299-W19-31 in February 1996 with a

value of 8.7 and in May 1996 with a value of 8.8. These exceedances were apparently the result of some changing groundwater flow directions. They were of short duration and do not appear to be significant.

Total Organic Halogen. Total organic halogen values ranged from 25 to 416 mg/L for 1996. There was a general increase in total organic halogen values across the U Tank Farm. The 416-mg/L value reported for August 1996 at well 299-W18-30 exceeded the critical mean value of 241 mg/L. The increasing total organic halogen values are probably a result of spreading of the carbon tetrachloride plume from the Plutonium Finishing Plant (Hartman and Dresel 1997). The U Tank Farm monitoring network, completed in 1993, was based on a west-to-east groundwater flow direction. A reversal in the direction of groundwater flow between mid-1993 and late 1995 resulted in flow toward the northwest, which rendered both upgradient and downgradient coverage inadequate. However, by the time this reversal was recognized, groundwater flow had returned toward the southeast. Under current flow conditions, some downgradient wells at the U Tank Farm may be impacted by the carbon tetrachloride plume from the Plutonium Finishing Plant prior to its being detected in the upgradient wells.

Technetium-99. There was a significant increase in technetium-99 at downgradient well 299-W19-31, with a level reaching 782 pCi/L in August 1996. The increase in technetium-99 in well 299-W19-31 corresponds to the change in groundwater flow back to an easterly direction and probably is related to that change.

200 Areas Liquid Effluent Disposal Facilities

216-A-10 and 216-A-36B Cribs. These deactivated cribs in the 200-East Area received liquid waste from the Plutonium-Uranium Extraction Plant. The waste stream at the 216-A-10 Crib was characteristically acidic and contained concentrated salts, hydrocarbon compounds, organic complexants, plutonium, uranium, and other radionuclides. The 216-A-36B Crib received ammonia scrubber distillate from nuclear fuel decladding operations, in which zirconium cladding was removed from irradiated fuel by boiling in a solution of ammonium fluoride and ammonium nitrate. Other waste stream constituents included cesium-137, cobalt-60, iodine-129, ruthenium-106, strontium-90, tritium, and uranium.

These cribs are in the indicator parameter phase of groundwater monitoring. Constituents including iodine-129, nitrate, strontium-90, and tritium were detected at levels that exceeded drinking water standards. However, the source of these groundwater contaminants is uncertain because they are present within large plumes in this area. Critical mean values were not exceeded for the indicator parameters (specific conductance, pH, total organic carbon, and total organic halogen) during 1996, except for one constituent at one monitoring well at the 216-A-36B Crib. Specific conductance exceeded the critical mean at well 299-E17-9 during May 1996. However, this well does not meet Resource Conservation and Recovery Act construction standards and is not used for statistical purposes. The elevated specific conductance is related to elevated nitrate concentrations.

216-A-29 Ditch. This is a deactivated earthen ditch approximately 2 km (1.2 mi) long that conveyed Plutonium-Uranium Extraction Plant chemical waste to the 216-B-3 Pond from 1955 to 1986. The ditch received effluents that contained dangerous chemical and radioactive contaminants. Of primary concern for Resource Conservation and Recovery Act regulations were discharges of sodium hydroxide and sulfuric acid, which occurred daily as a result of ion-exchange regeneration at the Plutonium-Uranium Extraction Plant.

In 1990, specific conductance increased beyond the critical mean and an assessment monitoring program was initiated. The assessment program confirmed that the ditch was the likely source of the elevated specific conductance. However, the constituents contributing to the high conductance were determined to be calcium, sodium, and sulfate, which are nonregulated substances. The groundwater monitoring program subsequently reverted to the indicator parameter monitoring phase, and specific conductance has been declining in both upgradient and downgradient wells at the site.

216-B-3 Pond. The 216-B-3 Pond (B Pond) is located immediately east of the 200-East Area and consists of a main pond and three expansion ponds (216-B-3A, 216-B-3B, and 216-B-3C). The main pond has been in use since 1945 and the expansions were built in the 1980s. Only the 216-B-3C section remains in operation. B Pond received liquid waste from B Plant and the Plutonium-Uranium Extraction Plant, consisting of chemical sewer waste, cooling water, and steam condensate. B Pond currently receives nondangerous, nonradioactive effluent primarily from the Plutonium-Uranium Extraction Plant and B Plant.

Groundwater monitoring at the B Pond system was changed to assessment level in 1990 because of elevated total organic halogen concentrations in downgradient wells 699-43-41E and 699-43-41F. Total organic halogen concentrations in these wells have generally declined since 1991. During 1996, 12 downgradient wells were sampled quarterly for semivolatile organic compounds that contribute to total organic halogen. No wells exceeded critical mean values for pH, specific conductance, or total organic carbon during 1996.

216-B-63 Trench. This trench, in service from March 1970 to February 1992, received liquid effluent from the B Plant chemical sewer, which consisted of a mixture of steam condensate and water. Past releases to the trench included aqueous sulfuric acid and sodium hydroxide solutions. Radioactive soils were dredged from the trench in August 1970 but no records exist of radioactive waste disposal to the trench.

Groundwater monitoring continues to provide no evidence that dangerous nonradioactive constituents from the site entered the groundwater from this trench. There were no exceedances in the indicator parameters of pH, specific conductance, total organic carbon, or total organic halogen.

216-U-12 Crib. This crib, located south of U Plant in the 200-West Area, received waste water containing both dangerous chemical wastes and radionuclides from April 1960 until February 1988. This facility is currently in the groundwater quality assessment phase of monitoring. Site-specific waste indicators include iodine-129, nitrate, technetium-99, tritium, total alpha, and total beta. Iodine-129, nitrate, technetium-99, and tritium are detected repeatedly and are being investigated to determine whether the crib is the source. Specific conductance has exceeded the 458-mS/cm critical mean in three downgradient wells (299-W22-41, 299-W22-42, and 699-36-70A) since groundwater monitoring began. Nitrate is the only constituent with consistently elevated concentrations in the downgradient wells and is the most significant contributor to the elevated specific conductance.

216-S-10 Pond and Ditch. This facility is located south-southwest of the 200-West Area, directly outside the perimeter fence. The facility consisted of an open, unlined ditch approximately 686 m (750 yd) long and an open, unlined percolation pond approximately 2.0 ha (4.9 acres) in size at the southwest end of the ditch. The ditch and pond received radioactive and dangerous chemical waste from the Reduction-Oxidation Plant from 1951 until 1985, when the pond and the lower part of the ditch were decommissioned and backfilled. The upper part of the ditch continued to receive nondangerous unregulated waste water after 1985.

The indicator parameters for this facility are specific conductance, field pH, total organic carbon, and total organic halogen. Field pH measured at well 299-W26-8 during 1996 was higher than the secondary drinking water standard, but was below the critical mean for this parameter. Chromium concentration was higher than the drinking water standard in upgradient well 299-W26-7, which suggests that the elevated chromium may be from upgradient sources rather than the 216-S-10 facility.

200 Areas Low-Level Burial Grounds

All low-level waste management areas at the Hanford Site are in the indicator-parameter phase of Resource Conservation and Recovery Act groundwater monitoring. A number of burial grounds are included within each low-level waste management area. Locations of the low-level waste management areas were shown in Figure 4.8.11.

Low-Level Waste Management Area-1. This waste management area consists of the 218-E-10 burial ground in the northwest corner of the 200-East Area. Disposal activities began in 1960 and continue to the present. Materials placed in this facility are primarily failed equipment and mixed industrial waste from the Plutonium-Uranium Extraction Plant, B Plant, and N Reactor. It is currently in the indicator parameter phase of groundwater monitoring.

Critical means for the contamination indicator parameters established for Low-Level Waste Management Area-1 were not exceeded during 1996. Although there is no evidence of any contaminant contribution from Low-Level Waste Management Area-1, contaminant plumes from other sources affect the groundwater quality.

Low-Level Waste Management Area-2. This waste management area is located in the northeast corner of the 200-East Area and includes all of burial ground 218-E-12B, which has been in use since 1968. The waste consists primarily of miscellaneous dry waste and submarine reactor compartments. Parts of two trenches contain transuranic waste.

Critical means for the contamination indicator parameters established for Low-Level Waste Management Area-2 were not exceeded during 1996. Values for iodine-129 were above the drinking water standard in several wells

along the southern boundary of Low-Level Waste Management Area-2. However, this is related to the widespread iodine-129 plume beneath the 200-East Area, and there is no evidence of contamination from Low-Level Waste Management Area-2.

Low-Level Waste Management Area-3. Burial grounds 218-W-3A, 218-W-3AE, and 218-W-5 make up Low-Level Waste Management Area-3, which is located in the north-central portion of the 200-West Area. These facilities cover 74.3 ha (181.4 acres). Burial ground 218-W-3A began accepting waste in 1970 and received primarily ion-exchange resins and failed equipment (e.g., tanks, pumps, ovens, agitators, heaters, hoods, jumpers, vehicles, and accessories). Burial ground 218-W-3AE began operation in 1981 and contains low-level and mixed waste, including rags, paper, rubber gloves, tools, and industrial waste. Burial ground 218-W-5 first received waste in 1986, and contains low-level and low-level-mixed waste, including lead bricks and shielding.

Carbon tetrachloride and nitrate are consistently above drinking water standards at Low-Level Waste Management Area-3 monitoring wells. However, the elevated values can be attributed to contaminant plumes originating to the south of Low-Level Waste Management Area-3. Trichloroethylene exceeded the 5-mg/L drinking water standard in upgradient wells 299-W10-19, 299-W10-20, and 299-W10-21. There appears to be no groundwater contamination directly attributable to Low-Level Waste Management Area-3, and there were no exceedances of the critical mean values for indicator parameters.

Low-Level Waste Management Area-4. This low-level waste management area consists of burial grounds 218-W-4B and 218-W-4C, which cover 24.4 ha (60 acres) in the south-central portion of the 200-West Area. Burial ground 218-W-4B first received waste in 1968 and contains mixed and retrievable transuranic waste in trenches and 12 caissons. One caisson is believed to contain mixed waste. Waste was first deposited in burial ground 218-W-4C in 1978. Transuranic, mixed, and low-level waste was placed in burial ground 218-W-4C, including contaminated soil, decommissioned equipment, and remote-handled transuranic waste.

There appears to be no groundwater contamination directly attributable to Low-Level Waste Management Area-4. Samples from downgradient wells did not exceed the critical means established for indicator parameters. Concentrations of carbon tetrachloride above drinking water standards were found in most wells in 1996. However, the source of the carbon tetrachloride is past disposal of liquid waste near the Plutonium Finishing Plant. Nitrate also exceeded the drinking water standard in several wells. The source of the contamination is the nitrate plume emanating from the vicinity of the Plutonium Finishing Plant.

Low-Level Waste Management Area-5. Low-Level Waste Management Area-5 was eliminated from further groundwater monitoring because no waste has been disposed to this facility and there are no plans for its use.

200 Areas Liquid Effluent Retention Facility

This facility consists of three lined surface impoundments (basins) located northeast of the 200-East Area and serves as temporary storage for condensate from the 242-A Evaporator. Constituents detected in the effluent stream from the 242-A Evaporator were acetone, aluminum, ammonium, 1-butanol, 2-butanone, cesium-137, ruthenium-106, strontium-90, and tritium.

Groundwater monitoring at this facility is in the indicator parameter monitoring phase. The indicator parameters are specific conductance, pH, total organic carbon, and total organic halogen. There were no exceedances of the critical mean values for these parameters, which indicates that no dangerous nonradioactive constituents have been released to groundwater.

300 Area Process Trenches

The site of the 316-5 Process Trenches is under the groundwater quality assessment stage of Resource Conservation and Recovery Act groundwater monitoring. These two unlined trenches were used for the disposal of most liquid wastes generated in the 300 Area beginning in 1975 and received uranium and other radioactive and chemical constituents. Uranium concentrations were higher than the drinking water standard at several wells near this facility in 1996.

Nonradioactive Dangerous Waste Landfill

The Nonradioactive Dangerous Waste Landfill is in the indicator parameter phase of groundwater monitoring. None of the indicator parameters of specific conductance, pH, total organic carbon, or total organic halogen exceeded critical mean values during 1996. Chlorinated hydrocarbons were detected in a few wells at concentrations below the drinking water standards.

Potential Radiation Doses from 1996 Hanford Operations

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5.0 Potential Radiation Doses from 1996 Hanford Operations

E. J. Antonio and K. Rhoads

During 1996, radionuclides reached the environment in gaseous and liquid effluents from Hanford Site operations. Monitored gaseous effluents were released from operating stacks and ventilation exhausts. Other potential sources include fugitive emissions from contaminated soil areas and unmonitored facilities. Liquid effluents were released from operating waste-water treatment facilities and from contaminated groundwater 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 1996 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. However, the amounts of most radioactive materials released during 1996 from Hanford sources 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 the GENII computer code Version 1.485 (Napier et al. 1988) and Hanford Site-specific parameters listed in Appendix D and in Bisping (1997) to 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 1996, tritium and iodine-129 were found in the Columbia River downstream of Hanford at greater concentrations than predicted based on direct discharge from the 100 Areas. All other concentrations of radionuclides were lower than those predicted from known releases. 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" and Section 4.8, "Groundwater Protection and Monitoring Program"). No direct discharges from the 300 Area to the Columbia River were reported in 1996.

The estimated dose[a] to the maximally exposed offsite individual from Hanford operations in 1996 was 0.007 mrem (7×10^{-5} mSv) compared to 0.02 mrem (2×10^{-4} mSv) reported for 1995. The dose to the local population of 380,000 (Beck et al. 1991) from 1996 operations was 0.2 person-rem (0.002 person-Sv) compared to 0.3 person-rem (0.003 person-Sv) reported for 1995.

(a) Unless stated otherwise, the term "dose" in this section is the "total effective dose equivalent" (see Appendix B, "Glossary").

The 1996 average dose to the population was approximately 0.0005 mrem (5×10^{-6} mSv) per person. The current DOE radiation dose limit (DOE Order 5400.5) for an individual member of the public is 100 mrem/yr (1 mSv/yr) from all pathways and 10 mrem/yr (0.1 mSv/yr) from airborne radionuclide emissions (40 CFR 61). The national average dose from natural sources is 300 mrem/yr (3 mSv/yr). Thus, 1996 Hanford emissions potentially contributed to the maximally exposed individual a dose equivalent to only 0.007% of the DOE dose limit, or 0.002% of the average dose received from natural radioactivity in the environment. For the average member of the local population, these contributions were approximately 0.0005% and 0.0002%, 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 (e.g., vegetation uptake and consumption factors), conservative values were selected from the literature for use in environmental transport models. Thus, radiological 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 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 contributions of the several sources of radioactive effluents released to the air and to the Columbia River from Hanford facilities. Historically, two separate locations 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 historically were major contributors of airborne effluents. At Riverview, the maximally exposed individual has the highest exposure to radionuclides in the Columbia River.

Since 1993, a third location across from the 300 Area has been considered. Because of the shift in site operations from strategic materials production to the current mission of research and environmental restoration, the significance of the air emissions from the 200 Areas production facilities has decreased relative to those from 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 air pathway exposures from emissions at the 200 Areas, 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 Ringold irrigate their crops with water taken from the Columbia River downstream of where groundwater enters the river from the 100 and 200-East Areas (see 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 pathway 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 the 300 Area, receives the 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 (Washington State

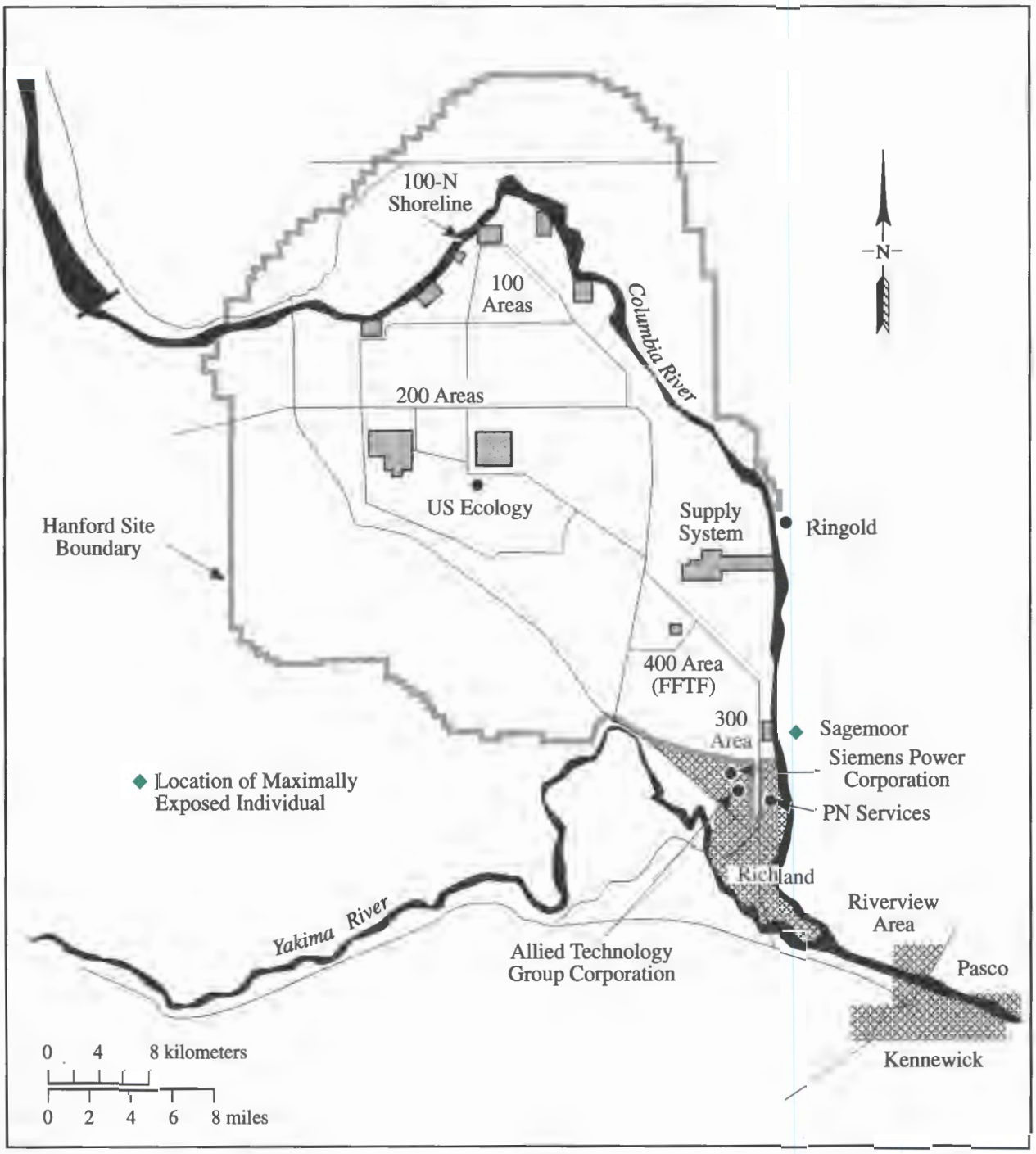

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Figure 5.0.1. Locations Important to Dose Calculations

Department of Health 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 1.5 km (1 mi) east of the 300 Area consisted totally of foods purchased from the Riverview area, which could contain radionuclides present in both liquid and gaseous effluents. The added contribution of radionuclides in the Riverview irrigation water maximizes the calculated dose from the air and water pathways combined.

