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# Hanford Site

# 1997 Environmental Report

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

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Addressees:

THE HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR (CY) 1997 (PNNL-11795), RICHLAND, WASHINGTON, SEPTEMBER 1998

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 of CY 1997 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 1997 and early CY 1998.

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., the Management and Integration Contractor; Bechtel Hanford, Inc., 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

John D. Wagoner
Manager

EAP:DCW

Enclosure:
Hanford Site Environmental
Report for 1997

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PNNL-11795
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# Hanford Site Environmental Report for Calendar Year 1997

**Editors**

R. L. Dirkes
R. W. Hanf

September 1998

Prepared for the U.S. Department of Energy by
Pacific Northwest National Laboratory
under contract DE-AC06-76RLO 1830, with
contributions from Fluor Daniel Hanford, Inc.
and its enterprise companies, Bechtel Hanford, Inc.
and its subcontractors, and MACTEC-ERS

Pacific Northwest National Laboratory
Richland, Washington 99352

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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 M 231.1-1, *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 that may be useful for understanding the report.

This report is produced for the Environmental Assurance, Permits and Policy Division of the DOE Richland Operations Office 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 (bill.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://hanford.pnl.gov/envreport/ or http://hanford.pnl.gov/envreport/1997.

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@apimc01.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 of compliance with environmental regulations
- describe the environmental programs at the Hanford Site
- discuss the estimated radionuclide exposure to the public from 1997 Hanford Site activities
- present the effluent monitoring, environmental surveillance, and groundwater protection and monitoring information
- discuss the 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 and 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 Richland North Area, in the northern part of the city of Richland (includes leased office buildings for DOE and its contractors).

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
- research
- environmental restoration/facilities stabilization.

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, Central Waste Complex, low-level burial grounds, 200 Areas Effluent Treatment Facility, Waste Receiving and Processing Facility, 242-A Evaporator, State-Approved Land Disposal Site, Liquid Effluent Retention Facility, and 200 Areas Treated Effluent Disposal Facility. 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, management of its wastes, and monitoring of its operations and effluents for environmental compliance.

The principal contractors include the following:

- Fluor Daniel Hanford, Inc.
- Battelle Memorial Institute
- Bechtel Hanford, Inc.
- Hanford Environmental Health Foundation
- MACTEC-ERS.

Non-DOE operations and activities include commercial power production by the Washington Public Power Supply System at its WNP-2 Reactor and operation of a commercial low-level radioactive waste burial site by US Ecology, Inc. Kaiser Aluminum and Chemical Corporation leases the 313 Building to operate a formerly DOE-owned extrusion press. The National Science Foundation is building the Laser Interferometer Gravitational-Wave Observatory facility near Rattlesnake Mountain. R. H. Smith Distributing operates vehicle fueling stations in the 1100 and 200 Areas. Washington State University at Tri-Cities operates three laboratories in the 300 Area. Livingston Rebuild Center, Inc. leases the 1171 Building to rebuild train locomotives. Johnson Controls, Inc. operates 42 diesel and natural gas fueled package boilers for producing steam in the 200 and 300 Areas and also has compressors supplying compressed air to the site. 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, supercompaction, and packaging disposal facility.

## Compliance with Environmental Regulations

DOE Order 5400.1, "General Environmental Protection Program," describes the environmental standards and regulations applicable at DOE facilities. These 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 summarizes the status of Hanford's compliance with applicable regulations and lists the environmental occurrences for 1997.

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 1997, a total of 562 enforceable Tri-Party Agreement milestones and 237 unenforceable target dates were

completed on or ahead of schedule. Fifty-seven milestones scheduled for 1997 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 1997, the Hanford Site was in compliance with requirements of the Act. Cleanup is under way at various areas on the site. Full-scale remediation of waste sites continued in the 100 Areas in 1997.

## 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 1997 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 February 1998. The inventory report contained information on hazardous materials in storage across the site. If required, a toxic chemical release inventory report is issued each year, which provides details regarding releases, offsite transfers, and source reduction activities involving any toxic chemicals used in excess of regulatory thresholds during the previous year. No such reporting thresholds were exceeded in 1996, so no report was required in 1997. During 1997, 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 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 1998.

Revisions to the Act 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 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 violations occurred at the 300 Area Treated Effluent Disposal Facility in 1997 despite the use of best available technology. An application to modify the facility's discharge permit has been submitted.

## 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 and are enforced by the Washington State Department of Health. In 1997, all Hanford Site water systems were in compliance with requirements and agreements.

## Toxic Substances Control Act

The application of this Act's 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 1997, 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. Four of these (bald eagle, peregrine falcon, Aleutian Canada goose, and steelhead trout) 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. Hanford Site activities complied with this Act in 1997.

## 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 1997, 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) of radioactive and nonradioactive effluent materials during 1997 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 two emergency occurrence reports filed in 1997 and early 1998. No environmentally significant unusual occurrence reports were filed in 1997. There were several off-normal environmental release-related occurrence reports filed during 1997.

## Waste Management and Chemical Inventories

Radioactive, hazardous, and mixed wastes are generated at approximately 200 facilities on the Hanford Site. These wastes are handled and prepared for safe storage on the site or are shipped off the site for treatment and disposal. In addition to newly generated waste, significant quantities of waste remain from over 50 years of nuclear material production. This waste from past operations at Hanford resides in waste sites or is stored in several places, awaiting cleanup and ultimate safe storage or disposal. Examples are high-level radioactive waste stored in single- and double-shell tanks and transuranic waste stored in vaults and on storage pads. Most of the environmental monitoring performed at Hanford is focused on protecting the public from exposure to this waste.

## Environmental Monitoring Information

Environmental monitoring of the Hanford Site consists of effluent monitoring, environmental surveillance, and groundwater and vadose zone 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 gross alpha and gross 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 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 1997 are not significantly different from totals in 1996.

**Near-Facility Environmental Monitoring**. The near-facility environmental monitoring program is designed to protect the environment adjacent to facilities and to 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, 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 62 locations near nuclear facilities. 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 detected in the 100-K, 100-N, and 200 Areas. Cobalt-60 was consistently detected in the 100-N Area. Air concentrations for these radionuclides were elevated near facilities compared to the concentrations measured off the site by Pacific Northwest National Laboratory.

***Surface-Water Disposal Units and 100-N Springs Monitoring***. Samples collected from surface-water disposal units (ponds, ditches) included water, sediment, and aquatic vegetation. Only water samples were taken at 100-N Area 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 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 1997, the concentrations detected in samples from shoreline springs were highest in springs nearest the effluent monitoring well.

***Near-Facility Radiological Surveys***. In 1997, there were approximately 3,990 ha (9,859 acres) of posted outdoor contamination areas and 614 ha (1,517 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 of 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 1997.

***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 off the site. The concentrations show a large degree of variance; in general, samples collected on or adjacent to waste disposal facilities had significantly higher concentrations than those collected farther away.

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

Four new thermoluminescent dosimeter monitoring sites were established in the 100-B,C Area during late 1997 to evaluate environmental restoration activities at the 116-B-11 Water Retention Basin and the 116-C-1 Liquid Waste Disposal Trench. The 1997 average was comparable to offsite background levels.

Five thermoluminescent dosimeter locations were established in the 100-D,DR Area during late 1996 to evaluate environmental restoration activities at the 116-D-7 and 116-DR-9 Water Retention Basins. The 1997 readings were comparable to offsite background levels.

This is the fifth year that thermoluminescent dosimeters have been placed in the 100-K Area, surrounding the 105-K East and 105-K West Fuel Storage Basins (K Basins) and adjacent reactor buildings. Three of the dosimeters have consistently shown elevated readings as a result of their proximity to radioactive waste storage areas or stored radioactive rail equipment.

A hand-held micro-rem meter (to measure low-level radiation exposure) was used to survey points along the 100-N Area shoreline springs. The radiation rates measured continued to decline in 1997, reflecting discontinued discharges to the 1301-N Liquid Waste Disposal Facility and the continuing decay of its radionuclide inventory.

The 1997 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. Although the results for these two facilities were noticeably higher than those for other 100-N Area thermoluminescent dosimeter locations, they were approximately 17% lower than exposure levels measured at these locations in 1996.

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 A Tank Farm complex (200-East Area). The average annual dose rate measured in 1997 was 110 mrem/yr, approximately 8% lower than the dose rate measured in 1996.

Two thermoluminescent dosimeter locations were established at the Environmental Restoration Disposal Facility during late 1996 to evaluate the disposal activities in progress. Readings in 1997 were comparable to offsite background levels.

The highest dose rates in the 300 Area were measured near installations such as the 340 Waste Handling Facility. The average annual dose rate measured in the 300 Area in 1997 was 110 mrem/yr, a decrease of 8% compared to the average measured in 1996. The average annual dose rate at the 300 Area Treated Effluent Disposal Facility in 1997 was 82 mrem/yr, a decrease of 4% compared to the average dose rate measured in 1996.

The average annual dose rate measured in the 400 Area in 1997 was 86 mrem/yr, an increase of 3% compared to the average dose rate measured in 1996.

***Investigative Sampling***. To confirm the absence or presence of radioactive or hazardous contaminants, investigative sampling was conducted in the operations areas 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 (animal burrows, deep-rooted vegetation) 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 in 1997 included sludge, soil, vegetation, and wildlife and were collected where known or suspected radioactive contamination was present or to verify radiological conditions at project sites. In 1997, 80 samples were analyzed for radionuclides, and 27 showed some level of contamination. In addition, 115 samples were collected and disposed of without isotopic analyses, though field instrument readings were recorded.

## Environmental Surveillance

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

**Air Surveillance**. Radioactive materials in air were sampled continuously at 39 onsite locations, 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 1997, no differences were observed between the annual average gross alpha and gross beta air concentrations measured at the site perimeter and those measured at distant community locations. Quarterly composite samples were analyzed for numerous specific gamma-emitting radionuclides; however, no radionuclides of Hanford origin were detected consistently.

Tritium concentrations for 1997 were slightly lower at the site perimeter compared to the distant station.

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 0.000001% 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 1 of the 9 onsite air samples, with the maximum concentration at 0.001% of the DOE derived concentration guide of 9 pCi/m$^3$. Strontium-90 was not detected at any of the perimeter and distant locations.

Plutonium-239,240 concentrations were significantly elevated for air samples collected at the site perimeter compared to the distant locations, indicating a Hanford influence. The average concentration at the perimeter locations was less than 0.002% of the DOE derived concentration guide of 0.02 pCi/m$^3$. The maximum onsite plutonium-239,240 concentration was 0.02% of the DOE derived concentration guide of 0.02 pCi/m$^3$.

Uranium isotopic concentrations (uranium-234, uranium-235, and uranium-238) were similar on the site, at the perimeter, and at the distant locations for 1997. The annual average uranium concentration at the site perimeter was 0.03% of the 0.1-pCi/m$^3$ DOE derived concentration guide.

No air samples were collected in 1997 to test for nonradionuclides.

**Surface-Water and Sediment Surveillance**. The Columbia River was one of the primary environmental exposure pathways to the public during 1997 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 concentrations of tritium, iodine-129, and uranium were significantly higher (5% significance level) at the Richland Pumphouse (downstream from the site) than at Priest Rapids Dam (upstream from the site), indicating contribution along the Hanford Reach. Transect sampling (multiple samples collected across the river) in 1997 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 Franklin County shoreline near the 300 Area and the Richland Pumphouse and likely resulted from groundwater seepage and irrigation return canals east of the river.

Several metals and anions were detected in transect samples collected upstream and downstream of the site. Nitrate concentrations were elevated along the Benton County shoreline at the Old Hanford Townsite and 300 Area. Nitrate, sulfate, and chloride were elevated along the Franklin County shoreline for the 300 Area and Richland Pumphouse transects. With the exception of nitrate, sulfate, and chloride, which had slightly higher average quarterly concentrations at the Richland Pumphouse, no consistent differences were found between average quarterly metal and anion contaminant concentrations in the Vernita Bridge and Richland Pumphouse transect samples. All metal and anion concentrations in Columbia River water collected in 1997 were less than the Washington State ambient surface-water quality criteria levels for both acute and chronic toxicity. Arsenic concentrations exceeded EPA standards; however, similar concentrations were measured for transect samples collected at Vernita Bridge (background location) and Richland Pumphouse.

In 1997, samples of Columbia River surface sediments were collected from permanently flooded monitoring sites above McNary Dam (downstream of the site) and 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 location. Sediment samples were also collected from four periodically inundated Columbia River shoreline springs. The concentrations of radionuclides in sediment collected from riverbank springs were similar at all locations and were comparable to river sediment collected behind Priest Rapids Dam. Similar concentrations of most metals were found in Columbia River and riverbank springs sediment samples. The highest maximum and median concentrations of chromium were found in riverbank springs sediment. River sediment was also analyzed for simultaneously extracted metals and acid volatile sulfide (SEM/AVS). The SEM/AVS ratios are typically a better indicator of sediment toxicity than traditional total metals concentrations. When the amount of sulfide exceeds the amount of the metals (SEM/AVS ratio is below 1), the metal concentration in the sediment porewater will be low because of the limited solubility of the metal sulfides. SEM/AVS ratios were below 1.0 for all metals, except for zinc that was above 1.0 for some samples.

Water samples were collected from six Columbia River shoreline spring areas in 1997. All radiological contaminant concentrations measured in riverbank springs water in 1997 were less than the DOE derived concentration guides, except for strontium-90 at the 100-N Area where one spring was nearly 10 times the standard. The tritium concentration at the Old Hanford Townsite riverbank spring exceeded the Washington State ambient surface-water quality criteria level and was close to the criteria for springs at the 100-B and 100-N Areas. 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 levels.

Nonradiological contaminants measured in riverbank springs located on the Hanford shoreline in 1997 were below Washington State ambient surface-water acute toxicity levels, except for chromium at the 100-D and 100-H Area springs. The Washington State ambient surface-water chronic toxicity levels for chromium and lead 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 at the 100-F Area, but all locations were below the EPA drinking water standard.

Water was collected from three onsite ponds located near operational areas in 1997. Although the ponds were not accessible to the public and did not constitute a direct offsite environmental impact during 1997, 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 median gross beta and uranium concentrations in West Lake exceeded the ambient surface-water quality criteria levels. Concentrations of most radionuclides in water collected from all three ponds during 1997 were similar to those observed during past years.

Irrigation water from the Riverview canal near Pasco was sampled three times in 1997 to determine radionuclide concentrations. Radionuclide concentrations in offsite irrigation water were below the DOE derived concentration

guides and ambient surface-water quality criteria levels and were similar to those observed in Columbia River water.

**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 1997, 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 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, alfalfa, and wine were collected from areas around the site and were analyzed for cobalt-60, strontium-90, iodine-129, cesium-137, and tritium.

Most farm products sampled did not contain measurable concentrations of cobalt-60 or cesium-137. Iodine-129 was measured in milk at concentrations that appeared to be slightly elevated in downwind locations. Concentrations of iodine-129 in milk collected at downwind locations have decreased in the past 5 years, approaching the concentrations observed in milk collected at the upwind location. Strontium-90 was present in milk in equivalent concentrations at upwind and downwind locations. Tritium concentrations in wine were equivalent to background levels in surface water and do not indicate any upwind or downwind influence from Hanford. Strontium-90 concentrations in alfalfa have previously been slightly elevated in samples irrigated with Columbia River water withdrawn downstream of the site. In 1997, this effect was not as apparent. Strontium-90 concentrations in alfalfa samples analyzed in 1997 are low and close to background levels. Measurable levels of man-made radioactivity were not detected in vegetables and fruit samples collected in 1997.

**Fish and Wildlife Surveillance**. Analyses of fish and wildlife samples in 1997 indicated that some species had accumulated radionuclides at concentrations greater than background levels. Sculpins were collected near the 100-N Area springs as part of a special study with the Washington State Department of Health. Sculpins were sampled because they have a small home range and their exposure in the 100-N Area springs is more constant than that of more mobile fish that are routinely sampled. Concentrations of strontium-90 in sculpins collected in the vicinity of the 100-N Area springs were significantly higher than in a control group of sculpins collected upstream. Sculpins are not consumed by humans, but they have value as a biomonitoring species. Concentrations of strontium-90 in Columbia River whitefish collected near the 100-N Area in 1997 were considerably lower than in sculpins. Unlike sculpins, whitefish may be consumed by people.

Geese were also collected from around the 100-N to 100-D Area and at the Old Hanford Townsite. Concentrations of cesium-137 were at the limit of detection (0.02 pCi/g) in muscle. Strontium-90 concentrations in goose bone were lower than observed in 1995 and were within or below the range of strontium-90 in background samples of other wildlife species collected over the past decade. Collectively, the concentrations of radionuclides measured in fish and geese samples indicate accumulations of small amounts of specific radionuclides that possibly originated either from historic fallout or Hanford Site activities.

Special surveillance studies were also conducted in conjunction with the Washington State Department of Health to establish trace metal concentrations in aquatic organisms from the 100-N Area springs. Metals data were collected from bass, caddis fly larvae and adults, carp, clams, sculpin, and sucker. These samples provided additional data to assess the potential distribution and possible impacts of metals in the Columbia River ecosystem.

**Soil and Vegetation Surveillance**. Soil and vegetation samples were collected for special surveillance activities in association with cleanup activities in the 300 Area operable units. Samples were collected around the cleanup area to the north of the 300 Area and at five locations in Franklin County across the Columbia River and east of the 300 Area. Neither soil nor vegetation samples indicated any transport of contaminated dust off the site.

Special samples were also collected from fruit trees grown on the site. Three apricot trees (leaf samples only) and a quince tree (leaves and fruit) were sampled. Two apricot trees were sampled from an abandoned orchard northeast of the 100-D Area. These samples had approximately 600 pCi/L of tritium in water distilled from leaf samples. Concentrations of strontium-90 in all tree leaf samples

were within levels associated with background concentrations in vegetation samples routinely monitored in undeveloped areas of the Hanford Site. These samples were also analyzed for metals. Observed concentrations of metals fell within the range of concentrations associated with natural background levels.

Metal concentrations were also determined for reed canary grass and milfoil collected from the 100-N Area springs and an upriver control station near the Vernita Bridge. Metal concentrations were within the range of natural concentrations.

**External Radiation Surveillance**. Using thermoluminescent dosimeters, radiological dose rates were measured at both onsite and offsite locations during 1997. Radioactive substances contributing to the measured dose rates were of either natural or man-made origin. The dose rates did not change significantly from the dose rates measured in previous years. The 1997 annual average background dose rate measured in communities distant from the Hanford Site was 67 ± 1 mrem/yr; in 1996, the average background was 71 ± 1. The 1997 annual average perimeter dose rate was 89 ± 10 mrem/yr; in 1996, the average measured dose rate was 88 ± 10 mrem/yr. All onsite thermoluminescent dosimeters averaged 85 ± 5 mrem/yr, which compares favorably with the average of 86 ± 5 mrem/yr measured in 1996. Columbia River shoreline dosimeters had a 1997 average of 90 ± 6 mrem/yr; in 1996, the average was 89 ± 7 mrem/yr. The average dose rate along the 100-N Area shoreline (121 ± 22 mrem/yr) was approximately 50% higher than the typical shoreline dose rate (85 ± 3 mrem/yr).

## Groundwater and Vadose Zone 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, to establish groundwater quality baselines, to assess groundwater remediation, and to 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 over 700 wells to determine the distribution 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 contaminants.

Vadose zone monitoring was conducted to characterize radioactive and hazardous waste in the soil column from past intentional liquid waste disposals, accidental spills, and leachate from solid waste burial grounds. Subsurface source characterization and vadose zone monitoring, using spectral gamma logging and soil-gas monitoring, were conducted during 1997 in the vicinity of single-shell underground waste storage tanks and selected liquid waste disposal sites.

**Groundwater Protection and Monitoring**. The Hanford Groundwater Monitoring Project was responsible for groundwater surveillance and monitoring activities at the Hanford Site. 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 25 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, measured sample concentrations 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 detected at levels greater than their respective EPA drinking water standards in one or more onsite wells included tritium, iodine-129, technetium-99, uranium, strontium-90, cesium-137, gross alpha, and gross beta. Tritium, uranium, and strontium-90 were detected at concentrations greater than their respective DOE 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 basins associated with the north Richland well field. Groundwater with tritium at levels above the EPA 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 levels greater than the EPA drinking water standard were also found in the 100-B,C, 100-D, and 400 Areas.

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 of the 200-East Area). The iodine-129 contamination extends as far east as the Columbia River but at concentrations less than the EPA drinking water standard. The iodine-129 and tritium plumes share common sources. Iodine-129 at levels greater than the EPA drinking water standard also extends into the 600 Area to the northwest of the 200-East Area, into the 600 Area in the southern part of the 200-West Area, and to the northeast in the north-central part of the 200-West 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 EPA drinking water standard in the 100-H and 200-West Areas and adjacent 600 Area. In the upper basalt-confined aquifer, technetium-99 concentrations were found above the EPA drinking water standard in one well in the northern part of the 200-East Area. Greater than 180,900,000 L (47,800,000 gal) of groundwater have been treated and greater than 43.4 g (1.4 oz) of technetium-99 have been removed from groundwater since a pump-and-treat system began operating in the 200-West Area in 1994. Assessment studies indicate that Waste Management Areas B-BX-BY, SX, T, and TX-TY (where the tank farms are located) are sources of technetium-99 contamination in groundwater.

Uranium was detected at levels greater than the EPA drinking water standard in groundwater in the 100-F, 100-H, 200, 300, and 600 Areas. Wells near U Plant in the 200-West Area showed concentrations greater the DOE derived concentration guide. A pump-and-treat system has removed 56.8 kg (125 lb) of uranium from groundwater in the 200-West Area since 1994. Groundwater with uranium concentrations greater than the EPA drinking water standard is discharging to the Columbia River from the 300 Area.

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 the 100-K and 200-East Areas and near the former Gable Mountain Pond in the 600 Area also contain strontium-90 at levels greater than the DOE derived concentration guide. Strontium-90 was detected at levels greater than the EPA drinking water standard in the 100, 200, and 600 Areas. Strontium-90 continues to be remediated in the 100-N Area by a pump-and-treat system.

Cesium-137 was detected above the EPA drinking water standard in a localized area associated with a former injection well in the 200-East Area. Plutonium was also detected in this localized area, but at concentrations less than the 100-mrem/yr dose equivalent guideline.

Cobalt-60 was detected in the 200-East Area and adjacent 600 Area but at concentrations less than the EPA drinking water standard.

Several nonradioactive chemicals regulated by the EPA and Washington State were also present in Hanford Site groundwater. These were nitrate, chromium, carbon tetrachloride, chloroform, trichloroethylene, cis-1,2-dichloroethylene, cyanide, and fluoride. Of these chemicals, nitrate, chromium, and carbon tetrachloride are the most widely distributed constituents in Hanford Site groundwater.

Nitrate concentrations exceeded the EPA drinking water standard in all areas, except the 100-B,C and 400 Areas. The nitrate plumes in the 100 Areas discharge to the Columbia River. A nitrate plume emanating 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 EPA drinking water standard. Nitrate levels greater than the EPA drinking water standard occur in two areas of the 200-West Area and adjoining 600 Area. A pump-and-treat system in the 200-West Area removed 2,260 kg (4,938 lb) of nitrate from groundwater in 1997.

Chromium was detected above the EPA drinking water standard in the 100-D, 100-H, and 100-K Areas and in localized sites in the 100-K, 200-East, 200-West, and 600 Areas. Pump-and-treat systems began operating in the 100-D, 100-H, and 100-K Areas in 1997 to remove chromium from groundwater.

An extensive plume of carbon tetrachloride at levels greater than the EPA drinking water standard occurs in groundwater in the 200-West Area and adjoining 600 Area. As of 1997, greater than 117,800,000 L (31,100,000 gal) of groundwater have been treated at two pump-and-treat systems operating in the 200-West Area, resulting in the removal of approximately 870 kg (1,918 lb) of carbon tetrachloride.

Levels of trichloroethylene and chloroform have been known to consistently occur above the EPA drinking water standard from year to year in the 200-West Area. However, the distribution of these levels for 1997 could not

be defined because of sample interference from high levels of carbon tetrachloride. 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 above the EPA drinking water standard in the 100-K and 300 Areas and near the former Horn Rapids Landfill in the southern part of the Hanford Site.

Cis-1,2-dichloroethylene concentrations were above the EPA drinking water standard in one well in the 300 Area. Cyanide was detected in groundwater in the 200-East Area but at levels below the EPA drinking water standard. Fluoride was detected at the same level as the EPA drinking water standard in one well in the 200-West Area.

**Tank Farms Vadose Zone Baseline Characterization Project**. The multiyear vadose zone baseline characterization project at the single-shell tank farms continued in 1997. This project involves spectral gamma-ray geophysical logging of approximately 800 existing boreholes surrounding the tank farms, creating a database of information and providing interpretations and three-dimensional visualizations (computer-generated illustrations) of the subsurface contamination. The geophysical logging method is used to determine the concentration of gamma-emitting radionuclides in the subsurface. These data are then used to outline the regions of major subsurface contamination and to identify where to focus the effort of a more comprehensive vadose zone characterization program.

During 1997, 211 additional boreholes, surrounding 42 tanks, were logged. Interpretations were made on a farmwide basis for four tank farms, and visualizations were prepared for the contamination at those farms.

**Vadose Zone Monitoring at Waste Disposal Facilities.** Radioactive and hazardous waste in the soil column from past intentional liquid waste disposals, accidental spills, and leachate from solid waste burial grounds are potential sources of current and future groundwater contamination. Subsurface source characterization and vadose zone monitoring, using spectral gamma-ray logging and soil-gas monitoring, were conducted during 1997. The efforts focused primarily on vadose zone soil contamination associated with past liquid disposals to cribs, trenches, drain fields, and reverse wells at Waste Management Area B-BX-BY, Plutonium Finishing Plant liquid waste disposal sites, and Nonradioactive Dangerous Waste Landfill (part of the Central Landfill). The objectives of vadose zone borehole monitoring are to document contamination location and to determine moisture and radionuclide movement in the soil column. Borehole spectral gamma-ray logging is an in situ measurement of subsurface gamma-emitting radionuclides obtained through cased monitoring wells. By periodically recording detector response at various depths, changes over time can be documented.

Sixteen wells were successfully surveyed from the ground surface to the water table. Four of the 16 gamma-ray logs obtained outside the tank farms in Waste Management Area B-BX-BY suggest that gamma-emitting radionuclides may have redistributed in sediments surrounding these four boreholes in the last 10 years.

Movement of small amounts of cobalt-60 at one 200-East Area well was inferred in a small zone between 33.2 and 34.7 m (109 and 114 ft), but the movement is interpreted to be horizontal (away from the borehole) not vertical (toward the water table). Recent logging of another 200-East Area well showed very minor changes in cobalt-60 at 37.2 and 42.1 m (122 and 138 ft). The cobalt appears to have moved deeper down the profile. The magnitude of the vertical migration was less than 1 pCi/g of cobalt-60. The amount of cobalt-60 migration is small at both locations and is not a significant risk.

Uranium from Hanford operations was identified in two 200-East Area wells at orders of magnitude higher than natural background concentrations. The uranium moved deeper in the last 10 years and, currently, is just above the water table. Groundwater at these wells has been showing rising uranium concentrations for the last 5 years. Uranium in deep sediments between 70.7 and 75.9 m (232 and 249 ft) appeared in the September 1997 log at one of the 200-East Area wells. Uranium in the sediments at another well increased by a factor of 5 (from 200 to 1,000 pCi/g) in a deep zone between 67.1 and 73.2 m (220 and 240 ft). The peak activity and whole plume seem to have migrated 1.2 to 6.1 m (3.9 to 20 ft) deeper into the profile. The significance of the uranium migration at these two locations, which are separated by approximately 100 m (328 ft), is under investigation. The source of the uranium may not be common for these two wells. Single-shell tank BX-102 is a likely source of the uranium in one of the wells.

Soil vapor extraction is being used to remove the carbon tetrachloride source from the vadose zone as part of the 200-West Area carbon tetrachloride expedited response action being conducted by Bechtel Hanford, Inc. To track

the effectiveness of the remediation effort, measurements of soil-gas concentrations of chlorinated hydrocarbons were made at individual on-line extraction wells, at soil-gas probes throughout the vadose zone, and at the inlets to the three soil vapor extraction systems.

Carbon tetrachloride rebound concentrations indicate that, in many areas, much of the readily accessible mass has been removed during soil vapor extraction operations and that the supply of additional carbon tetrachloride is limited by desorption and/or diffusion from contaminant sources (lower permeability zones such as the lower Hanford formation silt and Plio-Pleistocene layers). Under these conditions, the removal rate of the additional carbon tetrachloride, using soil vapor extraction, is controlled by the desorption and diffusion rates of the contaminant. The extraction systems are estimated to have removed 6% of the residual mass at the 216-Z-1A/ 216-Z-18 Well Fields and 21% of the residual mass at the 216-Z-9 Well Field. The location of the remaining carbon tetrachloride sources in the various strata is a result of its initial accumulation in the finer grained, lower permeability sediment and the relative inability of the extraction system to induce airflow through this lower permeability zone to effectively remove soil vapor.

Carbon tetrachloride concentrations measured in soil vapor near the water table increased relatively slowly during the rebound study and remained relatively constant during restart in July 1997. These relatively slow changes during the rebound study suggest that the volatilization of dissolved carbon tetrachloride from groundwater into the unsaturated zone, and/or the downward migration of carbon tetrachloride from the lower permeability zone toward the groundwater, was occurring slowly relative to the 8-month-long rebound study. The measured carbon tetrachloride vapor concentrations are an order of magnitude lower than the equilibrium vapor concentrations predicted for groundwater concentrations using Henry's Law. The vapor concentrations are also much lower than saturated vapor concentrations in equilibrium with a carbon tetrachloride nonaqueous-phase liquid, which suggests that the continuous carbon tetrachloride contamination source indicated for the groundwater at the 216-Z-9 Well Field may be within the aquifer rather than draining from the vadose zone sediments. The results obtained to date suggest that vapor-phase transport is secondary to dense nonaqueous-phase liquid as a groundwater contamination pathway, but field measurements of carbon tetrachloride vapor concentrations are not completely consistent with numerical modeling results.

Groundwater monitoring below the carbon tetrachloride disposal units suggests there is a continuing groundwater source that produces somewhat uniform carbon tetrachloride concentrations with depth in the aquifer. A dense nonaqueous-phase liquid that has drained from the vadose zone into the aquifer and is slowly dissolving could produce such a pattern. The continuing presence of relatively high dissolved carbon tetrachloride concentrations in groundwater in the immediate vicinity of the 216-Z-9 Trench, 35 years after termination of disposal operations, suggests that a dense nonaqueous liquid phase of carbon tetrachloride is slowly dissolving within the aquifer. Although this liquid phase may be slowly draining from the vadose zone to groundwater, the soil vapor concentrations monitored deep within the vadose zone suggest that extraction remediation may have removed much of the vadose zone source and that the continuing groundwater source is now within the aquifer. Carbon tetrachloride concentrations in the soil vapor and underlying groundwater do not appear to be in equilibrium, and the expected direction of carbon tetrachloride migration is from the groundwater to the vadose zone.

The Nonradioactive Dangerous Waste Landfill is a Resource Conservation and Recovery Act land disposal unit located approximately 5.6 km (3.5 mi) southeast of the 200-East Area. The landfill was used to dispose of nonradioactive dangerous waste and asbestos waste from 1975 to 1985. A soil vapor survey was conducted at the landfill during 1997 to assess the vertical extent of volatile organic compound contamination and the potential impacts to groundwater and to resample selected shallow vapor probes for changes in contaminant distribution that may indicate contaminant movement.

Six volatile organic compounds were detected during the 1997 survey: 1,1,1-trichloroethane, 1,1-dichloroethane, tetrachloroethylene, trichloroethylene, carbon tetrachloride, and chloroform. Of these contaminants, 1,1,1-trichloroethane was the most widespread and was detected in all but one of the samples from the deep probes at concentrations less than 1 part per million by volume (ppmv); however, 1,1,1-trichloroethane was not detected in the samples from the shallow probes. Carbon tetrachloride and chloroform were the only contaminants detected at concentrations exceeding 1 ppmv; in samples from two adjacent locations (one shallow and two deep probes within and beneath the chemical trenches). All of the same contaminants, except 1,1-dichloroethane, were detected in a 1993 survey.

Based on the 1997 results, the soil vapor contaminants tend to be distributed at low concentration levels within or south of the Nonradioactive Dangerous Waste Landfill trenches. The volatile organic compound concentrations detected in deep samples suggest that vertical migration of carbon tetrachloride occurred directly beneath the chemical trenches within a narrow zone. Comparison of analytical results for the 1993 and 1997 soil vapor samples collected from shallow probes indicates that the maximum carbon tetrachloride concentrations are still laterally within the chemical trenches at the landfill, suggesting that the contaminants have not migrated significantly laterally.

# Potential Radiological Doses from 1997 Hanford Operations

In 1997, potential radiological 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 using 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 1997 from site operations was 0.01 mrem (0.1 µSv) compared to 0.007 mrem (0.07 µSv) calculated for 1996. The radiological dose to the population within 80 km (50 mi) of the site, estimated to be 380,000 persons, from 1997 site operations was 0.2 person-rem (0.002 person-Sv), which remained unchanged from the population dose calculated for 1996 (0.2 person-rem [0.002 person-Sv]). The average per-capita dose from 1997 site operations was 0.0005 mrem (0.005 µSv). The national average dose from background sources, according to the National Council on Radiation Protection, is approximately 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 limit and 0.0002% of the national average background. Special exposure scenarios not included in the dose estimate above included the hunting and consumption of game animals residing on the Hanford Site and exposure to radiation at a publicly accessible location with the maximum exposure rate. Doses from these scenarios would have been small compared to the DOE dose limit. Radiological dose through the air pathway was 0.04% of the EPA limit of 10 mrem/yr (0.1 mSv/yr).

# Other Hanford Site Environmental Programs

## Climate and Meteorology

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 1997 was 12.7 km/h (7.9 mi/h), which was 0.3 km/h (0.2 mi/h) above normal; the peak gust for the year was 116 km/h (72 mi/h).

Precipitation for 1997 totaled 16.2 cm (6.4 in.), 102% of normal, with 19.8 cm (7.8 in.) of snow recorded.

Temperatures for 1997 ranged from –13.3°C (8°F) in January to 41.1°C (106°F) in August.

## Cultural Resources

Management of archaeological, historical, and traditional cultural resources at the Hanford Site is provided in a manner consistent with the National Historic Preservation Act, Native American Graves Protection and Repatriation Act, Archaeological Resources Protection Act, and American Indian Religious Freedom Act. During 1997, 151 proposed projects were reviewed to consider their potential effect on significant cultural resources. Other activities included the continuation of a multiyear monitoring study of cutbank erosion and associated impacts to National Register archaeological sites at Locke Island, a large channel island located in the northern extent of the Hanford Reach of the Columbia River. A similar monitoring study, focusing on eroding shorelines along the Columbia River, was also conducted during 1997. Mitigation of historic buildings and structures continued in 1997 as required by the programmatic agreement for the built environment and the historic district treatment plan.

Public involvement in the cultural resources program focused on the built environment and curation strategies for important Manhattan and Cold War Era artifacts and associated records. Native American involvement included

the completion of several field surveys, construction monitoring, and monthly cultural issues meetings.

## Community-Operated Environmental Surveillance Program

This 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 1997.

# Quality Assurance

Comprehensive quality assurance programs, which include various quality control practices and methods to verify data, are maintained to ensure data quality. The 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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Groups and organizations participating in the effluent monitoring program conducted by Waste Management Federal Services, Inc. included radiological control technicians and managers, facility operators, facility environmental engineers, environmental compliance officers and scientists, process analytical laboratories, ventilation balance, and field maintenance. Individuals in these organizations collected and analyzed samples, maintained monitoring and sampling equipment, measured stack flow rates, ensured that facility operations adhered to environmental regulations, and ensured that the effluent data reported were accurate. The Pacific Northwest National Laboratory radioactive airborne effluent data were provided by E. G. Damberg and M. J. Sula. Quantities of nonradioactive materials discharged to the atmosphere were provided by R. E. Johnson (Waste Management Federal Services of Hanford, Inc.) and J. G. Woolard (Bechtel Hanford, Inc.). The Comprehensive Environmental Response, Compensation, and Liability Act and Washington Administrative Code reportable spill data were provided by J. R. Culmer (Fluor Daniel Hanford, Inc.), S. J. Ingle (CH2M Hill Hanford, Inc. for Bechtel Hanford, Inc.) and H. T. Tilden II (Pacific Northwest National Laboratory).

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Community-operated environmental surveillance stations were managed by local teachers who were responsible for collecting the samples and maintaining the stations. The managers and alternate managers for each station included the following:

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Columbia Basin College, Pasco: L. DeWitt, Manager, and J. O'Neill, Alternate Manager

Heritage College, Toppenish: D. F. Brown, Manager, and R. A. Landvoy, Alternate Manager.

# Report Contributors

The production of this Hanford Site environmental report requires the knowledge, skills, experience, and cooperation of many people and several organizations. The contributions and cooperation, often under demanding time constraints, of the following individuals are gratefully acknowledged. The lead authors are listed on each main section of the report and their telephone numbers are included below.

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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 $1 \times 10^9$. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from its current location. If the value given is $2.0 \times 10^3$, the decimal point should be moved three places to the **right** so that the number would then read 2,000. If the value given is $2.0 \times 10^{-5}$, the decimal point should be moved five places to the **left** so that 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 in Table H.2.

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

| Symbol | Name | Symbol | Name |
|---|---|---|---|
| **Temperature** | | **Length** | |
| °C | degree Celsius | cm | centimeter ($1 \times 10^{-2}$ m) |
| °F | degree Fahrenheit | ft | foot |
| **Time** | | in. | inch |
| d | day | km | kilometer ($1 \times 10^3$ m) |
| h | hour | m | meter |
| min | minute | mi | mile |
| s | second | mm | millimeter ($1 \times 10^{-3}$ m) |
| yr | year | µm | micrometer ($1 \times 10^{-6}$ m) |
| **Rate** | | **Area** | |
| cfs (or $ft^3/s$) | cubic foot per second | ha | hectare ($1 \times 10^4$ $m^2$) |
| 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 ($1 \times 10^3$ g) |
| L | liter | mg | milligram ($1 \times 10^{-3}$ g) |
| $m^3$ | cubic meter | mg | microgram ($1 \times 10^{-6}$ g) |
| mL | milliliter ($1 \times 10^{-3}$ L) | ng | nanogram ($1 \times 10^{-9}$ 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 | $2.7 \times 10^{-11}$ | curie | curie | $3.7 \times 10^{10}$ | 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 in a given 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 37 billion. Therefore, one becquerel is equivalent to one nuclear disintegration per second.

## Radiological Dose Units

The amount of ionizing radiation energy absorbed 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 millirem (mrem) or in the SI unit, millisievert (mSv) (Table H.4). Millirem (millisievert) is a term that relates ionizing radiation and biological effect or risk (to humans). A dose of 1 mrem has a biological effect similar to the dose received from an approximate 1-day exposure to natural background radiation. An acute (short-term) dose of 100,000 to 400,000 mrem can cause radiation sickness in humans. An acute dose of 400,000 to 500,000 mrem, if left untreated, results in death approximately 50% of the time. Exposure to lower amounts of radiation (1,000 mrem or less) produces no immediate

**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 or Exposure

| 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 |

observable effects, but long-term (delayed) effects are possible. The average person in the United States receives an annual dose from exposure to naturally produced radiation of approximately 300 mrem. Medical and dental x-rays and air travel add to this total. (See Section 5.0.6, "Hanford Public Radiological Dose in Perspective," 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," for radiation absorbed dose, or the SI unit, gray (Gy), are also used in this report. The rad is a measure of the energy absorbed by any material, whereas a rem relates to both the amount of radiation energy absorbed by humans and its consequence. A roentgen (R) is a measure of radiation exposure with no SI equivalent. Generally speaking, one roentgen of exposure will result in an effective dose equivalent of 1 rem.

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

# Chemical and Elemental Nomenclature

The chemical contaminants discussed in this report are listed in Table H.6 along with their chemical (or elemental) names and their corresponding symbols.

# Understanding the Data Tables

## Total Propagated Analytical Uncertainty (2-Sigma Error)

Some degree of 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 decay.

Many of the individual measurements in this report are accompanied by a plus/minus (±) value, referred to as the total propagated analytical uncertainty (or 2-sigma error). For samples that are prepared or manipulated in the laboratory prior to counting (counting the rate of radioactive emissions from a sample), the total propagated analytical uncertainty includes both the counting uncertainty and the uncertainty associated 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.** Radionuclides and Their Half-Lives[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 | $1.3 \times 10^{8}$ 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 | $1.4 \times 10^{10}$ yr |
| $^{90}Sr$ | strontium-90 | 29.1 yr | U or uranium[b] | uranium total | --[c] |
| $^{95}Zr$ | zirconium-95 | 63.98 d | $^{234}U$ | uranium-234 | $2.4 \times 10^{5}$ yr |
| $^{99}Tc$ | technetium-99 | $2.1 \times 10^{5}$ yr | $^{235}U$ | uranium-235 | $7 \times 10^{8}$ yr |
| $^{103}Ru$ | ruthenium-103 | 39.3 d | $^{238}U$ | uranium-238 | $4.5 \times 10^{9}$ 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 | $2.4 \times 10^{4}$ yr |
| $^{125}Sb$ | antimony-125 | 2.8 yr | $^{240}Pu$ | plutonium-240 | $6.5 \times 10^{3}$ yr |
| $^{129}I$ | iodine-129 | $1.6 \times 10^{7}$ 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.
(c) Natural uranium is a mixture dominated by $^{238}U$, thus the half-life is approximately $4.5 \times 10^{9}$ years.

The total propagated analytical uncertainty gives information on what the measurement (or result) might be if the same sample were analyzed 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 of a given constituent is smaller then its associated uncertainty (e.g., 40 ± 200), the sample may not contain that constituent. Such low concentration values are considered to be below detection, meaning the concentration of the constituent 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 ±2 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

**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 | | |

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

## Negative Numbers

There is always a small amount of natural radiation in the environment. The instruments 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 essential 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 grams per liter (g/L) would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 1,000 g/L (Figure H.1). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure H.2).

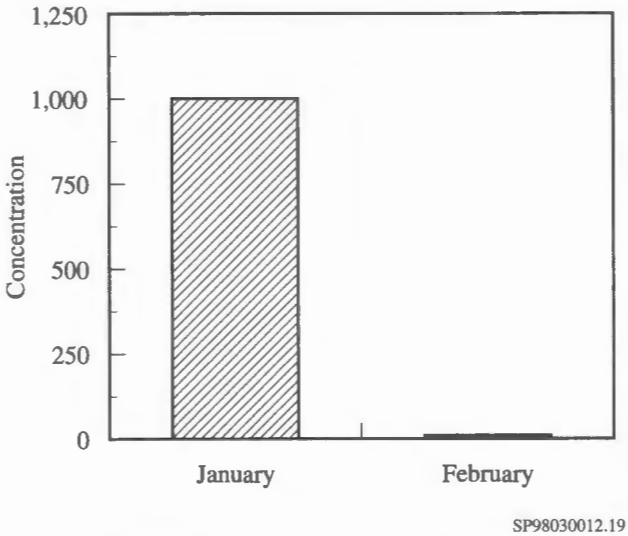


**Figure H.1**. Data Plotted Using a Linear Scale

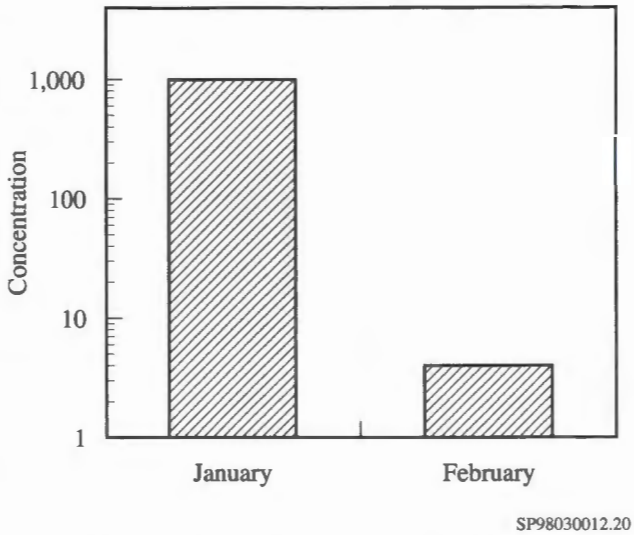


**Figure H.2**. Data Plotted Using a Logarithmic Scale

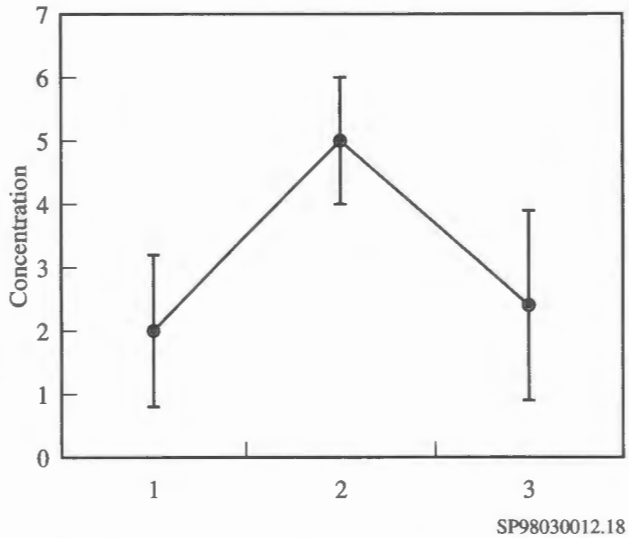


**Figure H.3**. Data with Error Bars Plotted Using a Linear Scale

The mean (average) and median (defined earlier) 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 two 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 true mean 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

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

different. Means that appear to be very different visually (means 2 and 3) may actually be quite similar when compared statistically.

When vertical lines are used with median values, the lower end of each bar represents the minimum concentration measured; 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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# 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, and MACTEC-ERS). 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 and projects.

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 and projects. Included are summary data and descriptions for the Hanford Groundwater Monitoring Project, the Near-Facility Environmental Monitoring Program, the vadose zone characterization project, the Surface Environmental Surveillance Project, the Hanford Cultural Resources Laboratory, wildlife studies, climate and meteorological monitoring, and information about other programs and projects. 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 efforts are contained in the Hanford Site environmental monitoring plan (DOE/RL 91-50, Rev. 2).

## 1.0.1 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 1995, wheat represented the largest single crop in terms of area planted in Benton and Franklin Counties. Total acreage planted in the two counties was 100,770 and 18,810 ha (249,000 and 46,500 acres) for winter and spring wheat, respectively. Corn, alfalfa, potatoes, asparagus, apples, cherries, and grapes are other major crops in Benton and Franklin Counties. Several processors in Benton and Franklin Counties produce food products, including potato products, canned fruits and vegetables, wine, and animal feed.

Estimates for 1996 placed population totals for Benton and Franklin Counties at 131,000 and 43,700, respectively (Washington State Office of Financial Management 1996a). 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.

The 1996 estimates distributed the Tri-Cities' population within each county as follows: Richland 35,990, Pasco 22,370, and Kennewick 48,010. The combined populations of Benton City, Prosser, and West Richland totaled 13,665 in 1996. The unincorporated population of Benton County was 33,335. In Franklin County, incorporated areas (cities and towns) other than Pasco have a total

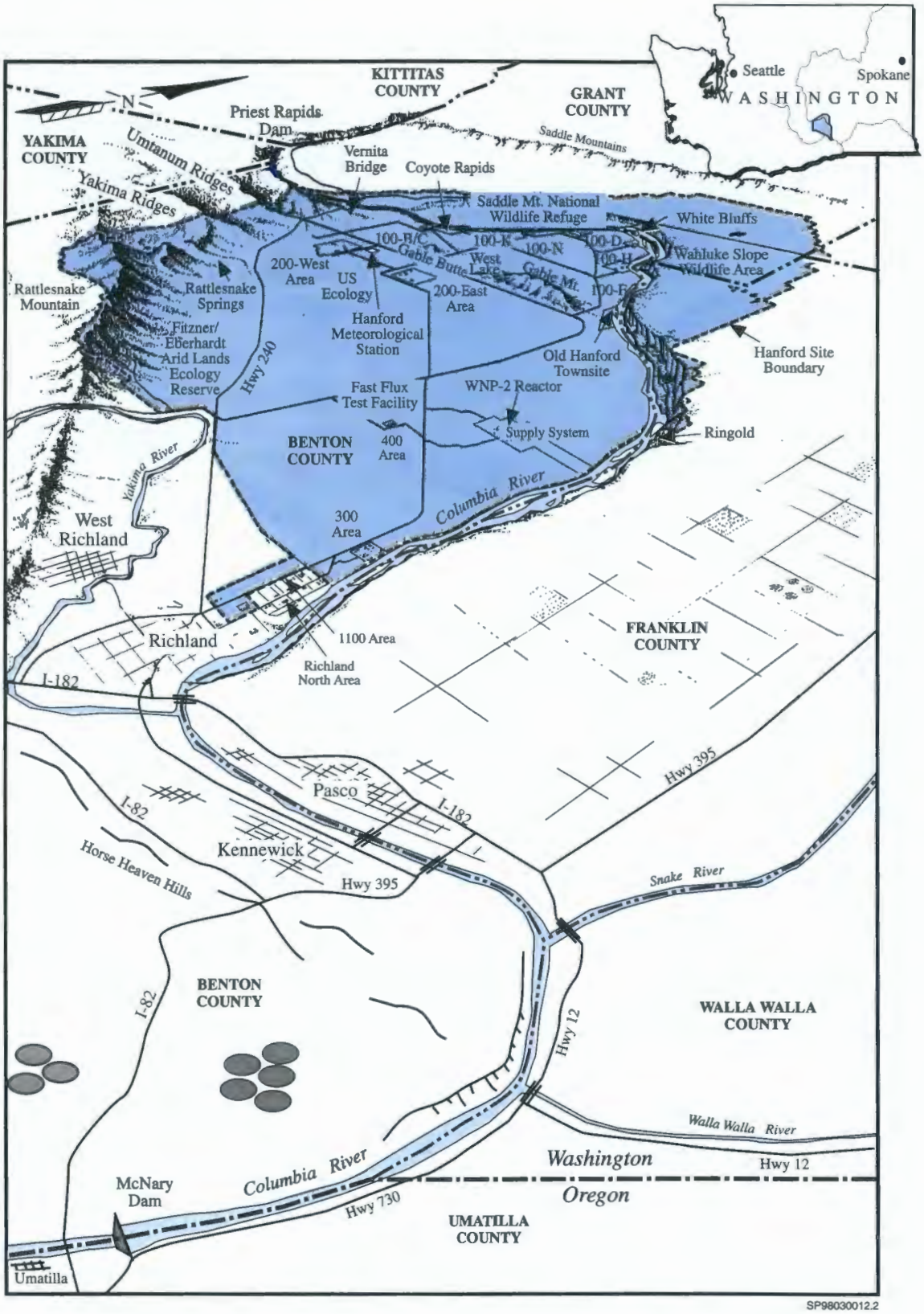


**Figure 1.0.1**. The Hanford Site and Surrounding Area

population of 3,263. The unincorporated rural population of Franklin County was 18,067 (Washington State Office of Financial Management 1996a).

The 1994 estimates of racial categories (Washington State Office of Financial Management 1996a) 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 1996b). In 1996, 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 54.5%, compared to 50.7% 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 26.6% of the total bicounty population compared to 22.7% for the state. In 1996, the 65-year-old and older age group constituted 9.7% of the population of Benton and Franklin Counties compared to 11.5% for the state.

### 1.0.1.1 Site Description

The entire Hanford Site was designated a National Environmental Research Park (one of four nationally) by the former U.S. Energy Research and Development Administration, a precursor to U.S. Department of Energy (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.
- The 1100 Area is located generally between the 300 Area and the city of Richland, and includes site support services such as general stores and transportation maintenance.
- The Richland North Area (off the site) includes the DOE and its contractor facilities, mostly leased office buildings, generally located in the northern part of the city of Richland.

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). The Fitzner/Eberhardt Arid Lands Ecology Reserve was established in 1967 by the U.S. Atomic Energy Commission, a precursor to DOE, to preserve shrub-steppe habitat and vegetation. In 1971, the reserve was classified a Research Natural Area as a result of a federal interagency cooperative agreement. In June 1997, DOE transferred management, including access management, of the reserve from Pacific Northwest National Laboratory to the U.S. Fish and Wildlife Service. The Service will continue to operate the reserve using the current management policy (PNL-8506) until a new management plan can be written. This is scheduled to occur within 3 years of the June 1997 transfer date.

Non-DOE operations and activities on Hanford Site leased land or in leased facilities 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. 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. R. H. Smith Distributing operates vehicle-fueling stations in the 1100 and 200 Areas. Washington State University at Tri-Cities

operates three laboratories in the 300 Area. Livingston Rebuild Center, Inc. has leased the 1171 Building, in the 1100 Area, to rebuild train locomotives. Johnson Controls, Inc. operates 42 diesel- and natural gas-fueled package boilers for producing steam in the 200 and 300 Areas (replacing the old coal-fired steam plants) and also has compressors supplying compressed air to the site. 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 facility.

Much of the above information is from PNNL-6415, Rev. 9, where more detailed information can be found.

## 1.0.2 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 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.

### 1.0.2.1 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. The 300 Area was also the location of nuclear fuel fabrication. Nuclear fuel in the form of pipe-like cylinders (fuel elements) 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). This practice has been discontinued.

### 1.0.2.2 The 100 Areas

The fabricated fuel elements 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 6.1, "Hanford Groundwater Monitoring Project," discusses these operations). 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 elements while the pipes carried water to cool the graphite pile. Placing large numbers of slightly radioactive uranium fuel elements into the reactor piles

created an intense radiation field and a radioactive chain reaction resulted in the conversion of some uranium atoms into plutonium atoms. Other uranium atoms were split into radioactive "fission products." The intense radiation field also caused some nonradioactive atoms in the structure to become radioactive "activation products."

The first eight reactors, constructed between 1944 and 1955, used water from the Columbia River for direct cooling. Large quantities of water were pumped through the reactor piles and discharged back into the river. The discharged cooling water contained radioactive materials that escaped from the fuel elements, 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 elements were pushed into the front face of a reactor's graphite pile, irradiated fuel elements 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 KE and KW Fuel Storage Basins (K Basins) for temporary storage, where it remains today. This fuel accounts for the majority of the total fuel inventory currently stored under water in the K Basins. From the early 1980s until its shutdown in 1987, 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.

## 1.0.2.3 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 1.0.2). 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 elements 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. Filters were added to the stacks 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. The 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 condensates from B Plant went to B Pond, cooling water and steam condensates from T Plant went to T Pond, and cooling water and steam condensates from U Plant and the Uranium-TriOxide Plant were routed to U Pond.

After T Plant stopped functioning as a separations facility, it was converted to a decontamination operation where large pieces of equipment and machinery could be cleaned up for reuse. B Plant was later converted into a facility to separate radioactive strontium and cesium from high-level waste. The strontium and cesium were then concentrated into a solid salt material, melted, and

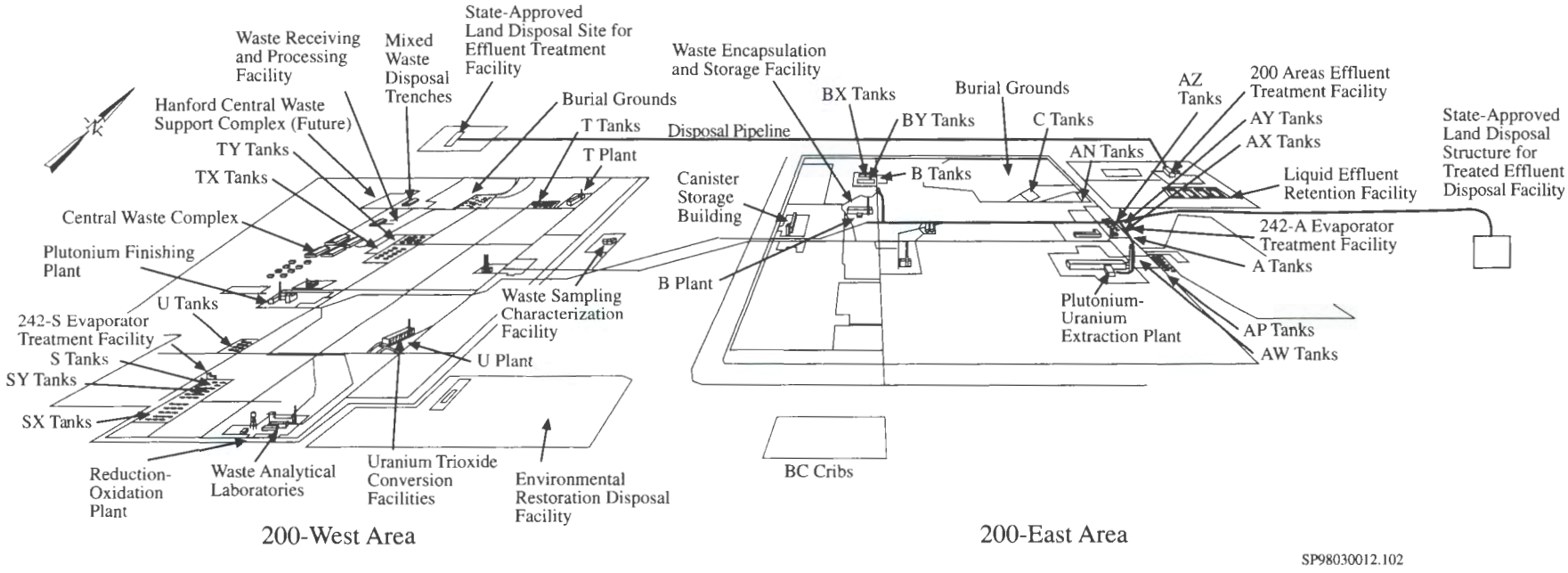


**Figure 1.0.2**. Waste Processing, Storage, and Disposal Facilities in the 200 Areas

encapsulated at the adjacent encapsulation facility. Canisters of encapsulated strontium and cesium were stored in a water storage basin at the encapsulation facility, where many remain today.

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) 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 other organic compounds. 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.

### 1.0.2.4 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. In January 1997, DOE made a decision to keep the Fast Flux Test Facility in standby while evaluating its potential for tritium and medical isotope production, as well as plutonium disposition. Tritium, a necessary ingredient in some nuclear weapons, decays relatively quickly so must be replenished. Medical isotopes are radioactive elements that are useful for the treatment of medical conditions such as cancer. Excess plutonium, no longer needed for national defense, could be disposed of by converting it to reactor fuel that could be burned in commercial reactors. A decision on these missions is expected by December 1998.

## 1.0.3 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, treatment, and disposal of radioactive, hazardous, mixed, or sanitary wastes from past and current operations

- **stabilizing facilities** by transitioning them from an operating mode to a long-term surveillance and maintenance mode. This includes maintaining facilities in a safe and compliant status, deactivating primary systems to effectively reduce risks, providing for the safe storage of nuclear materials and reducing risks from hazardous materials and contamination. These activities are intended to allow the lowest surveillance and maintenance cost to be attained while awaiting determination of a facility's final disposition.

- **maintaining the Fast Flux Test Facility reactor** and its associated support facilities while alternative future missions for the reactor are explored (i.e., medical isotope and/or tritium production, plutonium disposition)

- **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

- **developing 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 ensuring that its facilities are always in 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.

### 1.0.3.1 Site Policy for Protecting the Environment and Worker Safety and Health

The highest priority of the DOE Richland Operations Office is to achieve daily excellence in protection of the worker and the public and in stewardship of the environment, both on and off the Hanford Site. By meeting the most rigorous standards, the DOE Richland Operations Office provides safe and healthful workplaces and protects the environment of all Richland Operations activities. Fundamental to the attainment of this policy are personal commitment and accountability, mutual trust, open communications, continuous improvement, worker involvement, and full participation of all interested parties. Consistent with the strategic plan for the site (DOE/RL-96-92), the Richland Operations Office will reduce accidents, radiological and toxicological exposures, and regulatory noncompliances.

## 1.0.4 Site Management

Hanford Site operations and activities are managed by the DOE Richland Operations Office through the following contractors and 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 ascertain the contents and evaluate treatment alternatives.

- Waste Management Federal Services of Hanford, Inc. - responsible for waste management. They 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 addresses 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 and the Advanced Reactors Transition Project. The facility stabilization project is tasked with safely and cost effectively deactivating contaminated surplus facilities to a reduced cost, low-risk stabilized/ shutdown condition for either long-term surveillance and maintenance or final disposition. The Advanced Reactors Transition Project maintains the Fast Flux Test Facility and its associated support facilities in a safe and stable condition while DOE explores alternative future missions (i.e., medical isotope and/or tritium production).

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

- DynCorp Tri-Cities Services, Inc. - responsible for infrastructure services. They provide non-nuclear-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. In addition, the laboratory performs groundwater monitoring for the Hanford Groundwater Monitoring Project, which includes Resource Conservation and Recovery Act/ Comprehensive Environmental Response, Compensation, and Liability Act monitoring and surface environment surveillance both on and around the site.

- Bechtel Hanford, Inc., the environmental restoration contractor is responsible 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; decontamination and decommissioning of facilities; overall Hanford Site groundwater project management; and sitewide drilling management. The Bechtel Team includes two preselected subcontractors: CH2M Hill Hanford, Inc. and ThermoHanford, 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. These subcontractors 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.

- COGEMA Engineering 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 telecommunications 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, Inc. provides nuclear and non-nuclear services in the area of quality assurance and related activities.

- Waste Management Federal Services, Inc., Northwest Operations provides waste transportation services,

waste packaging systems engineering, environmental monitoring and investigations, groundwater well services, sampling and mobile laboratory services, and nuisance wildlife and vegetation management.

British Nuclear Fuels Limited, Inc., has contracted with DOE for Phase I, Part A of the Tank Waste Remediation System Privatization Project (September 26, 1996 - May 25, 1998). Contract deliverables include development of technical, operational, regulatory, business, and financial plans to provide treatment and immobilization services to process tank waste under Part B of the contract. If Part B of the contract is awarded in fiscal year 1998, the contractor will provide privatized services to process an initial portion of Hanford's tank waste.

# 1.0.5 Major Operations and Activities

## 1.0.5.1 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 1.0.2) and the storage of irradiated fuel in the 100-K Area. Major facilities are discussed below.