The 1996 hypothetical maximally exposed individual at Sagemoor was calculated to have received a higher dose than a maximally exposed individual located at either Ringold or Riverview. Radiological doses to the maximally exposed individual were calculated using the effluent data in 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 groundwater 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 1996, as well as the future, or committed dose from radionuclides that were inhaled or ingested during 1996. 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 radiological dose to the hypothetical maximally exposed individual in 1996 was calculated to be 0.007 mrem (7×10^{-5} mSv) compared to 0.02 mrem (2×10^{-4} mSv) calculated for 1995. The primary pathways contributing to this dose (and the percentage of all pathways) were the following:

- inhalation of airborne radionuclides (54%), principally iodine-129 released from the 200 Areas and radon-220 (lead-212) released from the 300 Area

Table 5.0.1. Dose to the Hypothetically Maximally Exposed Individual Residing 1.5 km (1 mi) East of the 300 Area from 1996 Hanford Operations

		Operating Area Contribution Dose, mrem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	3.7×10^{-8}	9.3×10^{-7}	5.7×10^{-5}	2.1×10^{-8}	5.8×10^{-5}
	Inhalation	1.3×10^{-5}	3.3×10^{-4}	3.6×10^{-3}	1.6×10^{-5}	4.0×10^{-3}
	Foods	3.0×10^{-7}	4.2×10^{-4}	8.7×10^{-5}	2.8×10^{-5}	5.4×10^{-4}
	Subtotal air	1.3×10^{-5}	7.5×10^{-4}	3.7×10^{-3}	4.4×10^{-5}	4.6×10^{-3}
Water	Recreation	4.0×10^{-6}	4.6×10^{-6}	0.0[a]	0.0	8.6×10^{-6}
	Foods	2.7×10^{-4}	2.1×10^{-3}	0.0	0.0	2.4×10^{-3}
	Fish	3.3×10^{-4}	1.4×10^{-4}	0.0	0.0	4.7×10^{-4}
	Drinking water	0.0	0.0	0.0	0.0	0.0
	Subtotal water	6.0×10^{-4}	2.2×10^{-3}	0.0	0.0	2.8×10^{-3}
Combined total		6.2×10^{-4}	3.0×10^{-3}	3.7×10^{-3}	4.4×10^{-5}	7.4×10^{-3}

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

- consumption of food irrigated with Columbia River water containing radionuclides (32%), principally tritium and strontium-90.

The DOE radiological dose limit for any member of the public from all routine DOE operations is 100 mrem/yr (1 mSv/yr) (40 CFR 61). The dose calculated for the maximally exposed individual for 1997 was 0.007% of the DOE limit. Thus, the Hanford Site was in compliance with applicable state and federal regulations.

The doses from Hanford operations for the maximally exposed individual for 1992 through 1996 are illustrated in Figure 5.0.2. During each year, the doses were estimated using methods and computer codes previously described. In 1992, the maximally exposed individual was located at Riverview. For 1993 through 1996, the hypothetical maximally exposed individual was located across the Columbia River from the 300 Area at Sagemoor.

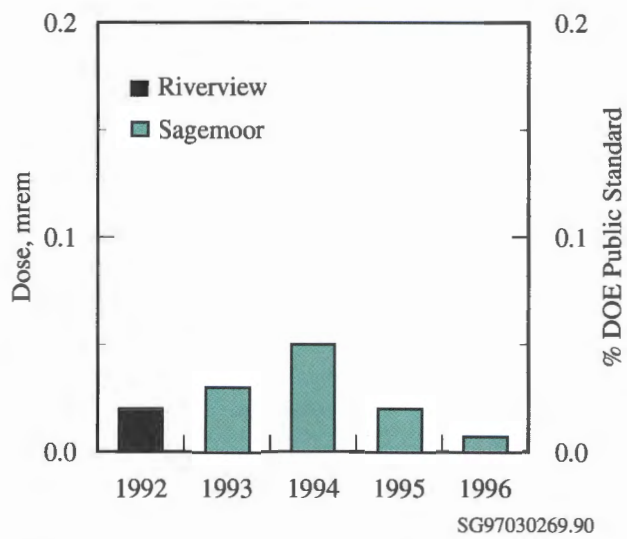

Figure 5.0.2. Calculated Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual, 1992 Through 1996

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. Three scenarios that could potentially lead to larger doses include 1) an individual who would spend time at the site boundary location with the maximum external radiation dose rate, 2) a sportsman who might consume contaminated wildlife that migrated from the site, and 3) a consumer 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 (see 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 (feet) of the N Reactor and supporting facilities.

The dose rate at the location with the highest exposure rate along the 100-N shoreline during 1996 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 1996, the external radiological dose received from Hanford operations would be approximately 0.01 mrem (1×10^{-4} mSv) above the natural background dose. If an individual spent an hour at this location, a dose would be received that is similar to the annual dose calculated for the hypothetical maximally exposed individual at Sagemoor. The public can approach the shoreline 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 the maximum contamination levels that might possibly exist in animals hunted offsite. Because 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 radiological doses that could have resulted if wildlife containing the maximum concentrations measured in onsite wildlife in 1996 migrated offsite, were hunted, and were eaten.

- The dose from eating 1 kg (2.2 lb) of deer meat that contains the maximum concentration of cesium-137 (0.025 pCi/g) measured in a deer collected onsite is estimated to be 1×10^{-3} mrem (1×10^{-5} mSv).

- The dose from eating 1 kg (2.2 lb) of bass meat that contains the maximum concentrations of cesium-137 (0.02 pCi/g) measured in bass collected from the Hanford Reach of the Columbia River is estimated to be 1×10^{-3} mrem (1×10^{-5} mSv).

- The dose from eating 1 kg (2.2 lb) of pheasant meat that contains the maximum concentration of cesium-137 (0.0047 pCi/g) measured in a pheasant collected onsite is estimated to be 2×10^{-4} mrem (2×10^{-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, which is addressed in more detail in Soldat et al. (1990).

Fast Flux Test Facility Drinking Water

During 1996, groundwater 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 (40 CFR 61). All annual average radionuclide concentrations measured during 1996 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 (0.26 gal/d) for 240 working days), the worker would receive an effective dose equivalent of <0.2 mrem (<0.002 mSv). The doses calculated here are well below the drinking water pathway dose limit of 4 mrem for public drinking water supplies operated by DOE.

Comparison with Clean Air Act Standards

Limits for radiation dose to the public from airborne emissions from DOE facilities are provided in 40 CFR 61, Subpart H. The regulation specifies that no member of the public shall receive a dose of more than 10 mrem/yr (0.1 mSv/yr) from exposure to airborne radionuclide effluents, other than radon, released at DOE facilities (EPA 1989). The regulation 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 1996 air emissions report (Gleckler et al. 1997).

The 1996 air emissions from monitored Hanford facilities, including radon-220 and radon-222 releases from the 300 Area, resulted in a potential dose to a maximally exposed individual across from the 300 Area of 0.005 mrem (5×10^{-5} mSv), which represents 0.05% of the standard. Of this total, radon emissions from the 327 Building contributed 0.003 mrem (3×10^{-5} mSv), and nonradon emissions from all monitored stack sources contributed 0.002 mrem (2×10^{-5} mSv). Therefore, the estimated annual dose from monitored stack releases at the Hanford Site during 1996 was well below the Clean Air Act standard. The Clean Air Act requires the use of CAP-88 (Parks 1992) 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 report. Nevertheless, the result of calculations performed with CAP88-PC for air emissions from Hanford facilities agrees well with that calculated using the GENII code (0.005 mrem or 5×10^{-5} mSv for air pathways).

The December 15, 1989 revisions to the Clean Air Act (40 CFR 61, Subpart H) 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 1996, the estimated dose from diffuse sources to the maximally exposed individual across the river from the 300 Area was 0.03 mrem (3×10^{-4} mSv), which was greater than the estimated dose at that location from stack emissions (0.005 mrem or 5×10^{-5} mSv). Doses at other locations around the Hanford Site perimeter ranged from 0.02 to 0.06 mrem (2×10^{-4} to 6×10^{-4} mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1996 was well below 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 1996 Hanford operations was estimated by calculating the radiological 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.

The collective dose calculated for the population was 0.2 person-rem (0.002 person-Sv) in 1996 compared to 0.3 person-rem (0.003 person-Sv) in 1995. The 80-km (50-mi) collective doses attributed to Hanford operations from 1992 through 1996 are compared in Figure 5.0.3.

Table 5.0.2. Dose to the Population from 1996 Hanford Operations

		Operating Area Contribution Dose, person-rem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	5.3×10^{-6}	7.7×10^{-5}	7.1×10^{-4}	6.6×10^{-7}	7.9×10^{-4}
	Inhalation	2.8×10^{-3}	4.4×10^{-2}	2.7×10^{-2}	7.7×10^{-4}	7.4×10^{-2}
	Foods	8.6×10^{-5}	4.6×10^{-2}	3.6×10^{-3}	2.4×10^{-3}	5.2×10^{-2}
	Subtotal air	2.9×10^{-3}	9.0×10^{-2}	3.1×10^{-2}	3.2×10^{-3}	1.3×10^{-1}
Water	Recreation	1.9×10^{-5}	5.7×10^{-5}	0.0[a]	0.0	7.6×10^{-5}
	Foods	2.9×10^{-4}	2.4×10^{-3}	0.0	0.0	2.7×10^{-3}
	Fish	1.2×10^{-4}	5.2×10^{-5}	0.0	0.0	1.7×10^{-4}
	Drinking water	7.5×10^{-4}	6.8×10^{-2}	0.0	0.0	6.9×10^{-2}
	Subtotal water	1.2×10^{-3}	7.1×10^{-2}	0.0	0.0	7.2×10^{-2}
Combined total		3.7×10^{-3}	1.6×10^{-1}	3.1×10^{-2}	3.2×10^{-3}	2.0×10^{-1}

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

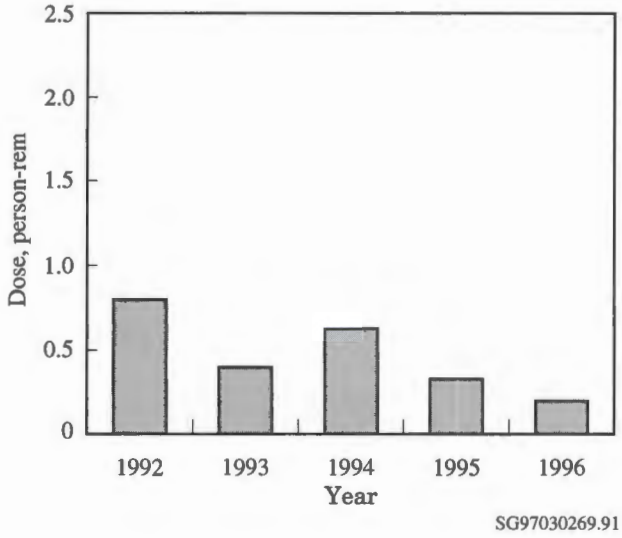

Figure 5.0.3. Calculated Effective Dose Equivalent to the Population Within 80 km (50 mi) of the Hanford Site, 1992 Through 1996

Primary pathways contributing to the 1996 dose to the population were the following:

- inhalation of radionuclides (37%) that were released to the air, principally iodine-129 from the Plutonium-Uranium Extraction Plant stack
- consumption of drinking water (35%) contaminated with radionuclides released to the Columbia River at Hanford, principally tritium and iodine-129
- consumption of foodstuffs (26%) contaminated with radionuclides released in gaseous effluents, primarily iodine-129 from the Plutonium-Uranium Extraction Plant stack.

The average per capita dose from 1996 Hanford operations based on a population of 380,000 within 80 km (50 mi) was 0.5 µrem (5×10^{-3} µSv). 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 0.0002% 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 1996 are a small percentage of the standards and of natural background.

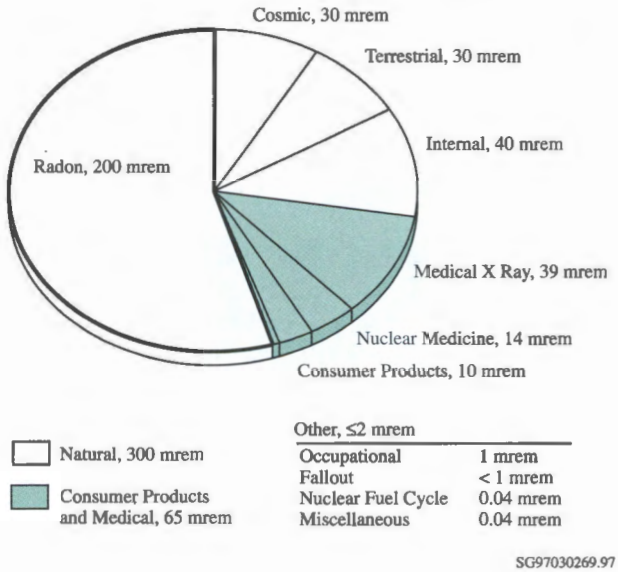

Figure 5.0.4. National Annual Average Radiation Doses from Various Sources (mrem) (National Council on Radiation Protection 1987)

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 power 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 PN Services (see 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

Table 5.0.3. Summary of Doses to the Public in the Vicinity of Hanford from Various Sources, 1996

Source	Maximum Individual, mrem[a]	Population, person-rem[a]
All Hanford effluents	0.007	0.2
DOE limit	100	--
Percent of DOE limit[b]	0.007%	--
Background radiation	300	110,000
Hanford dose percent of background	<0.01%	2×10^{-4}%
Doses from gaseous effluents	0.0046	--
EPA air standard[c]	10	--
Percent of EPA standard	0.046%	--

(a) To convert the dose values to mSv or person-Sv, divide by 100.
(b) DOE Order 5400.5.
(c) 40 CFR 61.

gathered from these companies, it was conservatively estimated that the total 1996 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 1996 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 Site into perspective. Several scientific studies (National Research Council 1980, 1990; United Nations Science Committee on the Effects of Atomic Radiation 1988) have been performed to estimate the possible risk of detrimental health effects from exposure to low levels of radiation. These studies have provided vital information to government and scientific organizations that recommend radiological dose limits and standards for public and occupational safety.

Although no increase in the incidence of health effects from low doses of radiation has actually been confirmed by the scientific community, some scientists accept the hypothesis that low-level doses might increase the probability of cancer or other health effects. 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 (Health Physics Society 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, the 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). Additional data (National Research Council 1990) support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time.

Government agencies are trying to determine what level of risk is safe for members of the public exposed to pollutants from industrial activities (e.g., 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 airliner 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. Table 5.0.5 lists some activities considered approximately equal in risk to the risk from the dose received by the maximally exposed individual from monitored Hanford effluents in 1996.

Dose Rates to Animals

Conservative (upper) estimates have been made of radiological dose to "native aquatic organisms," in accordance with DOE Order 5400.5 interim requirement for management and control of liquid discharges. Possible radiological dose rates during 1996 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.

The animal receiving the highest potential dose from N Springs water was a duck consuming aquatic plants. 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 10-to-1 dilution 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). 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 1×10^{-5} rad/d. This dose rate is 0.001% of the limit of 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 based on measured radionuclide concentrations in river water. The highest potential dose from all the radionuclides reaching the Columbia River from Hanford sources during 1996 was 2×10^{-4} 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 1×10^{-7} rad/d for a pheasant to 8×10^{-7} rad/d for a mule deer.

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 (483 km [300 mi])	2×10^{-6}[b]
Home accidents	100×10^{-6}[b]
Drinking 1 can of beer or 0.12 L (4 oz) 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 approximately 54 g (4 tbsp) of peanut butter per day (liver cancer)	8×10^{-6}
Eating 41 kg (90 lb) 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) for 70 yr	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford in 1996 (0.007 mrem, 7×10^{-5} mSv)	0 to 0.003×10^{-6}

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

(b) Real actuarial values. Other values are predicted from statistical models. For 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 the 0.007-mrem Dose Calculated for the 1996 Maximally Exposed Individual

Driving or riding in a car 0.7 km (approximately 0.5 mi)
Smoking 6/1,000 of a cigarette
Flying 2 km (approximately 1.2 mi) on a commercial airliner
Eating approximately 2/3 tbsp of peanut butter
Eating one 0.12-kg (<0.3-lb) charcoal-broiled steak
Drinking approximately 0.75 L (<1 qt) of chlorinated tap water
Being exposed to natural background radiation for approximately 13 min in a typical terrestrial location
Drinking approximately 0.038 L (1.3 oz) of beer or 0.015 L (0.5 oz) of wine

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Other Hanford Site Environmental Programs

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6.0 Other Hanford Site Environmental Programs

At the Hanford Site, a variety of environmental activities are performed to comply with laws and regulations, to enhance environmental quality, and to monitor the impact of environmental pollutants from site operations.