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 by the target date of December 2002 (agreed to by DOE and the regulators). At the end of 1997, construction of the Canister Storage Building for dry interim storage was nearly complete.

The 242-A Evaporator concentrates dilute liquid tank wastes by evaporation. The volume of tank wastes is reduced to eliminate the need to construct additional storage tanks and to minimize the volume of liquid in the tanks. The process condensate from the 242-A Evaporator and other liquid effluents are temporarily stored in the Liquid Effluent Retention Facility. This facility consists of three Resource Conservation and Recovery Act-compliant surface impoundments and provides flow and pH equalization. The wastewater from the Liquid Effluent Retention Facility is treated in the Effluent Treatment Facility to remove toxic metals, radionuclides, and ammonia and to destroy organics. The treated effluent has been delisted from the Resource Conservation and Recovery Act and is discharged to a state-approved land disposal site north of the 200-West Area under a state discharge permit (Washington Administrative Code [WAC] 173-216). 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. The liquid effluents are routed to another state-approved land disposal site near the 200-East Area and discharged under a separate state discharge permit (WAC 173-216).

Wastewater in the 300 Area that is nonradioactive and nonhazardous is received via the process sewer and treated in the 300 Area Treated Effluent Disposal Facility. The wastewater is treated to remove heavy metals and cyanide and to destroy organics. Potentially contaminated wastewater in the 300 Area is collected, monitored for radioactive contamination, and transferred to the 300 Area Treated Effluent Disposal Facility. Radioactive liquid waste in the 300 Area is collected and transferred by railcar to double-shell underground waste storage tanks in the 200-East 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. In addition, submarine reactor compartments are being received from the United States Navy for disposal. 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 2003, assuming on-schedule 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 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) has 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 are 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.

Two operational facilities are in the T Plant area: the T Plant canyon building used for waste verification, radiological decontamination of large equipment, and storage of pressurized water reactor spent fuel from a reactor in Shippingport, Pennslyvania; and the 2706-T facility used for waste verification, repackaging radioactive wastes, and small equipment decontamination. 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).

The Environmental Restoration Disposal Facility, near the 200-West Area, was opened in July 1996 to accept waste generated during the Hanford Site cleanup activities. This facility serves as the central disposal site for contaminated soil and other waste removed under the Environmental Restoration Program. Additional details about the Environmental Restoration Disposal Facility are provided in Section 1.0.5.3, "Environmental Restoration" and in Section 2.2, "Compliance Status," regarding Comprehensive Environmental Response, Compensation, and Liability Act compliance.

## 1.0.5.2 Facility Stabilization

The Facility Stabilization Project's mission is to transition those Hanford Site facilities for which it has responsibility from an operating mode to a long-term surveillance and maintenance mode. This includes maintaining facilities in a safe, compliant status, 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 costs to be attained while awaiting determination of a facility's final disposition and possible turnover to the DOE Environmental Restoration Program.

Currently, the Facility Stabilization Project is engaged in five major deactivation efforts at Hanford. The major efforts are the Plutonium-Uranium Extraction Plant, the Facility Stabilization and Environmental Restoration (FASTER) Team, the 300 Area Stabilization Project, the B Plant/Waste Encapsulation and Storage Facility, and the Plutonium Finishing Plant. (The FASTER Team is always referred to by its acronym.)

The Plutonium-Uranium Extraction Plant formerly processed irradiated fuel to extract plutonium and uranium. Plant operations were discontinued in 1989. A final stabilization run was conducted in early 1990 to process the fuel remaining in the plant and then the facility was transitioned to a standby condition. In 1992, DOE directed the plant's deactivation and transition to a surveillance and maintenance condition. Facility deactivation was completed in May 1997 and the plant is currently unoccupied, locked, and maintained under surveillance while awaiting eventual decontamination and decommissioning.

The FASTER Team provides comprehensive cleanup expertise and lessons learned from Plutonium-Uranium Extraction Plant deactivation to similar projects. This expertise is used in supporting the deactivation of several facilities at Hanford, primarily isolated facilities without associated staff. The FASTER Team is also involved with deactivation planning for DOE facilities at the Rocky Flats Plant in Colorado, the Savannah River Site in South Carolina, and the Brookhaven National Laboratory in New York.

The 300 Area Stabilization Project currently has two subprojects, the 300 Area Fuel Supply Shutdown Subproject and the 324/327 Building Transition Subproject. The 300 Area Fuel Supply Shutdown Subproject included buildings that date back to 1943 that housed manufacturing equipment for the production of fuel for the Hanford reactors. These production operations were discontinued in 1987 when N Reactor was shut down and placed in a stand-by mode. The 324/327 Building Transition Subproject includes the 324 and 327 Buildings, which were constructed in 1966 and 1953, respectively. These buildings house hot cells used for radiological research and development work. Both facilities were transferred to the Facility Stabilization Project in 1996.

B Plant went into service in 1944 to recover plutonium in a chemical separation process. Following the advent of the more efficient Plutonium-Uranium Extraction process, B Plant's mission was modified to recover the high-heat isotopes (primarily cesium-137 and strontium-90) from highly radioactive waste. The Waste Encapsulation and Storage Facility, a part of the B Plant complex, began operation in 1974 to encapsulate the recovered cesium and strontium and to provide safe interim storage for the capsules. In October 1995, DOE directed that B Plant be deactivated. This deactivation order did not include the Waste Encapsulation and Storage Facility, which will remain in service following the shutdown and deactivation of B Plant. The current mission is to place B Plant into a configuration suitable for long-term surveillance, pending final disposition while establishing the Waste Encapsulation and Storage Facility as a stand-alone facility capable of independent operation following B Plant shutdown and deactivation.

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 1996, DOE issued a shutdown order for the Plutonium Finishing Plant, authorizing deactivation and transition of the plutonium processing portions of the facility. An environmental impact statement record of decision with a supplementary analysis for an improved method of immobilization of plutonium was approved in 1997 (DOE/EIS-0244-FS/SA1).

### 1.0.5.3 Environmental Restoration

Environmental Restoration Project activities include decontamination and decommissioning of inactive facilities, surveillance and maintenance of deactivated facilities, transition of deactivated facilities and waste sites to the Environmental Restoration Program, characterization and cleanup of inactive waste sites, monitoring and remediation of contaminated groundwater, and management of remediation waste.

The decontamination and decommissioning project conducts final disposition of inactive surplus facilities in a manner consistent with remedial actions conducted within adjacent or nearby waste sites. A primary responsibility for the decontamination and decommissioning project is interim safe storage of inactive reactor facilities. In 1997, placing the 46-year-old C Reactor in a safe storage mode was nearly half finished. When the work is finished in 1998, C Reactor will be the first production reactor in the DOE complex to be placed in safe storage inside a significantly smaller, safer facility. The safe-storage enclosure is intended to protect the environment from contaminants in the reactor core for up to 75 years or until final disposition. In late 1997 and early 1998, work was accelerated, and the northwest and southwest portions of the reactor building have been demolished.

The Surveillance/Maintenance and Transition Project performs surveillance and maintenance of inactive facilities until final disposition activities commence. The project also provides for the transition of facilities and waste sites into the Environmental Restoration Program after deactivation is complete. The project includes the radiation area remedial action program, which is responsible for the surveillance, maintenance, and decontamination or stabilization of approximately 800 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 DOE Richland Operations Office Groundwater Management Project is responsible for monitoring and remediating contaminated groundwater resulting from past releases at inactive waste sites and other Hanford Site operations, overall site groundwater project management, and sitewide drilling management.

In 1997, groundwater management personnel completed installation of the final two pump-and-treat systems (operable units 100-HR-3 and 100-KR-4 in the 100-H and 100-K Areas). These systems were originally identified by Hanford Site regulators and stakeholders as necessary to contain chromium-contaminated groundwater plumes. If these plumes, comprising hundreds of millions of liters (gallons) of groundwater, remained unchecked, contaminant levels in the groundwater moving toward the Columbia River could pose an unacceptable level of risk. Currently, five pump-and-treat systems hydraulically control the movement of groundwater by pumping it to the surface, treating it through a series of systems to remove contaminants, and then injecting it back into the aquifer. The removed contaminants are then safely disposed at permitted sites, such as the Environmental Restoration Disposal Facility. Supplementing the pump-and-treat systems are three vapor extraction units, which are used to remove carbon tetrachloride (a toxic industrial solvent) from the Hanford Site's underground environment.

During 1997, groundwater management personnel worked closely with regulators and stakeholders to better define the potential impact of Hanford Site groundwater on the Columbia River ecosystem. Project personnel provided significant assistance in preparing the Columbia River comprehensive impact assessment screening advisory report that is expected to be completed in 1998.

The Environmental Restoration Disposal Facility was opened in July 1996 to accept waste generated during Hanford Site cleanup activities. The waste volumes of contaminated materials significantly escalated in 1997 when cleanup work at two new sites near the D and DR Reactors and in the 300 Area began. After a full year of remedial action and disposal activities, the Environmental Restoration Disposal Facility's first two disposal cells were half full. The amount of waste disposed is tracking closely with projections. Given the rate at which waste is being disposed and the volume of waste that remains in the soil underlying the site, a plan for facility expansion was put into place. Regulator and stakeholder comments on the plan were obtained, and the Environmental Restoration Disposal Facility expansion was intitiated. Engineering design has started, with construction scheduled to begin in 1998.

## 1.0.5.4 Research and Technology Development

Research and technology development activities are conducted in the 200, 300, 400, and Richland North Areas. 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 was completed 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 abovenormal 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. Monitoring studies will continue through 1998 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 1997, 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 2.5 years following the test injection. Concentrations of mobilized trace metals and sulfate have also continued to decrease during this time and are below all applicable standards. During 1998, monitoring of the site will continue and treatability tests will be conducted at the 100-D Area.

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 in September 1996. In September 1996, 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 Site 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. The system was deployed in an analytical chemistry laboratory hot cell at the Hanford Site in September 1996 and its use continued in 1997.

Interim safe storage activities at the C Reactor are providing a stage for showcasing innovative decontamination and decommissioning technologies. At least 20 technologies and approaches will be field tested to demonstrate safer, less expensive, and more efficient ways of decommissioning aging nuclear facilities. In 1997, 11 of these innovative or improved technologies were demonstrated. Eight have since been adopted, replacing baseline technologies. Four of these technologies have been deployed at other Hanford projects and at other DOE facilities. One has been selected for use at the Chornobyl Reactor in Ukraine.

## 1.0.6 Site Environmental Programs

### 1.0.6.1 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 1997 effluent monitoring and waste management and chemical inventory programs are summarized in Section 2.5, "Waste Management and Chemical Inventories," and Section 3.1, "Facility Effluent Monitoring."

### 1.0.6.2 Near-Facility Environmental Monitoring Program

This program provides facility-specific environmental monitoring immediately adjacent to onsite facilities. Monitoring is conducted to comply 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 1997 programs are summarized in Section 3.2, "Near-Facility Environmental Monitoring." The Hanford Environmental Restoration Contractor will be negotiating to cut back on near-field monitoring in the 100-N Area based on upcoming deactivation (July 1998) and no change in monitoring data obtained over the past 10 years.

### 1.0.6.3 Sitewide Environmental Surveillance

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 1997 sitewide environmental surveillance program are summarized in Section 4.0, "Environmental Surveillance Information."

### 1.0.6.4 Groundwater Monitoring and Vadose Zone Baseline Characterization

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 1997 are described in Section 6.1, "Hanford Groundwater Monitoring Project."

Vadose zone baseline characterization is being conducted to establish baseline levels of manmade radionuclides in the vadose zone beneath the single-shell tanks in the 200 Areas and beneath selected cribs and trenches used for waste disposal. The primary objective of these efforts is to detect and identify gamma-emitting radionuclides and determine their concentrations and distributions. Results for the vadose zone characterization activities in 1997 are summarized in Section 6.2, "Vadose Zone Characterization and Monitoring."

### 1.0.6.5 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 7.0, "Other Hanford Site Environmental Programs."

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# 2.0 Environmental and Regulatory Compliance Summary

This section briefly describes how environmental compliance is achieved for the Hanford Site. Included are sections describing 1) stakeholder and tribal involvement in the environmental restoration and waste management missions at the Hanford Site, 2) the current status of the site's compliance with principal regulations, 3) issues and actions arising from these compliance efforts, 4) an annual summary of environmentally significant occurrences, and 5) waste management and chemical inventory information.

It is the stated policy of the U.S. Department of Energy (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 (also known as the 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 reporting to ensure that environmental compliance is achieved and maintained at the Hanford Site.

# 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; and the public. Indian tribes also have a special and unique involvement with the Hanford Site. The following section describes the roles of the principal agencies, organizations, and public in environmental compliance and cleanup of the Hanford Site.

## 2.1.1 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/or 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 air quality, water quality, land use, cultural resources, and waste management.

EPA is the principal federal environmental regulator who develops, promulgates, and enforces environmental protection regulations and 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 hazardous waste management. In other activities, the state program is assigned direct oversight over the DOE Richland Operations Office as provided by federal law. For example, the Washington State Department of Health has direct authority under the Clean Air Act to enforce the standards and requirements under a statewide program for regulating radionuclide air emissions at applicable facilities (e.g., the Hanford Site). Where federal regulatory authority is not delegated or only partially authorized to the state, EPA Region 10 is responsible for reviewing and enforcing compliance with EPA regulations as they pertain to the Hanford Site. In addition, EPA periodically reviews the adequacy of various state environmental programs and reserves the right to conduct direct enforcement of federal environmental regulations.

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.

## 2.1.2 Hanford Federal Facility Agreement and Consent Order

This agreement (also known as the 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. Also, the Tri-Party Agreement was 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 agreement have been negotiated between the Washington State Department of Ecology, EPA, and 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 agreement undergo a process of public involvement that ensures communication and addresses the public's values prior to final approvals. Copies of the 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
Mail Stop B3-35
P.O. Box 1000
Richland, WA 99352

or

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

## 2.1.3 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 historic 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 contains 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 Tribal Government 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 attend formal meetings such as those of the State and Tribal Government Working Group and the Hanford Natural Resources Trustee Council. They actively participate in many issues, including groundwater remediation, land use, 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 (DOE Order 1230.2). 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 Site 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.

## 2.1.4 Hanford Natural Resource Trustee Council

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 in Title 40, Code of Federal Regulations, Part 300, Subpart 605 (40 CFR 300.605) 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 State 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.

To better address their responsibilities, the trustees have signed a memorandum of agreement formally establishing the Hanford Natural Resource Trustee Council. The primary purpose of the council is to facilitate the coordination and cooperation of the member trustees in their efforts in mitigating impacts to natural resource resulting from hazardous substance releases from within the Hanford Site or the remediation of those releases. The council also adopted by-laws to direct the process of arriving at consensus agreements.

The council is currently assessing potential injury to Columbia River aquatic resources resulting from the release of Comprehensive Environmental Response, Compensation, and Liability Act-designated hazardous substances from within the 100 Areas. This assessment involves the U.S. Fish and Wildlife Service preparing both an assessment plan and a study plan. The U.S. Fish and Wildlife Service is using the Natural Resource Damage Assessment Regulations in 43 CFR 11 as guidance in preparing the plans. The assessment plan will address current exposure pathways and potential injury to aquatic resources from hazardous substance releases within the 100 Areas. The study plan will address potential injury to fall chinook salmon from chromium releases within the 100 Areas that have migrated to the Columbia River. The results of the assessment will aid the trustees, regulators, and DOE in developing, evaluating, and selecting remedial actions that minimize or eliminate any injury to aquatic resources.

## 2.1.5 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. The Office of External Affairs (DOE Richland Operations Office) 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 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 February 1997 (Ecology et al. 1997).

Before each public participation 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 Site decisions is maintained and kept current. The mailing list is also used to send topic-specific information to those people who have requested it.

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 to the entire mailing list.

Most of Hanford's public resides in Washington, Oregon, and Idaho. To allow them better access to up-to-date Hanford Site 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 (800-321-2008). Members of the public can request information about any public participation activity and receive a response by contacting the Office of External Affairs (DOE Richland Operations Office) at (509) 376-7501.

There is also an Internet home page containing a calendar of public involvement opportunities. The Internet address is http://www.hanford.gov/whc/cal/cal.html.

## 2.1.6 Hanford Advisory Board

The Hanford Advisory Board was chartered in January 1994 to advise DOE on major Hanford Site cleanup policy questions. The board was the first of many such advisory groups created by DOE at weapons production cleanup sites across the national DOE complex. The board comprises 32 members (stakeholders) 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 five committees: 1) Dollars and Sense, which deals with DOE budget issues; 2) Health, Safety, and Waste Management; 3) Environmental Restoration; 4) the board's internal executive committee; and 5) the Public Involvement committee. Committees study issues and develop policy recommendations for board action.

The board held seven 2-day meetings in 1997. Members received in-depth briefings from the Tri-Party Agreement agencies, reviewed technical reports and proposed budgets, and sought out more information on major public policy issues. From October 1996 through September 1997, the board produced 22 new pieces of consensus advice (making a total of 75), cosponsored several public meetings, produced numerous pieces of "sounding board" advice, and engaged in an ongoing dialogue with the Tri-Party Agreement agencies.

Values adopted by the board provide a basis for its current work in promoting cleanup. These values are simplified into the following ten key principles:

- protect public and worker health and safety
- protect the Columbia River - stop actual and potential contamination of the Columbia River and prevent migration of contamination offsite
- avoid further harm - minimize use of land for waste management, avoid contaminating uncontaminated land, and avoid further damage to critical resources, especially cultural resources, habitat, and groundwater
- dilution is not the solution - all liquid wastes need to be treated according to applicable regulations prior to discharge or disposal
- treaty rights - preserve natural resource rights embodied in treaties, and enforce laws protecting natural and cultural resources
- regional importance - the Hanford Site has ecological, economic, and human resources of regional importance
- vision - an understanding of possible future uses of the Hanford Site can focus decisions about what manner of cleanup is needed and what is most important to accomplish over time; the public, the agencies, and the workers should be able to see the end of the cleanup, if not predict its exact date
- "get on with it" - demonstrate substantive progress on cleanup to ensure continued public support and funding
- public involvement and accountability - involve the public and respect tribal rights in development of the goals, scope, pace, and oversight of cleanup, and

establish management practices that ensure accountability, efficiency, and allocation of funds to high-priority items

- compliance culture - there should be a cooperative commitment to comply with environmental laws; the Tri-Party Agreement should not become a shield against enforcement of other laws.

## 2.1.7 Hanford Site Technology Coordination Group

The Hanford Site Technology Coordination Group structure implemented at Hanford in 1994 consists of a Management Council and four subgroups aligned with four environmental management focus areas: 1) decontamination and decommissioning, 2) mixed waste, 3) subsurface contaminants, and 4) tanks. The Management Council focuses on Hanford Site policy issues related to technology development and deployment. Subgroups of the Site Technology Coordination Group identify and prioritize the site's science and technology needs, identify technology demonstration opportunities, interface with the Environmental Management Focus Areas, and ensure that demonstrated technologies are deployed.

During 1997, the Hanford Site Technology Coordination Group did a number of things to increase project/user and stakeholder involvement in technology-related activities at the Hanford Site, including the addition of new members on the Management Council and the creation of a handbook that outlines the revised mission and redefined roles and responsibilities. There has also been an increased interest among the members in participating in technology deployment activities such as the Technology Deployment Initiative and the Hanford Technology Deployment Center.

The Management Council endorsed four science and technology needs packages developed by the subgroups for submittal to the four Environmental Management Focus Areas and the Environmental Management Science Program. In addition, they endorsed 18 Technology Deployment Initiative proposals and heard presentations on a number of new technologies being demonstrated and/or deployed on the Hanford Site. This year, the Management Council voted to add a new member from the state of Oregon, worked with the Hanford Advisory Board to increase its participation by filling three Hanford Advisory Board positions on the Management Council, and wrote and approved a Site Technology Coordination Group Communications Plan.

The Management Council is chaired by the DOE Richland Operations Office Deputy Manager and includes 16 voting members: five DOE Richland Operations Office Assistant Managers (Tank Waste Remediation System, Environmental Restoration, Waste Management, Facility Transition, and Technology); two representatives from the EPA; two representatives from the Washington State Department of Ecology; one representative from the Oregon Office of Energy; three representatives from the Hanford Advisory Board; and three representatives from American Indian tribes (Yakama Indian Nation, Nez Perce Tribe, and Confederated Tribes of the Umatilla Indian Reservation). Each of the Hanford Site contractors has one ex-officio member on the Management Council, and the Site Technology Coordination Group Subgroups leads also attend.

The elements of the revised mission statement are as follows:

- function by involving user organizations (both DOE and the contractors), technology providers, regulators, American Indian tribes, and stakeholders, and promoting broad information exchange among all interested parties; maintain a helpful attitude and serve as a conscience for technology improvement at Hanford; contribute to DOE-wide communications and lessons learned

- identify, prioritize using systems analysis, and seek consensus on Hanford Site and program-specific problems, science and technology needs, and requirements; recognize baseline schedule insertion points for technology; focus on the baseline, but also identify technologies to support potential baseline alternatives if they offer risk reduction benefits or high financial return on investment by improvements in environmental, safety, or health protection; devote 20% of the effort to science needs and 80% to technology needs and deployment

- be a forum for assessing and recommending potential technologies for application at Hanford; look for technologies that provide improved end states, effectiveness, improved schedules, or improved costs in accomplishing the required results; look for technologies to reduce surveillance and maintenance costs while maintaining safe operations; focus on life-cycle costs and benefits, improvements in environmental,

safety, or health protection, and improvements in performance, pollution prevention, and waste minimization relative to alternative remedies; make appropriate referrals for vendors (e.g., to DOE or the contractors)

- champion and facilitate demonstration and deployment of innovative, modified, or existing technologies that are new to Hanford and share information with other sites to best leverage all available resources

- create a viable market for technology with the DOE Richland Operations Office and contractor line project customers and eliminate barriers (e.g., "not invented here," resistance to change)

- promote competitive privatization and commercialization by communicating information on Hanford's science and technology needs and schedule insertion points, as well as demonstration and deployment opportunities, to commercial technology providers; help break barriers to involvement by companies new to Hanford

- provide input to decision makers (e.g., DOE Richland Operations Office, DOE Headquarters, Congress, and heads of regulatory agencies) on Hanford's highest priority science and technology needs to ensure critical needs are funded; provide feedback to them on the site's accomplishments.

# 2.2 Compliance Status

*D. G. Black*

This section summarizes the activities conducted to ensure that the Hanford Site is in compliance with federal environmental protection statutes and related 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.

## 2.2.1 Hanford Federal Facility Agreement and Consent Order, 1997 Performance

This agreement (also known as the Tri-Party Agreement; Ecology et al. 1989) was signed on May 15, 1989 by the Washington State Department of Ecology, EPA, and DOE. The agreement is a legally enforceable document that establishes a schedule and framework for the cleanup of the Hanford Site. Specifically, the agreement commits 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.

From 1989 through 1997, a total of 562 enforceable milestones and 237 unenforceable target dates were completed on or ahead of schedule. Two enforceable milestones were missed and five were completed later than scheduled.

In 1997, there were 59 specific cleanup milestones and target dates scheduled for completion. All of these commitments were completed on or before their required due dates except for two, which were delayed because of safety issues.

Highlights of the work accomplished in 1997 are listed in Section 2.3, "Activities, Accomplishments, and Issues."

## 2.2.2 Environmental Management Systems Development

The International Organization for Standardization was founded in 1947 and promotes the development of international manufacturing, trade, and communication standards. In 1996, the organization issued an international voluntary consensus standard ISO 14001, *Environmental Management Systems – Specifications with Guidance for Use*. This industry-driven standard represents the culmination of international environmental standardization efforts spanning nearly two decades.

The ISO 14000-series of standards (Cascio 1996) are based on the following five guiding principles:

- An organization should define its environmental policy and ensure commitment to its environmental management system.
- An organization should formulate a plan to fulfill its environmental policy.
- For effective implementation, an organization should develop the capabilities and support mechanisms necessary to achieve its environmental policy, objectives, and targets.
- An organization should measure, monitor, and evaluate its environmental performance.
- An organization should review and continually improve its environmental management system, with the objective of improving its overall environmental performance.

The basis for any environmental management system is compliance with applicable environmental laws, regulations, permits, and other requirements. An effective system

goes beyond compliance and provides an organization with a systematic approach to the development, implementation, and maintenance of an environmental policy. The precept is that through planning, implementation, checking, management review, and continuous improvement, organizations become more effective and efficient in the management of their activities and the impacts of those activities on the environment.

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 ISO 14000-series of standards. The *Environmental Management System Implementation Plan* was completed in June 1997 (HNF-EP-925). At that time, a decision was made to include ISO 14001 in developing an integrated safety management system. During development, the name of the management system was changed to integrated environment, safety, and health management system.

The *Integrated Environment, Safety and Health Management System Plan* (HNF-MP-003) establishes a single, defined safety and environmental management system that integrates environment, safety, and health requirements into the work planning and execution processes to effectively protect the workers, public, and the environment. That plan specifically addresses the Project Hanford Management and Integration Contract requirements for a safety and environmental management system that satisfies Defense Nuclear Facilities Safety Board Recommendation 95-2, addresses implementation of an environmental management system consistent with the principles of the ISO 14001 standard, and supports radiological control considerations. The Fluor Daniel Hanford, Inc. integrated environment, safety, and health management system is primarily based on the philosophies, principles, and requirements of DOE's *Safety Management System Policy* (DOE P 450.4) and the ISO 14001 standard and also incorporates the best practices of the following policies, standards, and initiatives: Voluntary Protection Program, Responsible Care® of the Chemical Manufacturer's Association; and Enhanced Work Planning/ Hanford Occupational Health Process.

Five safety management core functions defined in DOE P 450.4 provide the necessary planning, checks, and controls for any work that could potentially affect the workers, public, or the environment. An environmental management system is defined in the ISO 14001 standard as "the part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes, and resources for developing, implementing, achieving, reviewing, and maintaining the environmental policy."

The Fluor Daniel Hanford, Inc. integrated environment, safety, and health management system consists of seven core functions that capture both DOE P 450.4 and ISO 14001 elements:

- establish environment safety and health policy
- define scope of work
- identify hazards and requirements
- analyze hazards and implement controls
- perform work within controls
- provide feedback and process improvement
- perform management review.

A deliberate, careful comparison and integration of DOE P 450.4 and the ISO 14001 standard resulted in the development of the guiding principles and core functions identified in HNF-MP-003. These guiding principles and core functions are the cornerstones for development of the Fluor Daniel Hanford, Inc. integrated environment, safety, and health management system. Provided in HNF-MP-003 is an appendix that cross references the elements of ISO 14001 and the guiding principles and core functions. A person familiar with ISO 14001 can use this table as a cross-reference to identify sections that correlate to ISO 14001 standard elements.

The final plan was issued in September 1997. Plans for implementing the system at Fluor Daniel Hanford, Inc.-managed facilities are scheduled to be completed by September 1998 for most facilities and earlier for priority facilities.

### 2.2.2.1 Chemical Management System

The Hanford Site, with its numerous contractors, facilities, and processes uses a variety of approaches for chemical management. In an effort to develop a uniform set of requirements for managing chemicals on the Hanford Site, the prime contractors initiated a coordinated effort to create a joint plan of action for chemical management on the Hanford Site. A multicontractor chemical management system working group was formed, and a strategy for chemical management was developed.

As part of the strategy, the prime contractors developed chemical management system requirements for the Hanford Site. The requirements were approved by the prime contractors on November 25, 1997, and transmitted to DOE Richland Operations Office. These requirements are applicable within the Hanford Site to the acquisition, use, storage, transportation, and final disposition of chemicals, including hazardous chemicals as defined in the Occupational Safety and Health Administration's hazard communication standard (29 CFR 1910.1200, Appendixes A and B).

The prime contractors will use these requirements to evaluate the adequacy of their chemical management programs, identify opportunities for improvement, implement changes as appropriate, and drive the day-to-day management of chemicals. It is recognized, based on the complexity of chemical management operations and the nature and severity of associated hazards, that these chemical management system requirements will be applied using a graded approach.

Each of the prime contractors will do the following as part of the strategy for implementation of the chemical management system requirements:

- conduct a gap analysis of the existing chemical management practices against the chemical management system requirements
- review analysis of the gaps identified and translate into needs
- write an implementation plan to meet the needs
- implement the plan.

Implementation of the chemical management system requirements by the prime contractors will provide coordinated, consistent chemical management on the Hanford Site. In addition, it will provide an architecture for protection of human health and the environment. The chemical management system requirements incorporate best industry practices, drive continuous improvement, and will be incorporated into the integrated environmental, safety, and health management system of the prime contractors.

## 2.2.3 Comprehensive Environmental Response, Compensation, and Liability Act

### 2.2.3.1 Environmental Restoration Disposal Facility

The Environmental Restoration Disposal Facility opened in July 1996. The 918,000-$m^3$ (1.2-million-$yd^3$) earthen facility is located near the 200-West Area (see Figure 1.0.2) and is constructed with double liners and a leachate collection system. The facility serves as a central disposal site for contaminated waste removed during cleanup operations conducted under Comprehensive Environmental Response, Compensation, and Liability Act authority on the Hanford Site. The cleanup waste may include soil, rubble, or other materials (excluding liquids) contaminated with hazardous, low-level radioactive, or mixed (combined hazardous chemical and radioactive) wastes.

In 1997, the facility received 539,000 metric tons (594,000 tons) of contaminated soil and other waste from various locations on the Hanford Site. Since inception, it has received 627,000 metric tons (691,000 tons) of contaminated soil and other waste from various Hanford Site locations. After 1 year in operation, the facility's first two cells are half full. Plans are currently under way for the expansion of the facility to meet future disposal needs.

### 2.2.3.2 Waste Site Remediation Projects

Full-scale remediation of waste sites began in the 100 Areas in 1996, with remediation of liquid waste disposal sites in the 100-B,C and 100-D Areas continuing in 1997. The remediation project in the 300-FF-1 Operable Unit began operation at former solid and liquid waste sites in the 300 Area in 1997. Historically, both chemical and radiological materials were disposed of in the 300-FF-1 waste sites. Throughout the Hanford Site, cleanup operations were completed at six waste sites in 1997 and all Tri-Party Agreement milestones associated with these cleanup operations were either on or ahead of schedule for the year.

The number of remediation projects increased in 1997, which added to the amount of contaminated soils and other waste delivered to the Environmental Restoration Disposal Facility. The quantities of contaminated soils and other waste delivered to the facility from remediation projects in 1997 are provided in Table 2.2.1.

**North Slope**. Remediation of herbicide-contaminated soil and buried tanks used to store the herbicide 2,4-D was completed on the portion of the site located north of the Columbia River (see Figure 1.0.1) in 1997. The North Slope site contained soils with increased levels of 2,4-D and trace amounts of dioxin. The remediation process included shipping 93 metric tons (103 tons) of dioxin-contaminated soil offsite for incineration and disposal, bioremediating the remaining soils onsite, and transporting 10 crushed tanks offsite for disposal. Following remediation actions, the site was graded and seeded for revegetation. This effort completed cleanup activities on the North Slope.

## 2.2.3.3 Groundwater Projects

**Chromium**. 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 ecological concern (i.e., impact on Columbia River ecosystem). High levels of chromium are toxic to aquatic organisms, particularly those that use the riverbed sediment as habitat (DOE/RL-94-102, DOE/RL-94-113). In 1994, a groundwater extraction system was installed in the 100-D Area to test chromium removal from groundwater using ion exchange technology. A Record of Decision (1996a) was signed that approved full-scale implementation of groundwater extraction and chromium treatment systems in the 100-D, 100-H, and 100-K Areas.

**Table 2.2.1**. Quantities of Contaminated Soils and Other Wastes Disposed of at the Environmental Restoration Disposal Facility, 1997

| Location | Metric Tons (tons) | |
|---|---|---|
| 100-B,C Area | 259,000 | (285,000) |
| 100-DR Area | 221,000 | (244,000) |
| 300-FF-1 Operable Unit | 37,000 | (41,800) |
| 183-H Solar Evaporation Basins | 19,200 | (21,200) |
| 100-N Area | 697 | (768) |
| Other | 2,172 | (2,390) |
| Total | 539,000 | (594,000) |

The test system in the 100-D Area continued to operate until September 1996, when it was shut down to allow construction of the full-scale systems in the 100-D, 100-H, and 100-K Areas (DOE/RL-94-83). Full-scale operation began in July and October 1997 at the 100-HR-3 and 100-KR-4 pump-and-treat sites, respectively. Treated water is reinjected into the ground.

From October through December 1997, operations for the 100-HR-3 pump-and-treat system treated 64.7 million L (17.1 million gal) of water and removed 14.2 kg (31.3 lb) of hexavalent chromium from the aquifer. As of January 31, 1998, the 100-KR-4 pump-and-treat system treated 76.0 million L (20.0 million gal) of groundwater and removed 9.45 kg (20.8 lb) of hexavalent chromium from the aquifer.

Performance monitoring will continue 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 removing chromium from groundwater underlying the 100 Areas.

To further evaluate chromium contamination in groundwater near the Columbia River shoreline, 178 aquifer sample tubes were installed in 1997. The sample tubes were installed parallel to the shoreline, beginning near the 100-B,C Area and continuing downstream approximately 40 km (25 mi) to near the Old Hanford Townsite. Aquifer sample tubes were installed approximately every 610 m (2,000 ft), except in known chromium-contaminated plumes, where the tubes were installed approximately every 305 m (1,000 ft).

Collected data will provide information to support remediation operations, monitoring objectives, and environmental efforts now and into the future. For example, sample tube data will provide highly detailed information on the distribution of chromium in groundwater entering the river at locations very close to sensitive ecological receptors such as aquatic organisms.

**Strontium-90**. The 100-NR-2 pump-and-treat system began operation in 1995 north of the N Reactor complex to remove strontium-90 from contaminated groundwater so the flux of strontium-90 to the Columbia River is reduced. The system was upgraded in 1996 and continued to operate through 1997. Operation of the system was optimized to reduce costs without decreasing performance. Treated water is reinjected into the ground. For

1997, approximately 98.5 million L (26.0 million gal) of water were processed through the upgraded system, and approximately 0.17 Ci of strontium-90 was removed.

**Carbon Tetrachloride**. 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 into the aquifer. Based on the success of the test, a Record of Decision (1995) was issued, 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 started up in August 1996. Phase II operations ended August 8, 1997, and the transition to Phase III began. Following an equipment upgrade to meet Phase III operational requirements, operations were restarted August 29, 1997. The system treats contaminated groundwater using air-stripping and granular activated carbon technology. From January until September 1997, 154 million L (40.8 million gal) of groundwater were treated and 57.82 kg (127.5 lb) of carbon tetrachloride were removed.

**Uranium, Technetium-99, Carbon Tetrachloride, and Nitrates**. Another groundwater plume in the 200-West Area (underlying the 200-UP-1 Operable Unit) contains uranium, technetium-99, carbon tetrachloride, and nitrates. In 1994, a pilot-scale pump-and-treat system was initiated to test the removal of these contaminants from groundwater using ion exchange. Treated groundwater is reinjected into the aquifer. In 1995, a proposed plan was issued, identifying expansion of the existing system as the preferred alternative for an interim remedial action (DOE/RL-95-26). Public comments suggested that the 200 Areas Effluent Treatment Facility (see Figure 1.0.2) be considered as an alternative to expanding the existing pump-and-treat system, resulting in a reevaluation of the alternatives. A Record of Decision (1997) was issued, requiring that groundwater extracted from wells in the 200-UP-1 Operable Unit be pumped through 11 km (7 mi) of pipeline to the 200 Areas Effluent Treatment Facility for treatment. This transfer began on March 31, 1997. Following treatment, the water is discharged to the State-Approved Land Disposal Site north of the 200-West Area (see Figure 1.0.2).

From January through December 1997, which included a 2-month shutdown to switch operations, approximately 55.5 million L (14.6 million gal) of groundwater were treated. The treatment process removed 0.01 kg (0.02 lb) of technetium-99, 18.3 kg (40.3 lb) of uranium, 1.53 kg (3.38 lb) of carbon tetrachloride, and 3,790 kg (8,355 lb) of nitrates from subsurface water.

## 2.2.3.4 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 1997. The soil vapor is passed through granulated activated carbon, which absorbs carbon tetrachloride. The carbon tetrachloride is then shipped offsite for treatment. Because the rate of removal dropped off substantially in 1996, a system shutdown and study were initiated from November 1996 through June 1997 to evaluate the magnitude and rate of carbon tetrachloride concentration rebound. The evaluation was performed by measuring soil gas at extraction sites. Data indicated that carbon tetrachloride concentrations had increased at each of the three extraction systems during the eight-month evaluation period. The extraction systems were restarted in July 1997, and the mass-removal rates gradually declined to preshutdown rates. In 1997, 1,820 kg (4,000 lb) of carbon tetrachloride were removed from the 200-West Area vadose zone.

## 2.2.3.5 N Area Project

This project was established to coordinate cleanup activities in the 100-N Area and currently includes deactivation and remediation of facilities. Deactivation activities, which began at the N Reactor area in 1993, include removal of high and low dose materials and transfer of radioactive water from the reactor lift station to the 200 Areas Effluent Treatment Facility.

In 1997, cleanup continued in the 100-N Area, including deactivation of 78 of 85 facilities, containment of 90% of the reactor's high dose materials and 95% of the low dose materials, and removal of more than 1.5 million L (400,000 gal) of radioactively contaminated water from N Reactor facilities. Also completed during the year was installation of the emergency dump basin liner to prevent the spread of contamination and protect the basin's steel liner from the elements and definitive design for the N fuel storage basin shielding cover. The emergency dump basin was for emergency storage of N Reactor cooling water when N Reactor was operating.

### 2.2.3.6 Decommissioning Project

A national agreement (DOE and EPA 1995) to decommission contaminated facilities under Comprehensive Environmental Response, Compensation, and Liability Act authority was implemented at the Hanford Site in 1996 with the preparation of an engineering evaluation/cost analysis for decommissioning facilities in the 100-B,C Area (DOE/RL-96-85). After public review, an action memorandum was signed by the two agencies in January 1997. The memorandum authorizes the removal of certain facilities and the disposal of waste under the Act.

Decontamination and decommissioning continued in 1997, with demolition of the nonradioactive 190-C Water Treatment Facility and six other small facilities in the 100-B,C Area and a 35% reduction in the "footprint" of the C Reactor. In addition, throughout the Hanford Site, 11 technology demonstrations, decontamination and decommissioning of 16 buildings, Phase I feasibility study report on the canyon disposition initiative (DOE/RL-97-11, Rev. 1), and hazard classification requirements for 12 facilities were completed in 1998.

## 2.2.4 Emergency Planning and Community Right-To-Know Act

This Act requires states to establish a process for developing chemical emergency preparedness programs and to distribute within communities information on hazardous chemicals present in facilities. The Act has two subtitles: Subtitle A includes requirements for emergency planning (Sections 301-303) and emergency release notification (Section 304); Subtitle B requires periodic reporting of chemical inventories and associated hazards (Sections 311-312), releases, and waste management activities (Section 313).

Sections 301-303 require states to establish a state emergency response commission and local emergency planning committees. These organizations are tasked to gather information and develop emergency plans for local planning districts in the state. Facilities that produce, use, or store extremely hazardous substances in quantities above threshold planning quantities must identify themselves to the state emergency response commission and local emergency planning committee, provide any additional information the local emergency planning committee requires for development of the local emergency response plan, and notify the committee of any changes occurring at the facility that may be relevant to emergency planning. It should be noted that the entire Hanford Site is considered a facility for the purpose of determining threshold planning and reporting quantities. This does not include, however, activities conducted by others on Hanford Site lands covered by leases, use permits, easements, and other agreements whereby land is used by parties other than DOE.

Under Section 304, facilities must also notify the state emergency response commission and local emergency planning committee immediately after an accidental release of an extremely hazardous substance over the reportable quantity established for that substance, and follow up the notification with a written report. Extremely hazardous substances are listed in 40 CFR 355 (Appendixes A and B) along with the applicable threshold planning quantity and reportable quantity.

For a discussion on emergency planning and response activities following the 1997 Plutonium Finishing Plant tank overpressurization incident, refer to Section 2.4, "Environmental Occurrences."

Sections 311-312 require facilities that store hazardous chemicals in amounts above minimum threshold levels to report information regarding those 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 (29 CFR 1910.1200). The minimum threshold level is 4,545 kg (10,000 lb) for hazardous chemicals. If the chemical is an extremely hazardous substance, the minimum threshold level is 277 kg (500 lb) or the listed threshold planning quantity, whichever is less. 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 with associated hazard information. The listing must be updated within 3 months of any change to the list, including receipt of new chemicals above minimum threshold levels or discovery of significant new hazard information regarding existing chemicals. Section 312 requires annual submittal of more detailed quantity and storage information regarding the same list of chemicals in the form of a Tier One or Tier Two Emergency and Hazardous Chemical Inventory report. These

minimum threshold levels apply to the total quantities of such chemicals that are stored or received in aggregate at the Hanford Site, not to individual facilities at the site.

The Hanford Site provides appropriate hazardous chemical inventory information to the Washington State Department of Ecology Community Right-To-Know Unit; local emergency planning committees for Benton, Franklin, and Grant Counties; and to both the Richland and Hanford Site Fire Departments. Updated Material Safety Data Sheet listings were issued in April 1997 and March 1998, covering chemical inventory changes occurring during calendar year 1997. The 1997 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory (DOE/RL-98-17) was issued in February 1998.

Under Section 313, facilities must report total annual releases of certain listed toxic chemicals. The Pollution Prevention Act requires additional information with the report, and Executive Order 12856 (EPA 100-K-93-001) extends the requirements to all federal facilities, regardless of the types of activities conducted.

A toxic chemical release inventory report discusses releases and waste management activities, and includes source reduction information for each chemical manufactured, processed, or otherwise used in amounts over specific threshold levels.

The toxic chemical release reporting status for 1996 was confirmed in May 1997. No report was required because evaluation of toxic chemical use information showed that no reporting thresholds were exceeded in 1996.

The 1997 toxic chemical release inventory report will be issued in mid-1998 and will consist of information regarding releases, offsite transfers, and source reduction activities regarding phosphoric acid, the sole toxic chemical used in excess of applicable thresholds during 1997. The phosphoric acid was used mostly for B Plant deactivation cleanup work in the 200-East Area.

Table 2.2.2 provides an overview of 1997 Emergency Planning and Community Right-To-Know Act reporting.

## 2.2.5 Resource Conservation and Recovery Act

### 2.2.5.1 Hanford Facility Resource Conservation and Recovery Act Permit

This 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/RL-91-28, Rev. 3). 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.

**Table 2.2.2.** Emergency Planning and Community Right-to-Know Act Compliance Reporting, 1997[a]

| Sections of the Act | Yes | No | Not Required |
|---|---|---|---|
| 302-303: Planning notification | X[b] | | |
| 304: Extremely hazardous substances release notification | | | X |
| 311-312: Material safety data sheet/chemical inventory (for calendar year 1997) | X | | |
| 313: Toxic chemical release inventory reporting (for calendar year 1997) | 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 1997.

### 2.2.5.2 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 (Washington Administrative Code [WAC] 173-303), the Hanford Site is considered to be a single facility that encompasses 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 1997, 9 Part A, Form 3 revisions and 1 new Part A, Form 3 were certified and submitted to the Washington State Department of Ecology. Also in 1997, 4 Part B permit applications and 1 new Part B permit application were certified and submitted. In addition, three notices of intent for expansion were filed with the Washington State Department of Ecology, and one clean-closure action and two procedural closure actions were completed.

### 2.2.5.3 Resource Conservation and Recovery Act Groundwater Monitoring Project Management

Table 2.2.3 lists the Resource Conservation and Recovery Act facilities and units (or waste management areas) that currently require groundwater monitoring and notes their monitoring status. Samples were collected from approximately 239 Resource Conservation and Recovery Act wells sitewide in 1997. This is about the same number of wells sampled during 1996. 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 requirements (e.g., Comprehensive Environmental Response, Compensation, and Liability Act) at the Hanford Site. During 1997, no new Resource Conservation and Recovery Act wells were installed, but 11 new wells are scheduled to be added during 1998. Of these 11, 8 will replace network wells going dry as a result of declining groundwater conditions in the 200-West Area, one well is for an assessment at the B-BX-BY Waste Management Area in the 200-East Area, and one is to enhance the detection program at the U Waste Management Area in the 200-West Area. In addition, one borehole is being added to characterize and monitor a proposed new facility (the Immobilized Low-Activity Waste Disposal Complex) located in the 200-East Area.

At the end of 1997, 16 waste management areas were monitored under detection programs, with no evidence that they were adversely affecting groundwater quality. Nine waste management areas were monitored under assessment or compliance programs to determine the impacts of contamination detected in groundwater at those areas. Highlights of 1997 Resource Conservation and Recovery Act monitoring activities are summarized below.

Four of the seven single-shell tank waste management areas were monitored under assessment programs in 1997 primarily to determine the source of contamination detected in downgradient and surrounding wells. The groundwater quality assessment results for Waste Management Areas T, TX-TY, S-SX (200-West Area) and B-BX-BY (200-East Area) were released in early 1998 (PNNL-11809, PNNL-11810, PNNL-11826). These results concluded that the tank farms cannot be ruled out as a potential source of groundwater contamination. The report findings require groundwater monitoring at Waste Management Areas T, TX-TY, S-SX, and B-BX-BY to continue under a new phase (II) of assessment, which will be defined during 1998.

The interim status groundwater quality assessment results for the 216-U-12 Crib (200-West Area) were reported during 1997 (PNNL-11574), and concluded that the crib is the source of nitrate and technetium-99 contamination in the groundwater. Regulations require the site remain in assessment monitoring. The objectives of the assessment monitoring program are to 1) determine if the flux of constituents out of the vadose zone into the groundwater is increasing or decreasing, 2) monitor the known contaminants until a near-term interim corrective action is defined, and 3) monitor under interim status assessment until a final-status monitoring plan is implemented during closure of the facility.

The interim status groundwater quality assessment results for the 216-B-3 Pond (200-East Area) were reported during 1997 (PNNL-11604) and, it was concluded that the pond contributed no detectable hazardous waste contamination to groundwater, despite erratic elevated total

**Table 2.2.3.** Status of Resource Conservation and Recovery Act Facilities and Waste Management Areas Requiring Groundwater Monitoring, 1997

| TSD[a] Units, Date Initiated | 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: Compliance Evaluation | Regulatory Requirements | Associated (CERCLA)[c] Groundwater Operable Units | Year Scheduled for Part B or Closure |
|---|---|---|---|---|---|---|
| 120-D-1 Ponds, April 1992 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | 100-HR-3 | 1998[d] |
| 183-H Solar Evaporation Basins, June 1985 | | | X | WAC 173-303-645 (10) | 100-HR-3 | 1994[d] |
| 1301-N LWDF,[e] December 1987 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | 100-NR-2 | 1999[d] |
| 1324-N/NA Pond, December 1987 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | 100-NR-2 | 1998[d] |
| 1325-N LWDF,[e] December 1987 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | 100-NR-2 | 1999[d] |
| 216-B-3 Pond, November 1988 | X | | | 40 CFR 265.93(d) WAC 173-303-400 | 200-PO-1 | 2000[d] |
| 216-A-29 Ditch, November 1988 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | 200-PO-1 | 2000[d] |
| 216-A-10 Crib,[f] November 1988 | | X, 1997 | | 40 CFR 265.93(b) WAC 173-303-400 | 200-PO-1 | >2000[d] |
| 216-A-36B Crib,[f] May 1988 | | X, 1997 | | 40 CFR 265.93(b) WAC 173-303-400 | 200-PO-1 | 2000[d] |
| 216-A-37-1 Crib,[f] 1997 | | X, 1997 | | 40 CFR 265.93(d) WAC 173-303-400 | 200-PO-1 | 1998[d] |
| 216-B-63 Trench, August 1991 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | 200-PO-1 | >2000[d] |
| 216-S-10 Pond, August 1991 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | | >2000[d] |

**Table 2.2.3.** (contd)

| TSD[a] Units, Date Initiated | 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: Compliance Evaluation | Regulatory Requirements | Associated (CERCLA)[c] Groundwater Operable Units | Year Scheduled for Part B or Closure |
|---|---|---|---|---|---|---|
| 216-U-12 Crib, September 1991 | | X, 1993 | | 40 CFR 265.93(d) WAC 173-303-400 | 200-UP-1 | >2000[d] |
| LERF,[g] July 1991 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | | 1997[h] |
| LLBG[i] WMA-1,[j] September 1988 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | | 1997[h] |
| LLBG[i] WMA-2,[j] September 1988 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | | 1997[h] |
| LLBG[i] WMA-3,[j] October 1988 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | | 1997[h] |
| LLBG[i] WMA-4,[j] October 1988 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | 200-ZP-1 | 1997[h] |
| WMA-A-AX[j] SST,[k] February 1990 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | | >2000[d] |
| WMA-B-BX-BY[j] SST,[k] February 1990 | | X, 1996 | | 40 CFR 265.93(d) WAC 173-303-400 | | >2000[d] |
| WMA-C[j] SST,[k] February 1990 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | 200-PO-1 | >2000[d] |
| WMA-S-SX[j] SST,[k] October 1991 | | X, 1996 | | 40 CFR 265.93(d) WAC 173-303-400 | 200-UP-1 | >2000[d] |
| WMA-T[j] SST,[k] February 1990 | | X, 1993 | | 40 CFR 265.93(d) WAC 173-303-400 | 200-ZP-1 | >2000[d] |

**Table 2.2.3.** (contd)

| TSD[a] Units, Date Initiated | 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: Compliance Evaluation | Regulatory Requirements | Associated (CERCLA)[c] Groundwater Operable Units | Year Scheduled for Part B or Closure |
|---|---|---|---|---|---|---|
| WMA-TX-TY[j] SST,[k] September-October 1991 | | X, 1993 | | 40 CFR 265.93(d) WAC 173-303-400 | 200-ZP-1 | >2000[d] |
| WMA-U[j] SST,[k] October 1990 | X | | | 40 CFR 265.93(b) WAC 173-303-400 | 200-ZP-1 | >2000[d] |
| 316-5 Area Process Trenches, June 1985 | | | X, 1996 | WAC 173-303-645 (10) | 300-FF-5 | 1996[d] |
| NRDWL,[l] October 1986 | X | | | WAC 173-303-400 | 40 CFR 265.93(b) 200-PO-1 | >2000[d] |

(a) Treatment, storage, and/or disposal.
(b) Specific parameters (pH, specific conductance, total organic carbon, and total organic halides) 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 groundwater quality assessment column indicates that 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 were 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) Nonradioactive Dangerous Waste Landfill.
> = Beyond the year 2000.

organic halides in the groundwater. The site reverted to a detection monitoring program in October 1997.

The 183-H Solar Evaporator Basins (100-H Area) were monitored under final-status regulations during 1997. The basins have contaminated the groundwater with technetium-99, uranium, nitrate, and chromium to levels exceeding applicable concentration limits. Corrective action will be addressed under the Comprehensive Environmental Response, Compensation, and Liability Act program, and an interim remedial action (pump-and-treat system) for chromium began in 1997. Groundwater monitoring to meet Resource Conservation and Recovery Act requirements will continue during the remediation process.

The 316-5 Process Trenches (300 Area) changed from an interim-status assessment program to a final-status compliance-monitoring program in December 1996. The site was immediately moved to a corrective action program because the regulatory concentration limits for some constituents (radioactive and chemical) were exceeded. A corrective action plan was submitted to the Washington State Department of Ecology and is scheduled to be implemented in 1998 (WHC-SD-EN-AP-185). Natural attenuation of the contaminants through continued declining concentrations is the corrective action approved under the Comprehensive Environmental Response, Compensation, and Liability Act (Record of Decision 1996b). Groundwater monitoring will continue under the Resource Conservation and Recovery Act to determine the attenuation of the elevated contaminants.

The monitoring programs for the 216-A-10, 216-A-36B, and 216-A-37-1 Cribs (200-East Area) were combined into a single assessment program in 1997. Specific conductance is elevated downgradient of the cribs and has a direct correlation with nitrate and tritium contaminant plumes in the area.

The results of groundwater monitoring are discussed in detail in Section 6.1, "Hanford Groundwater Monitoring Project."

### 2.2.5.4 Resource Conservation and Recovery Act Inspections

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 1997. Each of these notices lists specific violations. There were four Resource Conservation and Recovery Act-related notices of violation and warning letters in 1997. Of these, one has had all corrective actions completed and has been closed. Two of the 1997 issues were formal violations, resulting in fines totaling $200,000. Below is a brief summary of the three most significant of these four issues.

- The Washington State Department of Ecology issued a Notice of Correction for improper waste storage (satellite accumulation area) at the 222-S Laboratory in the 200-West Area in early 1996. On November 7, 1996, the Washington State Department of Ecology levied a $90,000 penalty against DOE Richland Operations Office and its subcontractors for improper storage of waste in February 1996. DOE Richland Operations Office issued a letter to the Pollution Control Hearings Board requesting relief from the penalty. A hearing has been set for early 1998.

- The Washington State Department of Ecology issued a Notice of Violation and Penalty to DOE Richland Operations Office for the storage of incompatible waste at the Plutonium Finishing Plant in the 200-West Area. The contents of a tank containing liquid chemicals evaporated and concentrated, resulting in a reaction causing the tank to pressurize and explode. No workers were seriously injured but the explosion caused damage to a portion of the Plutonium Reclamation Facility, which is part of the Plutonium Finishing Plant. The Notice of Violation included a penalty of $110,000 levied against DOE Richland Operations Office and its subcontractors. A request for a relief from penalty was filed with the Pollution Control Hearings Board. A hearing date has not yet been set. Emergency preparedness and notifications were highlighted as problems in the Notice of Violation. All Hanford Site contractors are working with the Washington State Department of Ecology to improve emergency preparedness onsite and to evaluate the status and condition of all tanks on the Hanford Site.

- In December 1997, at T Plant in the 200-West Area, some questionable materials were found in containers of debris waste from the 324, 325, and 327 Buildings in the 300 Area. Offices in these facilities had been cleaned out, and potentially hazardous materials (e.g., flashlight batteries, light bulbs, and metal-laden materials) from these offices were accidentally placed into the containers and shipped to T Plant for verification and disposal. The Washington State Department of Ecology performed an investigation of the suspect waste containers and issued a Notice

of Correction for improper designation of waste. This issue was closed on March 25, 1998.

## 2.2.6 Clean Air Act

Local, state, and federal agencies enforce standards and requirements for regulation of air emissions at federal facilities such as the Hanford Site, under the Clean Air Act (Section 118). A summary of the major agency interfaces and applicable regulations for the Hanford Site is provided in the following paragraphs.

The Washington State Department of Health's Division of Radiation Protection regulates radioactive air emissions statewide through delegated authority from EPA and its implementing regulation (WAC 246-247). Applicable controls and annual reporting of all radioactive air emissions are required. The Hanford Site operates under state license FF-01 for such emissions. The conditions specified in the license will be incorporated into the Hanford Site air operating permit, scheduled to be issued in mid-1998 in accordance with Title V of the Clean Air Act and 1990 amendments and the federal and state programs under 40 CFR 70 and WAC 173-401, respectively. The Hanford Site air operating permit will include a compilation of requirements for both radioactive emissions now covered by the existing FF-01 license and nonradioactive emissions. It requires the owner (DOE Richland Operations Office) to submit periodic reports and an annual compliance certification to the state.

Revised 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 all Hanford Site sources and/or are tracked for milestone progress, as discussed below, in accordance with a schedule with the Washington State Department of Health.

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 was signed by the EPA Region 10 and DOE and provides a compliance plan and schedule that are 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 agreement milestones were met during 1997, and Hanford Site air emissions remained below all regulatory limits set for radioactive and other pollutants.

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). The implementing requirements (e.g., WAC 173-400 and 173-460) specify applicable controls, reporting, notifications, permitting, and provisions of compliance with the general standards for applicable Hanford Site sources.

Pursuant to 40 CFR 61, Subpart M, EPA 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* (BHI-00010, Rev. 2) and/or in accordance with approved contractor procedures. The plan is updated annually by the DOE Richland Operations Office Site Infrastructure Division 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, 1990 Amendments, requires regulation of the service, maintenance, repair, and disposal of appliances containing Class I and Class II ozone-depleting substances (refrigerants) through implementation of the requirements in 40 CFR 82. In 1994, the site management and operation contractor was assigned the lead by DOE directive to coordinate the development of a sitewide plan to implement the Title VI requirements. As a result, implementation of the EPA requirements for ozone-depleting substance management on the Hanford Site was administered through the sitewide implementation plan (DOE/RL-94-86). The continued need for this implementation plan is being evaluated by DOE Richland Operations Office to determine if it should be updated to reflect changes in Hanford Site contractor relationships and applicable federal regulations.

The Benton County Clean Air Authority enforces Regulation 1, which pertains to detrimental effects, fugitive dust, open burning, 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, Subpart M). In 1997, there were no compliance issues identified for the Hanford Site pursuant to these regulations.

During 1997, routine reports and/or notifications of air emissions were provided to each air quality agency in accordance with requirements.

### 2.2.6.1 Clean Air Act Enforcement Inspections

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 of Correction in 1997 and none from the Washington State Department of Ecology. A brief summary of the three most significant of these issues follows.

- The Washington State Department of Health investigated the chemical tank overpressurization at the Plutonium Finishing Plant (200-West Area) to determine if any radioactive releases occurred (see Section 2.2.5.4, "Resource Conservation and Recovery Act Inspections" for details of the event). There was no indication that above-background levels of contaminants were released from the building following the explosion. No response has been received subsequent to the investigation from the Washington State Department of Health on this issue.

- A Notice of Correction was issued by the State of Washington Department of Health to DOE Richland Operations Office for the use of outdated procedures in T Plant (200-West Area). Two manuals referenced in the procedures were canceled, with no replacements implemented. The Washington State Department of Health indicated that the canceled manuals need to be reissued. Their concern is that quality control procedures were deleted with no replacements issued. New procedures are being prepared and are scheduled to be implemented in June 1998. This implementation date has been accepted by the Washington State Department of Health.

- A Notice of Correction was issued by the Washington State Department of Health to DOE Richland Operations Office for failure to notify within 24 hours the excursion at the Waste Encapsulation Storage Facility in the B Plant Complex (200-East Area). The Notice of Correction indicated that the filters in the 296-B-10 Stack were potentially compromised, resulting in the exceedance of the as low as reasonably achievable control technology standard set forth in WAC-246-247-080(5). The Washington State Department of Health indicated that notification was not received until 6 days after the event and that a clear policy is needed to ensure the department is properly notified. DOE Richland Operations Office sent notices to its contractors asking them to demonstrate the implementation of the notification requirements found in the regulations, has indicated that the notification policy will be included in the air operating permit expected to be issued to the site by the Washington State Department of Ecology in 1998. This issue remains open.

## 2.2.7 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 that govern effluent discharges to the Columbia River.

A request to remove inactive outfalls 005, 006, 007, 009, and N Springs (100-N Area) from the monitoring and reporting requirements in the permit (#WA-000374-3) was submitted to EPA in August 1997. The EPA indicated informally that DOE could discontinue monitoring of these outfalls without a permit modification, with the exception of the well that monitors N Springs. A formal response has not been received from the EPA. The active outfalls at the Hanford Site include two located in the 100-K Area (outfalls 003 and 004) and one in the 300 Area (outfall 013). There was one instance of noncompliance, related to a missed sample at N Springs, for this permit in 1997 (Table 2.2.4).

An application for a permit modification for the 300 Area Treated Effluent Disposal Facility (permit #WA-002591-7) was submitted to the EPA in November 1997. The application requested the transfer of outfalls 003 and 004 (100-K Area) from existing permit #WA-000374-3 to permit #WA-002591-7. The 100-N outfalls (005, 006, 007, 009, and N Springs), currently identified in permit #WA-000374-3, were not included in the application because discharges to these outfalls have ceased. A summary discussing why another outfall (013A in the

**Table 2.2.4.** Water Permit Exceedances or Noncompliances at the Hanford Site, 1997

| Permit/Outfall | Parameter | Date(s) Exceeded | Comments |
|---|---|---|---|
| **National Pollutant Discharge Elimination System** | | | |
| 300 Area Treated Effluent Disposal Facility | Bis (2-ethylhexyl) phthlate | June 1997, August 1997 | None |
| | Nitrite | June 1997 | Only testing method available does not differentiate between nitrite and nitrate unless specified. |
| | Radium-228 | November 1997 | Later clarification with EPA regardinging reporting indicated that this would not have been a noncompliance. |
| 1301 (N Springs, 100-N Area) | Oil and grease, iron, ammonia, chromium, and temperature | December 1997 | Missed sampling because of equipment malfunction. |
| **State Waste Discharge Permit ST 4508** | | | |
| Hanford Site | 20-minute discharge duration limit | July 11, 1997, August 18, 1997, August 19, 1997 | None |
| **State Waste Discharge Permit ST 4507** | | | |
| 100-N Sewage Lagoon | Biochemical oxygen demand | July 31, 1997 | None |
| **State Waste Discharge Permit ST 4503** | | | |
| 183-N Backwash Discharge Pond | pH and trihalomethanes | August 1997 | Attributed to elevated chlorine; system operations modified. |
| **State Waste Discharge Permit ST 4500** | | | |
| 200 Areas Effluent Treatment Facility | Sulfate | February 6, 1997, April 21, 1997, June 30, 1997 | Attributed to dissolution of calcium sulfate in soil. |
| **State Waste Discharge Permit ST 4502** | | | |
| 200 Areas Treated Effluent Disposal Facility | Iron | January 12, 1997 | None |
| **State Waste Discharge Permit ST 4501** | | | |
| 400 Area Secondary Cooling Water | Total dissolved solids | January 2, 1997 | Cooling towers were contributing factor; system operations were modified. |
| | Manganese | July 7, 1997 | Elevated manganese present in source water. |
| | Manganese and total dissolved solids | August 27, 1997 | Elevated manganese present in source water; cooling towers were contributing factor; system operations were modified. |

300 Area) should be exempt from permitting was also attached to the application. A revised permit is expected to be issued in 1998.

Permit #WA-002591-7 covers the 300 Area Treated Effluent Disposal Facility, which had 4 permit exceedances in 1997. All four were the result of contaminant levels in effluents exceeding the permit limits. This facility was in normal operation 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 permit despite the use of the best available technology.

The Hanford Site is covered by two stormwater permits (WAR-00-000F, WAR-10-000F). In compliance with the industrial stormwater discharge permit, an annual comprehensive site compliance evaluation was performed and documented in 1997 (HNF-SD-ENV-EE-004).