This section summarizes activities conducted in 1996 to monitor the meteorology and climatology of the site, to assess the status of the Hanford ecosystem, to monitor Hanford cultural resources, and to actively involve the public in surveillance activities near the site.

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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 for dose assessments. Support is provided through weather forecasting and 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 Range to the west of Yakima greatly influences 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 affects the wind regime.

The Hanford Meteorology Station is located on the 200 Areas 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 for 1945 through 1996 are reported by Hoitink and Burk (1997). From 1945 through 1996, 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 approximately 76%, and lowest during summer, averaging approximately 36%. Average annual precipitation at the Hanford Meteorology Station was 15.9 cm (6.26 in.). The wettest year on record, 1995, received 31 cm (12.30 in.) of precipitation; 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 approximately 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 approximately 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 1996 Monitoring

1996 was cooler than normal and the second wettest year on record. The average temperature for 1996 was 11.3°C (52.4°F), which was 0.5°C (0.9°F) below normal (11.8°C [53.3°F]). Nine months during 1996 were cooler than normal, and three months were warmer than normal. July

had the highest positive departure, 1.8°C (3.3°F); February, at 2.9°C (5.2°F) below normal, had the largest negative departure. The minimum temperatures of -27.8°C (-18°F) on January 31 and February 1 were the coldest temperatures recorded at the Hanford Meteorology Station in more than 40 years since a low of -30.0°C (-22°F) recorded on January 26, 1957.

Precipitation for 1996 totaled 31.0 cm (12.19 in.), 195% of normal (15.9 cm [6.26 in.]), with 146.0 cm (57.5 in.) of snow (compared to an annual normal snowfall of 35.1 cm [13.8 in.]). This was the snowiest calendar year on record. The previous snowiest calendar year was 1985 with 94.2 cm (37.1 in.).

The average wind speed for 1996 was 12.9 km/h (8.0 mph), which was 0.5 km/h (0.3 mph) above normal, and the peak gusts for the year were 89 km/h (55 mph) on February 23 and again on April 23. Figure 6.1.1 shows the 1996 wind roses (diagrams showing direction and frequencies of wind) at 10 m (32.8 ft) for the 28 meteorological monitoring stations on and around the Hanford Site.

Table 6.1.1 provides monthly climatological data from the Hanford Meteorology Station for 1996.

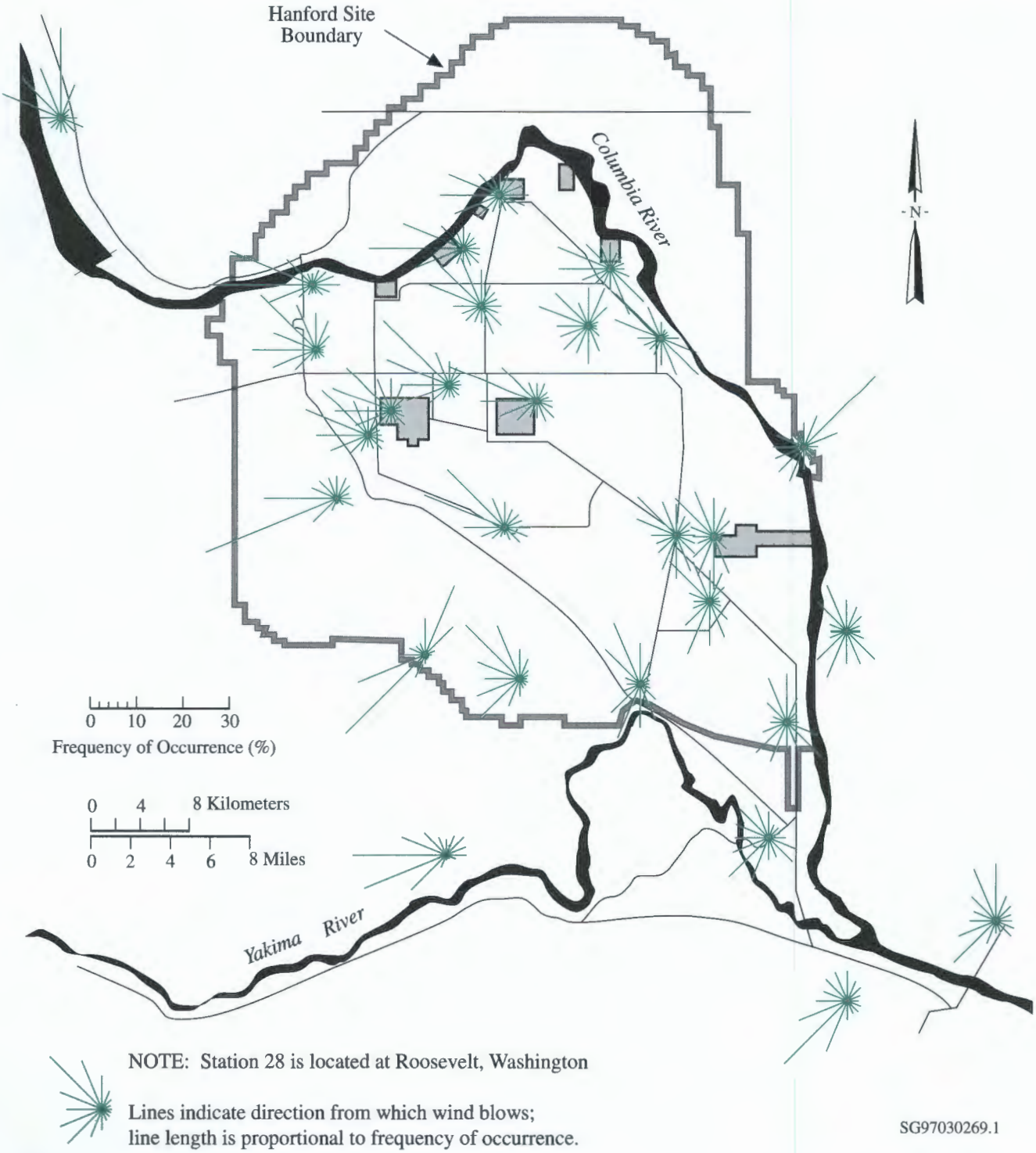

Figure 6.1.1. Hanford Meteorological Monitoring Network Wind Roses (at 10 m [32.8 ft]), 1996. Individual lines indicate direction from which wind blows. Length of line is proportional to frequency of occurrences from a particular direction.

Table 6.1.1. Monthly Climatological Data from the Hanford Meteorology Station, 1996

Hanford Meteorology Station, 40 km (25 mi) northwest 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	2.1	-5.7	-1.8	-1.4	14.4	15	-27.8	31	3.6	+1.6	42.4	+32.5	82.9	+6.5	10.5	0.0	87	WSW	3
F	6.3	-5.4	0.4	-2.9	17.2	8	-27.8	1	3.1	+1.5	15.0	+9.9	70.3	0.0	11.6	0.0	89	SSW	23
M	13.5	0.8	7.1	-0.4	20.0	14	-7.8	1	2.1	+0.9	1.0	+0.2	59.4	+3.5	12.4	-1.0	74	WNW	15
A	20.1	5.6	12.8	+1.3	27.8	8	-1.1	4	1.1	0	0	-T[c]	51.0	+3.8	14.8	+0.3	89	SW	23
M	21.9	7.1	14.5	-1.8	30.0	26+[d]	-1.7	8	1.6	+0.3	0	0	47.4	+4.7	15.0	+0.3	68	NW	27+[d]
J	29.2	11.9	20.6	-0.4	36.7	7	7.2	19	0.1	-0.8	0	0	36.3	-2.5	15.1	+0.3	69	SSW	23
J	35.7	17.0	26.4	+1.8	42.2	26+[d]	9.4	18	0.4	-0.1	0	0	31.0	-2.5	14.3	+0.2	77	WNW	9
A	33.7	14.8	24.2	+0.3	42.8	10	8.9	19	0.1	-0.6	0	0	33.2	-2.6	15.3	+2.6	69	WSW	11
S	26.6	9.4	18.0	-0.7	34.4	11	1.1	25	0.6	-0.2	0	0	45.2	+2.5	12.9	+1.0	79	NW	21
O	18.0	4.7	11.3	-0.3	30.0	10	-4.4	21	2.2	+1.3	0	-T[c]	59.4	+4.2	11.6	+1.1	69	W	13
N	8.3	-1.2	3.6	-1.0	18.9	8	-8.3	24	6.8	+4.5	30.2	+25.6	78.4	+5.0	9.8	-0.5	71	SW	6
D	2.4	-4.8	-1.2	-0.9	11.1	31+[d]	-21.1	28	9.4	+6.8	57.4	+42.9	81.2	+0.9	11.4	+1.9	71	S	2
Y[e]	18.2	4.5	11.3	-0.5	42.8	Aug 10	-27.8	Feb 1+[d]	31.0	+15.1	146.0	+111.0	56.3	+2.0	12.9	+0.5	89	SW	Apr 23+[d]

NOTE: See conversion table in "Helpful Information."

(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) Trace.

(d) + after date indicates latest of several occurrences.

(e) Yearly averages, extremes, and totals.

6.2 Ecosystem Monitoring (Plants and Wildlife)

L. L. Cadwell, J. L. Downs, D. R. Geist, M. A. Simmons, and B. L. Tiller

The Hanford Site is a relatively large, undisturbed area of shrub-steppe that contains a rich, natural diversity of plant and animal species adapted to the region's semiarid environment. Terrestrial vegetation on 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 (Neitzel 1996). Nearly 600 species of plants have been identified on the Hanford Site (Sackschewsky et al. 1992). Recent work by The Nature Conservancy has further delineated 36 distinct plant community types (Soll and Soper 1996) from within those 10 major communities.

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 on Rattlesnake Mountain. These include Rattlesnake Springs, Dry Creek, Snively Springs, and West Lake, a small, natural pond near the 200 Areas.

More than 1,000 species of insects (Soll and Soper 1996), 12 species of reptiles and amphibians (Neitzel 1996), 44 species of fish (Gray and Dauble 1977, Neitzel 1996), 214 species of birds (Soll and Soper 1996), and 39 species of mammals (Neitzel 1996) have been found on the Hanford Site. Deer and elk are the major large mammals, 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 are commonly used by local Native American tribal members.

Although no Hanford Site plant species have been identified from the federal list of threatened and endangered species (50 CFR 17.12), recent biodiversity inventory work conducted by The Nature Conservancy has identified 82 populations of 17 rare plant taxa. In addition, The Nature Conservancy described 53 occurrences of 9 priority plant communities (Soll and Soper 1996). The U.S. Fish and Wildlife Service lists the peregrine falcon as endangered and the bald eagle and Aleutian Canada goose as threatened (50 CFR 17.11). The peregrine falcon and Aleutian Canada goose are migrants through the Hanford Site, and the bald eagle is a common winter resident and has initiated nesting on the Hanford Site but never nested successfully. 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.

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 mainstem 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 6.2.1). 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. The number of fall Chinook salmon redds counted in the Hanford Reach increased through the decades of the 1960s, 1970s, and 1980s until reaching a high in 1989 of nearly 9,000 (see Figure 6.2.1).

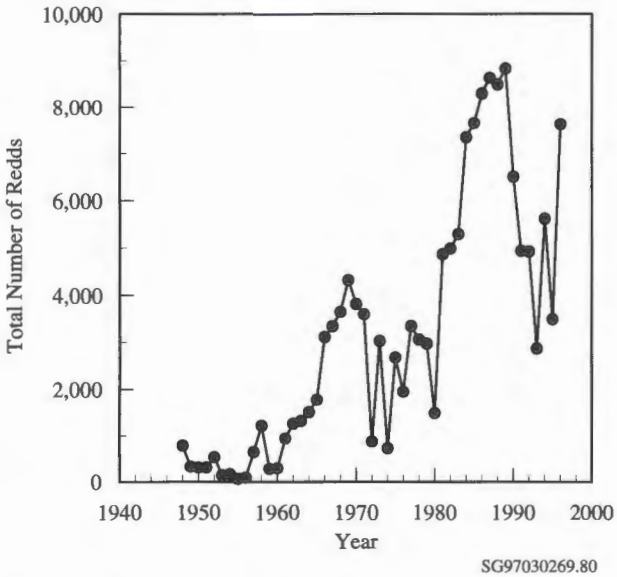

Figure 6.2.1. Chinook Salmon Spawning Redds in the Hanford Reach, 1948 Through 1996

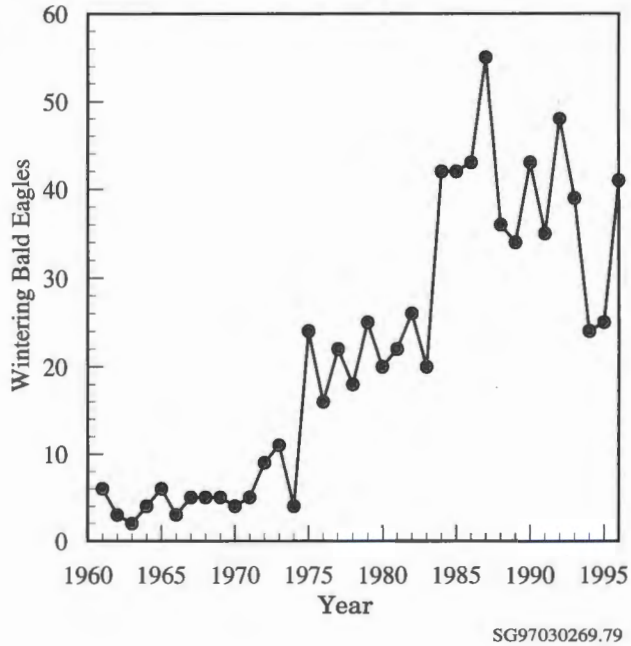

Figure 6.2.2. Bald Eagles Observed Along the Hanford Reach, Fall and Winter Months, 1961 Through 1996

In the early 1990s, redd counts declined to approximately one-third the 1989 peak, but they appear to have rebounded in recent years. In 1996, approximately 7,600 redds were observed. It should be noted that aerial surveys do not yield absolute counts of redds because visibility varies, depending on water depth and other factors, and because the number of redds in high-density locations cannot be accurately counted. We have noted, however, that redd survey data generally track adult escapement figures obtained by counting migrating adult fish at fish ladders on the Columbia River.

Bald Eagle

The bald eagle is listed as a federally threatened species (50 CFR 17.11) and also a Washington State threatened species (Washington State Department of Wildlife 1994). Historically, bald eagles have wintered along the Hanford Reach of the Columbia River. However, when monitoring began in the early 1960s, numbers were low (Figure 6.2.2). 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 pesticide in 1972. A total of 41 wintering bald eagles were counted on the Hanford Reach in 1996, which is up from 25 observed in 1995. Changes in the number of eagles on the Hanford Site generally correspond to changes in the number of returning fall Chinook salmon, a major fall and winter food source for eagles (compare Figures 6.2.1 and 6.2.2 to see similarity in the patterns of salmon redd counts and bald eagle counts). Thus, it appears that the number of bald eagles occupying the Hanford Reach in any given year may be directly related to the local abundance of food.

Protection for bald eagles is guided by the *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (Fitzner and Weiss 1994) and coordinated with representatives of the U.S. Fish and Wildlife Service.

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. The presence of a bald eagle pair attending a nest site along the Hanford Reach near White Bluffs triggered the closure of roads and a small portion of the Hanford shoreline during late winter and early spring 1996. The eagles eventually left the area without successfully nesting.

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. Power-line 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 (50 CFR 17.11). In recent years, the number of ferruginous hawks nesting on the Hanford Site has increased. The site continues to provide hawk nesting habitats that are administratively protected from human intrusion. An evaluation of selected aspects of ferruginous hawk ecology on the Hanford Site and adjacent lands was completed as part of a Master of Science degree in raptor biology (Leary 1996). That work suggests that ferruginous hawks nesting on the Hanford Site are attracted to the area because of suitable nesting habitat, but that much of the foraging for prey species is conducted in privately owned agricultural fields located several kilometers (miles) from the nest sites. Thus, male ferruginous hawks were observed to travel up to 15 km (9.3 mi) from their Hanford nest sites to hunt, making several trips each day to deliver prey to their mates and offspring. Leary's results showed that medium-sized mammals such as northern pocket gophers, which can be serious agricultural pests, are the primary prey of ferruginous hawks. Thus, we have gained a new appreciation of how the ecology of this large raptor takes on a regional perspective and does not recognize land ownership boundaries. It is likely that the success and relative abundance of ferruginous hawks nesting at Hanford depend on both Hanford lands for quality nesting habitat and adjacent private agricultural lands for suitable foraging habitat.

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. Since that time, the herd has grown and it now occupies portions of the Hanford Site, the United States Army's Yakima Training Center, and private land along Rattlesnake Ridge. Herd size was estimated from census data at approximately 450 animals prior to the 1996 hunting season (Figure 6.2.3). Although accurate estimates of elk harvest on adjacent private lands are not available, the harvest appears to be small, with less than 10% of the herd being harvested and the majority of the harvest consisting of bulls. Thus, growth of the herd is largely unconstrained, and increasing damage to natural plant communities on Hanford and to crops on adjacent private land is likely. Several observations were made in 1996 of elk having crossed to the north side of State Highway 240, making future sitings of elk near the 100 and 200 Areas probable.

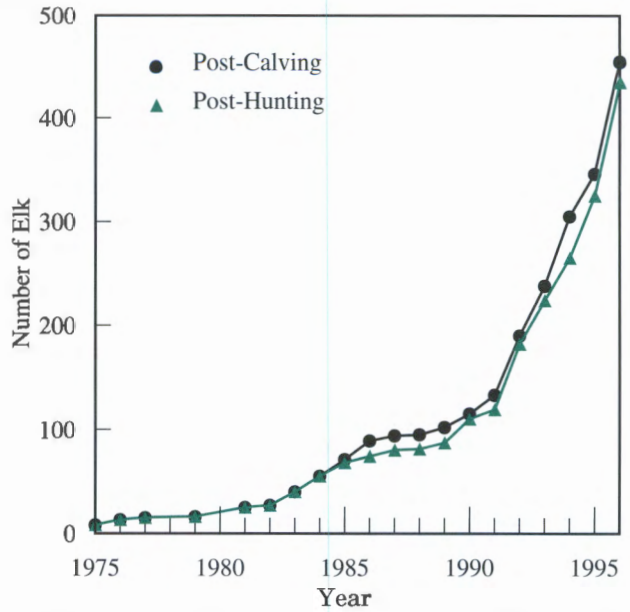

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Figure 6.2.3. Elk on the Hanford Site Counted by Aerial Surveillance During the Post-Calving (August through September) and Post-Hunting Periods (December through January), 1975 Through 1996

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 different from 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, and because observations were made that some male deer had abnormal antler development, studies were initiated in the early 1990s 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, 3) evaluate the level of strontium-90 in deer from the 100 Areas, and 4) evaluate the occurrence of abnormal antler development in male deer. A report detailing the results of the strontium-90 in deer was published in 1995 (Tiller et al. 1995), and the remaining work was recently reported (Tiller et al. 1997) and is highlighted below.

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. Approximately 330 deer were estimated to reside in the region of the Hanford Site bordering the Columbia River, and the total Hanford Site mule deer population, exclusive of the lands lying north of the Columbia River, was estimated at 650.

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 (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 radionuclide levels in tissues were low and there were no effects found in other tissues. Testicular atrophy and abnormal antler development have 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. Several plants known to produce estrogen-like compounds also were found in deer diets during the summer and may influence their reproductive performance.

Establishment/Sampling of Permanent Monitoring Plots

Methods for monitoring the fauna and flora at Hanford are currently undergoing review with the goal to improve the measurement of natural and human-caused change and to evaluate ecosystem health. Management goals for both inventory and monitoring were identified in *Hanford Site Biological Resources Management Plan* (DOE 1996f). As an initial step in the process of improved biological resource monitoring, 30 permanent plots were established in selected habitat types across the site to collect baseline information. Plot locations were determined based on the condition of the site, the sensitivity of the habitat type to land use change, and the amount of prior information available for the sampling area. Vegetation surveys were conducted on these 20-ha (49.4-acre) plots during the spring and summer months of 1996 to provide biodiversity and monitoring information on the plant communities found on the Hanford Site. Obtaining baseline information on vegetation associations onsite is especially relevant to resource monitoring because plant communities function as integrators of physical environment. The soils, climate, topography, and history of a land area determine the type and extent of vegetation that have developed on the site. Important vegetation parameters measured on the plots include the canopy cover by species and the number of species found there.

Canopy cover is a measure of the percentage of the ground area that lies beneath the plant canopy (the extent of the foliage) (Table 6.2.1) and provides information on the dominant plant species in the community, species associations, and amount of habitat available for wildlife. In shrub-steppe plant communities, there can be several different layers in the canopy, and the total canopy cover may be greater than 100%. For example, grasses and forbs often grow beneath and intermix with shrubs, and the total percent canopy cover is a sum for each species in each canopy layer in the area sampled. Along with the vascular plants sampled along transects in each plot, the percentage of the ground covered with "biotic crust" (i.e., lichens, mosses, and algae that grow and form a crust on the soil surface) was also estimated. Biotic crusts play important roles in fixing nitrogen and stabilizing soils in semiarid and arid ecosystems. The mean values of total percent canopy cover calculated for each plot are listed in Table 6.2.1 as well as the canopy cover of native versus alien plant species. Alien plant species are those that have been introduced into this ecosystem from other parts of the country or other continents. Prominent examples

Table 6.2.1. Summary of Mean Canopy Cover and Species Abundance for 30 Permanent Monitoring Plots Established in 1996

	Mean Percent Canopy Cover				Number of Species		
Plot	Total	Alien	Native	Biotic Crust	Total	Alien	Native
1	46.5	32.2	14.3	28.2	32	8	24
2	74.6	55.3	19.3	3.6	36	7	29
3	62.6	42.4	20.2	14.1	37	8	29
4	56.5	45.1	11.5	20.2	34	8	26
5	56.4	28.6	27.8	24.8	45	7	38
6	48.8	23.2	25.7	17.8	37	7	30
7	86.6	32.3	54.4	37.1	34	9	25
8	67.1	6	61.1	70	35	8	27
9	64	37.1	26.9	19	35	10	25
10	67.2	35.6	31	24.4	48	7	41
11	43	14.4	28.6	27	44	8	36
12	86.6	11.7	74.8	56.8	62	8	54
13	91.6	19.3	72.3	42.8	55	9	46
14	62.9	45	17.8	17.7	36	8	28
15	60.2	37.5	22.8	23.2	36	7	29
16	54.5	22.3	32.2	21.2	39	7	32
17	81.6	44.5	37.1	37.8	48	10	38
18	59.5	20.2	39.3	40.6	22	3	19
19	70.9	55.9	14.9	28.5	26	7	19
20	70.2	36.8	33.4	35.2	46	8	38
21	78.6	58.6	20	50.3	29	9	20
22	61.5	13.3	48.3	38.3	34	5	29
23	81.8	40.9	40.9	48.8	36	9	27
24	71.7	2.9	68.7	59.8	47	9	36
25	69.6	23.5	46.2	40	41	8	33
26	60.7	10.8	49.9	48.7	35	6	29
27	54.3	31.9	22.4	29.7	42	9	33
28	75.1	23.6	51.5	48.6	46	8	38
29	67.6	24.9	42.8	42.2	32	3	29
30	91.1	37.4	53.7	41.7	50	9	41

of alien plant species on the Hanford Site include Russian thistle (*Salsola kali*), cheatgrass (*Bromus tectorum*), and knapweeds (*Centaurea* spp.). The presence, increase, or dominance of alien plant species within a community can be indicative of disturbance to that community.

The total plant canopy cover found on the 30 plots across the site ranged from 56% to 92%, with alien species canopy cover ranging from 3% (4.2% of total canopy cover) to 58% (75% of total canopy cover). Estimates of the amount of biotic crust cover ranged from 3% to 60%; total cover (vascular plant cover and biotic crust cover ranged from 66% to 143%.

Another important measure is the species richness of the plant community, which can be expressed most simply by the total number of plant species that occur in the plot. Table 6.2.1 gives species richness numbers based on all plant species found on the 20-ha (49.4-acre) plots and summarizes this information for alien and native

species. Plots with the greatest numbers of species were located at elevations above 610 m (2,000 ft) on the Fitzner/Eberhardt Arid Lands Ecology Reserve. High species diversity was also found on plots occurring in 1) sand dune areas on the Columbia Plateau, 2) lithosols, and 3) areas with mature shrub overstory. Plots in areas that have been impacted by wildfires, in general, had slightly fewer species.

The information obtained from the plot sampling will be used to assess impacts from both human activities, to evaluate ecosystem health, and to provide technical data useful for Hanford Site land use planning.

6.3 Cultural Resources

M. K. Wright and D. W. Harvey

The DOE Richland Operations Office established a cultural resource program in 1987 that has been managed by the Hanford Cultural Resources Laboratory as part of Pacific Northwest National Laboratory (Chatters 1989). Pacific Northwest National Laboratory, Bechtel Hanford, Inc., and CH2M Hill provided support for the cultural resource program on the Hanford Site throughout 1996. Westinghouse Hanford Company provided support for that portion of the program involving the built environment (buildings and structures) during fiscal year 1996. As a result, the management of archaeological, historical, and traditional cultural resources of the Hanford Site is provided 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.

Native American Involvement

Members of the Confederated Tribes of the Umatilla Indian Reservation, Yakama Indian Nation, Nez Perce Tribe, and Wanapum Band were actively involved in the cultural resource program during 1996. Monthly cultural resource issues meetings provided a venue for the exchange of information between DOE, tribal staff members, and site contractors about projects and activities on the Hanford Site.

A traditional cultural resources workshop held in July 1996 provided a forum for tribal elders of the Yakama, Wanapum, and Nez Perce Tribes to express their views on the management of Hanford's traditional cultural properties.

Public Involvement

The cultural resources staff of Pacific Northwest National Laboratory, Bechtel Hanford, Inc., CH2M Hill, and Westinghouse Hanford Company assisted DOE in organizing and conducting two public meetings for the purpose of reviewing the cultural resources program. During the meetings, the public was introduced to the primary types of cultural and historic resources found on the Hanford Site, the program's legal and regulatory framework, and its mission and responsibilities. The public meetings provided participants an opportunity to discuss and make recommendations concerning the final contents of programmatic documents and future public involvement in the program.

Section 106 Activities

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 can take place. Cultural resource reviews are required to evaluate the effect the proposed project may have on any property that may be eligible for or listed in the National Register of Historic Places.

During 1996, 271 cultural resource reviews were requested, 9 of which required archaeological surveys, 1 required test excavation, and 33 involved building modification or demolition (Figure 6.3.1). The surveys covered a total of 0.25 km^2 (0.09 mi^2) and resulted in the discovery of one isolated find and additional information about three previously recorded archaeological sites (Figure 6.3.2).

Section 110 Activities

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 reuse of historic properties. Agencies are also required to maintain and manage historic

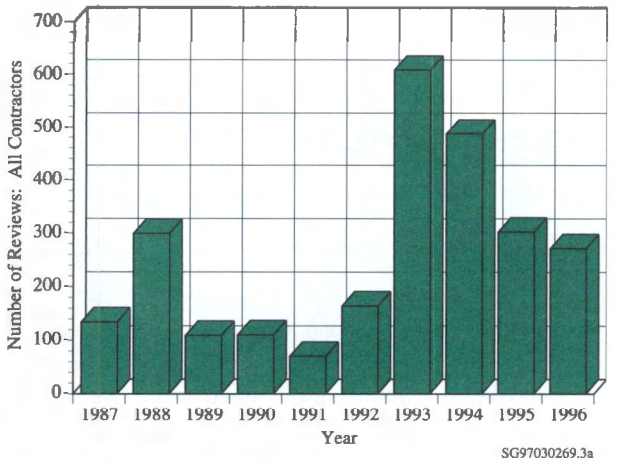

Figure 6.3.1. Cultural Resource Reviews Requested Each Calendar Year

Figure 6.3.2. Historic Sites are Common Across the Hanford Site

properties in a way that considers preservation of their values and ensure that preservation-related activities are completed in consultation with other agencies, Indian tribes, and the general public.

Management activities conducted to fulfill Section 110 requirements included finalization of the programmatic agreement for the built environment, creation of the Hanford Site Manhattan Project and Cold War Era Historic District (Figure 6.3.3), and completion of a Multiple Property Documentation form to assist with evaluation of historic properties for listing in the National Register of Historic Places. Approximately 450 buildings/structures have been documented on historic property inventory forms and are on file at the Hanford Cultural Resources Laboratory (Figure 6.3.4). One Historic American Engineering Record document and a historic overview of the significant N Reactor complex was finalized.

Historic District

During 1996, a programmatic agreement that addresses management of the built environment constructed during the Manhattan Project and Cold War periods was completed and accepted by DOE, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Officer. To ensure that the measures of the programmatic agreement were carried out, DOE established a Historic Buildings Task Group to identify, inventory, and evaluate all buildings/structures not evaluated previously for National Register eligibility. The task group was composed of individuals who possessed knowledge, background information, and skills directly related to the built environment of the Hanford Site.

Using National Register criteria as well as historic contexts and themes associated with nuclear technology, energy production, and human health and environmental protection, the task group identified a Register-eligible Hanford Site Manhattan Project and Cold War Era Historic District. The district served to organize and delineate the evaluation and mitigation of Hanford's built environment. The identification and evaluation process resulted in the selection of approximately 185 buildings, structures, and complexes as contributing properties within the historic district recommended for mitigation. Mitigation consists of site forms that document buildings and structures identified as the most representative samples of property types that exemplify the history of the Manhattan Project and Cold War periods on the Hanford Site. Three levels of mitigation have been selected. Historic American Engineering Record documents will be written for three facilities (B Reactor, T Plant, and 313 Metal Fuels Fabrication Facility) that represent key plutonium production processes and were the first of their kind in the world. Expanded historic property inventory forms will be written for those properties (41 in all) that capture or represent critical processes or events at Hanford whose contributions cannot be summarized on the standard site form. Standard historic property inventory forms will be prepared for the remainder of the buildings and structures in the historic district.

Figure 6.3.3. 105-C Reactor, One of Several Structures Included in the Hanford Site Manhattan Project and Cold War Era Historic District

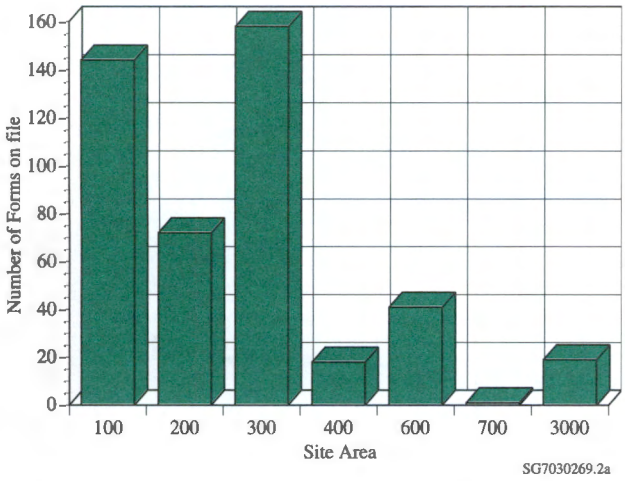

Figure 6.3.4. Hanford Buildings Documented with a Washington State Historic Property Inventory Form

Approximately 900 buildings and structures were identified as either contributing properties not selected for mitigation or as noncontributing buildings and structures and will be documented in a database maintained by DOE. According to the programmatic agreement, certain property types such as mobile trailers, modular buildings, storage tanks, towers, wells, and structures with minimal or no visible surface manifestations were exempt from the identification and evaluation requirement.

National Register Multiple Property Documentation
Historic properties are those cultural resources worthy of preservation that are listed or are eligible for listing in the National Register of Historic Places. To assist with the evaluation of potential historic properties, five historic contexts were completed as part of the National Register Multiple Property Documentation process. These

contexts are being used to determine National Register eligibility for sites and buildings on the Hanford Site associated with the prehistoric period (18,000 B.C. - 1805 A.D.), the contact period between early explorers and native peoples (Lewis and Clark 1805 - Hanford Engineer Works 1943), the pre-1943 Euroamerican settlement period (Lewis and Clark 1805 - Hanford Engineer Works 1943), and the Manhattan Project/Cold War periods (1942-1990).

Monitoring

Locke Island contains some of the best preserved evidence of prehistoric village sites extant in the Columbia Basin and is included within the Locke Island National Register Archaeological District. Field monitoring of this large island was conducted during 1996 to evaluate a complex fluvial erosion problem exhibited along its northeastern shoreline. During 1996 approximately 41,000 m^3 (53,628 yd^3) of cutbank sediment and over 70 concentrations containing a variety of cultural materials and features were lost during the erosional process. Agency and management responsibilities associated with the protection of cultural resources on Locke Island were also explored.

Education and Research

Educational activities associated with the cultural resources program included presenting lectures to groups ranging from public school classrooms to civic groups, colleges, and professional societies. The annual Aboriginal Lifeways, Prehistoric Artifact Recognition and Documentation Certification training sponsored by the Confederated Tribes of the Umatilla Reservation included two classes conducted by Bechtel Hanford, Inc. and CH2M Hill staff. Pacific Northwest National 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 conducted by student interns and Hanford Cultural Resources Laboratory staff 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 resettlement of the Hanford Site, and the built 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 Hanford have been actively participating in site environmental surveillance activities through the Community-Operated Environmental Surveillance Program. The program consists of two components: radiological air sampling and agricultural product sampling.

During 1996, nine radiological air sampling stations were operated by local teachers at selected locations around the perimeter of the site. Each station consisted of equipment for collecting air samples and for monitoring ambient radiation levels. Four of the nine stations also included large, lighted informational displays that provided 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 telephone numbers were 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 See Environmental Surveillance in Action at Four of Nine Local Community-Operated Environmental Surveillance Stations

Two teachers from schools located near the stations were selected to operate each station. Each pair of teachers was responsible for collecting a variety of air samples, preparing the samples and collection records for submission to the analytical laboratory, monitoring the performance of station equipment, performing minor station maintenance, and participating in scheduled training. They also served as spokespersons for the Community-Operated Environmental Surveillance Program and were points of contact for local citizens. Pacific Northwest National Laboratory staff worked 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 1996 are discussed in Section 4.1, "Air Surveillance." Results of gamma radiation measurements are discussed briefly in Section 4.7, "External Radiation Surveillance."

In 1996, the community-operated air sampling network expanded from eight to nine stations. In addition to the stations operating in 1995 in Basin City, Richland, Pasco, Kennewick, north Franklin County, Othello, Mattawa, and Toppenish, Washington, the program now includes a station in Benton City (see Figure 4.1.1). The new station is located on the campus of the Kiona-Benton High School and has not been enhanced with an informational display.

Citizen participation in farm product sampling activities in 1996 involved obtaining agricultural products from students living in areas downwind of the site. Middle-school-aged students, including 4-H Club members, were asked to grow leafy vegetables that are not grown commercially around Hanford but are common in local gardens. Portions of these vegetables were purchased and

analyzed for radioactive contaminants. Following analysis, Pacific Northwest National Laboratory staff visited the schools to discuss the results with the students and their teachers. Analytical results for these samples are discussed in Section 4.4, "Food and Farm Product Surveillance."

Quality Assurance

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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 collected and analyzed according to documented standard analytical procedures. Analytical data quality is verified by a continuing program of internal laboratory quality control, participation in interlaboratory crosschecks, replicate sampling and analysis, submittal of blind standard samples and blanks, and splitting samples with other laboratories.