DOE Richland Operations Office was issued a pretreatment permit (CR-IU005) from the city of Richland in 1997 for the discharge of wastewater from the Environmental and Molecular Sciences Laboratory. Also, there are numerous sanitary waste discharges to the ground, as well as 400 Area sanitary waste discharge to the Washington Public Power Supply System treatment facility. Sanitary waste from the 300 Area, 1100 Area, and other facilities north of, and in, Richland discharge to the city of Richland treatment facility.

Refer to Table 2.2.4 for a summary of all site water permit exceedances and noncompliances in 1997.

### 2.2.7.1 Liquid Effluent Consent Order

The Washington State Department of Ecology liquid effluent consent order (DE 91NM-177), which regulates Hanford Site liquid effluent discharges to the ground, contains compliance milestones for Hanford Site liquid effluent streams designated as Phase I, Phase II, and Miscellaneous Streams. State waste discharge permit applications are being submitted to the Washington State Department of Ecology for all liquid effluent streams subject to regulation by the Consent Order. Three new state waste discharge permits were issued by the Washington State Department of Ecology in 1997 and include Permit ST 4508 for hydrotest, maintenance, and construction discharges (issued May 30, 1997); Permit ST 4507 for the 100-N Sewage Lagoon (issued May 12, 1997); and Permit ST 4503 for the 183-N Backwash Discharge Pond (issued May 12, 1997). A single one time/limited duration discharge permit was obtained for Project L-275 in support of fire protection line construction and flushing activities.

In 1997, there were 12 noncompliances among the 7 state waste discharge permits currently in place at the Hanford Site. Refer to Table 2.2.4 for additional information.

The first Hanford Site miscellaneous streams categorical permit was issued by the Washington State Department of Ecology for hydrotest, maintenance, and construction discharges. The permit became effective May 30, 1997 and expires on May 30, 2002. The Washington State Department of Ecology issued the second miscellaneous streams categorical permit for cooling water and condensate discharges on May 1, 1998. A permit application covering the third and last miscellaneous streams categorical permit for stormwater discharges is due to the Washington State Department of Ecology by September 1998.

## 2.2.8 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. The Washington State Department of Health enforces these regulations. 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 1997, one constituent in one water supply system sample was detected at a concentration in excess of its maximum contaminant level. Results of a sample collected at the Fast Flux Test Facility on June 25, 1997 indicated manganese concentrations of 0.082 mg/L, which is above the 0.05-mg/L maximum contaminant level. Groundwater in the 400 Area, which is used as the drinking water source at the Fast Flux Test Facility, contains naturally occurring manganese. Manganese is considered a secondary contaminant per WAC 246-290-310 and poses no threat to human health and the environment. Appropriate notifications were made and no further action was required.

## 2.2.9 Toxic Substances Control Act

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 EPA expects to issue a revision to these regulations during 1998. The state of Washington also regulates certain classes of polychlorinated biphenyls through the dangerous waste regulations in WAC 173-303.

Electrical transformers on the Hanford Site have been sampled and characterized. Fourteen transformers with polychlorinated biphenyl concentrations 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 naval 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 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 reactor compartment disposal trench.

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 most recent report (DOE 1998) was submitted by DOE Richland Operations Office to Headquarters in January 1998. In 1997, Pacific Northwest National Laboratory continued research under a research and development permit from the EPA to study degradation of polychlorinated biphenyls in waste matrices. The research and development permit was extended from December 12, 1997 to December 12, 1998 to allow continued research of polychlorinated biphenyl destruction techniques.

## 2.2.10 Federal Insecticide, Fungicide, and Rodenticide Act

This Act is administered by the 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 1997, the Hanford Site was in compliance with these state and federal standards that regulate the storage and use of pesticides.

## 2.2.11 Endangered Species Act

Many rare species of native plants and animals are known to exist on the Hanford Site. Four species that may occur onsite (the bald eagle, peregrine falcon, Aleutian Canada goose, and steelhead trout) 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 7.2, "Ecosystem Monitoring (Plants and Wildlife)."

Bald eagles, a threatened species, are seasonal visitors to the Hanford Site. Several nesting attempts along the Hanford Reach were documented by Pacific Northwest National Laboratory in the 1990s. In compliance with the Endangered Species Act, the Hanford Site bald eagle management plan (DOE/RL-94-150) was finalized in 1994. That plan established temporal 800-m (2,600-ft) access restriction zones around all active nest sites and 6 major communal roosting sites. If activities at the historical nesting sites are observed in January and early February, access roadways are restricted. In 1997, two nests were built by pairs of eagles. The nesting eagles eventually left the area without successfully producing offspring.

The peregrine falcon and the Aleutian Canada goose are rarely observed on the site. Steelhead and salmon are regulated as evolutionary significant units by the National Marine Fisheries Service based on their historical geographic spawning areas. The upper Columbia River evolutionary significant unit was listed as threatened in August 1997. In March 1998, the Mid-Columbia River evolutionary significant units for steelhead and spring-run chinook salmon were proposed for listing as threatened and endangered, respectively. A Hanford Site

steelhead management plan is being prepared. That plan will serve as the formal consultation with the National Marine Fisheries Service as required under the Endangered Species Act. Like the bald eagle management plan, that plan will discuss mitigation strategies and will list project activities that can be conducted without impacting steelhead trout or their habitats.

As part of the National Environmental Policy Act review process, an ecological review was conducted on all projects to evaluate their potential of affecting federal- and/or state-listed species within the proposed project area (PNNL-6415, Rev. 9). The ecological review included quantifying impacts that might result and identifying mitigation strategies to minimize or eliminate such impacts.

## 2.2.12 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 1997, 151 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 1997.

## 2.2.13 National Environmental Policy Act

This Act requires preparation of appropriate documentation to analyze potential impacts associated with proposed federal actions. An environmental impact statement is required to analyze the impacts associated with major federal actions that have the potential to affect the quality of the human environment significantly. Other National Environmental Policy Act documents include an environmental assessment, which is prepared to determine if a proposed action has the potential to impact the environment significantly 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 called categorical exclusions, are exempt from further National Environmental Policy Act review. Typically, over 20 specific categorical exclusions are documented by DOE Richland Operations Office annually, involving a wide variety of actions by multiple contractors. In addition, sitewide categorical exclusions are applied to hundreds of routine, typical actions conducted daily on the Hanford Site. There were 19 sitewide categorical exclusions in 1997.

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 451.1A. In accordance with DOE Order 451.1A, DOE documents prepared for Comprehensive Environmental Response, Compensation, and Liability Act projects 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.

### 2.2.13.1 Recent Environmental Impact Statements

Potential environmental impacts associated with ongoing, major activities at the Hanford Site have been analyzed

in environmental impact statements issued in the past several years, followed by records of decision. Additional National Environmental Policy Act reviews, as appropriate, are being conducted during the course of the actions, moving forward as described in the records of decision.

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 is to 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). No final decision regarding the Hanford Reach has been attained to date; discussions in the Senate and House of Representatives are ongoing.

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/EIS-0189). The proposed actions are the retrieval of radioactive wastes from double- and single-shell waste tanks at the Hanford Site and subsequent stabilization of the wastes in forms suitable for disposal. The Record of Decision was issued in February 1997 (62 FR 8693).

### 2.2.13.2 Programmatic Environmental Impact Statements

A final programmatic environmental impact statement was issued in December 1996 (DOE/EIS-0229) to analyze alternatives for the long-term storage of all weapons-usable fissile materials and the disposition of plutonium that is no longer needed for national defense purposes. This environmental impact statement considers the Hanford Site as one of four candidates for storage of weapons-usable materials. The environmental impact statement record of decision was issued in January 1997 (62 FR 3014).

A final programmatic environmental impact statement was issued in May 1997 (DOE/EIS-0200F) to evaluate management and siting alternatives for the treatment, storage, and disposal of five types of radioactive and hazardous waste. Hanford was considered in all alternatives. A record of decision was issued in 1998 (63 FR 3629) on treatment and storage of transuranic waste. Other records of decision are expected on this environmental impact statement.

### 2.2.13.3 Site-Specific Environmental Impact Statements In Progress

An environmental impact statement is being prepared for the Hanford Remedial Action Program. The proposed action would develop a comprehensive land use plan for the Hanford Site. A draft environmental impact statement was issued in August 1996 (DOE/EIS-0222D). In response to public comment, a second draft is being prepared with the cooperation of tribal governments, counties, the city of Richland, and federal agencies. It is expected that the second draft environmental impact statement will be issued for public comment during the summer of 1998. A final environmental impact statement is expected in the autumn of 1998.

## 2.2.14 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* (DOE/RL-96-63, Rev. 1). 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 November 1996. However, these do not apply to treatment, storage, and disposal units.) The initial Hanford Facility Resource Conservation and Recovery Act 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 treatment, storage, and disposal 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 1998. 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. Stormwater discharges to the Columbia River are permitted by the National Pollutant Discharge Elimination System. Waste discharge permits are required by WAC 173-216. These permits are summarized in Section 2.2.7.1, "Liquid Effluent Consent Order."

Other Hanford Site permitting addressed in the permitting status report (DOE/RL-96-63, Rev. 1) includes research, development, and demonstration; solid waste handling; onsite sewage systems; and permitting of underground petroleum storage tanks. Also refer to Appendix C, Table C.6.

# 2.3 Activities, Accomplishments, and Issues

*D. G. Black*

This section further describes DOE's progress in meeting its mission at the Hanford Site. Section 2.2, "Compliance Status," described activities relating to compliance with regulations. This section describes other major ongoing activities. Ongoing compliance self-assessments, knowledge gained in implementing Tri-Party Agreement 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.

## 2.3.1 Hanford Federal Facility Agreement and Consent Order

Fifty-seven Tri-Party Agreement milestones scheduled for 1997 were completed, along with 3 scheduled for 1998. Highlights of physical work accomplished (documents not included), with the associated milestone numbers, include the following:

- restarted the 200-ZP-2 carbon tetrachloride vapor extraction system in the 200-West Area (Milestone M-15-36)
- initiated remedial action for the 300-FF-1 Operable Unit in the 300 Area (Milestone M-16-03B)
- completed 200-ZP-1 Operable Unit treatment system upgrades in the 200-West Area (Milestone M-16-04B)
- began system operations at the 100-HR-3 Operable Unit in the 100-H Area (Milestone M-16-06B) and at the 100-KR-4 Operable Unit in the 100-K Area (Milestone M-16-11)
- completed implementation of "best available technology/all known, available, and reasonable methods of prevention, control, and treatment" for all Phase II liquid effluent streams at the Hanford Site (Milestone M-17-00B)
- replaced the piping from the 300 Area process sewer to the 300 Area Treated Effluent Disposal Facility (Milestone M-17-06K)
- completed construction and initiated operations of the Waste Receiving and Processing Facility in the 200-West Area (see Figure 1.0.2) (Milestone M-18-00)
- awarded a commercial contract for stabilization of low-level mixed waste stored at the Central Waste Complex in the 200-West Area (see Figure 1.0.2) (Milestone M-19-01-T02)
- obtained a Washington State Department of Ecology decision accepting the existing solidification treatment at the 183-H Solar Evaporation Basins in the 100-H Area (Milestone M-19-03)
- completed construction upgrades to existing underground waste transfer lines in the 200 Areas (Milestone M-32-02-T02)
- completed vapor space monitoring of underground tanks in the 200 Areas that generate flammable gas (Milestone M-40-10)
- started interim stabilization of 8 underground single-shell tanks in the 200 Areas (Milestones M-41-21 and -22) and completed salt well pumping of 4 single-shell tanks (Milestone M-41-27-T-02)
- completed construction of the cross-site transfer line between underground tanks in the 200-West and 200-East Areas (Milestone M-43-07B)
- started the definitive design phase for underground storage tank system upgrades (Milestone M-43-10)
- completed conceptual design for the initial single-shell underground tank waste retrieval systems (Milestone M-45-04A)

- established the criteria for determining allowable leakage volumes and acceptable leak monitoring/ detection and mitigation measures necessary to permit underground waste tank sluicing operations (Milestone M-41-27-T01)

- awarded two design-only privatization contracts for Phase I low-activity waste pretreatment and immobilization for underground tank waste (Milestone M-60-08)

- completed data quality objectives that identify the underground tank waste characterization information needs in support of Phase I privatization contracts (Milestone M-60-14-T01)

- completed deactivation of the Plutonium-Uranium Extraction Plant canyon in the 200-East Area (see Figure 1.0.2) (Milestone M-80-06)

- initiated operations at the Central Waste Complex storage facilities in the 200-West Area (see Figure 1.0.2) (Milestone M-91-01)

- submitted a recommendation for the final disposition of the 105-C fuel storage basin in the 100-B,C Area (Milestone M-93-01).

Since the last issue of this report, new negotiated changes to the Tri-Party Agreement established 40 new enforceable milestones and 14 new unenforceable target dates.

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

### 2.3.1.1 Waste Management

There was one approved change request related to facility transition during 1997.

Target milestones for the M-32-02 series, "Completion of 219-S Tank Interim Status Actions," in the 200-West Area were changed. During construction of project W-178, "219-S Secondary Containment Upgrade," higher than anticipated contamination levels were encountered. The contamination and radiological dose rate levels significantly exceeded the budget estimate assumptions. Levels of this magnitude required the decontamination of the 219-S facility A and B cells to minimize exposure to workers. As a result, the project's work scope was separated into two phases. Phase I, integral to transfer line replacement, was completed in early 1997 with all available funding consumed. Phase II, the balance of the project, was placed on hold until additional funding could be obtained. Phase II funding has been budgeted.

### 2.3.1.2 Environmental Restoration Program

The M-93-00 series of milestones was negotiated to create schedules for the cleanup and removal of eight of Hanford's surplus production reactors. DOE has considered the environmental impacts, risks, costs, benefits, and institutional and programmatic needs associated with decommissioning the B,C, D, DR, F, H, KE, and KW Reactors in the 100 Areas. The selected final disposition alternative, in a phased approach, is interim safe storage followed by deferred one-piece removal of the eight surplus reactors. (Because of interest in a B Reactor engineering accomplishment museum and/or landmark, it was recognized that cleanup activities at B Reactor might take a different course.)

DOE will prepare and present for public comment appropriate environmental documentation for N Reactor. N Reactor had not been shut down when the environmental documentation for the other eight reactors was prepared in 1993. N Reactor is expected to follow a disposition path similar to the other surplus reactors, and its disposition is within the scope of the new M-93 series of milestones.

A change request approved in March 1997 also established 3 new milestones in the M-16 series for remedial action and disposal of waste sites in the 300-FF-1 Operable Unit in the 300 Area.

### 2.3.1.3 Tank Waste Remediation System

A change was made to revise the strategy for existing milestone M-44-00, Tank Waste Characterization. The change resulted from an extensive review of progress on the milestone through a partnering effort between the Washington State Department of Ecology and DOE Richland Operations Office. As tank projects have matured, their waste information needs have been refined. The milestone change allows characterization sampling and analysis efforts to be tailored to meet these needs. The change removes the requirement for sampling a

predetermined number of tanks and links the sampling and analysis activities directly to the project's tank waste information needs.

Three new target dates were also created to submit data quality objectives for tank waste retrieval and high-level waste feed to the treatment system. This was done in support of the tank waste remediation system privatization contracts.

## 2.3.2 Pollution Prevention Program

Pollution prevention is DOE's preferred approach to environmental management. The Hanford Site Pollution Prevention Program is an organized and continuing effort to reduce systematically the quantity and toxicity of hazardous, radioactive, mixed, and sanitary wastes. 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 program; 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. Disposal to the environment is the last option.

Overall responsibility for the Hanford Site Pollution Prevention Program resides with DOE Richland Operations Office. The office defines overall program requirements that each prime contractor is responsible for meeting.

Hanford Site pollution prevention efforts in 1997 helped to prevent the generation of an estimated 9,300 $m^3$ (12,200 $yd^3$) of radioactive mixed waste, 440 metric tons (480 tons) of Resource Conservation and Recovery Act hazardous/dangerous waste, 2.5 billion L (660 million gal) of process wastewater, and 6,800 metric tons (7,500 tons) of sanitary waste. Total savings in 1997 exceeded $14,700,000 for these activities.

During 1997, the Hanford Site recycled 510 metric tons (560 tons) of office paper, 45 metric tons (50 tons) of cardboard, 3,700 metric tons (4,100 tons) of ferrous metal, 145 metric tons (160 tons) of nonferrous metal, 12 metric tons (13 tons) of lead, 2.2 metric tons (2.4 tons) of solid chemicals, 0.68 metric ton (0.75 ton) of aerosol cans, 14 metric tons (15 tons) of fluorescent light tubes, 37.7 metric tons (41.5 tons) of lead acid/gel cell batteries, and 1,100 metric tons (1,200 tons) of miscellaneous materials. Savings in 1997 exceeded $1,500,000.

Numerous generator-specific initiatives were put into place that enabled these waste reductions and cost savings. To celebrate these pollution prevention activities, the *Hanford Site Pollution Prevention Accomplishments* (HNF-1740) was published in October 1997. The book outlines 56 initiatives that were implemented and are now in use at locations throughout the Hanford Site.

## 2.3.3 Environmental and Molecular Sciences Laboratory

The William E. Wiley Molecular Sciences Laboratory, an 18,600 $m^2$ (200,200 $ft^2$) facility in the Richland North Area, was completed and DOE Headquarters authorized full operation in October 1997. Over 179 permanent staff members have been moved into the laboratory from other facilities.

The city of Richland issued an industrial wastewater permit (CR-IU005) to DOE that allows for process wastewater from this 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. Routine discharges under this permit have begun. Additionally, as required by the permit, an accidental spill prevention plan was developed and submitted to the city (PNNL-11311). That plan describes measures taken to prevent, control, and mitigate the effects of accidental releases of hazardous materials from the laboratory to the city.

## 2.3.4 Spent Fuel Project Activities

In February 1994, the Spent Nuclear Fuel Project was established to provide safe, economic, and environmentally sound management of Hanford Site spent nuclear fuel in a manner that readies it for 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 the site's inventory consists of approximately 2,100 metric tons (2,300 tons) of irradiated N Reactor fuel stored in the KE and KW Fuel Storage Basins.

In 1997, 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; see Figure 1.0.2). Construction of the building is nearly complete, and during finalization, the project is completing design activities and fabricating process-related equipment on other parts of the project. In addition, construction of the cold vacuum drying facility is in progress at the 100-K Area. This facility will condition the fuel following removal from wet storage to stabilize it for dry storage at the Canister Storage Building.

## 2.3.5 Facility Stabilization Project

This project's mission is to transition those Hanford Site facilities for which it has responsibility from an operating mode to a long-term surveillance and maintenance mode. This includes maintaining facilities in a safe and compliant status, 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 costs to be attained while awaiting determination of a facility's final disposition and possible turnover to the DOE Environmental Restoration Program.

Currently, the Facility Stabilization Project is engaged in five major deactivation efforts at the Hanford Site. The major efforts are the Plutonium-Uranium Extraction Plant, the Facility Stabilization and Environmental Restoration Team, the 300 Area Stabilization Project, the B Plant/ Waste Encapsulation and Storage Facility, and the Plutonium Finishing Plant. The mission of each project and related accomplishments during 1997 are summarized below.

### 2.3.5.1 Plutonium-Uranium Extraction Plant

The mission of the Plutonium-Uranium Extraction Plant deactivation project is to transition the facility to a long-term, low-cost, surveillance and maintenance state that is safe and environmentally secure. The plant was constructed to obtain plutonium for national defense needs. With no further need for plutonium, DOE provided a deactivation order for the facility in December 1992.

Plant deactivation was completed in May 1997; more than $75 million under budget and 14 months ahead of schedule. This was the first facility of this complexity and size to be deactivated under the current-day regulations and requirements. The facility, which required approximately $35 million annually to maintain a standby condition, now requires less than $1 million per year to maintain the surveillance and maintenance phase until the final disposition of the facility is determined.

The deactivation of the plant involved the removal, reduction, and/or stabilization of radioactive sources and hazardous substances in a safe, cost-effective manner. The deactivation project was also marked by a concerted recycling effort to reduce waste and maximize the reuse of resources. The plant is currently unoccupied and locked, and is being maintained under surveillance while awaiting eventual decontamination and decommissioning.

### 2.3.5.2 Facility Stabilization and Environmental Restoration

The Facility Stabilization and Environmental Restoration Team (always referred to by its acronym FASTER) is a group organized in 1997 to share comprehensive cleanup experience and lessons learned from the Uranium TriOxide Plant and Plutonium-Uranium Extraction Plant deactivation projects with similar projects at other DOE sites nationwide.

The FASTER Team is supporting the deactivation of several facilities at the Hanford Site, primarily isolated facilities without associated staff. The team is also involved with deactivation planning for facilities at the

Rocky Flats Plant in Colorado, the Savannah River Site in South Carolina, and the Brookhaven National Laboratory in New York.

### 2.3.5.3 300 Area Stabilization Project

This project currently has two subprojects: 1) 300 Area Fuel Supply Shutdown Subproject and 2) 324/327 Building Transition Subproject.

The 300 Area subproject includes buildings dating back to 1943 that housed manufacturing equipment for production of fuel for Hanford Site reactors. These processing operations were discontinued in 1987 when the last of the Hanford Site reactors (N Reactor) was shut down and placed in a standby mode.

The transition subproject includes the 324 and 327 Buildings, which were constructed in 1966 and 1953, respectively. These buildings house hot cells that were utilized for radiological research and development work. Both facilities were transferred to the Facility Stabilization Project in 1996.

The current mission of the 300 Area Stabilization Project is to complete deactivation and closure activities, while maintaining the facilities in a safe and compliant status until eventual decontamination and decommissioning.

During 1997, the following significant accomplishments were achieved:

- completed transfer of the 308 Building plutonium fuels development and fabrication facility to the Hanford Site environmental restoration contractor
- completed 313 Building Phase I cleanout activities in support of Resource Conservation and Recovery Act closure of the Waste Acid Treatment System in the 300 Area
- transferred 10 million Ci of radioactive materials from the 324 Building to safe storage at the plutonium-uranium extraction facility
- completed shipment of 327 Building legacy fuel pins and pieces from past research activities to the Central Waste Complex in the 200-West Area ahead of schedule.

### 2.3.5.4 B Plant/Waste Encapsulation and Storage Facility

B Plant went into service in 1944 to recover plutonium by a chemical separation process. Following the advent of the more efficient Plutonium-Uranium Extraction Plant process, B Plant's mission was modified to recover the high-heat isotopes (primarily cesium-137 and strontium-90) from highly radioactive waste. In October 1995, DOE directed that B Plant be deactivated. The current mission is to place it into a configuration suitable for long-term surveillance, pending final disposition.

The Waste Encapsulation and Storage Facility project's mission is to provide safe interim storage of encapsulated radioactive material (cesium and strontium). This facility has not received a deactivation order and will remain in service following the shutdown and deactivation of B Plant.

The B Plant deactivation schedule has been accelerated with a goal for completion by the end of September 1998, which is 4 years ahead of schedule. This accelerated schedule is expected to save more than $100 million.

Significant accomplishments achieved during the accelerated 1997 deactivation effort include the following:

- All 1997 Tri-Party Agreement milestones associated with facility deactivation at B Plant were completed on or ahead of schedule.
- The final 15,000 L (4,000 gal) of highly radioactive organic solvent waste from past B Plant processing operations were removed from the facility and shipped to an offsite Resource Conservation and Recovery Act-permitted mixed waste treatment, storage, and disposal facility for final disposition.
- B Plant effluent systems were deactivated, eliminating all liquid discharges to the soil and the 200 Areas Treated Effluent Disposal Facility from B Plant. In addition, work began on construction and installation of a new ventilation system that will replace the existing main stack during long-term surveillance of the facility. Included as part of this overall effort was the isolation of the original B Plant sand filter and contaminated high-efficiency particulate air filters.

- Over 370 $m^2$ (4,000 $ft^2$) of radiologically contaminated area were decontaminated and released for unconditional use during 1997. In addition, over 1,900 L (500 gal) of excess chemical and hazardous products were recycled or excessed, as were over 3,000 kg (6,600 lb) of lead.

- The B Plant/Waste Encapsulation and Storage Facility project received a DOE 1997 Pollution Prevention Award. This award recognized the continued successful reduction of hazardous material inventory in 1997, finishing with a total of 193 products in use at the project. This was down from 236 at the start of 1997, and down over 80% from a high of over 1,100 in 1993.

- A significant effort has been the separation of those systems common to both B Plant and the Waste Encapsulation and Storage Facility. Waste Encapsulation and Storage Facility systems and structures continue to be upgraded to ensure their future operability. Systems upgraded in 1997 included pool cell cooling, liquid effluent monitoring, and solid waste handling. The Waste Encapsulation and Storage Facility closed-loop cooling system reduced the pool cell cooling water discharge from approximately 4,900 L/min (1,300 gal/min) to less than 19 L/min (5 gal/min); a total reduction of over 2.6 billion L (680 million gal) annually. Previously discharged to the ground via the B Pond system, this effluent stream, as well as all others from the Waste Encapsulation and Storage Facility, have been rerouted to the 200 Areas Treated Effluent Disposal Facility.

- The last cesium capsules being stored in the 300 Area were returned to the Waste Encapsulation and Storage Facility for storage in 1997, and remaining unencapsulated cesium salts are expected to follow in 1998. A Resource Conservation and Recovery Act Part A permit application was submitted to the Washington State Department of Ecology for the storage of all Hanford Site cesium and strontium capsules and unencapsulated salts at the Waste Encapsulation and Storage Facility. This was done to satisfy the conditions of a Tri-Party Agreement milestone and will result in the regulated storage of cesium and strontium capsules and operation of Waste Encapsulation and Storage Facility as a Resource Conservation and Recovery Act treatment, storage, and disposal facility.

## 2.3.5.5 Plutonium Finishing Plant

The Plutonium Finishing Plant went into service in 1949 to process plutonium nitrate solutions into metallic forms for the production of nuclear weapons. Operation of this plant continued into the late 1980s when the processes were shut down. In 1996, DOE issued a shutdown order for the plant, authorizing deactivation and transition of the plutonium processing portions of the facility in preparation for decommissioning. The current 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.

The plant's stabilization plans were established with the approval of a 1996 final environmental impact statement record of decision (61 FR 36352). This established the alternatives for removing readily retrievable material that remained in equipment and piping at the facility and for stabilizing or cementing stored and retrievable plutonium-bearing material. A supplemental analysis provided an alternate packaging method for immobilized plutonium-bearing materials. This analysis was approved in 1997 as a supplement to the Plutonium Finishing Plant final environmental impact statement (DOE/EIS-0244-FS/SA1).

In May 1997, a chemical overpressurization occurred at the Plutonium Reclamation Facility, a building within the Plutonium Finishing Plant complex. The incident occurred in a tank containing a solution of hydroxylamine nitrate and nitric acid. Because the tank was vented, evaporation of water caused the concentration of the reactants to increase. A spontaneous reaction of the two chemicals generated large quantities of steam and gas that overpressurized the tank. The pressure blew the lid off the tank, causing structural damage to the room and cutting a small fire suppression water line.

Subsequent to this incident, a significant effort was undertaken to review and improve the emergency management and response system, not only at the Plutonium Finishing Plant, but across the entire Hanford Site. In addition, an extensive chemical vulnerability assessment was conducted to identify and correct other potentially hazardous situations that may exist.

Significant items completed during 1997 to prepare the Plutonium Finishing Plant to continue the plutonium-bearing material stabilization and immobilization processes and to deactivate the processing buildings included the following:

- A notice of intent to submit a Resource Conservation and Recovery Act permit application requesting expansion of interim status for the Plutonium Finishing Plant treatment and storage unit was issued in July 1997. The notice of intent was prepared in support of agreements reached between DOE, Washington State Department of Ecology, Fluor Daniel Hanford Inc., and B&W Hanford Company. The notice of intent provides details for proposed treatment and storage of mixed waste at the Plutonium Finishing Plant in support of transition activities. The Resource Conservation and Recovery Act permit application will be prepared and submitted in 1998.

- A deactivation program management plan for the Plutonium Finishing Plant (excluding the storage vaults) was completed in July 1997 (HNF-SD-CP-PMP-008).

- Installation of a full-scale, direct denitration calciner was completed in December 1997. This equipment will be used at the Plutonium Finishing Plant for plutonium stabilization (converting plutonium nitrate to plutonium oxide or plutonium).

- Stakeholders expressed an interest in expediting the deactivation of the Plutonium Finishing Plant complex and moving forward to facility dismantlement. Through discussions with stakeholders, the *Plutonium Finishing Plant Vision 2006* (HNF-2902), which states the majority of the complex would be dismantled by an integrated project team to a "clean-slab-on-grade," was devised. Studies of this concept are being undertaken to evaluate the feasibility and potential cost savings of dismantlement. In addition, preparation of a plan, providing details of this concept, was initiated and will be completed in 1998.

## 2.3.6 Fast Flux Test Facility

### 2.3.6.1 History and Possible Future Missions

The Fast Flux Test Facility, a 400-MW thermal reactor cooled by liquid sodium, located in the 400 Area, was built in 1978 to test plant equipment and fuel for the liquid metal reactor development program. Although the facility is not a breeder reactor, this program demonstrated the technology of commercial breeder reactors. Breeder reactors are so termed because they can produce both power and nuclear fuel to supply other reactors.

In January 1997, the Secretary of Energy directed that the facility be maintained in "standby" condition until DOE could evaluate and decide whether it should be part of the nation's tritium production strategy. Studies and analyses to address safety issues, environmental impacts, and economic viability of producing tritium and medical isotopes at the facility have been conducted in support of a final decision on its future by the Secretary of Energy.

Meanwhile, deactivation activities that do not preclude a restart are continuing. Fuel has been taken out of the reactor vessel, and fuel assemblies (sealed metal tubes that hold fuel pellets) are being stored in aboveground, dry storage casks. Twenty-three of the facility's 100 plant systems are currently deactivated. The facility continues to be maintained in accordance with state and federal requirements.

The facility is being considered for at least three possible uses: tritium production, plutonium disposition, and medical isotope production.

**Tritium Production**. Tritium is an essential part of nuclear weapons produced by the United States. An isotope of hydrogen, tritium has a half-life of 12.3 years; meaning that half the existing material is lost every 12.3 years through radioactive decay. The President of the United States has decided that new tritium must be produced to maintain the effectiveness of its nuclear weapons stockpile. DOE is responsible for supplying tritium to the weapons stockpile.

All of DOE's tritium-producing reactors (located at the Savannah River Site in South Carolina) have been shut down since 1988. Because of their age and condition, there are no practical means to restart these reactors. Currently, DOE is studying two options for tritium: one is to build an accelerator at the Savannah River Site and the other is to use a commercial nuclear plant. The Fast Flux Test Facility is not being evaluated in competition with these two technologies. Instead, its restart would be considered an "insurance policy" for the DOE, as the reactor could be brought on line more quickly than the two potential long-term options and at a substantially lower cost.

If the Fast Flux Test Facility were called on to produce tritium, it could also produce medical isotopes and burn surplus weapons plutonium. These two activities would be secondary missions.

**Plutonium Disposition**. With the end of the Cold War, the United States is faced with the task of safe storage and disposition of approximately 50 metric tons (55 tons) of plutonium no longer needed for national defense, including approximately 4 metric tons (4.4 tons) at Hanford. DOE selected two options for the disposition of this surplus material: immobilization in ceramic or glass forms and incorporation of the plutonium into mixed oxide fuel to be burned by existing commercial reactors. The Fuels and Materials Examination Facility, adjacent to the Fast Flux Test Facility, is one candidate site for fabricating the mixed oxide fuel.

**Medical Isotope Production**. Medical isotopes are produced in accelerators or reactors or by extracting them from byproduct materials created by the weapons program. Dozens of different isotopes can be created, each with unique characteristics and potential uses. These isotopes can be used for diagnosis or therapy. Diagnostic isotopes are used for imaging internal organs, similar to the result of an x-ray. Therapeutic isotopes can be injected directly into a tumor or attached to an antibody that seeks out and locates the tumor. In this manner, the cancer cells are destroyed with little or no damage to the surrounding healthy cells.

New therapeutic applications for radioisotopes are showing great promise in clinical trials, but only small quantities are available for research. If clinical trials are successful and there is subsequent Food and Drug Administration approval, the number and size of current operating reactors in the United States would not be able to meet the expected medical need. The Fast Flux Test Facility is capable of producing a wide variety of isotopes. Over the reactor's 10-year life, approximately 60 different medical and industrial isotopes were created for researchers and medical practitioners.

**The Decision Process**. In, or before, December 1998, DOE is expected to make a decision on whether the Fast Flux Test Facility could play a role in tritium production for the nation's nuclear weapons stockpile. That decision will be based on studies, analyses, and public input. A decision to further consider restart as an option would trigger a full National Environmental Policy Act review.

## 2.3.7 Advanced Reactors Transition Project

This project includes the Fast Flux Test Facility reactor complex, the Fuels and Materials Examination Facility, nuclear energy legacy facilities, and the 309/Plutonium Recycle Test Reactor facility. The mission of this project is to maintain the Fast Flux Test Facility and its associated support facilities in a safe and stable condition.

Fast Flux Test Facility deactivation activities completed in 1997 included removal of 56 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, work began to replace the Freon 12 refrigerant in the eight Fast Flux Test Facility chiller units with non-ozone-depleting R-134a refrigerant.

Nuclear fuel was removed from the 308 Building (a DOE Nuclear Energy Program subproject) in the 300 Area, and deactivation activities for this building were completed. Cleanout of the rupture loop ion exchange vault in the 309 Building, which housed the Plutonium Recycle Test Reactor, was completed, and characterization was performed on the rupture loop annex.

A Resource Conservation and Recovery Act clean-closure certification for the 4843 Alkali Metal Storage Facility in the 400 Area was accepted by the Washington State Department of Ecology in 1997. Efforts are ongoing to complete Resource Conservation and Recovery Act clean closure for the 3718-F Alkali Metal Treatment and Storage Facility in the 300 Area.

As part of the nuclear energy legacy facility deactivation program, approximately 150,000 L (40,000 gal) of nonradioactive sodium from the 1720-DR and 3718-M tanks (in the 100-D and 300 Areas, respectively), were transferred to railroad tank cars and sold to an offsite vendor.

## 2.3.8 Tank Waste Remediation System Activities

### 2.3.8.1 Waste Tank Status

The status of the 177 waste tanks as of December 1997 was reported in HNF-EP-0182-117. 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[a]
  - 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, 119 single-shell tanks have been stabilized, with the tank stabilization program to be completed in 2000. At the end of 1997, 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 1997, pumping to double-shell tanks was performed on six single-shell tanks. Portions of Tanks 241-T-104, T-110, and SX-104 were pumped. Tanks 241-BY-109, BY-103, and S-110 were pumped and declared stabilized.

### 2.3.8.2 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 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/EH-0173T), 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 flammable gas, organic, high-heat, and criticality safety issues as described below. The tanks of concern are placed on a Watch List and categorized by safety issue. In 1996, all 24 ferrocyanide tanks had been removed from the Watch List, and the issue was deemed resolved by DOE and the Defense Nuclear Facilities Safety Board. At the end of 1997, there were 38 tanks remaining 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).

### 2.3.8.3 Watch List Tanks

In early 1991, all Hanford Site high-level waste tanks were evaluated and organized into categories to ensure

(a) "Assumed leaker" refers to tanks that have leaked or are assumed to have leaked. No tanks are known to be currently leaking.

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 (WHC-EP-0691). If ferrocyanide is present, laboratory studies show 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 (WHC-EP-0691). There were originally 24 ferrocyanide tanks on the Watch List: 4 were removed in 1993, 2 in 1994, and 18 in 1996. The ferrocyanide levels have decreased by at least 90%, and in some cases by 99%, over what was originally in the tanks. Experimental studies (PNNL-12111) 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 (WHC-SD-WM-SARR-038, Rev. 1). 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. Twenty-five tanks have been 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.

In November 1995, more stringent flammable gas controls were placed on all 177 high-level waste storage tanks after several events occurred where hydrogen gas was found during several waste intrusive activities. All rotary-mode sampling using the sampling trucks was suspended until a safety assessment of this sampling method could be approved for tanks because they might be retaining pockets of gas within the waste matrix.

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. The unreviewed safety question for Tank 241-SY-101 was closed 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 to measure 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.

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 1998.

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 and a hearing is scheduled for June 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 (WHC-SD-WM-SARR-033, Rev. 1). Concentrations and temperatures required to support propagating exothermic reactions are comparable to those for ferrocyanide (WHC-SD-WM-ER-496). 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 was 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 (WHC-SD-WM-SARR-001). Ten tanks that contained organic complexants were added to the Watch List following a review of sampling data and waste transfer records (WHC-EP-0182-79).

Other work indicates that aging processes have destroyed or significantly lowered the energy content of the organic tanks (WHC-EP-0823, WHC-SD-WM-SARR-033, Rev. 1), making them less hazardous. In addition, WHC-EP-0899-1 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 is 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 through 1997, 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 (FAI/96-45, FAI/96-48). 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 (WHC-SD-WM-SARR-003). 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 (WHC-SD-WM-TI-725). 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. Verification of the criticality safety program controls will be completed in May/June 1998. Successful completion of this review will enable DOE to close the criticality safety issue and satisfy the related Tri-Party Agreement milestone. The Tri-Party Agreement milestone for resolution of the criticality safety issue is scheduled for September 1999.

### 2.3.8.4 Vadose Zone Characterization Near Single-Shell Underground Waste Storage Tanks

Since 1995, the DOE Grand Junction Office has been performing a baseline spectral gamma borehole logging characterization of the vadose zone around the single-shell underground waste storage tanks at Hanford. This characterization work is being done in part to comply with Resource Conservation and Recovery Act requirements to identify contamination sources and to determine the nature and extent of the contamination from the single-shell tanks. The work will also assist with closure of the tanks under the Act.

The characterization program involves establishing a baseline of the contamination distribution of gamma-emitting radionuclides in the vadose zone by logging the

existing boreholes surrounding the tanks with spectral gamma-ray logging systems. Once the concentrations of the subsurface radionuclides are determined at a single borehole, these data or logs are correlated with other borehole log data to produce three-dimensional representations of the contamination plumes in the vadose zone. The logs and the visual representations provide a basic understanding of the contamination distribution; they can be used to guide more comprehensive characterization and provide a baseline for future data comparisons such as assessing at what rate certain contaminants have or are migrating.

This project, as planned, has inherent limitations. These limitations were understood in the original planning; however, as designed, the project serves as the initial investigation needed prior to beginning a thorough vadose zone characterization. First, the gamma-emitting radionuclides are assayed because they are much easier to detect and quantify, whereas many of the radionuclides and hazardous constituents that pose health and safety risks are not detected. The project is also limited to providing log assays of the contamination in existing boreholes. No new boreholes are being drilled for logging alone, though the equipment has been used to log three new characterization boreholes put in the SX Tank Farm in the 200-West Area. This includes the extension of borehole 41-09-39 to groundwater, results of which will be reported in next year's Hanford Site environmental report. Another limitation relates to questions about the representativeness of the three-dimensional contamination plume visualizations. The accurate determination of the distributions and quantification of contaminants is just beginning. Statistically rigorous cross-borehole correlations are not yet developed, thereby making the representativeness of portions of some visualizations questionable.

The baseline characterization program has been successful in its original objective by identifying the nature of the vadose zone contamination problem and locating areas needing further and more comprehensive characterization. The utility of the baseline characterization has been shown by the discovery of cesium-137 deeper in the vadose zone than previously predicted, thereby questioning the understanding of the mobility of cesium-137 at the Hanford Site.

The first step of the baseline characterization is to log the boreholes. The log data are then analyzed, interpreted, and reported in a tank summary data report for each tank. Once all tank summary data reports are complete for a particular tank farm, a more comprehensive tank farm report is prepared. The tank farm report provides a correlation of the data from all boreholes in the farm to produce an understanding of the distribution of contamination around the farm.

The logging operations for the baseline characterization began in 1995 and should be completed in early 1999. During 1997, 211 additional boreholes were logged surrounding tanks in the A, B, BX, and C Tank Farms in the 200-East Area.

Preparation of tank summary data reports also began in 1995. During 1997, 42 additional reports were prepared using data from boreholes logged in 1996 and 1997.

The first tank farm report was prepared in 1996. During 1997, tank farm reports were prepared for the AX Tank Farm in the 200-East Area and the TX, TY, and U Tank Farms in the 200-West Area. The BY Tank Farm report was primarily prepared in 1996 and was published in January 1997. It was discussed in last year's environmental report, so it will not be discussed here.

Also during 1997, improvements were made to the visualizations of the contamination. It was determined, with the help of the SX Tank Farm expert panel, that the amount of contamination carry-down during drilling could be significant. As a result, modifications were made to the visualizations to remove contamination that was thought to be due to contamination carry-down during drilling. Some borehole log data, showing isolated regions of contamination deep in the vadose zone that could not be correlated with similar regions in other boreholes, were attributed to contamination carry-down and those data were removed from the visualization database. Additionally, a gamma-ray spectrum shape factor analysis method was implemented, beginning with the logging done in fiscal year 1997. This analytical method was developed during 1996 and 1997 to provide information on the radial distribution of contamination around the boreholes. This method basically allows a qualitative assessment of the gamma-ray spectra to help differentiate between regions in the borehole where contamination is located adjacent to the casing versus regions where contamination is distributed uniformly in the formation or remote to the borehole. When used in conjunction with other analysis and interpretation methods, shape factor analysis helps in the identification of regions of contamination carry-down. Since implementation, the shape factor analytical method has resulted in additional improvements to the quality and accuracy of the visualizations.

The baseline characterization work in 1997 helped to identify several areas of concern that will require additional and more comprehensive characterization. This work also identified potential sources for suspected and known groundwater contamination plumes, providing a starting point for the more comprehensive vadose zone characterization work.

For a more comprehensive description of the single-shell tank vadose zone spectral gamma logging program and references to detailed reports, the reader is referred to Section 6.2, "Vadose Zone Characterization and Monitoring."

### 2.3.8.5 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 wastes into a low-radioactivity fraction and a high-radioactivity and transuranic fraction. In separate facilities, both fractions will be vitrified in 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 to Tri-Party Agreement milestones was approved, allowing DOE to proceed with the planned privatization of the initial pretreatment and immobilization function of the Tank Waste Remediation Program. The approach to privatization will be conducted in two phases.

Phase I 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 vitrify as an option in this phase. 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 the fixed-price privatization framework; 4) ascertain the financial viability of the private marketplace to accomplish the mission; 5) establish conditions for DOE to be a "smart buyer" and for private companies to be "smart providers" of treated waste products for Phase II; and 6) balance the private companies' objectives with DOE's objectives.

Phase I will be divided into two subparts. Subpart A includes a 20-month period for establishing the technical, operational, regulatory, and financial elements required by the contractors to provide waste treatment services at fixed unit prices. DOE selected two companies in 1997 to establish these requirements. Contracts were awarded to British Nuclear Fuels Ltd. and Lockheed Martin Advanced Environmental Systems to work on this part of Phase I. Both companies provided a proposal to DOE in 1997 to continue work on Phase I. In May 1998, DOE authorized British Nuclear Fuels Ltd. to proceed with Phase I, Subpart B, which consists of a 10- to 14-year period for providing waste treatment services in privatized facilities. DOE will order a minimum quantity of waste treatment services during this phase and may provide additional orders.

Phase II 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; 3) meet or exceed the Tri-Party Agreement benchmark performance milestones; and 4) as in Phase I, balance the private vendor's objectives with DOE's objectives. At the end of any contract, the contractor will deactivate all contractor-provided facilities.

## 2.3.9 Solid Waste Management Activities

### 2.3.9.1 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 operation in March

1997, the Waste Receiving and Processing Facility is staffed to analyze, characterize, and prepare drums for disposal of waste resulting from plutonium operations at Hanford. The 4,800-$m^2$ (52,000-$ft^2$) facility is near the Central Waste Complex in the 200-West Area (see Figure 1.0.2). The facility is designed to process approximately 6,800 drums and 80 boxes of waste annually for 30 years.

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 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 in Carlsbad, New Mexico for permanent storage. Materials requiring further processing to meet disposal criteria will be retained at Hanford pending treatment.

### 2.3.9.2 Radioactive Mixed Waste Disposal Facilities

The Radioactive Mixed Waste Disposal Facilities at the Hanford Site are the first in DOE's 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 Trenches 218-W-5, 31, and 34. Trench 34 is currently operating in a storage mode containing long-length contaminated equipment, macroencapsulated tubes, and a United States Navy reactor core basket. The facilities consist of rectangular landfills with approximate base dimensions of 76 by 30 m (250 by 100 ft). The bottoms of the 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 for 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 excavations that houses the sumps for leachate collection. Access to the bottom of the landfills is provided by ramps along the perimeters.

### 2.3.9.3 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 the 2706-T Building. 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 1997 included the following:

- performing content 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
- storing 27 metric tons (30 tons) of Shippingport, Pennsylvania pressurized water reactor spent fuel in a water basin.

Plans for upgrading the 2706-T Building liquid waste storage tank system were finalized in 1996. These upgrades will make the 2706-T tank system fully compliant with the regulations and will allow for improved liquid waste handling capabilities. Construction on this project started in January 1997; completion is expected by September 1998.

### 2.3.9.4 Radioactive Mixed Waste Treatment and Disposal

After years of accumulating and storing mixed waste at Hanford, emphasis turned to treatment and disposal during 1997. During the year, 490 $m^3$ (640 $yd^3$) of mixed

waste contained in 1,150 drums, boxes, and specialty containers were treated and/or disposed at the Hanford Site. The waste materials were obtained from a number of projects, and included the following:

- Mixed low-level debris (925 drums) was compacted, overpacked, and macroencapsulated in high-density polyethylene tubes using commercially available technology. This technology demonstration was jointly funded by DOE Waste Management Programs and Technology Development organizations.

- Three thermocouples that had been removed from underground radioactive waste storage tanks were macroencapsulated with grout infill and placed in the mixed waste trench for storage and ultimate disposal.

- A 22-$m^3$ (29-$yd^3$) United States Navy core basket was prepared and transported from the Central Waste Complex to the mixed waste trench where it is awaiting final disposal. The core basket contains radioactive debris generated from the decommissioning of nuclear submarine reactors and was encapsulated in a heavy steel shell.

- High-efficiency particulate air filters (196 $m^3$ [256 $yd^3$]) were disposed of.

- Stabilized Battelle Columbus sludge (3 $m^3$ [3.9 $yd^3$]) was disposed of.

- Contaminated soil (28 $m^3$ [36.6 $yd^3$] was disposed of.

- The cost of mixed waste treatment was avoided altogether on soils and high-efficiency particulate air filters that had been previously designated as mixed waste. The containers were carefully reanalyzed and, with the support of regulators, were redesignated as low-level waste and disposed of.

### 2.3.9.5 Radioactive Mixed Waste Treatment Contracts

In November 1995, a contract was awarded to Allied Technology Group, Inc. for thermal treatment of mixed waste in accordance with the Resource Conservation and Recovery Act and Toxic Substances Control Act. The contract provides for treating up to 3,585 $m^3$ (4,690 $yd^3$) of mixed waste over 5 years with five 1-year renewal options. Waste processing is scheduled to begin in fiscal year 2001.

During 1997, a competitive procurement was conducted for the processing of mixed waste requiring nonthermal treatment in accordance with the Resource Conservation and Recovery Act. The resulting contract provides for treatment of up to 1,660 $m^3$ (2,170 $yd^3$) of mixed waste debris and up to 200 $m^3$ (260 $yd^3$) of nondebris inorganic mixed waste. The contract, which was also awarded to Allied Technology Group, Inc., runs from fiscal years 1999 through 2001. These contracts, together with follow-on procurements, will provide cost-effective alternatives for continuing to treat mixed waste in the future.

### 2.3.9.6 Navy Reactor Compartments

Eleven defueled United States Navy reactor compartment disposal packages were received and placed in Trench 94 in the 200-East Area during 1997. This brings the total number received to 71. 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.

### 2.3.9.7 325 Building Hazardous Waste Treatment Units

The 325 Building hazardous waste treatment units in the 300 Area receive, store, and treat mixed and hazardous waste generated by Pacific Northwest National Laboratory programs. The units consist of the Shielded Analytical Laboratory and the Hazardous Waste Treatment Unit. These units are operating under final status granted in February 1998.

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 facility is used for bench-scale treatment of mixed and dangerous waste from various

Pacific Northwest National Laboratory programs and for treating transuranic and transuranic mixed waste by neutralization and stabilization.

### 2.3.9.8 Underground Storage Tanks

There are 15 underground storage tanks on the Hanford Site registered with the Washington State Department of Ecology (WAC 173-360). Four of the tanks contain gasoline or diesel fuel (two each) for vehicles and the remaining 11 are diesel storage tanks for supplying emergency diesel generators. Six of the 15 tanks (emergency diesel generator tanks) will be modified, replaced, or eliminated to meet new compliance standards for leak detection and inventory control that go into effect on December 22, 1998.

## 2.3.10 Liquid Effluent Activities

### 2.3.10.1 242-A Evaporator

Available storage space to support remediation of 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 two processing campaigns in 1997. Dilute waste from the double-shell tanks was processed, resulting in a waste volume reduction of 3.98 million L (1.05 million gal) while producing 4.72 million L (1.25 million gal) of process condensate. One campaign is scheduled for 1998.

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. 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 were discharged to the 200 Areas Treated Effluent Disposal Facility starting in 1997.

### 2.3.10.2 Liquid Effluent Retention Facility

The Liquid Effluent Retention Facility consists of three Resource Conservation and Recovery Act-compliant surface impoundments for storing and treating process condensate from the 242-A Evaporator and other aqueous wastes. The facility provides treatment through equalization of the flow and adjustment of pH of the feed to the 200 Areas Effluent Treatment Facility. The maximum capacity of the Liquid Effluent Retention Facility is 92 million L (24.3 million gal). 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 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. Aqueous waste is currently being received from both Resource Conservation and Recovery Act- and Comprehensive Environmental Response, Compensation, and Liability Act-regulated cleanup activities. Approximately 39 million L (10.3 million gal) of aqueous waste were stored in the basins at the end of 1997.

### 2.3.10.3 200 Areas Effluent Treatment Facility

The 200 Areas Effluent Treatment Facility is a series of unit operation providing treatment and storage for hazardous and radioactive aqueous waste. The treated effluent is stored in verification tanks, sampled and analyzed, and discharged to the State-Approved Land Disposal Site (north of the 200-West Area). The treatment process constitutes best available technology, and the unit operations include 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; approximately 59 million L (15.5 million gal) of aqueous waste were treated in 1997.

The treated effluent is sampled to verify that the concentrations of radioactive and hazardous waste constituents have been reduced to regulatory levels; then discharged via a dedicated pipeline to the State-Approved Land Disposal Site. The disposal site is located north of the 200-West Area and 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 site maximizes the time for migration to the Columbia River to allow for

radioactive decay. The Final Delisting (40 CFR 261, Appendix IX, Table 2) excludes the treated effluent from the requirements of dangerous waste regulations and the Resource Conservation and Recovery Act; however, certain effluent quality restrictions are imposed. The disposal site is permitted by the Washington State Department of Ecology under WAC 173-216. The permit requires monitoring of the groundwater and the treated effluent to ensure that concentrations for certain constituents are not exceeded.

Secondary waste from treating aqueous waste is 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 and treatment facility. The secondary waste from treating regulated aqueous waste 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. The secondary waste from treating Comprehensive Environmental Response, Compensation, and Liability Act-regulated aqueous waste is transferred to the Environmental Restoration Disposal Facility near the 200-West Area for disposal.

### 2.3.10.4 200 Areas Treated Effluent Disposal Facility

This disposal facility is a collection and disposal system for non-Resource Conservation and Recovery Act-permitted waste streams that have implemented "best available technology/all known and reasonable treatment." Implementation of regulatory "best available technology/all known and reasonable treatment" is the responsibility of the generating facilities. Generating facilities currently include the Plutonium Finishing Plant, 222-S Laboratory, T Plant, B Plant and Waste Encapsulation and Storage Facility, 242-A Evaporator, A Tank Farm, 244-AR Vault, and 242-A-81 Water Services Building.

This facility began operation in April 1995 and has a capacity of 12,900 L/min (3,400 gal/min). Approximately 696 million L (184 million gal) of treated effluent were discharged in 1997. 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 and the groundwater to ensure that concentrations for certain constituents are not exceeded.

### 2.3.10.5 300 Area Treated Effluent Disposal Facility

Wastewater 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 wastewater 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 wastewaters, with a storage capacity of up to 5 days at the design flow rate of 1,100 L/min (300 gal/min). 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 operation in December 1994. In 1997, approximately 331 million L (87 million gal) of wastewater were treated.

### 2.3.10.6 340 Waste Handling Facility

This facility provides receipt, storage, and loadout capability for low-level mixed 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 204-AR Unloading Facility in the 200-East Area for neutralization and transfer to double-shell tanks for storage. The 340 Waste Handling Facility does not have a Resource Conservation and Recovery Act permit for storage; therefore, wastes cannot be stored for more than 90 days.

The facility will cease receiving waste in September 1998 when the new waste handling facility, with storage and truck loadout capability, is provided in the 325 Building. The 340 facility will then be cleaned out, decontaminated, and decommissioned.

### 2.3.10.7 Phase II Liquid Effluent Streams

DOE committed to implement "best available technology/ all known and reasonable treatment" for nine wastewater streams and to permit the streams under WAC 173-216 by October 1997. This activity was required by the Washington State Department of Ecology Consent Order #DE 91NM-177 and Tri-Party Agreement Milestone M-17-00B and included 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) was completed in 1997 and connected 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 wastewater (including 282-E and 283-E), and B Plant/Waste Encapsulation Storage Facility cooling water. Another stream, the A Tank Farm cooling water, was connected to the 200 Areas Treated Effluent Disposal Facility as part of Project W-030. State waste discharge permit #ST-4502 was revised so that additional streams may be disposed of to the 200 Areas Treated Effluent Disposal Facility.

### 2.3.10.8 Miscellaneous Streams

Miscellaneous streams are lower priority wastewater 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/RL-93-94, Rev. 1) was approved by the Washington State Department of Ecology in February 1995. That plan and schedule ensure 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 includes more than 640 miscellaneous streams. Not included in the inventory are 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. 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 have been submitted or permits have been issued for the following:

- hydrotesting, maintenance, and construction discharges; permit #ST-4508 was issued in May 1997
- cooling water discharges and uncontaminated steam condensate; permit #ST-4509 was issued in May 1998
- stormwater discharges; permit application to be submitted in 1998.

Another categorical permit was planned for vehicle washing, coal ramp washdowns, and safety shower discharges. These streams have either been eliminated or were included in another existing permit. A best management practices report (DOE/RL-96-40) was submitted to the Washington State Department of Ecology in August 1997, identifying preferred options and an implementation plan to remediate those streams that have a potential to affect the groundwater.

## 2.3.11 Revegetation and Mitigation Planning

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. Revegetation/mitigation plans will include the use of native plant species (seeds and shrubs) as appropriate to restore the areas disturbed by remediation activities.

The *Hanford Site Biological Resources Management Plan* (DOE/RL-96-32) 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/RL-96-88) contains strategy that is part of the broader biological resource policy contained in the biological resources management plan (DOE/RL-96-32). The strategy 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 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 site personnel in implementing mitigation in a cost-effective and timely manner.

# 2.4 Environmental Occurrences

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Onsite and offsite environmental releases of radioactive and regulated materials are reported to DOE and other federal and state agencies as required by law. The specific agencies notified depend on the type, amount, and location of the individual occurrences. In some cases, an occurrence may be under continuing observation and evaluation. All emergency, unusual, and off-normal occurrences at the Hanford Site are 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 was one emergency occurrence report filed in 1997 and one emergency occurrence filed in early 1998.

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 1997 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." Several of these occurrences are discussed in Section 2.2.5.4, "Resource Conservation and Recovery Act Inspections;" Section 2.2.6.1, "Clean Air Act Enforcement Inspections;" and Section 2.2.7, "Clean Water Act." The following summarizes some of the emergency and off-normal environmental occurrences not previously discussed or that were not discussed in detail.

For each occurrence summarized below, the title and report number from the Hanford Site Occurrence Notification Center is given in the heading.

## 2.4.1 Emergency Occurrences

- Chemical Explosion at Plutonium Reclamation Facility
  (RL-PHMC-PFP-1997-0023)

On May 14, 1997, at 7:53 p.m., a chemical explosion occurred at the Plutonium Reclamation Facility in the 200-West Area. This facility is part of the Plutonium Finishing Plant and is located approximately 50 km (30 mi) north of Richland, Washington. Additional information on the emergency occurrence is provided in two DOE documents (DOE/RL-97-59, DOE/RL-97-62).

The facility was used to recover plutonium from plutonium-bearing scrap and was in operation from 1964 to 1987, when it was placed in an interim standby status. In 1992 and 1993, in preparation for a readiness demonstration, several hundred gallons of hydroxylamine nitrate solution in dilute nitric acid was prepared in Tank A-109 (the 1,500 L [400-gal] stainless-steel tank involved in the explosion) in Room 40 of the facility. On December 22, 1993, the readiness demonstration was cancelled and the facility, including Tank A-109, was placed in a short-term shutdown on the direction of DOE Richland Operations Office. Some of the acid solution was left in the tank. Between December 1993 and May 1997, the tank experienced water loss because of evaporation. The loss of water concentrated the solution until conditions were reached that caused the normally unreactive solution to undergo a chemical reaction. The reaction generated a rapid release of gases, which generated pressure inside the tank. The pressure blew the lid off the tank, severely damaged Room 40, and cut a small water line. Damage to the facility included the deformation of a wall, the interior doors, and the roof above Room 40.

Environmental releases associated with the explosion included a yellow-brown-colored gaseous plume coming from the main Plutonium Finishing Plant stack and water that was discharged from the severed line. Real-time air measurements of the chemicals released were not possible. Laboratory studies after the accident revealed that the airborne release would have likely consisted of nitric acid, nitrous oxide, various oxides of nitrogen, and water vapor. Of these, only nitric acid and the oxides of nitrogen are recognized to pose a potential health hazard. Atmospheric dispersion modeling was performed to estimate the maximum concentrations at ground level, and these concentrations were below applicable occupational exposure limits. The results of the dispersion modeling indicated that the offsite concentrations of chemicals were negligible. Based on extensive sampling, surveys, and stack monitoring data, no radioactivity was released from the facility stack or the damaged area of the roof. Water from the severed line flooded the building and some of it flowed outside through doorways. Surveys inside and outside the building revealed radioactive contamination on the first floor of the facility and a small area outside that was isolated. The radioactive contamination in the area outside the facility was slightly above background levels. This contamination was likely the result of water flowing across the walls and floors of previously contaminated areas of the facility.

No one was present in Room 40 at the time of the accident. During the initial stages of the emergency response, eight workers passed under the plume path when directed to report to the on-scene emergency center. All eight workers were transferred to and later released from a local medical center. Ongoing occupational health evaluations are being provided as necessary. For further information, see DOE/RL-97-62.

- Small Bottle of Suspect Material Discovered – Alert-Level Emergency Declared (RL-PHMC-327FAC-1998-0002; Initial Update Report)

On January 28, 1998, a small bottle labeled "picric acid" and containing an unknown dry solid was discovered in a crawlspace off the basement of the 327 Building in the 300 Area. Building personnel had entered the crawlspace to perform an inspection for future steam line work. The bottle was found in a plastic pail next to the crawlspace wall. Because of the location of the bottle and because the dry solid form of picric acid could potentially explode if exposed to flame or friction, an alert-level emergency (defined as the potential degradation of the level of safety of the facility) was declared. The facility was evacuated, appropriate notifications were made, an incident command post was established, and protective actions were initiated. An entry plan was developed and, following approval, an entry was made into the crawlspace to videotape the bucket, container, and surrounding area. The alert-level emergency was terminated on January 28, 1998 on discovery that the quantity of picric acid involved (approximately 35 to 50 g [0.077 to 0.11 lb]) could not result in a large-enough explosion to compromise the facility. The bottle and its contents were stabilized and removed from the facility on January 30, 1998. Subsequent analysis confirmed that the material was picric acid. No personal injury, personal contamination, or environmental releases occurred as a result of this event.

## 2.4.2 Off-Normal Occurrences

- Environmental Restoration Disposal Facility #1 Leachate Tank Leak (RL-BHI-ERDF-1997-0001)

On January 1, 1997, the leachate tanks at the Environmental Restoration Disposal Facility near the 200-West Area were discovered to be leaking. Site personnel discovered a 1- by 1-m (3- by 3-ft) puddle at the base of the tanks below a flange to a crossover pipe between two tanks. The amount of the leak material is believed to be less than 190 L (50 gal). The soil beneath the flange was removed and disposed of in the Environmental Restoration Disposal Facility. The radiological and hazardous chemicals present in the leachate were determined not to pose a hazard to the environment. However, the EPA requires 100% containment of the leachate and notification of any leachate spill.

While investigating this occurrence, it was also noted that the primary liners in the tanks had leaked (each tank has two liners). The secondary liners were not identified to be leaking, and it is believed that no leachate was discharged to the environment from the liner leaks. The leachage was removed from the tanks and the liners were repaired.

- Abovenormal Stack Emissions Resulting from Operation of East K-3 Filter Bank at the Waste Encapsulation and Storage Facility (RL-PHMC-WESF-1997-0001)

On January 1, 1997, elevated emissions were recorded from the 296-B-10 Stack at the Waste Encapsulation and

Storage Facility in the 200-East Area. This nonroutine release lasted for a maximum of 90 minutes and resulted in an additional dose equivalent to the maximally exposed individual of 0.000002 mrem. The elevated emissions were mitigated by switching the facility's exhaust system to an alternate bank of high-efficiency particulate air filters.

It has since been determined that the most probable contributing factor to this release was extensive flooding (possibly from snowmelt) experienced in the area of the K-3 filter housing, which is located below grade. Portions of the exhaust ductwork were partially submerged, and water worked its way into the ductwork downstream of the high-efficiency particulate air filters. This water then entered the air stream, carrying with it some preexisting contamination from the inside of the duct. All high-efficiency particulate air filter banks have since been tested to verify filter integrity.

- Overflow of Wastewater from Septic System Servicing Trailer at 222-S Laboratory (RL-HMC-ANALLAB-1997-0003)

A septic system servicing the MO0291 trailer at the 222-S Laboratory complex in the 200-West Area overflowed approximately 110 L (30 gal) of waste on January 22, 1997. The overflow was caused by a tripped pump breaker, which was reset. Sanitary maintenance sent a septic pumper truck and removed approximately 6,400 L (1,700 gal) of waste on January 22, 1997. Chlorine bleach was used as a disinfectant on the affected areas.