Quality assurance/quality control for the Hanford Site monitoring program 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 well 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 and Groundwater Monitoring

Comprehensive quality assurance programs, including various quality control practices, are maintained to ensure the quality of data collected through the environmental surveillance and groundwater monitoring programs. Quality assurance plans are maintained for all program activities and define the appropriate controls and documentation required by EPA and/or DOE for the project-specific requirements.

Project Management Quality Assurance

Site environmental surveillance, groundwater monitoring, 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 DOE Order 5700.6C. The program is defined in a quality assurance manual (Pacific Northwest Laboratory 1992).

The groundwater monitoring and site 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 service contracts or material purchases that could have a significant impact on quality within the project are approved and awarded.

Sample Collection Quality Assurance/ Quality Control

Environmental surveillance samples were collected by staff trained to conduct sampling according to approved and documented procedures (Hanf and Dirkes 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 (3.0, "Facility-Related Monitoring, Waste Management, and Chemical Inventory Information," and 4.0, "Environmental Surveillance Information").

Samples for the Hanford Site Groundwater Monitoring Program are collected by trained staff according to approved and documented procedures (Pacific Northwest Laboratory 1993, Westinghouse Hanford Company 1988). 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 1996

groundwater field quality control sample results are provided in the 1996 fiscal year site groundwater monitoring report (Hartman and Dresel 1997). The percentages of acceptable field blank and duplicate results in fiscal year 1996 were very high, 94% for blanks and 98% for field duplicates.

Analytical Results Quality Assurance/ Quality Control

Routine hazardous and nonhazardous chemical analyses for environmental and groundwater surveillance and monitoring water samples are performed primarily by DataChem Laboratories, Inc., Salt Lake City, Utah, and Quanterra Environmental Services, St. Louis, Missouri. The laboratories participate in the EPA Water Pollution and Water Supply Performance Evaluation Studies. The laboratories maintain an internal quality control program that meets the requirements of EPA (1986b), which is audited and reviewed by Pacific Northwest National Laboratory and internally. Pacific Northwest National Laboratory submits additional quality control double-blind spiked samples for analysis.

Routine radiochemical analyses for environmental surveillance and groundwater monitoring samples are performed primarily by Quanterra Environmental Services' Richland laboratory. Data from Lockheed Analytical Laboratory, Las Vegas, Nevada, were used in the groundwater evaluations. The laboratories participate 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. The laboratories also maintain an internal quality control program, which is audited and reviewed internally and by Pacific Northwest National Laboratory. Additional information on these quality control efforts is provided in the following subsections.

DOE and EPA Comparison 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 with known values and other participating laboratory concentrations. Summaries of the results during the year are provided in Table 7.0.1. The percentage of EPA-acceptable results was high for both laboratories, indicating excellent performance.

The DOE Quality Assessment Program and EPA's Laboratory Intercomparison Studies provided standard samples of environmental media (e.g., 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

Table 7.0.1. EPA Water Pollution/Water Supply Study Results

Laboratory	Water Supply Study January 1996 % Acceptable	Water Pollution Study April 1996 % Acceptable	Water Supply Study September 1996 % Acceptable
DataChem Laboratories, Inc.	94.9[a]	100	93.8[b]
Quanterra Environmental Services	98.3[c]	97.3[d]	95.2[e]

(a) Unacceptable results were for 1-1, dichloroethylene, 1-2,dibromo-3-chloropropane, ethylenedibromide, 1,1,2-trichloroethane, 1,2,3-trichloropropane.
(b) Unacceptable results were for nitrate as N, dieldrin, vinyl chloride, tetrachloroethylene.
(c) Unacceptable result for molybdenum.
(d) Unacceptable results were for aroclor 1016/1242(polychlorinated biphenyl [PCB]), aroclor 1248(PCB), PCB in oil, chlordane.
(e) Unacceptable results were for 1,1-dichloroethylene, 1,2,3-trichloropropane, and sulfate.

and DOE have established criteria for evaluating the accuracy of results (Jarvis and Siu 1981; Sanderson et al. 1996, 1997). Summaries of the 1996 results for the programs are provided in Tables 7.0.2 and 7.0.3.

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. Blind spiked quality control samples and blanks were prepared and submitted to check the accuracy and precision of analyses at DataChem Laboratories, Inc. and Quanterra Environmental Services. In 1996, blind spiked samples were submitted for air filters, vegetation, soil, water, and groundwater. Overall, 81% of nonradiochemistry blind spiked determinations were within control limits and 85% of Quanterra Environmental Services' radiochemistry blind spiked determinations were within control limits (Table 7.0.4 and 7.0.5). Overall, this indicates acceptable results.

The Hanford Site Groundwater Monitoring project also submitted total organic halogen and anion (chloride, fluoride, nitrate, and sulfate) split blind spiked samples to several laboratories for evaluation during the year. The discussion and summary of data can be found in Appendix F of Hartman and Dresel (1997).

Pacific Northwest National Laboratory also participates in a Quality Assurance Task Force, a program conducted by the Washington State Department of Health. Public and private organizations from Idaho, Oregon, and Washington participate in analyzing the intercomparison samples. A large soil sample was collected in June 1996 from the 100 Areas to be used as the intercomparison sample. The soil was contaminated with liquid effluent from the single-pass-through reactors. The sample was processed by the Washington State Department of Health by drying, mixing, and sieving. The sample was not pulverized but screened through a 2.0-mm (#10) sieve. The samples were analyzed in triplicate by 11 organizations.

The intercomparison sample was chosen to be representative of the type of sample that may be encountered in cleanup of the 100 Areas liquid disposal facilities. The samples were analyzed for gamma-emitting radionuclides. The primary radionuclides identified were potassium-40, cobalt-60, cesium-137, europium-152, europium-154, and europium-155. The between-laboratory precision for cobalt-60, cesium-137, europium-152, and europium-154 was in the range of 11% to 14% (1-sigma). The europium-155 concentration was low, below, or near the minimum detectable concentration for some laboratories and, therefore, the precision was higher. Table 7.0.6 provides the Pacific Northwest National Laboratory results with respect to the grand mean of the study. The results fell within the ±2 standard error of the mean of the concentration of the other participating laboratories and were acceptable.

Laboratory Internal Quality Assurance Programs

DataChem Laboratories, Inc. and Quanterra Environmental Services are required to maintain internal quality control programs. Periodically, the laboratories are internally audited for compliance to the quality control programs. At DataChem and Quanterra St. Louis laboratories, the quality control programs meet the quality control criteria of EPA (1986b). The laboratories are also required 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 at least annually for each analytical method.

The internal quality control program Quanterra Environmental Services' Richland involves routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation check sources and background counts, replicate and spiked sample analyses, matrix and reagent blanks, and maintenance of control charts to indicate analytical deficiencies. Available calibration standards traceable to the National Institute of Standards and Technology were used for radiochemical calibrations. Minimum detectable concentration verification is conducted (when requested by the project) 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 1980).

Periodically, inspections of services are performed, which document conformance with contractual requirements of

Table 7.0.2. Summary of Laboratory Performance on DOE Quality Assessment Program Samples, 1996

Medium	Radionuclides	Number of Results Reported for Each Analyte	Number Within AcceptableControl Limits[a]
	Quanterra Environmental Services, Richland, Washington		
Air filter particulate	^{241}Am, ^{57}Co, ^{60}Co, ^{134}Cs, ^{137}Cs, Total alpha, ^{54}Mn, ^{238}Pu, ^{106}Ru, ^{125}Sb, ^{90}Sr, ^{234}U, ^{238}U, U total	2	2
	Total beta	2	1
	^{144}Ce, ^{239}Pu	1	1
Soil	^{241}Am, ^{137}Cs, ^{40}K, ^{238}Pu, ^{239}Pu, ^{90}Sr, U total	2	2
	^{244}Cm, ^{60}Co, ^{234}U, ^{238}U	1	1
Vegetation	^{241}Am, ^{244}Cm, ^{60}Co, ^{134}Cs, ^{40}K, ^{239}Pu, ^{90}Sr	2	2
Water	^{241}Am, ^{60}Co, ^{137}Cs, Total alpha, Total beta, ^{3}H, ^{54}Mn, ^{238}Pu, ^{239}Pu, ^{90}Sr	2	2
	U total	2	1
	^{55}Fe	1	1
	Lockheed Analytical Laboratory, Las Vegas, Nevada		
Air filters	^{241}Am, ^{57}Co, ^{60}Co, ^{134}Cs, ^{137}Cs, Total alpha, Total beta, ^{54}Mn, ^{238}Pu, ^{106}Ru, ^{125}Sb, ^{90}Sr, ^{234}U, ^{238}U, U total	2	2
	^{144}Ce, ^{239}Pu	1	1
Soil	^{241}Am, ^{137}Cs, ^{40}K, ^{238}Pu, ^{239}Pu, ^{90}Sr, U total	2	2
	^{244}Cm, ^{60}Co, ^{234}U, ^{238}U	1	1
Vegetation	^{60}Co, ^{134}Cs, ^{40}K, ^{239}Pu, ^{90}Sr	2	2
	^{241}Am, ^{244}Cm	2	1
Water	^{241}Am, ^{60}Co, ^{137}Cs, Total alpha, ^{3}H, ^{54}Mn, ^{238}Pu, ^{239}Pu, ^{90}Sr	2	2
	^{55}Fe	1	1

(a) Control limits are from Sanderson et al. (1996, 1997).

Table 7.0.3. Summary of Laboratory Performance on EPA Intercomparison Program Samples, 1996

Medium	Radionuclides	Number of Results Reported for Each Analyte	Number Within Control Limits for Each Analyte[a]
	Quanterra Environmental Services, Richland, Washington		
Water	^{133}Ba, ^{3}H, ^{131}I, ^{65}Zn	2	2
	^{60}Co, ^{134}Cs, ^{137}Cs, ^{89}Sr, ^{90}Sr	4	4
	Total alpha, Total beta, U total, ^{226}Ra	5	5
	^{228}Ra	5	4
	Lockheed Analytical Laboratory, Las Vegas, Nevada		
Water	^{131}I	1	1
	^{133}Ba, ^{3}H, ^{65}Zn	2	2
	^{60}Co, ^{137}Cs, Total alpha, Total beta, ^{89}Sr, ^{90}Sr	4	4
	^{134}Cs	4	3
	^{226}Ra, ^{228}Ra	5	5
	U total	5	4

(a) Control limits are from Jarvis and Siu (1981).

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 at DataChem Laboratories, Inc. in 1996; however, the laboratory was frequently contacted regarding questions on results, clarification of methodology, status of scheduled improvements, etc. There was at least one inspection of services performed at Quanterra Environmental Services in Richland, Washington and St. Louis, Missouri.

Internal laboratory quality control program data are summarized by the laboratories monthly or 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 cosampled various environmental media and measured external radiation levels at multiple locations during 1996. Media that were cosampled included 23 groundwater wells, 5 Columbia River sites, 6 riverbank springs, 2 onsite drinking water systems, 4 offsite water systems, 12 Columbia River sediment sites, 3 air monitoring stations, 15 thermoluminescent dosimeter sites, 1 mule deer, 1 quail, and 1 pheasant. Also cosampled were upwind and downwind samples of leafy vegetables and wine. Results will be published in the Washington State Department of Health 1996 annual report.

The Food and Drug Administration also cosampled leafy vegetables, potatoes, and fruit from upwind and downwind sampling locations. The data are presented in Table 7.0.7.

Table 7.0.4. Summary of Groundwater Surveillance Project Quarterly Blind Spiked Determinations, 1996

	Quanterra Environmental Services and DataChem Laboratories[a]		Quanterra Environmental Services, Richland and St. Louis Laboratories[a]	
Constituent	Number of Results Reported[b]	Number Within Control Limits[c]	Number of Results Reported[b]	Number Within Control Limits[c]
^{3}H	9	9	3	3
^{60}Co	9	9	3	3
^{90}Sr	9	9	3	3
^{99}Tc	9	6	3	3
^{129}I	9	8	3	3
^{137}Cs	9	9	3	3
^{239}Pu	9	5	3	2
U total	9	8	3	3
Chloroform	9	9	3	3
Carbon tetrachloride	9	6	3	2
Trichloroethylene	9	9	3	3
Chromium	9	9	3	3
Cyanide	9	8	3	3
Fluoride	9	6	3	0
Nitrate	9	9	3	3

(a) In the first three quarters, Quanterra Environmental Services and DataChem Laboratories, under a Pacific Northwest National Laboratory contract, were the primary laboratories. During the fourth quarter, contract services were changed to Quanterra Analytical Services under Rust Federal Services Hanford, Inc. Radiochemical data analyses were performed all four quarters by the Richland laboratory.
(b) Blind samples were submitted in triplicate each quarter and compared to actual spike values.
(c) Control limit of ±30%.

Table 7.0.5. Summary of Surface Environmental Surveillance Project Blind Spiked Determinations, 1996

Medium	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Air filters	^{7}Be, ^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{238}Pu, ^{239}Pu	14	11
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}U, ^{238}Pu, ^{239}Pu	13	9
Water	^{3}H, ^{54}Mn, ^{57}Co, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{234}U, ^{238}U, ^{239}Pu	19	16
Vegetation	^{40}K, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu	15	12

(a) Control limit of ±30%.

Table 7.0.6. Comparison[a] of the Quality Assurance Task Force 1996 Intercomparison Sample

Radionuclide	Number of Samples	Intercomparison Sample Concentration, pCi/L
^{40}K		
PNNL (QES)	3	14.1 ± 1.4
Grand mean	30	15.2 ± 2.4
^{60}Co		
PNNL (QES)	3	7.5 ± 0.5
Grand mean	33	7.7 ± 0.8
^{137}Cs		
PNNL (QES)	3	12.2 ± 0.4
Grand mean	33	12.9 ± 1.5
^{152}Eu		
PNNL (QES)	3	38.6 ± 0.9
Grand mean	33	42.9 ± 5.9
^{154}Eu		
PNNL (QES)	3	5.6 ± 0.2
Grand mean	33	6.6 ± 0.6
^{155}Eu		
PNNL (QES)	3	0.5 ± 0.1
Grand mean	7	0.4 ± 0.1

(a) Pacific Northwest National Laboratory (PNNL) analyses by Quanterra Environmental Services (QES) are compared against grand mean (±2 standard error of the mean) of participating laboratories.

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 1996 results is shown in Table 7.0.8. On average, the thermoluminescent dosimeter measurements were biased 1% 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 Westinghouse Hanford Company (1989) and Pacific Northwest Laboratory (1992). These quality assurance programs comply with DOE Order 5700.6C using American Society of Mechanical Engineers (1989) as their basis. The programs also adhere to the guidelines and objectives in EPA (1980, 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 such as sample analysis performed through contracts must meet the requirements of these plans. Suppliers are audited before the contract selection is made for equipment and services that may significantly impact the quality of a project.

Table 7.0.7. Comparison of Food and Drug Administration Cosampling, 1996

Media	Area	Organization	Potassium-40, pCi/g[a]	Strontium-90, pCi/g[a,b]	Cesium-137, pCi/g[b]
Cherries	Sagemoor	FDA[c]	2.1 ± 0.9	NA[d]	<0.045
		PNNL[e]	2.38 ± 0.41	<0.0021	<0.0071
	Sunnyside	FDA	1.7 ± 0. 8	NA	<0.045
		PNNL	2.08 ± 0.37	<0.0020	<0.0071
Leafy vegetables	Riverview	FDA	2.7 ± 0.9	NA	<0.045
		PNNL	2.63 ± 0.54	0.0087 ± 0.0044	<0.011
	Sunnyside	FDA	2.0 ± 0.9	NA	<0.045
		PNNL	2.63 ± 0.45	<0.0022	<0.0090
Potatoes	Sunnyside	FDA	4.3 ± 0.9	NA	<0.045
		PNNL	4.23 ± 0.53	<0.0034	<0.0061

(a) ±2-sigma total propogated analytical uncertainty.
(b) < values are ±2-sigma total propogated analytical uncertainties.
(c) FDA = Food and Drug Administration.
(d) NA = Not analyzed.
(e) PNNL = Pacific Northwest National Laboratory.

Table 7.0.8. Comparison of Thermoluminescent Dosimeter Results with Known Exposure, 1996

Quarter	Known Exposure, mR[a]	Determined Exposure, mR[b]	% of Known Exposure
February	19 ± 0.70	19.29 ± 0.21	102
	21 ± 0.78	21.28 ± 0.65	101
	27 ± 1.00	28.03 ± 0.71	104
May	17 ± 0.63	17.38 ± 0.17	102
	22 ± 0.81	22.59 ± 0.18	103
	28 ± 1.04	28.80 ± 0.21	103
August	18 ± 0.67	17.92 ± 0.21	100
	25 ± 0.93	24.83 ± 0.58	99
	27 ± 1.00	26.88 ± 0.26	100
November	20 ± 0.74	19.94 ± 0.022	100
	24 ± 0.89	23.95 ± 0.039	100
	28 ± 1.04	27.79 ± 3.5	99

(a) ±2-sigma.
(b) ±2 times the standard deviation.

Sample Collection Quality Assurance

Effluent monitoring and near-facility environmental monitoring samples are collected by staff trained for the task in accordance with approved procedures. Established sampling locations are accurately identified and documented to ensure continuity of data for those sites. Effluent and near-facility environmental sampling locations for the Hanford Site are described in DOE (1994a).

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). Table 7.0.9 provides a summary of Hanford's analytical laboratory utilization for effluent monitoring and near-field monitoring samples, which are grouped by contractor and sample media.

The quality of the analytical data are ensured by several means. Counting room instruments, for instance, are kept within calibration limits through daily checks, the results of which are stored in computer databases. Radiochemical standards used in analyses are regularly measured and the results reported and tracked. Formal, written laboratory procedures are used in analyzing samples. Analytical procedural control is ensured through administrative procedures. Chemical technologists at the laboratory qualify to perform analyses through formal classroom and on-the-job training.

The participation of the analytical laboratories in EPA and DOE laboratory intercomparison programs also assists in ensuring the quality of the data produced. Laboratory intercomparison program results can be found in Tables 7.0.10 through 7.0.14 for the Waste Sampling and Characterization Facility, 222-S Analytical Laboratory, and the Pacific Northwest National Laboratory Analytical Chemistry Laboratory. Laboratory intercomparison results for Quanterra Environmental Services were previously provided in Tables 7.0.2 and 7.0.3. In 1996, the EPA intercomparison program deleted some of the analysis categories (e.g., air filters) from the program because of budget reductions.

Table 7.0.9. Laboratories Utilized by Contractor and Sample Type, 1996

	Laboratories Utilized for Effluent Monitoring Samples					Laboratory Utilized for Near-Facility Environmental Monitoring Samples		
	Westinghouse Hanford Company		Pacific Northwest National Laboratory	Bechtel Hanford, Inc.		Westinghouse Hanford Company		
Laboratory	Air	Water	Air	Air	Water	Air	Water	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					

Table 7.0.10. Waste Sampling and Characterization Facility Performance on DOE Quality Assessment Program Samples, 1996

Medium	Radionuclide	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, uranium	31	30	1[a]
Soil	^{40}K, ^{137}Cs	4	4	0
Vegetation	^{40}K, ^{60}Co, ^{137}Cs	6	6	0
Water	Total alpha, total beta, ^{3}H, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}U, ^{238}Pu, ^{239}Pu, ^{241}Am, uranium	23	22	1[b]

(a) One ^{144}Ce analysis was not within control limits.
(b) One ^{90}Sr analysis was not within control limits.

Table 7.0.11. 222-S Analytical Laboratory Performance on DOE Quality Assessment Program Samples, 1996

Medium	Radionuclide	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Soil	^{40}K, ^{137}Cs	4	2	2[a]
Vegetation	^{40}K, ^{137}Cs, ^{239}Pu, ^{241}Am, ^{244}Cm	7	5	2[b]
Water	^{3}H, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, uranium	17	14	3[c]

(a) One ^{40}K and one ^{137}Cs analysis were not within control limits.
(b) One ^{60}Co and one ^{137}Cs analysis were not within control limits.
(c) One ^{60}Co, one ^{241}Am, and one uranium analysis were not within control limits.

Table 7.0.12. Pacific Northwest National Laboratory Performance on DOE Quality Assessment Program Samples, 1996

Medium	Radionuclide	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	23	23	0
Water	^{3}H, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, uranium	18	17	1[a]

(a) One uranium analysis was not within control limits.

Table 7.0.13. Waste Sampling and Characterization Facility Performance on EPA Intercomparison Program Samples, 1996

Category	Radionuclide	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Total alpha-beta in water	Total alpha, total beta	6	4	2[a]
Gamma in water	^{60}Co, ^{65}Zn, ^{134}Cs, ^{137}Cs, ^{133}Ba	10	9	1[b]
Strontium in water	^{89}Sr, ^{90}Sr	2	2	0
Uranium-radium in water	Uranium (natural), ^{226}Ra, ^{228}Ra	9	9	0
Tritium in water	^{3}H	1	1	0
Blind A[c]	Total alpha, uranium (natural), ^{226}Ra, ^{228}Ra	8	7	1[d]
Blind B[e]	Total beta, ^{60}Co, ^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs	12	11	1[f]

(a) Two total alpha analyses were not within control limits.
(b) One ^{134}Cs analysis was not within control limits.
(c) Blind A samples are liquid samples with unknown quantities of alpha emitters analyzed for total alpha and each radionuclide component.
(d) One ^{226}Ra analysis was not within control limits.
(e) Blind B samples are liquid samples with unknown quantities of beta emitters analyzed for total beta and each radionuclide component.
(f) One ^{90}Sr analysis was not within control limits.

Table 7.0.14. 222-S Analytical Laboratory Performance on EPA Intercomparison Program Samples, 1996

Category	Radionuclide	Number of Results Reported	Number Within Control Limits	Number Outside of Control Limits
Total alpha-beta in water	Total alpha, total beta	1	1	0
Gamma in water	^{60}Co, ^{65}Zn, ^{134}Cs, ^{137}Cs, ^{133}Ba	10	10	0
Uranium-radium in water	Uranium (natural)	2	1	1[a]
Tritium in water	^{3}H	2	0	2[b]
Blind A[c]	Total alpha, uranium (natural)	4	2	2[d]
Blind B[e]	Total beta, ^{60}Co, ^{134}Cs, ^{137}Cs	8	8	0

(a) One uranium (natural) analysis was not within control limits.
(b) Two tritium analyses were not within control limits.
(c) Blind A samples are liquid samples with unknown quantities of alpha emitters analyzed for total alpha and each radionuclide component.
(d) Two uranium (natural) analyses were not within control limits.
(e) Blind B samples are liquid samples with unknown quantities of beta emitters analyzed for total beta and each radionuclide component.

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Appendixes

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Appendix A

Additional Monitoring Results for 1996

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Appendix A

Additional Monitoring Results for 1996

This appendix contains additional information on 1996 monitoring results, supplementing the data summarized in the main body of the report. More detailed information is available in Bisping (1997).

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Table A.1. Radionuclide Concentrations in Columbia River Water at Priest Rapids Dam, 1996 Compared to Values from the Previous 5 Years

Radionuclide[a]		1996 No. of Samples	1996 Concentration,[b] pCi/L (10^{-6} µCi/L) Maximum	1996 Concentration,[b] pCi/L (10^{-6} µCi/L) Average	1991-1995 No. of Samples	1991-1995 Concentration,[b] pCi/L Maximum	1991-1995 Concentration,[b] pCi/L Average	Ambient Surface-Water Quality Standard, pCi/L
Composite System								
Alpha		13	1.1 ± 0.76	0.38 ± 0.21	59	1.3 ± 0.92	0.44 ± 0.099	15[c,d]
^{7}Be		13	12 ± 24	-0.72 ± 5.1	59	19 ± 15	-1.7 ± 7.3	6,000[e]
Beta		13	3.0 ± 1.7	0.99 ± 0.47	59	4.9 ± 2.4	1.1 ± 0.36	50[c,d]
^{60}Co		13	1.5 ± 0.9	0.17 ± 0.61	59	1.6 ± 0.99	-0.032 ± 0.21	100[e]
^{134}Cs		13	0.61 ± 1.1	-0.23 ± 0.32	59	1.4 ± 1.1	0.055 ± 0.16	20,000[e]
^{137}Cs		13	1.2 ± 1.7	0.12 ± 0.31	59	1.2 ± 1.2	0.093 ± 0.13	200[e]
^{154}Eu		13	5.2 ± 2.9	0.93 ± 1.2	59	4.4 ± 2.7	0.20 ± 0.49	200[e]
^{155}Eu		13	3.5 ± 4.1	0.78 ± 0.87	58	3.5 ± 5.1	-0.26 ± 0.32	600[e]
^{40}K		13	140 ± 43	45 ± 23	59	280 ± 54	40 ± 10	--[f]
^{106}Ru		5	2.7 ± 11	-5.9 ± 8.4	50	13 ± 12	-1.5 ± 1.9	30[e]
^{125}Sb		5	0.25 ± 2.5	-1.0 ± 1.2	50	3.2 ± 2.2	-0.11 ± 0.47	300[e]
^{90}Sr		13	0.11 ± 0.037	0.079 ± 0.0075	59	0.18 ± 0.085	0.088 ± 0.0070	8[c,d]
^{99}Tc		13	0.29 ± 0.54	0.0077 ± 0.08	59	1.2 ± 2.8	-0.017 ± 0.27	900[e]
Tritium		13	37 ± 8.9	31 ± 1.6	59	110 ± 16	41 ± 2.9	20,000[e]
^{234}U		13	0.27 ± 0.057	0.24 ± 0.018	59	0.44 ± 0.13	0.23 ± 0.014	--
^{235}U		13	0.023 ± 0.015	0.0088 ± 0.0031	59	0.032 ± 0.039	0.0096 ± 0.0021	--
^{238}U		13	0.22 ± 0.05	0.18 ± 0.018	59	0.35 ± 0.11	0.19 ± 0.011	--
U-Total		13	0.51 ± 0.076	0.42 ± 0.033	59	0.83 ± 0.17	0.43 ± 0.025	--
^{129}I[g]		4	0.000020 ± 0.0000022	0.000013 ± 0.0000058	16	0.00013 ± 0.000013	0.000019 ± 0.000016	1[e]
Continuous System								
^{239,240}Pu	P	4	0.000073 ± 0.000016	0.00003 ± 0.000029	19	0.000097 ± 0.000040	0.000025 ± 0.000011	--
	D	4	0.000037 ± 0.000049	0.000012 ± 0.000021	19	0.00063 ± 0.00021	0.000066 ± 0.000069	--

(a) 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").
(b) Maximum values are ± total propagated analytical uncertainty (2-sigma). Averages are ±2 standard error of the calculated mean.
(c) WAC 246-290.
(d) 40 CFR 141.
(e) WAC 173-201A-050 and EPA (1976).
(f) Dashes indicate no concentration guides are available.
(g) From 1991 through 1995, iodine-129 concentrations were obtained from the dissolved fraction of the continuous system.

Table A.2. Radionuclide Concentrations in Columbia River Water at the Richland Pumphouse, 1996 Compared to Values from the Previous 5 Years

Radionuclide[a]		1996 No. of Samples	1996 Concentration,[b] pCi/L (10^{-6} µCi/mL) Maximum	1996 Concentration,[b] pCi/L (10^{-6} µCi/mL) Average	1991-1995 No. of Samples	1991-1995 Concentration,[b] pCi/L Maximum	1991-1995 Concentration,[b] pCi/L Average	Ambient Surface-Water Quality Standard,[c] pCi/L
Composite System								
Alpha		13	1.7 ± 0.93	0.43 ± 0.24	59	3.4 ± 1.5	0.66 ± 0.58	15[c,d]
^{7}Be		13	20 ± 12	5.9 ± 3.6	59	16 ± 14	-2.7 ± 19	6,000[e]
Beta		13	2.8 ± 1.7	1.1 ± 0.49	59	9.2 ± 3.0	0.95 ± 1.5	50[c,d]
^{60}Co		13	0.73 ± 0.65	-0.0087 ± 0.30	59	2.0 ± 1.1	0.11 ± 0.80	100[e]
^{134}Cs		13	1.1 ± 0.89	0.0049 ± 0.35	59	1.2 ± 0.89	-0.19 ± 0.70	20,000[e]
^{137}Cs		13	1.3 ± 1.3	0.48 ± 0.39	59	1.6 ± 1.5	0.098 ± 0.60	200[e]
^{154}Eu		13	1.0 ± 3.2	-1.1 ± 0.82	59	4.3 ± 2.6	0.31 ± 1.6	200[e]
^{155}Eu		13	1.5 ± 2.8	0.43 ± 0.61	58	3.5 ± 2.8	-0.059 ± 1.3	600[e]
^{40}K		13	100 ± 28	53 ± 17	59	77 ± 27	37 ± 19	--[f]
^{106}Ru		5	4.8 ± 6.5	1.3 ± 4.3	50	18 ± 12	0.39 ± 6.4	30[e]
^{125}Sb		5	0.86 ± 2.5	0.20 ± 0.86	50	3.9 ± 2.5	-0.08 ± 1.6	300[e]
^{90}Sr		13	0.31 ± 0.081	0.097 ± 0.036	58	0.18 ± 0.073	0.089 ± 0.026	8[c,d]
^{99}Tc		13	0.20 ± 0.53	0.0053 ± 0.087	59	6.5 ± 2.7	0.32 ± 0.96	900[e]
Tritium		13	140 ± 16	68 ± 16	59	210 ± 23	96 ± 32	20,000[d]
^{234}U		13	0.39 ± 0.072	0.25 ± 0.028	59	0.50 ± 0.13	0.27 ± 0.077	--
^{235}U		13	0.015 ± 0.013	0.0075 ± 0.0026	59	0.048 ± 0.022	0.010 ± 0.0096	--
^{238}U		13	0.27 ± 0.056	0.21 ± 0.016	59	0.53 ± 0.14	0.21 ± 0.066	--
U-Total		13	0.66 ± 0.092	0.47 ± 0.041	59	1.1 ± 0.19	0.49 ± 0.14	--
^{129}I[g]		4	0.00016 ± 0.0000078	0.00011 ± 0.000059	14	0.00017 ± 0.000020	0.00011 ± 0.000021	1[e]
Continuous System								
^{239,240}Pu	P	4	0.000041 ± 0.0000083	0.000027 ± 0.000012	17	0.000056 ± 0.000026	0.000017 ± 0.0000067	--
	D	4	0.000081 ± 0.000077	0.000031 ± 0.000035	17	0.00062 ± 0.00020	0.000082 ± 0.000071	--

(a) 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").
(b) Maximum values are ± total propagated analytical uncertainty (2-sigma). Averages are ±2 standard error of the calculated mean.
(c) WAC 246-290.
(d) 40 CFR 141.
(e) WAC 173-201A-050 and EPA (1976).
(f) Dashes indicate no concentration guides are available.
(g) From 1991 through 1995, iodine-129 concentrations were obtained from the dissolved fraction of the continuous system.

Table A.3. Radionuclide Concentrations Measured in Columbia River Water Along Transects of the Hanford Reach, 1996

Transect/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Minimum	Mean
Vernita Bridge				
Tritium	16	33 ± 8.6	25 ± 7.8	29 ± 1.3
^{90}Sr	16	0.13 ± 0.055	0.044 ± 0.03	0.083 ± 0.011
U-Total	16	0.52 ± 0.079	0.35 ± 0.063	0.42 ± 0.024
100-N Area				
Tritium	11	45 ± 9.5	20 ± 130	35 ± 4.4
^{90}Sr	10	0.18 ± 0.054	0.071 ± 0.034	0.11 ± 0.022
U-Total	11	0.48 ± 0.077	0.31 ± 0.058	0.39 ± 0.031
100-F Area				
Tritium	10	38 ± 8.9	31 ± 8.3	35 ± 1.3
^{90}Sr	10	0.11 ± 0.042	0.058 ± 0.033	0.089 ± 0.01
U-Total	10	0.45 ± 0.08	0.35 ± 0.06	0.41 ± 0.02
Old Hanford Townsite				
Tritium	10	9,000 ± 770	32 ± 8.4	960 ± 1,800
^{90}Sr	10	0.12 ± 0.052	0.081 ± 0.038	0.1 ± 0.0082
U-Total	10	0.61 ± 0.087	0.34 ± 0.059	0.4 ± 0.049
300 Area				
Tritium	10	150 ± 18	29 ± 8.3	53 ± 25
^{90}Sr	10	0.11 ± 0.044	0.063 ± 0.04	0.085 ± 0.011
U-Total	10	1.1 ± 0.12	0.39 ± 0.068	0.6 ± 0.14
Richland Pumphouse				
Tritium	42	120 ± 15	27 ± 8.4	40 ± 6.4
^{90}Sr	41	0.21 ± 0.066	0.045 ± 0.059	0.10 ± 0.0096
U-Total	42	0.63 ± 0.089	0.33 ± 0.06	0.44 ± 0.019

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2-sigma). Mean values are ±2 standard error of the mean.

Table A.4. Select Provisional U.S. Geological Survey Columbia River Water Quality Data, 1996[a]

Analysis	Units	Vernita Bridge (upstream)				Richland Pumphouse (downstream)				Washington Ambient Surface-Water Quality Standard[b]
		No. of Samples	Maximum	Median	Minimum	No. of Samples	Maximum	Median	Minimum	
Temperature	°C	6	19.0	10.8	4.5	5	18.5	13.0	3.5	20 (maximum)
Dissolved oxygen	mg/L	6	13.4	12.9	11.0	5	13.2	12.5	9.5	8 (minimum)
Turbidity	NTU[c]	6	1.4	0.6	0.4	5	1.6	0.6	0.4	5 + background
pH	pH units	6	8.1	8.0	7.7	5	8.1	8.0	8.0	6.5 - 8.5
Fecal coliform	#/100 mL	0	NR[d]	NR	NR	0	NR	NR	NR	100
Suspended solids, 105°C	mg/L	6	5	3	2	5	6	4	1	--[e]
Dissolved solids, 180°C	mg/L	6	100	85	73	5	96	85	63	--
Specific conductance	µS/cm[f]	6	141	135	131	5	141	138	130	--
Total hardness, as $CaCO_3$	mg/L	6	66	62	56	5	67	60	57	--
Phosphorus, total	mg/L	6	<0.01	<0.01	<0.01	5	0.02	0.01	<0.01	--
Chromium, dissolved	µg/L	0	NR	NR	NR	5	11	<1	<1	--
Dissolved organic carbon	mg/L	6	2.2	1.6	1.3	5	2.2	1.5	1.2	--
Iron, dissolved	µg/L	6	15	6	<3	5	46	12	6	--
Ammonia, dissolved, as N	mg/L	6	0.03	0.02	<0.002	5	0.03	<0.015	<0.015	--
Nitrogen, total Kjeldahl, as N	mg/L	0	NR	NR	NR	0	NR	NR	NR	--
Nitrite + Nitrate, dissolved, as N	mg/L	6	0.14	0.11	0.09	5	0.13	0.12	0.09	--

(a) Provisional data from U.S. Geological Survey National Stream Quality Accounting Network (NASQAN), subject to revision.
(b) From WAC 173-201A.
(c) NTU = nephelometric turbidity units.
(d) NR = not reported.
(e) Dashes indicate no standard available.
(f) µ Siemens/cm.