- Procedural Noncompliance – Onsite Shipping of Hazardous Material from 100-DR-1 (RL-HI-REMACT-1997-0003)

A shipment of hazardous waste was initiated at Operable Unit 100-DR-1 in the 100-D Area on March 21, 1997. Approximately 2 to 4 $m^3$ (3 to 5 $yd^3$) of material containing 13,700 mg/kg of lead were transported to and disposed of in the Environmental Restoration Disposal Facility, exceeding the 5,000-mg/kg maximum limit. This exceedance was discovered on March 24, 1997 and reported on March 25, 1997. This material was removed from the facility and transported back to the originating operable unit, pending final disposition. The material was then shipped back to the facility, encapsulated in concrete, and disposed of in a trench. Because of complete containment within the liners, there was no environmental release.

- Unaccounted-for Loss of Radiologically Contaminated Water from 105-N Lift Station (RL-BHI-NREACTOR-1997-0010)

On April 14, 1997, N Basin, in the 100-N Area, project personnel noticed a decrease in the water level in the pump well (sump) of the 105-N Lift Station. This pump well is used for the collection of water from N Reactor contaminated drains, with most of the recent inventory of water coming from overflow from the 105-N Basin and rainwater. The impact to the environment should be minimal because the loss of water was approximately 25% of the Comprehensive Environmental Response, Compensation, and Liability Act reportable quantity and approximately 50% of the DOE reportable limit. The lift station has been drained and deactivated.

- Spill of Regulated Substance Reported to City of Richland (RL-PNNL-PNNLBOPER-1997-0020)

On July 15, 1997, approximately 9.5 L (2.5 gal) of 50% ethylene glycol coolant were spilled down a floor drain in Room 442 of the Research Technology Laboratory (520 Building) in the Richland North Area. The spill occurred during routine maintenance of a piece of research equipment. The floor drain is connected to the city of Richland sewer. The city of Richland was notified as required There was no impact to the environment from this release.

- 241-BY Transfer Line SN-200 Potentially Leaking (RL-PHMC-TANKFARM-1997-0074)

On September 11, 1997, approximately 950 L (250 gal) of water, which contained 76 L (20 gal) of dilute citric acid water, potentially leaked from transfer line 200-SN. The transfer line is in a controlled contamination area inside the BY single-shell tank farm in the 200-East Area. The addition of the liquid was part of an attempt to clear a blockage in the line that likely resulted from the line being inactive for an extended period of time. The liquid addition was halted when the liquid did not arrive at the expected end point. All interconnected pits were inspected for water addition. The transfer line was inspected for indications of a pipe leak; however, no moisture or radiation were detected.

- High Tritium Level in Groundwater Monitoring Well K-109A
  (RL-PHMC-KBASINS-1997-0022)

On September 25, 1997, a routine monthly sample at groundwater well 199-K-109A, near the 105-KE D Sump in the 100-KE Area was collected. The analysis revealed a reading of 386,200 pCi/L of tritium. On October 7, 1997 a second water sample was collected and analyzed by K Basin personnel that showed 386,300 pCi/L of tritium. The tritium concentrations increased over three times from recent measurements. The most likely cause of the elevated tritium concentration is that a steady increase in groundwater levels in this area led to a leaching of existing contamination from past-practice waste sites associated with reactor operations.

- Elevated Level of Regulated Contaminant Found in Environmental Sample of Receiving Water for 300 Area Treated Effluent Disposal Facility
  (RL-PHMC-300LEF-97-0005)

On October 10, 1997, the 300 Area Treated Effluent Disposal Facility received laboratory analysis results for the annual Columbia River water samples taken upriver and downriver of the facility's discharge point on September 17, 1997. The results indicated radium-226 at 8.3 pCi/L and radium-228 at 5.9 pCi/L downstream of the discharge point. The maximum contaminant level specified by the Washington State Department of Natural Resources land lease for the facility are 3 pCi/L for radium-226 and 5 pCi/L for radium-228. Reanalysis of the samples was requested, and the results were still above the permit limits. Notifications were made to the Washington State Department of Health. A review of the data taken from the effluent samples prior to the discharge indicated that during the facility's operating history, no effluent sample exceeded the detection limits for total radium (0.07 to 0.23 pCi/L). Biweekly compliance sampling for effluent was conducted on the same date as the elevated river sample, with undetected levels of total radium (0.16 pCi/L detection limit). These data indicate that the 300 Area Treated Effluent Disposal Facility may not be the source of the contamination.

- 200-ZP-1 Interim Action Pump-and-Treat System Exceeds Maximum Contaminant Level for Carbon Tetrachloride
  (RL-BHI-GROUNDWTR-1997-0003)

On December 26, 1997, liquid effluent from the 200-ZP-1 interim action pump-and-treat system in the 200-West Area was reported as exceeding its discharge criterion of 5 µg/L for carbon tetrachloride. The system collects groundwater containing carbon tetrachloride from six extraction wells, reduces the contamination level, and releases the water to a well upgradient of the extraction wells and within the existing plume boundary. Treated liquid releases on December 26, 1997 contained carbon tetrachloride levels of approximately 11 µg/L. The cause of the increased carbon tetrachloride in the effluent stream was associated with the die-off of green algae in the stripper column coupled with normal degradation in the operating efficiency of the stripper column. Corrective actions, such as adding packing material, were taken to prevent future occurrences.

- Diesel Fuel Station Spill
  (RL-PHMC-FSS-1977-0001)

On February 4, 1997, diesel fuel was discovered on soil near the 6291 Building (Fuel Station) in the 200-East Area. The fuel station was shut down for a short time. No dangerous waste or radioactive materials were released. The diesel contamination was above the regulatory limit (WAC 173-340) level, but below the reportable quantity under 40 CFR 302.4. It is expected that naturally occurring bacteria will reduce the level of contamination without the need for aggressive remediation.

# 2.5 Waste Management and Chemical Inventories

*L. P. Diediker*

## 2.5.1 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, or 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 handled in several ways. High-level waste is stored in single- and double-shell tanks. Low-level waste is stored in double-shell tanks or on storage pads or is buried. The method used to manage low-level waste depends on its source, composition, and concentration. 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/RL-98-08). Dangerous wastes are treated, stored, and prepared for disposal at several onsite facilities. Also, dangerous wastes generated on the site are also shipped offsite for disposal, destruction, or recycling.

Historically, nondangerous wastes generated on the Hanford Site were buried in the Solid Waste Landfill near the 200 Areas. Beginning in December 1995, nondangerous wastes were disposed of at the city of Richland's municipal landfill located at the southern edge of the Hanford Site boundary. Since 1996, medical and nonregulated drummed wastes have been shipped to Waste Management of Kennewick; asbestos has been shipped to Basin Disposal, Inc. in Pasco and to the Environmental Restoration Disposal Facility near the 200-West Area.

Nondangerous 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 decommissioning projects in the 100 Areas are buried in situ or in designated sites in the 100 Areas.

An annual report documents the quantities and types of solid wastes generated onsite, received from offsite, shipped offsite, and disposed of at the Hanford Site (HNF-EP-0125-10). Solid waste program activities are regulated by the Resource Conservation and Recovery Act and Toxic Substances Control Act, discussed in Section 2.2, "Compliance Status." Solid waste quantities generated onsite, received from offsite, shipped offsite, and disposed of at the Hanford Site from 1992 through 1997 are shown in Tables 2.5.1 through 2.5.3. Table 2.5.4 provides a detailed summary of the radioactive solid wastes stored or disposed of in 1997.

The quantities of liquid wastes generated in 1997 and stored in underground storage tanks are included in the annual dangerous waste report (DOE/RL-98-08). Table 2.5.5 is a summary of the liquid wastes generated from 1992 through 1997 stored in underground tanks.

**Table 2.5.1.** Quantities of Solid Wastes[a] Generated on the Hanford Site, kg (lb)

| Waste Category | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|
| Mixed | 48,600<br>(107,163) | 150,000<br>(330,750) | 568,000<br>(1,252,440) | 132,000<br>(291,060) | 199,000<br>(438,795) | 442,000<br>(974,610) |
| Radioactive | 683,000<br>(1,506,015) | 1,120,000<br>(2,469,600) | 1,390,000<br>(3,064,950) | 1,890,000<br>(4,167,450) | 3,870,000<br>(8,533,350) | 6,590,000<br>(14,530,950) |

(a) Solid waste includes containerized liquid waste.

**Table 2.5.2.** Quantities of Solid Wastes[a] Received from Offsite, kg (lb)

| Waste Category | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|
| Mixed | 40,900<br>(90,185) | 208,000<br>(458,640) | 96,000<br>(211,680) | 52,800<br>(116,424) | 2,070<br>(4,564) | 3,560<br>(7,850) |
| Radioactive | 1,010,000<br>(2,227,050) | 1,590,000<br>(3,505,950) | 1,360,000<br>(2,998,800) | 1,310,000<br>(2,888,550) | 1,670,000<br>(3,682,350) | 1,430,000<br>(3,153,150) |

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

**Table 2.5.3.** Quantities of Hazardous Wastes[a] Shipped Offsite, kg (lb)

| Waste Category | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|
| Containerized | 181,000<br>(399,105) | 124,000<br>(273,420) | 267,000<br>(588,735) | 224,000<br>(493,920) | 590,000<br>(1,300,950) | 110,000<br>(242,550) |
| Bulk Solids | 433,000<br>(954,765) | 250,000<br>(551,250) | 2,870,000<br>(6,328,350) | 478,000<br>(1,053,990) | 0 | 335,000<br>(738,675) |
| Bulk Liquids | 11,100<br>(24,476) | 94,000<br>(207,270) | 249,000<br>(549,045) | 130,000<br>(286,650) | 98,800<br>(217,854) | 5,025,000<br>(11,080,125) |
| Total | 625,000[b]<br>(1,378,125) | 468,000[c]<br>(1,031,940) | 3,390,000[d]<br>(7,474,950) | 832,000<br>(1,834,560) | 689,000<br>(1,519,245) | 5,470,000<br>(12,061,350) |

(a) Does not include Toxic Substances Control Act wastes.
(b) Includes 419,000 kg (923,895 lb) from demolition of 2727-S Building, 200-West Area.
(c) Includes 250,000 kg (551,250 lb) from demolition of 190-B Building, 100-B Area.
(d) Includes 2,660,000 kg (5,865,300 lb) from North Slope cleanup and 161,000 kg (355,005 lb) from carbon tetrachloride soil extraction near the Plutonium Finishing Plant, 200-West Area.

**Table 2.5.4**. Radioactive Solid Wastes Stored or Disposed of on the Hanford Site, 1997

| Constituent | Quantity, Ci | |
|---|---|---|
| | Low Level[a] | Transuranic[b] |
| Tritium | 47,000 | 41 |
| Carbon-14 | 20 | 0.21 |
| Manganese-54 | 1.5 | 58 |
| Iron-59 | 0.00062 | 0 |
| Cobalt-60 | 21,000 | 41 |
| Nickel-63 | 14,000 | 0 |
| Strontium-90 | 1,100 | 3,900,000[c] |
| Yttrium-90 | 1,100 | 3,900,000[c] |
| Technetium-99 | 0.36 | 1.0 |
| Cesium-137 | 1,500 | 5,000,000[c] |
| Barium-137m | 1,400 | 4,800,000[c] |
| Thorium-232 | 0.026 | 0.000093 |
| Uranium-233 | 0.053 | 0 |
| Uranium-234 | 8.0 | 0.0037 |
| Uranium-235 | 0.14 | 0.0026 |
| Uranium-236 | 0.0092 | 0.00022 |
| Uranium-238 | 9.5 | 0.0023 |
| Neptunium-237 | 0.01 | 0.000046 |
| Plutonium-238 | 0.87 | 91 |
| Plutonium-239 | 5.1 | 300 |
| Plutonium-240 | 1.8 | 120 |
| Plutonium-241 | 120 | 8,500 |
| Plutonium-242 | 0.0011 | 0.071 |
| Americium-241 | 2.0 | 31 |
| Americium-243 | 0.014 | 2.5 |
| Curium-244 | 0.48 | 2.5 |

(a) The quantities of low-level wastes include both radioactive and mixed waste totals.
(b) Transuranic waste quantities (>100 nCi/gm) also include both radioactive and mixed transuranic waste.
(c) Glass logs (vitrified waste) from Germany.

**Table 2.5.5**. Quantities of Bulk Liquid Wastes[a] Generated and Stored on the Hanford Site, L (gal)

| 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|
| 12,600,000 | 22,200,000 | 10,700,000 | 18,200,000 | 2,420,000 | 11,300,000 |
| (3,328,920) | (5,865,240) | (2,826,940) | (4,808,440) | (639,364) | (2,985,460) |

(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 2.5.6.** Average Balance of Ten Chemicals Stored in Greatest Quantity on the Hanford Site, 1997

| Hazardous Chemical | Average Quantity, kg (lb) |
|---|---|
| Coal | 7,500,000 (16,537,500) |
| Mineral oil | 1,800,000 (3,969,000) |
| Sodium | 1,100,000 (2,425,500) |
| Diesel fuel (Grades 1 and 2) | 590,000 (1,300,950) |
| Crystalline silica (quartz, cristobalite, tridymite) | 430,000 (948,150) |
| No. 6 fuel oil | 390,000 (859,950) |
| Bentonite | 360,000 (793,800) |
| Ethylene glycol | 250,000 (551,250) |
| Argon | 95,000 (209,475) |
| Carbon | 94,000 (207,270) |

## 2.5.2 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 Section 2.2, "Compliance Status"). The 1997 Tier Two Emergency and Hazardous Chemical Inventory (DOE/RL-98-17) was issued in February 1998 in compliance with Section 312 of the Act. Table 2.5.6 summarizes the information reported, listing the 10 chemicals stored in greatest quantity on the Hanford Site in 1997.

# 3.0 Facility-Related Monitoring

The following sections include information about facility-related environmental monitoring programs at the Hanford Site, including effluent monitoring (Section 3.1) and near-facility environmental monitoring (Section 3.2).

The monitoring of effluents and contaminants at Hanford Site facilities is necessary to determine the effects these materials may have on the public, workers at the site, and the environment. Effluent monitoring is conducted by the various site contractors at their facilities pursuant to requirements in DOE Order 5400.1. At the Hanford Site, effluent monitoring includes 1) collection of samples for analyses, 2) measurements of liquid and airborne effluents for the purposes of characterizing and quantifying contaminants released to the environment, 3) providing source terms for assessing potential impacts to the public, 4) providing a means to control effluents at or near the point of discharge, and 5) 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, waste storage and disposal units, and remediation efforts.

More detailed program sampling and effluent information is contained in *Hanford Site Near-Facility Environmental Monitoring Annual Report, Calendar Year 1997* (HNF-EP-0573-6) and in *Environmental Releases for Calendar Year 1997* (HNF-EP-0527-7).

# 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 the comprehensive Hanford Site environmental monitoring plan (DOE/RL-91-50, Rev. 2).

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 gross alpha and beta activity and, as warranted, specific radionuclides. Nonradioactive constituents are also either monitored or sampled, as applicable.

Small quantities of tritium, carbon-14, cobalt-60, strontium-90, technetium-99, antimony-125, iodine-129, cesium-134, cesium-137, radon-220, radon-222, uranium-234, uranium-235, uranium-238, neptunium-237, 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 naturally occurring concentrations. The 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 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 recent years. In 1997, releases of radioactive and nonradioactive constituents in effluents were less than applicable standards.

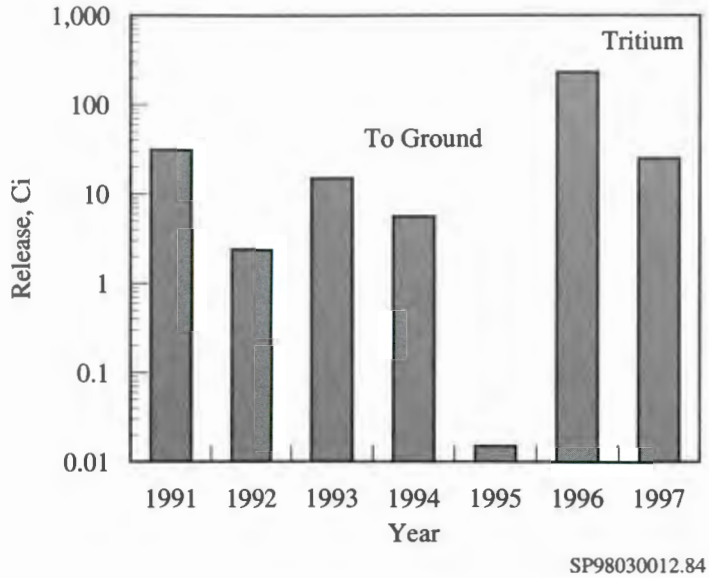
Effluent release data are documented in several reports, in addition to this one, and all are available to the public. For instance, the U.S. Department of Energy (DOE) annually submits to the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Health a report of radioactive airborne emissions from the site (DOE/RL-98-33), in compliance with Title 40, Code of Federal Regulations, Part 61 (40 CFR 61), National Emission Standards for Hazardous Air Pollutants, and Washington Administrative Code (WAC) 246-247, Radiation Protection—Air Emissions. Data quantifying the radioactive liquid and airborne effluents discharged by the site management and integration contractor and its enterprise companies and the environmental restoration contractor are reported to DOE annually in the environmental releases report (HNF-EP-0527-7). 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.

## 3.1.1 Airborne Emissions

### 3.1.1.1 Radioactive Airborne Emissions

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

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



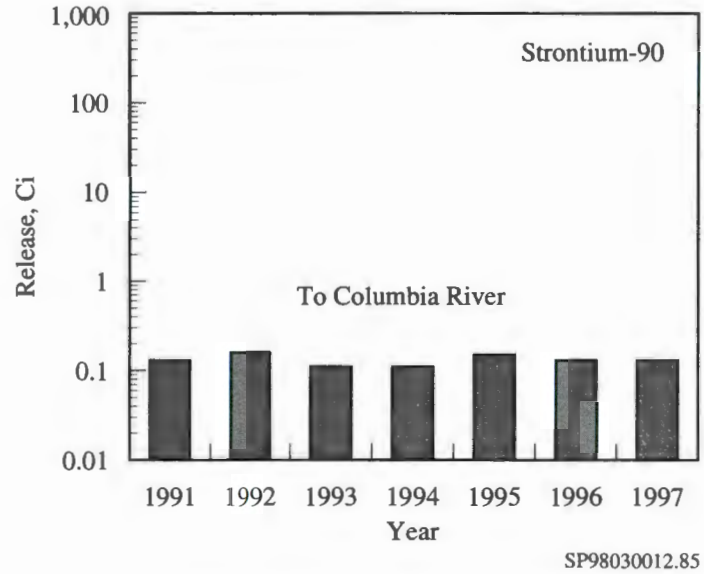




**Figure 3.1.1**. Liquid Releases of Selected Radionuclides from Hanford Site Facilities, 1991 Through 1997

to the environment, usually from a stack or vent. Samples are analyzed for gross alpha and beta activity, as well as selected radionuclides. The selection of the specific radionuclides 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, and 400 Areas. The sources for these emissions are summarized below.

- In the 100 Areas, emissions originate from the deactivation of N Reactor, the two water-filled storage basins (K Basins) containing irradiated fuel, a recirculation facility that filters radioactive water from

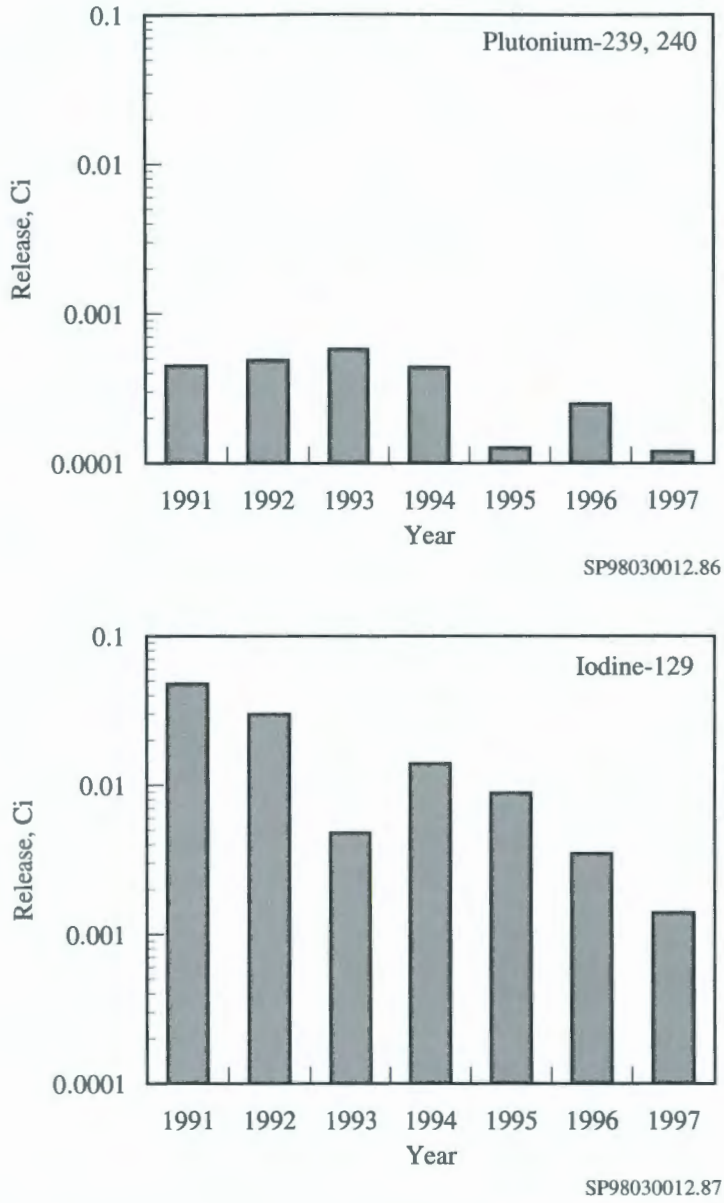



**Figure 3.1.2**. Airborne Releases of Selected Radionuclides from Hanford Site Facilities, 1991 Through 1997

the N Reactor basin that was used for storage of irradiated fuel, and a radiochemistry laboratory. Five radioactive emission points were active in the 100 Areas during 1997.

- 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 Laboratory, underground tanks for storage of high-level radioactive waste, and waste evaporators. During 1997, 54 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 1997, 27 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 1997. The 400 Area had five radioactive emission discharge points active during 1997.

A summary of the Hanford Site's 1997 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.

### 3.1.1.2 Nonradioactive Airborne Emissions

Nonradioactive air pollutants emitted from power generating and chemical processing facilities are monitored when activities at a facility are known to generate potential 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 all located in the 200-East Area. Ammonia emissions are monitored only when activities at these facilities are capable of generating them. In 1997, the 242-A Evaporator operated for several months, producing reportable ammonia emissions. Also, the 200-West Area tank farms produced reportable ammonia emissions in 1997. The ammonia releases from the 242-A Evaporator and tank farms in the 200 Areas are summarized in Table 3.1.2.

Onsite operating power plants 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 in WAC 173-400. Power plant emissions are calculated from the quantities of fossil fuel consumed, using EPA-approved formulas.

In March 1997, DOE issued an energy savings performance contract to replace the Hanford Site's coal- and oil-fired boilers with smaller, cleaner operating, and more energy efficient diesel- and natural gas-fired boilers. On December 15, 1997, operation of the 200-West Area's package boiler ceased. On December 29, 1997, operation of the Hanford Site's last coal-fired boiler ceased and 14 new diesel-fired boilers came on-line in the 200 Areas.

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 the EPA's permission. Table 3.1.2 summarized the 1997 emissions of nonradioactive constituents (it should be noted that the 100, 400, and 600 Areas have no nonradioactive emission sources of regulatory concern). Table 3.1.2 also included emissions estimates from the 200-West Area's carbon tetrachloride vapor extraction project, even though these emissions do not require reporting because they are below reportable quantities.

## 3.1.2 Liquid Effluents

### 3.1.2.1 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 wastewater from laboratories and chemical sewers. These wastewater streams are sampled and analyzed for gross alpha and beta activity, as well as selected radionuclides.

Only facilities in the 200 Areas discharged radioactive liquid effluents to ground disposal facilities in 1997. A summary of radioactive liquid effluents discharged to the 200 Areas' ground disposal facilities in 1997 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.

### 3.1.2.2 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

**Table 3.1.1.** Radionuclides Discharged to the Atmosphere at the Hanford Site, 1997

| | | Release, Ci[a] | | | | |
|---|---|---|---|---|---|---|
| Radionuclide | Half-Life | 100 Areas | 200-East Area | 200-West Area | 300 Area | 400 Area |
| Tritium (as HTO)[b] | 12.3 yr | NM[a] | NM | NM | $1.5 \times 10^{0}$ | $7.9 \times 10^{0}$ |
| Tritium (as HT)[b] | 12.3 yr | NM | NM | NM | $2.1 \times 10^{1}$ | NM |
| Cobalt-60 | 5.3 yr | ND[a] | ND | ND | $8.3 \times 10^{-10}$ | NM |
| Zinc-65 | 244.4 d | ND | ND | ND | ND | NM |
| Strontium-90 | 29.1 yr | $2.1 \times 10^{-5}$ | $2.5 \times 10^{-4}$[c] | $3.0 \times 10^{-4}$[c] | $1.5 \times 10^{-5}$[c] | NM |
| Zirconium-95 | 64.02 d | ND | ND | ND | ND | NM |
| Ruthenium-106 | 368 d | ND | ND | NM | ND | NM |
| Tin-113 | 115.1 d | ND | ND | NM | ND | NM |
| Antimony-125 | 2.77 yr | $3.7 \times 10^{-9}$ | ND | NM | ND | NM |
| Iodine-129 | $1.6 \times 10^{7}$ yr | NM | $1.4 \times 10^{-3}$ | NM | ND | NM |
| Iodine-131 | 8.040 d | NM | ND | NM | ND | ND |
| Cesium-134 | 2.1 yr | ND | ND | ND | ND | NM |
| Cesium-137 | 30 yr | $5.5 \times 10^{-5}$ | $9.1 \times 10^{-4}$ | $7.7 \times 10^{-9}$ | $7.9 \times 10^{-7}$ | $4.6 \times 10^{-6}$[d] |
| Europium-152 | 13.6 yr | ND | ND | ND | ND | NM |
| Europium-154 | 8.8 yr | ND | ND | ND | ND | NM |
| Europium-155 | 5 yr | ND | ND | ND | ND | NM |
| Radon-220 | 56 s | NM | NM | NM | $5.0 \times 10^{1}$ | NM |
| Radon-222 | 3.8 d | NM | NM | NM | $1.6 \times 10^{0}$ | NM |
| Plutonium-238 | 87.7 yr | $5.8 \times 10^{-7}$ | $1.8 \times 10^{-7}$ | $2.2 \times 10^{-6}$ | $9.5 \times 10^{-10}$ | NM |
| Plutonium-238,240 | $2.4 \times 10^{4}$ yr | $3.9 \times 10^{-6}$[e] | $6.3 \times 10^{-6}$[e] | $1.1 \times 10^{-4}$[e] | $1.1 \times 10^{-6}$[e] | $3.8 \times 10^{-7}$[e] |
| Plutonium-241 | 14.4 yr | $4.0 \times 10^{-5}$ | $6.4 \times 10^{-6}$ | $4.6 \times 10^{-5}$ | NM | NM |
| Americium-241 | 432 yr | $2.5 \times 10^{-6}$ | $4.8 \times 10^{-6}$ | $2.0 \times 10^{-5}$ | $6.5 \times 10^{-9}$ | NM |

(a) 1 Ci = $3.7 \times 10^{10}$ Bq; NM = not measured; ND = not detected.
(b) HTO = tritiated water vapor; HT = elemental tritium.
(c) This value includes gross beta release data. Gross beta and unspecified beta results assumed to be strontium-90 for dose calculations.
(d) The 400 Area's cesium-137 value is derived fully from gross beta measurements.
(e) This value includes gross alpha release data. Gross alpha and unspecified alpha results assumed to be plutoniun-239,240 for dose calculations.

**Table 3.1.2.** Nonradioactive Constituents Discharged to the Atmosphere at the Hanford Site, 1997[a]

| Constituent | Release, kg | | |
|---|---|---|---|
| | 200-East Area | 200-West Area | 300 Area |
| Particulate matter | $1.41 \times 10^{3}$ | $5.62 \times 10^{1}$ | $1.07 \times 10^{4}$ |
| Nitrogen oxides | $1.61 \times 10^{5}$ | $1.65 \times 10^{4}$ | $3.80 \times 10^{4}$ |
| Sulfur oxides | $2.35 \times 10^{5}$ | $1.97 \times 10^{2}$ | $1.44 \times 10^{5}$ |
| Carbon monoxide | $5.33 \times 10^{4}$ | $1.78 \times 10^{2}$ | $3.46 \times 10^{3}$ |
| Lead | $1.4 \times 10^{2}$ | $3.46 \times 10^{-2}$ | $2.05 \times 10^{1}$ |
| Volatile organic compounds[b] | $1.15 \times 10^{3}$ | $1.81 \times 10^{2}$ | $1.94 \times 10^{2}$ |
| Ammonia[c] | $3.60 \times 10^{3}$ | $2.79 \times 10^{3}$ | NM[d] |
| Arsenic | $1.50 \times 10^{2}$ | $1.16 \times 10^{-2}$ | $1.2 \times 10^{1}$ |
| Beryllium | $2.02 \times 10^{1}$ | $6.92 \times 10^{-3}$ | $4.44 \times 10^{-1}$ |
| Cadmium | $1.19 \times 10^{1}$ | $3.05 \times 10^{-2}$ | $2.23 \times 10^{1}$ |
| Carbon tetrachloride | NE[d] | $2.27 \times 10^{-1}$[e] | NE |
| Chromium | $4.34 \times 10^{2}$ | $1.32 \times 10^{-1}$ | $1.35 \times 10^{1}$ |
| Cobalt | NE | NE | $1.28 \times 10^{1}$ |
| Copper | $2.73 \times 10^{2}$ | $7.75 \times 10^{-1}$ | $2.94 \times 10^{1}$ |
| Formaldehyde | $6.12 \times 10^{1}$ | $1.12 \times 10^{0}$ | $4.28 \times 10^{1}$ |
| Manganese | $6.01 \times 10^{2}$ | $3.88 \times 10^{-2}$ | $7.82 \times 10^{0}$ |
| Mercury | $4.43 \times 10^{0}$ | $8.31 \times 10^{-3}$ | $3.38 \times 10^{0}$ |
| Nickel | $3.57 \times 10^{2}$ | $4.98 \times 10^{-2}$ | $2.46 \times 10^{2}$ |
| Polycyclic organic matter | NE | $4.35 \times 10^{2}$ | $5.80 \times 10^{3}$ |
| Selenium | $5.42 \times 10^{1}$ | $6.5 \times 10^{-2}$ | $4.01 \times 10^{0}$ |
| Vanadium | $3.74 \times 10^{1}$ | $1.93 \times 10^{-1}$ | $3.19 \times 10^{2}$ |

(a) The estimate of volatile organic compound emissions do not include emissions from certain laboratory operations.
(b) Produced from burning fossil fuel for steam and electrical generators.
(c) Ammonia releases are from the 200-East Area tank farms, 200-West Area tank farms, and operation of the 242-A Evaporator.
(d) NE = no emissions; NM = not measured.
(e) This is an estimated value because over 99% of the measured values are below the 1-ppmv (parts per million-volume) detection limit.

environment at designated discharge points are sampled and analyzed to determine compliance with the National Pollutant Discharge Elimination System permits and the state waste discharge permits 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 the EPA's permission. A synopsis of the National Pollutant Discharge Elimination System and state waste discharge permit violations in 1997 is given in Section 2.2.7, "Clean Water Act."