Table A.5. Radionuclide Concentrations in Columbia River and Riverbank Spring Sediment, 1996 Compared to Values from the Previous 5 Years

		1996			1991-1995[a]		
		Number of	Concentration, pCi/g		Number of	Concentration, pCi/g	
Location	Radionuclide	Samples	Maximum[b]	Median[c]	Samples	Maximum[b]	Median
River Sediment							
100-F Slough	^{60}Co	1	0.033 ± 0.011		6	0.032 ± 0.015	0.026
	^{137}Cs	1	0.47 ± 0.053		6	0.76 ± 0.082	0.29
	^{155}Eu	1	0.033 ± 0.026		6	0.064 ± 0.048	0.038
	$^{239,240}Pu$	1	0.0024 ± 0.00072		6	0.0024 ± 0.00082	0.0013
	^{90}Sr	1	0.0062 ± 0.0047		6	0.013 ± 0.0052	0.0033
	^{235}U	1	0 ± 0.11		6	0.056 ± 0.024	0.022
	^{238}U	1	1.4 ± 0.41		6	1.4 ± 0.17	0.86
Hanford Slough	^{60}Co	1	0.27 ± 0.046		6	0.32 ± 0.046	0.083
	^{137}Cs	1	0.59 ± 0.068		6	0.57 ± 0.067	0.37
	^{155}Eu	1	0.083 ± 0.045		6	0.16 ± 0.077	0.074
	$^{239,240}Pu$	1	0.0076 ± 0.0014		6	0.0073 ± 0.0023	0.0028
	^{90}Sr	1	0.016 ± 0.009		6	0.017 ± 0.0052	0.0061
	^{235}U	1	0.16 ± 0.15		6	0.24 ± 0.16	0.085
	^{238}U	1	1.7 ± 0.66		6	2.4 ± 0.89	0.8
McNary Dam	^{60}Co	4	0.069 ± 0.015	0.048	28	0.37 ± 0.061	0.1
	^{137}Cs	4	0.54 ± 0.061	0.45	28	1.2 ± 0.14	0.53
	^{155}Eu	4	0.09 ± 0.043	0.064	28	0.15 ± 0.085	0.073
	$^{239,240}Pu$	4	0.0097 ± 0.0025	0.008	28	0.014 ± 0.0018	0.009
	^{90}Sr	4	0.048 ± 0.011	0.026	28	0.061 ± 0.014	0.027
	^{235}U	4	0.12 ± 0.16	0.022	28	0.2 ± 0.16	0.055
	^{238}U	4	2.3 ± 0.81	1.6	28	2.3 ± 0.71	1.2
Priest Rapids Dam	^{60}Co	4	0.0022 ± 0.014	-0.0034	24	0.038 ± 0.049	0.0029
	^{137}Cs	4	0.67 ± 0.077	0.35	24	1 ± 0.15	0.44
	^{155}Eu	4	0.063 ± 0.039	0.047	24	0.11 ± 0.084	0.049
	$^{239,240}Pu$	4	0.014 ± 0.0036	0.0074	24	0.018 ± 0.0032	0.0084
	^{90}Sr	4	0.019 ± 0.0058	0.013	24	0.025 ± 0.0068	0.014
	^{235}U	4	0.17 ± 0.16	0.038	24	0.33 ± 0.17	0.054
	^{238}U	4	1.5 ± 0.56	0.98	24	2.2 ± 0.71	0.89

Table A.5. (contd)

Location	Radionuclide	1996 Number of Samples	1996 Concentration, pCi/g Maximum[b]	1996 Concentration, pCi/g Median[c]	1991-1995[a] Number of Samples	1991-1995[a] Concentration, pCi/g Maximum[b]	1991-1995[a] Concentration, pCi/g Median
Richland	^{60}Co	1	0.039 ± 0.019		5	0.075 ± 0.024	0.065
	^{137}Cs	1	0.24 ± 0.033		5	0.41 ± 0.053	0.34
	^{155}Eu	1	0.03 ± 0.036		5	0.077 ± 0.045	0.059
	$^{239,240}Pu$	1	0.002 ± 0.00068		5	0.003 ± 0.00071	0.0023
	^{90}Sr	1	0.005 ± 0.0035		5	0.003 ± 0.003	0.0023
	^{235}U	1	0.068 ± 0.13		5	0.14 ± 0.08	0.076
	^{238}U	1	2.1 ± 0.54		5	1.6 ± 0.19	1.2
White Bluffs Slough	^{60}Co	1	0.2 ± 0.031		6	0.11 ± 0.025	0.081
	^{137}Cs	1	0.46 ± 0.053		6	0.97 ± 0.11	0.82
	^{155}Eu	1	0.065 ± 0.034		6	0.56 ± 0.026	0.049
	$^{239,240}Pu$	1	0.0049 ± 0.00097		6	0.0073 ± 0.0017	0.0041
	^{90}Sr	1	0.01 ± 0.0057		6	0.017 ± 0.0055	0.0062
	^{235}U	1	0.14 ± 0.14		6	0.19 ± 0.044	0.036
	^{238}U	1	1.9 ± 0.52		6	2.3 ± 0.26	1.2
Riverbank Spring Sediment						1993-1995[a]	
100-B Spring	^{60}Co	1	0.01 ± 0.012		1	0.029 ± 0.0097	
	^{137}Cs	1	0.024 ± 0.013		1	0.095 ± 0.015	
	^{155}Eu	1	0.074 ± 0.036		1	0.065 ± 0.021	
	^{90}Sr	1	0.0027 ± 0.0033		1	0.0041 ± 0.005	
	^{235}U	1	0.1 ± 0.08		1	-0.017 ± 0.14	
	^{238}U	1	1.3 ± 0.38		1	1.1 ± 0.5	
100-F Spring	^{60}Co	1	0.04 ± 0.021		1	0.0044 ± 0.015	
	^{137}Cs	1	0.32 ± 0.04		1	0.19 ± 0.035	
	^{155}Eu	1	0.055 ± 0.031		1	0.037 ± 0.035	
	^{90}Sr	1	0.0097 ± 0.01		1	0.0043 ± 0.0044	
	^{235}U	1	0.17 ± 0.076		1	0.17 ± 0.13	
	^{238}U	1	1.4 ± 0.54		1	1.2 ± 1	

Table A.5. (contd)

Location	Radionuclide	1996 Number of Samples	1996 Concentration, pCi/g Maximum[b]	1996 Concentration, pCi/g Median[c]	1993-1995[a] Number of Samples	1993-1995[a] Concentration, pCi/g Maximum[b]	1993-1995[a] Concentration, pCi/g Median
300 Area Spring	^{60}Co	1	0.0048 ± 0.012		3	0.016 ± 0.0076	0.014
	^{137}Cs	1	0.15 ± 0.026		3	0.074 ± 0.017	0.07
	^{155}Eu	1	0.045 ± 0.032		3	0.13 ± 0.14	0.064
	^{90}Sr	1	0.0073 ± 0.011		3	0.012 ± 0.006	0.0076
	^{235}U	1	0.073 ± 0.071		3	0.41 ± 0.17	0.12
	^{238}U	1	1.2 ± 0.48		3	5.2 ± 1.1	4.2
Hanford Spring	^{60}Co	1	0.059 ± 0.016		3	0.09 ± 0.021	0.086
	^{137}Cs	1	0.17 ± 0.024		3	0.29 ± 0.032	0.25
	^{155}Eu	1	0.068 ± 0.034		3	0.062 ± 0.02	0.061
	^{90}Sr	1	0.0079 ± 0.005		3	0.0086 ± 0.011	0.0068
	^{235}U	1	0.25 ± 0.077		3	0.23 ± 0.14	0.023
	^{238}U	1	1.3 ± 0.36		3	1.9 ± 0.54	0.97

(a) 1996 river sediment values compared to values from 1991 through 1995; 1996 riverbank spring sediment values compared to values from 1993 through 1995.
(b) Values are ± total propagated analytical uncertainty (2-sigma).
(c) Median values are not provided when only one sample was analyzed.

Table A.6. Median Metal Concentrations in Columbia River Sediment, 1996

Metal	Median Concentration, mg/kg (dry weight)			
	Priest Rapids Dam	Hanford Reach	McNary Dam	Riverbank Springs
Aluminum	6,300	5,400	8,100	5,800
Antimony	2.4	4.1	4	2.1
Barium	48	44	60	52
Beryllium	0.21	0.20	0.29	0.21
Cadmium	2.2	1.6	0.93	1.1
Calcium	2,800	3,000	2,900	3,200
Chromium	13	12	11	18
Cobalt	4.3	4.0	4.4	4.6
Copper	11	14	12	8.8
Iron	12,000	11,000	13,000	14,000
Magnesium	3,200	2,800	2,800	3,000
Manganese	160	120	270	180
Nickel	13	11	11	9.4
Potassium	820	710	1,000	760
Silver	<0.52	<0.52	<0.52	<0.52
Sodium	260	260	300	220
Strontium	20	19	21	22
Tin	11	8.6	9.6	7.0
Vanadium	30	28	28	34
Zinc	200	240	100	84

Table A.7. Radionuclide Concentrations Measured in Riverbank Spring Water, 1996 Compared to Values from the Previous 5 Years

Location/Radionuclide	1996 No. of Samples	1996 Concentration,[a] pCi/L (10^{-6} µCi/L) Maximum	1991-1995 No. of Samples	1991-1995 Concentration,[a] pCi/L Maximum	1991-1995 Concentration,[a] pCi/L Median	Washington State Ambient Surface-Water Quality Standard,[b] pCi/L
100-B Spring						
Alpha	1	1.2 ± 0.98	5	3.5 ± 1.8	1.8	15
Beta	1	10 ± 2.4	5	38 ± 4.6	11	50
^{90}Sr	1	0.031 ± 0.045	5	0.072 ± 0.11	0.02	8
^{99}Tc	1	18 ± 2.3	5	25 ± 3.2	10	900[c]
Tritium	1	24,000 ± 1,800	5	23,000 ± 1,700	14,000	20,000
100-D Spring						
Alpha	1	0.27 ± 0.48	6	2.9 ± 1.9	1.3	15
Beta	1	4.3 ± 1.8	6	21 ± 3.3	9.4	50
^{90}Sr	1	1.8 ± 0.34	6	9.4 ± 1.8	4.4	8
Tritium	1	1,000 ± 200	6	13,000 ± 1,000	6,500	20,000
100-F Spring						
Alpha	1	41 ± 18	2	3.7 ± 1.7	3.2	15
Beta	1	65 ± 11	2	2.0 ± 1.6	1.9	50
^{90}Sr	1	0.094 ± 0.057	2	0.099 ± 0.091	0.034	8
Tritium	1	1,800 ± 240	2	1,600 ± 230	1,100	20,000
U-Total	1	9.2 ± 0.79	2	2.6 ± 0.35	1.7	--[d]
100-N Spring[c]						
Alpha	1	0.46 ± 0.63	6	8.9 ± 14	1.6	15
Beta	1	4.5 ± 1.8	6	24,000 ± 1,700	6.6	50
^{90}Sr	1	0.053 ± 0.048	6	11,000 ± 2,000	0.10	8
Tritium	1	17,000 ± 1,300	6	31,000 ± 2,400	20,000	20,000
300 Area Spring						
Alpha	1	21 ± 4.6	7	110 ± 21	55	15
Beta	1	9.6 ± 2.4	7	29 ± 4.7	16	50
^{129}I	1	0.0022 ± 0.00035	3	0.0049 ± 0.00063	0.0044	1
^{99}Tc	1	1.2 ± 0.61	6	14 ± 1.9	5.7	900[c]
Tritium	1	3,400 ± 360	7	12,000 ± 940	9,900	20,000
U-Total	1	34 ± 2.5	7	65 ± 6.2	28	--

Table A.7. (contd)

Location/Radionuclide	1996 No. of Samples	1996 Concentration,[a] pCi/L (10^{-6} µCi/L) Maximum	1991-1995 No. of Samples	1991-1995 Concentration,[a] pCi/L Maximum	1991-1995 Concentration,[a] pCi/L Median	Washington State Ambient Surface-Water Quality Standard,[b] pCi/L
Hanford Spring						
Alpha	1	1.2 ± 0.86	7	4.9 ± 2.2	3.0	15
Beta	1	18 ± 3.2	7	95 ± 140	26	50
^{129}I	1	0.086 ± 0.01	4	0.22 ± 0.014	0.14	1
^{99}Tc	1	38 ± 4.5	7	130 ± 16	110	900[c]
Tritium	1	41,000 ± 3,100	7	170,000 ± 13,000	140,000	20,000
U-total	1	1.6 ± 0.2	5	2.6 ± 0.29	1.2	--

(a) Maximum values are ± total propagated analytical uncertainty (2-sigma).
(b) WAC 246-290, 40 CFR 141, and Appendix C, Table C.2.
(c) WAC 173-201A-050 and EPA (1976).
(d) Dashes indicate no concentration guides available.
(e) 1991 sample is from well 199-N-8T, 1992 sample is from well 199-N-46, 1993-1996 samples are from shoreline spring.

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Appendix B

Glossary

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Appendix B

Glossary

absorbed dose - Energy absorbed per unit mass from any kind of ionizing radiation in any kind of matter.

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 approximately 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 times or from different locations.

confined aquifer - An aquifer bounded above and below by less-permeable layers. Groundwater 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, as a result of 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, and not receive 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 groundwater 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. 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.

grab sample - A sample that is randomly collected or "grabbed" from the collection site.

groundwater - 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.

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.

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 for 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 groundwater 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 photon 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.

spent fuel - Uranium metal or oxide and its metal container that have 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.

transuranic - An element with an atomic number greater than 92 (92 is the atomic number of uranium).

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 groundwater 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

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Appendix C

Standards and Permits

Operations at the Hanford Site must conform to a variety of governmental standards and permits designed to ensure the biological and physical quality of the environment for public health, ecological, or aesthetic considerations. The primary environmental quality standards and permits applicable to Hanford operations in 1996 are listed in the following tables. The State of Washington has promulgated water quality standards for the Columbia River, Washington Administrative Code 173-201A (WAC 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 Title 40, Code of Federal Regulations, Part 141 (40 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. This DOE order establishes limits for public radiation dose and gives guidance for keeping radiation exposures to members of the public as low as reasonably achievable. 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. 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 DOE Order 5400.5, the derived concentration guides are established that reflect the concentrations of individual radionuclides in water and air that an individual could continuously consume, inhale, or be immersed in at average annual concentrations without exceeding an effective dose equivalent of 100 mrem per year. 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 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.

References

Clean Water Act. 1977. Public Law 95-217, as amended, 91 Stat. 1566 and Public Law 96-148, as amended.

Clean Air Act. 1986. Public Law 88-206, as amended, 42 USC 7401 et seq.

40 CFR 61. U.S. Environmental Protection Agency, "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations.*

40 CFR 131.36. U.S. Environmental Protection Agency, "Toxics Criteria for Those States not Complying with the Clean Water Act Section 303(c)(2)(B)." *Code of Federal Regulations.*

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) as a result of 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 nonpoint sources shall not exceed 2.8°C
pH	1) 6.5 to 8.5 range 2) <0.5 unit induced variation
Turbidity	≤5 nephelometric turbidity units 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 EPA drinking water regulations for radionuclides, as published in EPA (1976) or subsequent revisions thereto (see Table C.2)
Toxic substances	Shall not be introduced above natural background levels into waters of the state that have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent on those waters, or adversely affect public health, as determined by the department (see Table C.3)

40 CFR 141. U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations; Radionuclides; Proposed Rule." *Code of Federal Regulations.*

DOE Order 5400.5. "Radiation Protection of the Public and the Environment."

U.S. Environmental Protection Agency (EPA). 1976. *National Interim Primary Drinking Water Regulations.* EPA-570-9-76-003, Office of Water Supply, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1996. *Drinking Water Regulations and Health Advisories.* EPA 822-R-96-001, Office of Water, Washington, D.C.

Washington Administrative Code (WAC) 173-201A. "Water Quality Standards for Surface Waters of the State of Washington."

Washington Administrative Code (WAC) 246-290. "Group A Public Water Systems."

Table C.2. Selected Drinking Water Standards

Radiological Constituent	Primary Maximum Contaminant Level	Interim Drinking Water Standard	Agency[a]	Status
Total alpha[b]	15 pCi/L		DOH,[c] EPA[d]	Final
Radium-226		3	DOH[c]	Final
Beta and gamma radioactivity	4 mrem/yr[e]		DOH,[c] EPA[d]	Final
Tritium		20,000[f] pCi/L	DOH,[c] EPA[d]	Interim
Beryllium-7		6,000[f] pCi/L	EPA[g]	Interim
Cobalt-60		100[f] pCi/L	EPA[g]	Interim
Stontium-90		8[f] pCi/L	DOH,[c] EPA[d]	Interim
Technetium-99		900[f] pCi/L	EPA[g]	Interim
Ruthenium-106		30[f] pCi/L	EPA[g]	Interim
Antimony-125		300[f] pCi/L	EPA[g]	Interim
Iodine-129		1[f] pCi/L	EPA[g]	Interim
Iodine-131		3[f] pCi/L	EPA[g]	Interim
Cesium-134		20,000[f] pCi/L	EPA[g]	Interim
Cesium-137		200[f] pCi/L	EPA[g]	Interim
Europium-154		200[f] pCi/L	EPA[g]	Interim
Europium-155		600[f] pCi/L	EPA[g]	Interim
Uranium	20 µg/L[h]		EPA[i]	Proposed
Fluoride	4 mg/L		DOH,[c] EPA[d,i]	Final/under review
Nitrate, as NO_3^-	45 mg/L		DOH,[c] EPA[d,i]	Final
Chromium	100 µg/L, 100 µg/L[j]		EPA,[d,i] DOH[c]	Final, Final
Cyanide	200 µg/L		EPA[c,d,i]	Final
Trichlorethylene	5 µg/L		DOH,[c] EPA[d,i]	Final
Tetrachloroethylene	5 µg/L		DOH,[c] EPA[d,i]	Final
Carbon tetrachloride	5 µg/L		DOH,[c] EPA[d,i]	Final
Chloroform (THM)[k]	100 µg/L		DOH,[c] EPA[i]	
Cis-1,2-dichloroethylene	0.07 mg/L		EPA[i]	Final

(a) DOH = Washington State Department of Health, EPA = U.S. Environmental Protection Agency.
(b) Including radium-226 but excluding radon and uranium.
(c) WAC 246-290.
(d) 40 CFR 141.
(e) 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 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.
(f) Concentration assumed to yield an annual dose of 4 mrem/yr.
(g) EPA (1976).
(h) Equivalent to a nationwide EPA standard of 30 pCi/L and a sitewide standard of 13.4 pCi/L (see Section 4.8, "Groundwater Protection and Monitoring Program").
(i) EPA (1996).
(j) Recently modified from 50 µg/L.
(k) Standard is for total trihalomethanes (THM).

Table C.3. Select Surface Freshwater Quality Criteria for Toxic Pollutants

Compound	Level that Yields Acute Toxicity, µg/L[a]	Level that Yields Chronic Toxicity, µg/L[a]	Level to Protect Human Health for the Consumption of Water and Organisms, µg/L[b]
Total Recoverable Metals			
Antimony	--	--	14
Arsenic	360.0	190.0	0.018
Cadmium	2.0[c]	0.71[d]	--
Chromium(III)[e]	1,100[f]	130[g]	--
Chromium(VI)	16.0	11.0	--
Copper	10[h]	7.1[i]	
Lead	38[j]	1.5[k]	--
Mercury	2.4	0.012	0.14
Nickel	860[l]	95[m]	610
Selenium	20.0	5.0	--
Silver	1.4[n]	--	--
Thallium	--	--	1.7
Zinc	70[o]	64[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) WAC 173-201A-040.
(b) 40 CFR 131.36.
(c) exp(1.128[ln(hardness)]-3.828). Limiting value for 1991-1996 U.S. Geological Survey results is 55 mg $CaCO_3$/L. 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 (see 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. DOE 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)
Tritium	2,000,000	100,000
Carbon-14	70,000	500,000
Chromium-51	1,000,000	60,000
Manganese-54	50,000	2,000
Cobalt-60	5,000	80
Zinc-65	9,000	600
Krypton-85	NS[d]	3,000,000
Strontium-90	1,000	9
Technetium-99	100,000	2,000
Ruthenium-103	50,000	2,000
Ruthenium-106	6,000	30
Antimony-125	60,000	1,000
Iodine-129	500	70
Iodine-131	3,000	400
Cesium-137	3,000	400
Cerium-144	7,000	30
Europium-154	20,000	50
Europium-155	100,000	300
Uranium-234	500	0.09
Uranium-235	600	0.1
Uranium-238	600	0.1
Plutonium-238	40	0.03
Plutonium-239	30	0.02
Plutonium-240	30	0.02
Americium-241	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 Site operations and may be adjusted upward (larger) if accurate solubility information is available.

(c) From DOE Order 5400.5.

(d) NS = no numerical standard but the effective dose equivalent cannot exceed 100 mrem/yr.

Table C.6. Environmental Permits

Clean Water Act Permit

Additional details are given in Section 2.2, "Compliance Status."

Clean Air Act Permits

Prevention of Significant Deterioration Permit No. PSD-X80-14, issued to DOE Richland Operations Office by EPA Region 10; 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 DOE 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-0038, issued by Washington State Department of Fish and Wildlife to Pacific Northwest National Laboratory for 1996; covered the collection of food fish, shellfish, and wildlife, including game fish, 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.

National Pollutant Discharge Elimination Permits (governing effluent discharges to the Columbia River)

Permit #WA-000374-3 includes two outfalls in the 100-K Area, one in the 300 Area, and two inactive outfalls in the 100-N Area.

Permit #WA-002592-7 includes the outfall for the 300 Area Treated Effluent Disposal Facility.

Copies of the regulations concerning these permits may be obtained from the following organizations:

State of Washington
Department of Ecology
P.O. Box 47600
Olympia, WA 92504-7600

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

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Appendix D

Dose Calculations

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Appendix D

Dose Calculations

E. J. Antonio

The radiological dose that the public could have received in 1996 from Hanford Site 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.

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 empirically derived 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 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, molluscs, 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 1996 air emissions report (Gleckler et al. 1997).

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 on 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 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 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 (50-mi) 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 is the sum of the product of the individual doses and the number of individuals exposed for all 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. Specific pathways include external exposure from radionuclides in the water or on the shoreline and ingestion of river water while swimming. 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 Hanford Site operating areas are shown in Bisping (1997). These distributions are based on 1990 Bureau of the 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 (1997). 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 Bisping (1997).

400 Area Drinking Water

Drinking water at the Fast Flux Test Facility contained slightly elevated levels of tritium. The potential doses to 400 Area workers consuming this water in 1996 are given in Table D.10.

Table D.1. Food Pathway Parameters Used in Dose Calculations, 1996

Medium	Holdup, days[a] Maximally Exposed Individual	Holdup, days[a] Average Individual	Growing Period, days	Yield, kg/m²	Irrigation Rate, L/m²/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, 1996

Medium	Consumption, kg/yr Maximally Exposed Individual	Consumption, kg/yr 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, 1996

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, 1996

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 Area 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, 1996

Facility name	100-N Area
Releases (Ci)	^{60}Co (5.1 x 10^{-7}), ^{90}Sr (2.9 x 10^{-5}), ^{106}Ru (5.4 x 10^{-7}), ^{125}Sb (1.9 x 10^{-7}), ^{134}Cs (1.3 x 10^{-8}), ^{137}Cs (5.1 x 10^{-5}), ^{154}Eu (4.5 x 10^{-7}), ^{155}Eu (1.9 x 10^{-7}), ^{238}Pu (5.2 x 10^{-7}), $^{239,240}Pu$ (4.5 x 10^{-6})[a], ^{241}Pu (4.1 x 10^{-5}), ^{241}Am (2.0 x 10^{-6})
Meteorological conditions	1996 annual average, calculated from data collected at the 100-N Area and the Hanford Meteorology Station from January 1996 through December 1996, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual at residence, 1.9 x 10^{-8} s/m^3 at 41 km (25.5 mi) SE; maximally exposed individual at food source, 8.3 x 10^{-9} s/m^3 at 53 km (33 mi) SSE; 80-km (50-mi) population, 4.0 x 10^{-3} s/m^3 person-s/m^3
Release height	10-m (33-ft) effective stack height
Population distribution	375,000 (Bisping 1997, Table D-1)
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., Napier et al. 1988a, 1988b, 1988c)
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

(a) This value includes total alpha release data. Total alpha and unspecified alpha results assumed to be $^{239,240}Pu$ for dose calculations.

Table D.6. Technical Details of 100-N Area Liquid Release Dose Calculations, 1996

Facility name	100-N Area
Releases (Ci)	^{3}H (1.3 x 10^{-1}), ^{60}Co (2.3 x 10^{-3}), ^{90}Sr (1.2 x 10^{-1}), ^{125}Sb (3.5 x 10^{-3}), ^{137}Cs (3.8 x 10^{-3}), ^{155}Eu (1.2 x 10^{-3}), ^{238}Pu (4.0 x 10^{-5}), ^{241}Am (1.1 x 10^{-4})
Mean river flow	4,500 m^3/s (161,717 ft^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 (33,075 lb/yr) total harvest of Columbia River fish
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., Napier et al. 1988a, 1988b, 1988c)
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, 1996

Facility name	200 Areas
Releases (Ci)	200-East Area ^{60}Co (7.7 x 10^{-10}), ^{90}Sr (6.2 x 10^{-5})[a], ^{106}Ru (9.5 x 10^{-8}), ^{125}Sb (2.0 x 10^{-6}), ^{129}I (3.9 x 10^{-3}), ^{134}Cs (3.0 x 10^{-9}), ^{137}Cs (5.5 x 10^{-4}), ^{238}Pu (2.2 x 10^{-7}), $^{239,240}Pu$ (6.7 x 10^{-6})[b], ^{241}Pu (1.7 x 10^{-5}), ^{241}Am (9.2 x 10^{-6}) 200-West Area ^{90}Sr (3.6 x 10^{-4})[a], ^{137}Cs (6.5 x 10^{-7}), ^{238}Pu (4.2 x 10^{-6}), ^{239,240Pu} (2.4 x 10^{-4})[b], ^{241}Pu (3.5 x 10^{-4}), ^{241}Am (3.7 x 10^{-5})
Meteorological conditions	1996 annual average, calculated from data collected at the Hanford Meteorology Station from January 1996 through December 1996, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual at residence, 1.3 x 10^{-8} s/m^3 at 34 km (21 mi) SE; maximally exposed individual at food source, 9.8 x 10^{-9} s/m^3 at 45 km (28 mi) SE; 80-km (50-mi) population, 1.6 x 10^{-3} person-s/m^3
Release height	89-m (292-ft) effective stack height
Population distribution	376,000 (Bisping 1997, Table D-2)
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., Napier et al. 1988a, 1988b, 1988c)
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

(a) This value includes total beta release data. Total beta and unspecified beta results assumed to be ^{90}Sr for dose calculations.

(b) This value includes total alpha release data. Total alpha and unspecified alpha results assumed to be $^{239,240}Pu$ for dose calculations.

Table D.8. Technical Details of 300 Area Airborne Release Dose Calculations, 1996

Facility name	300 Area
Releases (Ci)	^{3}H (as HTO)[a] (1.8×10^{0}), ^{3}H (as HT)[a] (1.7×10^{0}), ^{90}Sr (2.0×10^{-5})[b], ^{137}Cs (3.3×10^{-6}), ^{220}Rn (5.4×10^{1}), ^{222}Rn (5.0×10^{-1}), ^{238}Pu (1.9×10^{-8}), $^{239,240}Pu$ (1.9×10^{-6})[c], ^{241}Am (7.0×10^{-8})
Meteorological conditions	1996 annual average, calculated from data collected at the 300 Area and the Hanford Meteorology Station from January 1996 through December 1996, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual at residence, 9.3×10^{-7} s/m^3 at 1.5 km (1 mi) E; maximally exposed individual at food source, 1.0×10^{-7} s/m^3 at 13 km (8 mi) SSE; 80-km (50-mi) population, 7.3×10^{-3} person-s/m^3
Release height	10 m (33 ft)
Population distribution	282,000 (Bisping 1997, Table D-3)
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., Napier et al. 1988a, 1988b, 1988c)
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

(a) HTO = tritiated water vapor; HT = elemental tritium.
(b) This value includes total beta release data. Total beta and unspecified beta results assumed to be ^{90}Sr for dose calculations.
(c) This value includes total alpha release data. Total alpha and unspecified alpha results assumed to be $^{239,240}Pu$ for dose calculations.

Table D.9. Technical Details of 400 Area Airborne Release Dose Calculations, 1996

Facility name	400 Area
Releases (Ci)	^{3}H (as HTO)[a] (3.6×10^{0}), ^{90}Sr (9.0×10^{-9})[b], ^{137}Cs (5.5×10^{-6})[c], $^{239,240}Pu$ (8.3×10^{-7})[d]
Meteorological conditions	1996 annual average, calculated from data collected at the 400 Area and the Hanford Meteorology Station from January 1996 through December 1996, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual at residence, 1.0×10^{-7} s/m^3 at 11 km (7 mi) SE; maximally exposed individual at food source, 3.4×10^{-8} s/m^3 at 23 km (14 mi) SSE; 80-km (50-mi) population, 4.9×10^{-3} person-s/m^3
Release height	10 m (33 ft)
Population distribution	283,000 (Bisping 1997, Table D-4)
Computer code	GENII, Version 1.485, December 3, 1990 (e.g., Napier et al. 1988a, 1988b, 1988c)
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

(a) HTO = tritiated water vapor.
(b) This value includes total beta release data. Total beta and unspecified beta results assumed to be ^{90}Sr for dose calculations.
(c) ^{137}Cs value for the 400 Area is derived fully from total beta measurements.
(d) This value includes total alpha release data. Total alpha and unspecified alpha results assumed to be $^{239,240}Pu$ for dose calculations.

Table D.10. Annual Dose to Workers in the 400 Area from Ingestion of Drinking Water Obtained from Groundwater 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]	0.005 ± 0.194	0.044	7.66×10^{-8}	3.4×10^{-9} (3.4×10^{-7})
Total beta[e]	5.68 ± 1.82	50	1.35×10^{-8}	6.8×10^{-7} (6.8×10^{-5})
Tritium	5,693 ± 189	50,554	1.73×10^{-11}	8.7×10^{-7} (8.7×10^{-5})
^{90}Sr	0.203 ± 0.378	1.8	3.85×10^{-8}	6.9×10^{-8} (6.9×10^{-6})
^{129}I	0.011 ± 0.00092	0.098	7.46×10^{-8}	7.3×10^{-9} (7.3×10^{-7})
Total				1.6×10^{-6} (1.6×10^{-4})

(a) Drinking water concentrations are annual average concentrations obtained from monthly samples taken during 1996.
(b) Intake is based on the assumption that a worker ingests 1 L/d of groundwater 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.

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Appendix E

Radionuclides Detected by Gamma Spectroscopy (Gamma Scan)

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Appendix E

Radionuclides Detected by Gamma Spectroscopy (Gamma Scan)

One of the several forms of radiation is gamma radiation. Gamma radiation is emitted by many radionuclides. Gamma spectroscopy, sometimes called a gamma scan, is used in the environmental surveillance program to detect the presence of the radionuclides shown in Table E.1. These radionuclides may be natural or result from Hanford Site activities. They include activation products formed by the absorption of a neutron by a stable element and fission products that occur following fission (splitting) of nuclear fuel radionuclides like plutonium-239 or uranium-235. These radionuclides may not be discussed in the main body of this report if they are below detection levels.

Table E.1. Radionuclides Analyzed by Gamma Spectroscopy

Radionuclide	Symbol	Source
Beryllium-7	^{7}Be	Natural
Sodium-22	^{22}Na	Activation product
Sodium-24	^{24}Na	Activation product
Potassium-40	^{40}K	Natural
Manganese-54	^{54}Mn	Activation product
Cobalt-58	^{58}Co	Activation product
Cobalt-60	^{60}Co	Activation product
Iron-59	^{59}Fe	Activation product
Zinc-65	^{65}Zn	Activation product
Zirconium/Niobium-95	$^{95}Zr/Nb$	Activation product and fission product
Molybdenum-99	^{99}Mo	Activation product and fission product
Ruthenium-103	^{103}Ru	Activation product and fission product
Ruthenium-106	^{106}Ru	Fission product
Antimony-125	^{125}Sb	Activation product
Iodine-131	^{131}I	Fission product
Cesium-134	^{134}Cs	Activation product
Cesium-137	^{137}Cs	Fission product
Barium/Lanthanum-140	$^{140}Ba/La$	Fission product
Cerium-141	^{141}Ce	Activation product and fission product
Cerium/Praseodymium-144	$^{144}Ce/Pr$	Fission product
Europium-152	^{152}Eu	Activation product
Europium-154	^{154}Eu	Activation product
Europium-155	^{155}Eu	Activation product

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Appendix F

Threatened and Endangered Species

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Appendix F

Threatened and Endangered Species

T. M. Poston and B. L. Tiller

This appendix discusses the threatened and endangered plants and animals potentially found on the Hanford Site as listed by the federal government in Title 50, Code of Federal Regulations, Part 17, Washington Natural Heritage Program (1994), and Washington State Department of Fish and Wildlife (1996). In 1996, the U.S. Fish and Wildlife Service consolidated its listing categories of candidate species from three designations to one (61 FR 7595). There are no candidate species on the federal list that could potentially occur on the Hanford Site.

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 and one insect 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 Washington State (Table F.1). There are 22 state-level candidate species of plants and animals (Table F.2) and 23 monitored plant species (Table F.3).

Table F.1. Federally or State Listed Threatened (T) and Endangered (E) Species Occurring or Potentially Occurring on the Hanford Site

Common Name	Scientific Name	Federal	State
Plants			
Columbia milkvetch	*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
White eatonella	*Eatonella nivea*		T
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*
Insects	
Columbia River tiger beetle[a]	*Cicindela columbica*
Juniper hairstreak	*Mitoura siva*
Silver-bordered bog fritillary	*Boloria selene atrocastalis*
Birds	
Burrowing owl	*Athene cunicularia*
Common loon	*Gavia immer*
Flammulated owl[b]	*Otus flammeolus*
Golden eagle	*Aquila chrysaetos*
Lewis' woodpecker[b]	*Melanerpes lewis*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Merlin	*Falco columbarius*
Northern goshawk[b]	*Accipter gentilis*
Sage sparrow	*Amphispiza belli*
Sage thrasher	*Oreoscoptes montanus*
Trumpeter swan[a]	*Cygnus columbianus*
Western sage grouse[b]	*Centrocercus urophasianus phaios*
Reptiles	
Striped whipsnake	*Masticophis taeniatus*
Mammals	
Merriam's shrew	*Sorex merriami*
Pacific western big-eared bat[a]	*Corynorhinus townsendii*[c]
Washington ground squirrel	*Spermophilus washingtoni*

(a) Probable, but not observed, on the Hanford Site.
(b) Reported, but seldom observed, on the Hanford Site.
(c) Formally known as *Plecotus townsendii*.

Table F.3. Washington State Plant Species of Concern Occurring on the Hanford Site

Common Name	Scientific Name	Status[a]
Bristly combseed	*Pecto carya*	S
Bristly cryptantha	*Cryptantha interrupta*	M2
Columbia River mugwort	*Artemisia lindleyana*	M3
Crouching milkvetch	*Astragalus succumbens*	M3
Desert dodder	*Cuscuta denticulata*	M1
Desert evening primrose	*Oenothera cespitosa*	S
False pimpernel	*Lindernia anagallidea*	S
Fuzzy-beard tongue penstemon	*Penstemon eriantherus*	M3
Geyer's milkvetch	*Astragalus geyeri*	S
Gray cryptantha	*Cryptantha leucophaea*	S
Kittitas larkspur	*Delphinium multiplex*	M3
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
Suksdort's monkey flower	*Mimulus suksdorfii*	S

The following species may inhabit the Hanford Site but have not been recently collected.

Coyote tobacco[b]	*Nicotiana attenuata*	S
Dense sedge	*Carex densa*	S
Few-flowered blue-eyed Mary[b]	*Collinsia sparsiflora*	S
Palouse milkvetch[b]	*Astragalus arrectus*	S
Thompson's sandwort	*Arenaria franklinii* v. *thompsonii*	M2

(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.

(b) Known collections are questionable in terms of location and/or identification.

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