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.

**Table 3.1.3.** Radionuclides in Liquid Effluents Discharged to Ground Disposal Facilities in the 200 Areas, 1997

| Radionuclide | Half-Life | Release, Ci[a] |
|---|---|---|
| Tritium | 12.3 yr | $2.5 \times 10^{1}$ |
| Carbon-14 | 5,730 yr | $2.2 \times 10^{-5}$ |
| Strontium-90 | 29.1 yr | $1.5 \times 10^{-4}$ |
| Technetium-99 | $2.6 \times 10^{6}$ yr | $4.2 \times 10^{-5}$ |
| Ruthenium-106 | 368 d | ND[b] |
| Tin-113 | 115 d | ND |
| Antimony-125 | 2.8 yr | ND |
| Iodine-129 | $1.57 \times 10^{7}$ yr | $1.3 \times 10^{-4}$ |
| Cesium-134 | 2.1 yr | ND |
| Cesium-137 | 30 yr | $4.6 \times 10^{-4}$ |
| Radium-226 | 1,600 yr | $5.5 \times 10^{-5}$ |
| Uranium-234 | $2.45 \times 10^{5}$ yr | $2.3 \times 10^{-4}$ |
| Uranium-235 | $7.04 \times 10^{8}$ yr | $1.9 \times 10^{-5}$ |
| Uranium-238 | $4.47 \times 10^{9}$ yr | $1.7 \times 10^{-4}$ |
| Neptunium-237 | $2.14 \times 10^{6}$ yr | $1.8 \times 10^{-6}$ |
| Plutonium-238 | 87.7 yr | $7.4 \times 10^{-5}$ |
| Plutonium-239,240 | $2.4 \times 10^{4}$ yr | $7.0 \times 10^{-5}$ |
| Americium-241 | 432 yr | $1.8 \times 10^{-4}$ |

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

**Table 3.1.4.** Radionuclides in Liquid Effluents Discharged to the Columbia River from the 100 Areas, 1997

| Radionuclide | Half-Life | Release, Ci[a] |
|---|---|---|
| Tritium | 12.3 yr | $1.3 \times 10^{-1}$ |
| Cobalt-60 | 5.3 yr | ND[b] |
| Strontium-90 | 29.1 yr | $1.3 \times 10^{-1}$ |
| Ruthenium-106 | 368 d | ND |
| Antimony-125 | 2.8 yr | ND |
| Cesium-134 | 2.1 yr | ND |
| Cesium-137 | 30 yr | ND |
| Plutonium-238 | 87.7 yr | ND |
| Plutonium-239,240 | $2.4 \times 10^{4}$ yr | ND |
| Americium-241 | 432 yr | $5.9 \times 10^{-7}$ |

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

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

Reportable releases include spills or discharges of hazardous substances or dangerous wastes to the environment, other than releases permitted under state or federal law. 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.

Spills or nonpermitted discharges of dangerous wastes or hazardous substances to the environment are required to be reported (WAC 173-303-145). This requirement applies to spills or discharges onto the ground, into the groundwater, into the surfacewater, or into the air such that human health or the environment is threatened, regardless of the quantity of dangerous waste or hazardous substance.

There were seven releases reported under the Act's reportable quantity or WAC 173-303-145 requirements by Hanford Site contractors in 1997. Table 3.1.5 contains a synopsis of 1997 reportable releases pursuant to these regulations.

**Table 3.1.5**. Comprehensive Environmental Response, Compensation, and Liability Act and Washington Administrative Code Reportable Spills, 1997

| Material | Quantity | Location |
|---|---|---|
| Carbon tetrachloride | Undetermined | Transuranic Waste Storage and Assay Facilty, 200-West Area |
| Diesel fuel | Undetermined | Conoco Station, 300 Area |
| No. 2 diesel fuel | Undetermined | 241-A-701 Building, 200-East Area |
| Nitrogen dioxide | 5.15 kg (11.35 lb) | Plutonium Finishing Plant, 200-West Area |
| Radioactive air | $1.4 \times 10^{-4}$ Ci, $^{90}Sr$<br>$1.4 \times 10^{-5}$ Ci, $^{137}Cs$ | B Plant, 200-East Area |
| | $<3.1 \times 10^{0}$ Ci, $^{219}Rn$<br>$<4.6 \times 10^{1}$ Ci, $^{220}Rn$<br>$<5.0 \times 10^{-1}$ Ci, $^{222}Rn$ | 324 Building, 300 Area |
| Radioactive water | Undetermined | 105-KW, 100-K Area |

# 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 effluent treatment and control practices and contamination control in waste management and restoration activities. These include air, surface and spring waters, surface contamination, soil and vegetation, investigative sampling (which can include wildlife), and external radiation. Sampling and analysis information and analytical results for 1997 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 1997* (HNF-EP-0573-6).

## 3.2.1 Near-Facility Environmental Monitoring

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, 5400.5, 5484.1, and 5820.2A; WAC 246-247; and 10 CFR 835 and 40 CFR 61.

Routine monitoring activities include sampling and monitoring ambient air, water from surface-water disposal units, external radiation dose rate, soil, sediment, vegetation, and animals. Some of the parameters typically monitored are pH, radionuclide concentrations, radiation exposure rate 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 1997 are summarized in Table 3.2.1, which shows the type, quantity, and general 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.

## 3.2.2 Air Monitoring

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

### 3.2.2.1 Collection of Air Samples and Analytes of Interest

Radioactivity in air was sampled by a network of continuously operating samplers at 62 locations near nuclear facilities: 3 at the 100 B,C Area, 4 at the 100-D,DR Area, 4 the 100-K Area, 4 in the 100-N Area, 37 in the 200 Areas, 3 at the Environmental Restoration Disposal

**Table 3.2.1**. Near-Facility Routine Environmental Samples and Locations, 1997

| 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 | TWRS[b] |
| Air | 62 | 3 | 4 | 4 | 4 | 3 | 38[c] | 6 | 0 |
| Water | 14 | 0 | 0 | 0 | 12 | 0 | 2 | 0 | 0 |
| External radiation | 165 | 4 | 5 | 11 | 48[d] | 3 | 63 | 21 | 10 |
| Soil | 80 | 0 | 2 | 0 | 7 | 1 | 55 | 15 | 0 |
| Vegetation | 66 | 0 | 0 | 0 | 10 | 0 | 41 | 15 | 0 |

(a) Environmental Restoration Disposal Facility.
(b) Tank Waste Remediation System.
(c) Includes one station located at the Wye Barricade.
(d) Twenty-two thermoluminescent dosimeters and 26 survey points.

Facility, 3 at the 300-FF-1 Operable Unit (north of the 300 Area), 2 at the 3732 Building (300 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 in the 600 Area. To avoid duplication of sampling, the Near-Facility Environmental Monitoring Program relied on analytical results obtained from existing Pacific Northwest National Laboratory air samplers in the 300 and 400 Areas. 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 station 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 gross 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 gross 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 strontium-90, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239,240, and gamma-emitting radionuclides (e.g., cobalt-60, cesium-137). Samples from the 100-K Area were also analyzed for americium-241 and plutonium-241.

### 3.2.2.2 Radiological Results for Air Samples

Of the radionuclide analyses performed, strontium-90, cesium-137, plutonium-239,240, and uranium were consistently detected in the 100-K, 100-N, and 200 Areas. Cobalt-60 was consistently detected 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 1997 and the preceding 5 years for selected radionuclides compared to DOE derived concentration guides (DOE Order 5400.5) and the background air concentration as measured by the Pacific Northwest National Laboratory in distant communities. The DOE derived concentration guides are reference values that are used as 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.

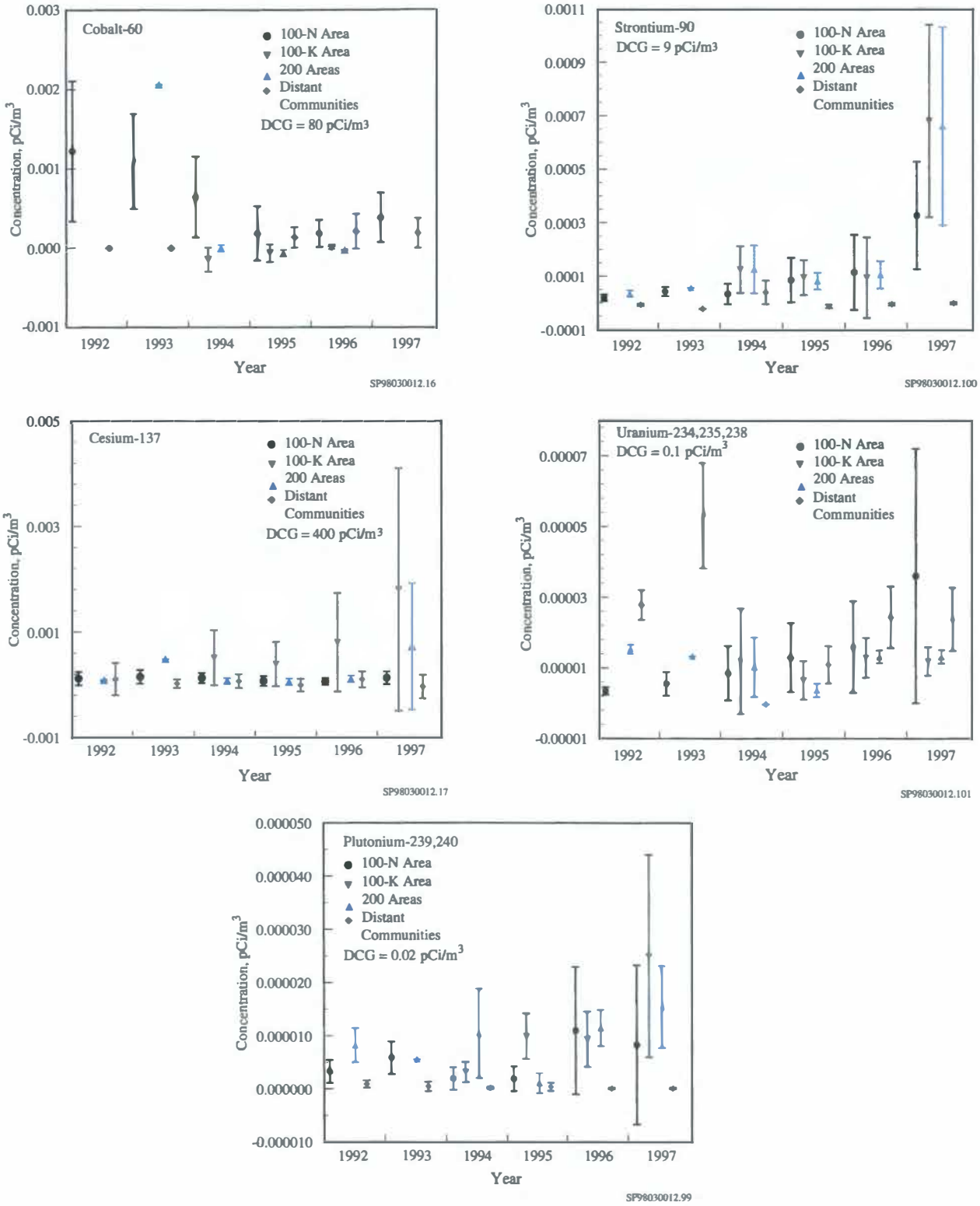



**Figure 3.2.1**. Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Air Samples Compared to Those in Distant Communities, 1992 Through 1997. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol. Cobalt-60 was not detected in the 100-K and 200 Areas in 1997.

**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 radionuclide 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 radionuclide concentrations were much less than the DOE derived concentration guides and only slightly greater than levels measured offsite.

**100-K Area**. Analytical results from four 100-K Area ambient air samplers show quantities of strontium-90, cesium-137, plutonium-239,240, plutonium-241, and americium-241 above detection levels. These levels were much less than the DOE derived concentration guides; however, they were greater than levels measured offsite. Facility emissions in 1997 did not differ significantly from those in 1996, and radionuclide concentrations seen in the ambient air samples were near detection limits.

**100-N Area**. Analytical results from four ambient air samplers in the 100-N Area show quantities of strontium-90, uranium-234, and uranium-235 above detection levels. Radionuclide concentrations were much less than the DOE derived concentration guides; however, they were slightly greater than levels measured offsite.

**200 Areas**. Analytical results from 37 ambient air samplers 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 and plutonium-239,240 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 project-specific air monitors that provided downwind monitoring. The analytical results indicate that radionuclide concentrations in 1997 were much less than the DOE derived concentration guides and only slightly greater than levels measured offsite.

**300-FF-1 Operable Unit**. Near-facility air sampling was conducted at the 300-FF-1 Operable Unit remediation site in the 300 Area through a network of continuous air samplers. This network utilized one existing Hanford Site monitor for upwind monitoring and three project-specific downwind air monitors. Additional downwind monitoring is provided by existing Pacific Northwest National Laboratory air samplers. Monitoring began in May 1997, and the analytical results indicated that radionuclide concentrations were much less than the DOE derived concentration guides and only slightly greater than levels measured offsite.

**3732 Building**. Near-facility air sampling was conducted during the demolition of the 3732 Building in the 300 Area through the use of two continuous air samplers. These samplers provided downwind monitoring during a 2-week demolition period in September 1997, and the analytical results indicated that radionuclide concentrations were much less than the DOE derived concentration guides and only slightly greater than levels measured offsite.

## 3.2.3 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-East Area that received potentially radiologically contaminated effluent were sampled during 1997: the 200-East Area Powerhouse Ditch and the 216-B-3C Expansion Pond.

### 3.2.3.1 Collection of Surface-Water and Riverbank Springs Samples and Analytes of Interest

Samples collected from surface-water disposal units in the 200-East Area included water, sediment, and aquatic vegetation. Only water samples were taken at riverbank springs. The sampling methods are discussed in detail in WMNW-CM-4. Samples were also collected from a

small discharge pond in the 400 Area by Pacific Northwest National Laboratory. Analytical results for the 400 Area samples are reported in Section 4.2, "Surface Water and Sediment Surveillance," and are not discussed here.

All radiological analyses were performed onsite at the Waste Sampling and Characterization Facility near the 200-West Area in 1997. Radiological analyses of 200-East Area water samples 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. Analyses for riverbank springs included tritium, strontium-90, 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.

### 3.2.3.2 Radiological Results for Surface-Water Disposal Units

Radiological results for liquid samples from the 200-East Area surface-water disposal units are summarized in Table 3.2.2. In all cases, radionuclide concentrations were less than the DOE derived concentration guides.

Radiological results for aquatic vegetation and sediment samples taken from the 200-East Area surface-water disposal units are summarized in Tables 3.2.3 and 3.2.4,

**Table 3.2.2.** Radiological Results (pCi/L) for Liquid Samples from Surface-Water Disposal Units, 200 Areas, 1997

| Sample Location | No. of Samples | | $^{3}H$[a] | $^{90}Sr$ | $^{137}Cs$ | $^{238}Pu$ | $^{239,240}Pu$ | $^{Total}U$ |
|---|---|---|---|---|---|---|---|---|
| 216-B-3C Expansion Pond (200-East Area) | 9 | Mean | ND[b] | ND | ND | ND | ND | 0.65 |
| | | Maximum | ND | ND | ND | ND | ND | 0.99 |
| 200-East Area Powerhouse Ditch | 12 | Mean | ND | 0.3 | ND | 0.0064 | 0.014 | 0.47 |
| | | Maximum | ND | 3.0 | ND | 0.036 | 0.073 | 0.58 |
| | | DCG[c] | 2,000,000 | 1,000 | 3,000 | 40 | 30 | 500[d] |

(a) The detection limit for tritium was between 170 and 220 pCi/L. Samples were collected quarterly.
(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 (pCi/g, dry wt.) for Aquatic Vegetation Samples from Surface-Water Disposal Units, 200 Areas, 1997

| Sample Location | No. of Samples | $^{90}Sr$ | $^{137}Cs$ | $^{239,240}Pu$ | $^{234}U$ | $^{235}U$ | $^{238}U$ |
|---|---|---|---|---|---|---|---|
| 216-B-3C Expansion Pond (200-East Area) | 1 | 0.34 | 0.38 | 0.0038 | 0.017 | 0.008 | 0.0085 |
| 200-East Area Powerhouse Ditch | 1 | 0.37 | ND[a] | ND | 0.013 | 0.0099 | 0.0078 |

(a) ND = Not detected.

**Table 3.2.4.** Radiological Results (pCi/g, dry wt.) for Sediment Samples from Surface-Water Disposal Units, 200 Areas, 1997

| Sample Location | No. of Samples | $^{90}Sr$ | $^{137}Cs$ | $^{239,249}Pu$ | $^{234}U$ | $^{235}U$ | $^{238}U$ |
|---|---|---|---|---|---|---|---|
| 216-B-3C Expansion Pond (200-East Area) | 1 | 0.71 | 11 | 0.20 | 0.33 | 0.06 | 0.29 |
| 200-East Area Powerhouse Ditch | 1 | ND[a] | ND | 0.0049 | 0.38 | 0.022 | 0.39 |

(a) ND = Not detected.

respectively. Although there were some levels above background in both aquatic vegetation and sediment, all results were much less than the standards cited in the *Hanford Site Radiological Control Manual* (HSRCM-1, Rev. 2).

### 3.2.3.3 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 from these facilities enter the Columbia River along the riverbank region sometimes called N Springs. The amount of radionuclides entering the river at these springs is calculated based on analysis of monthly samples collected from monitoring well 199-N-46 located near the shoreline. A more detailed discussion of the release calculations may be found in HNF-EP-0527-07.

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 underreported). To verify releases, conservatively high radionuclide concentrations in samples collected from well 199-N-46 are multiplied by the estimated groundwater discharge into the river. The groundwater flow rate at these springs was estimated using a computer model developed by Gilmore et al. (PNL-8057). The estimated groundwater flow rate used to calculate 1997 releases from the springs was 43 L/min (11 gal/min). The results of the springs samples can then be compared to the concentrations measured in well 199-N-46 to ensure that concentrations in the well reflect the highest concentrations of radionuclides in the groundwater.

In 1997, the concentrations of tritium and strontium-90 detected in samples from riverbank springs were highest in springs nearest well 199-N-46. The highest cobalt-60 concentrations, though very low, were from a location approximately 200 m (656 ft) down river (northeast) of well 199-N-46. All of the riverbank springs concentrations were lower than those measured in the well. The data from riverbank springs sampling are summarized in Table 3.2.5.

### 3.2.3.4 Nonradiological Results for Surface-Water Disposal Units

Nonradiological results for water samples taken from the 200-East Area surface-water disposal units are summarized in Table 3.2.6. The results for pH were well within the standard of 2.0 to 12.5 for liquid effluent discharges based on the limits given 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).

**Table 3.2.5.** Concentration (pCi/L) of Radionuclides in 100-N Area Columbia River Shoreline Springs, 1997

| Radionuclide | Facility Effluent Monitoring Well 199-N-46 | Shoreline Springs Maximum | Shoreline Springs Average | DCG[a] |
|---|---|---|---|---|
| Tritium | 16,000 | 3,000 | 210 | 2,000,000 |
| Cobalt-60 | <2.2 | 9.1 | 1.3 | 5,000 |
| Strontium-90 | 11,000 | 3,200 | 345 | 1,000 |

(a) DCG = DOE derived concentration guide (DOE Order 5400.5).

**Table 3.2.6.** Nonradiological Results for Water Samples from Surface-Water Disposal Units, 200 Areas, 1997

| | pH | | | | Nitrate ($NO_3$), mg/L | | |
|---|---|---|---|---|---|---|---|
| Sample Location | No. of Samples | Mean | Maximum | Minimum | No. of Samples | Mean | Maximum |
| 216-B-3C Expansion Pond (200-East Area) | 36 | 8.4 | 8.9 | 7.9 | 3 | 0.22 | 0.37 |
| 200-East Area Powerhouse Ditch | 52 | 8.8 | 9.3 | 8.0 | 4 | 0.17 | 0.24 |

## 3.2.4 Radiological Surveys

Radiological surveys are used to monitor and detect contamination on the Hanford Site. The two main types of posted radiologically controlled areas are underground radioactive materials and contamination areas. Controlled areas include contamination areas, soil contamination areas, and high contamination areas.

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

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 materials area may result in the growth of contaminated vegetation. Insects or animals may burrow into an underground radioactive materials 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 cause an area of contamination 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 1997, the Hanford Site had approximately 3,990 ha (9,859 acres) of posted outdoor contamination areas and 614 ha (1,517 acres) of posted underground radioactive materials areas not including active facilities. The number of hectares (acres) of contamination areas is approximately six times larger than the underground radioactive materials 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 area in 1996, and the area was enlarged to 3,832 ha (9,469 acres). Table 3.2.7 lists the contamination areas and underground radioactive material areas in 1997. A global positioning system was used in 1996 and 1997 to measure the surface contamination areas more accurately than in previous years. Area measurements are entered into the Hanford Geographical Information System, a computer database maintained by the environmental restoration contractor.

The posted contamination areas vary in number and size 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 1997. Approximately 13.4 ha (33.1 acres) were reclassified from contamination/soil contamination areas to underground radioactive materials areas, 1.9 ha (4.7 acres) were posted as soil contamination areas, and 5.2 ha (12.8 acres) were changed from no posting to underground radioactive materials areas. 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

**Table 3.2.7.** Outdoor Contamination Status, 1997

| Area | Contamination Areas,[a] ha | (acres) | Underground Radioactive Material Areas,[b] ha | (acres) |
|---|---|---|---|---|
| 100-B,C | 8 | (20) | 39 | (96) |
| 100-D,DR | 0.1 | (0.2) | 39 | (96) |
| 100-F | 0.7 | (1.7) | 33 | (82) |
| 100-H | 0.1 | (0.2) | 14 | (35) |
| 100-K | 9 | (22) | 62 | (153) |
| 100-N | 29 | (73) | 0.2 | (0.5) |
| 200-East[c] | 62 | (153) | 139 | (343) |
| 200-West[c] | 30 | (74) | 221 | (546) |
| 300 | 19 | (47) | 13 | (32) |
| 400 | | 0 | | 0 |
| 600[d] | 3,832 | (9,469) | 54 | (133) |
| **Totals** | 3,990 | (9,859) | 614 | (1,517) |

(a) Includes areas posted as contamination/soil contamination or as radiologically controlled and areas that had both underground and contamination/soil contamination.
(b) Includes areas with only underground contamination. Does not include areas that had contamination/soil contamination as well as underground radioactive material.
(c) Includes tank farms.
(d) Includes BC Cribs controlled area, 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). The first cell of the Environmental Restoration Disposal Facility was added during 1997.

**Table 3.2.8.** Zone Status Change of Posted Contamination Areas, 1997 (changes from stabilization activities or newly discovered sites)

| Area | Zone Change | Area, ha | (acres) |
|---|---|---|---|
| 100 | CA to URM[a] | 1.7 | (4.2) |
| 200-East | CA to URM | 5.6 | (13.8) |
| 200-West | CA to URM | 4.1 | (10.1) |
| 300 | CA to URM | 0 | |
| 400 | CA to URM | 0 | |
| 600 | CA to URM | 2.0 | (5.0) |
| | NP to CA | 1.9 | (4.7) |
| | NP to URM | 5.2 | (12.8) |

(a) CA = Contamination/soil contamination area.
URM = Underground radioactive material area.
NP = No posting.

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 1997.

## 3.2.5 Soil and Vegetation Sampling from Operational Areas

Soil and vegetation samples were collected on or adjacent to waste disposal units and from locations downwind and near or within the boundaries of the operating facilities. Samples were collected to detect potential migration and deposition of facility effluents. Special samples were also taken where physical or biological transport problems were identified. Migration can occur as the result of resuspension from radioactively contaminated surface areas, absorption of radionuclides by the roots of vegetation growing on or near underground and surface-water disposal units, or by waste site intrusion by animals.

In 1994, routine annual soil and vegetation sampling was eliminated in the 100 Areas, except for the 100-N Area. Historical data indicated that the previously monitored 100 Area sites exhibited no signs of contamination migration trends, and continued monitoring would not be cost effective. At the 100-N Area, 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.

In accordance with state regulations, soil samples were collected at the 100-D Area and the Environmental Restoration Disposal Facility remediation projects managed and operated by the environmental restoration contractor to determine the effectiveness of contamination controls. The sample collected at the Environmental Restoration Disposal Facility site in 1997 represents the initial (baseline) sample to be used for future comparison. At the 100-D Area, the 1997 sample was a follow-up to the 1996 sample collected from the same location.

### 3.2.5.1 Collection of Soil and Vegetation Samples and Analytes of Interest

The sampling methods and locations used are discussed in detail in WMNW-CM-4. 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 1997. Figure 3.2.2 shows average soil values for 1997 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 higher than concentrations in samples collected farther away and significantly higher than historical concentrations measured offsite. 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 and fission products in the 100-N Area, fission products in the 200 Areas, and uranium in the 300/400 Areas.

***100-D Area and Environmental Restoration Disposal Facility***. The sampling results indicate that, at both sites, radionuclide concentrations were comparable to those measured offsite. At the 100-D Area, the 1997 results were higher than the 1996 results, though within the historical ranges observed in soil samples collected in the 100 Areas from 1981 through 1990. The apparent increase in soil sample concentrations does not correlate with the results observed in the nearby air samplers and most likely is due to the relatively small data set being used for comparison. These samples will continue to be collected annually, and the results carefully monitored to determine any trends.

***100-N Area***. The analytical results from soil samples collected in the 100-N Area in 1997 generally exhibit concentrations at or near historical onsite levels. However, concentrations of cobalt-60, strontium-90, plutonium-238, and plutonium-239,240 were noticeably elevated at a sampling location near the retired 1301-N Liquid Waste Disposal Facility. Additionally, contamination levels were greater than those measured offsite, and the concentrations of cobalt-60, strontium-90, and plutonium-239,240 were greater than those measured in the 200 and 300/400 Areas. The cobalt-60, strontium-90, and plutonium-239,240 concentrations 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, radioactive decay, and improved waste management practices. However, for cesium-137, the results were greater than offsite measurements and values obtained 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 these areas were higher than those measured from the 100 and 200 Areas and slightly lower than levels measured at the same locations in 1996. 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 1997. Figure 3.2.3 shows average vegetation values for 1997 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 1997. 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 300/400Areas.

***100-N Area***. Analytical results from vegetation samples collected in the 100-N Area in 1997 were comparable to those seen in 1996. The values observed for strontium-90 in samples collected near the N Springs were typically higher than those seen at other locations in the 100-N Area. Generally, 1997 radionuclide levels in 100-N Area vegetation were greater than those measured offsite; levels for cobalt-60, strontium-90, and cesium-137 were higher compared to the concentrations measured in the 200 and 300/400 Areas.

***200 Areas***. Analytical results from vegetation samples taken in 1997 in the 200 Areas were comparable to those seen in 1996. Before 1992, radionuclide levels in these

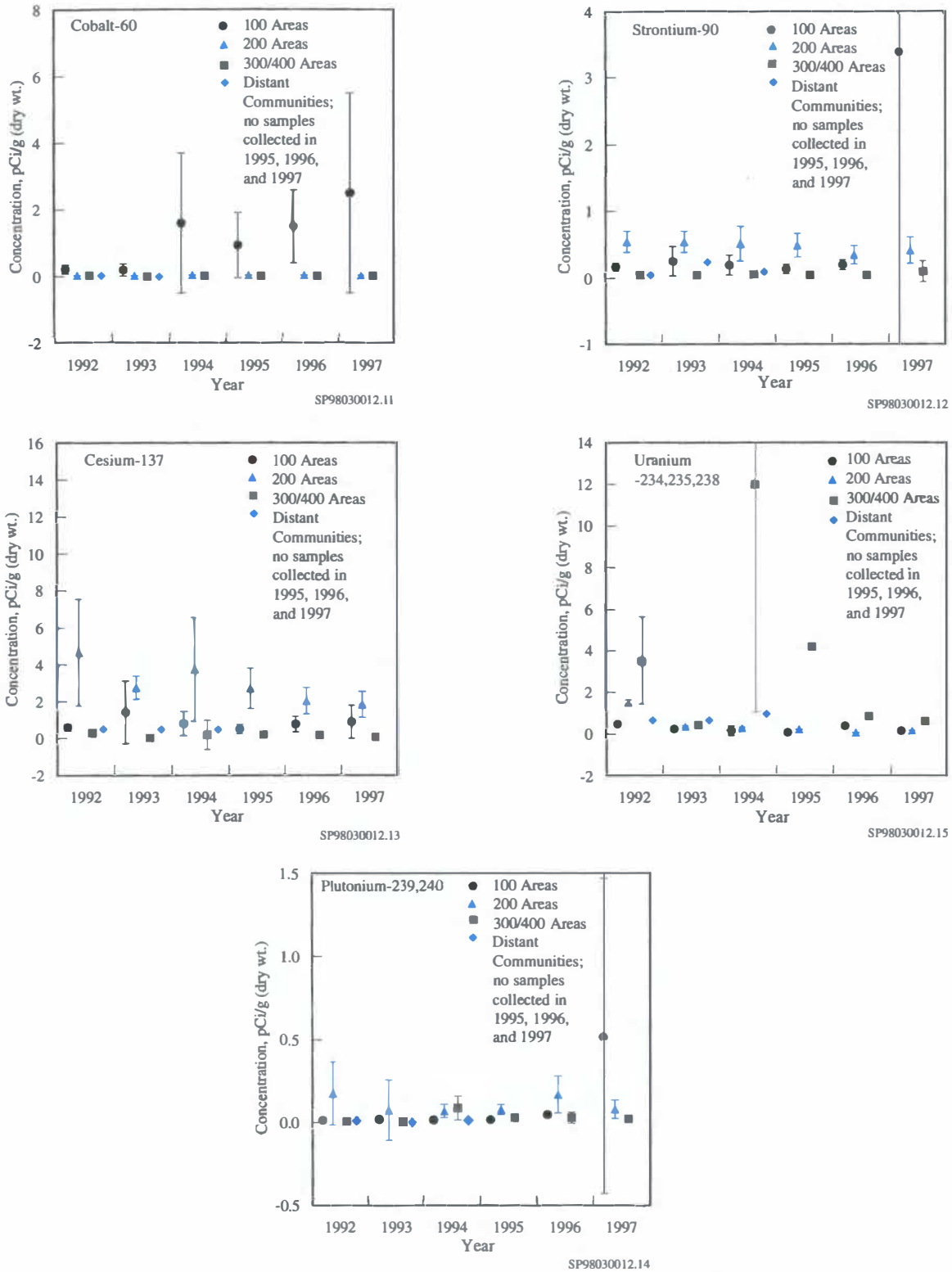



**Figure 3.2.2.** Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Soil Samples Compared to Those in Distant Communities, 1992 Through 1997. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols. The 1994, 1995, 1996, and 1997 100 Areas data include the 100-N Area only.

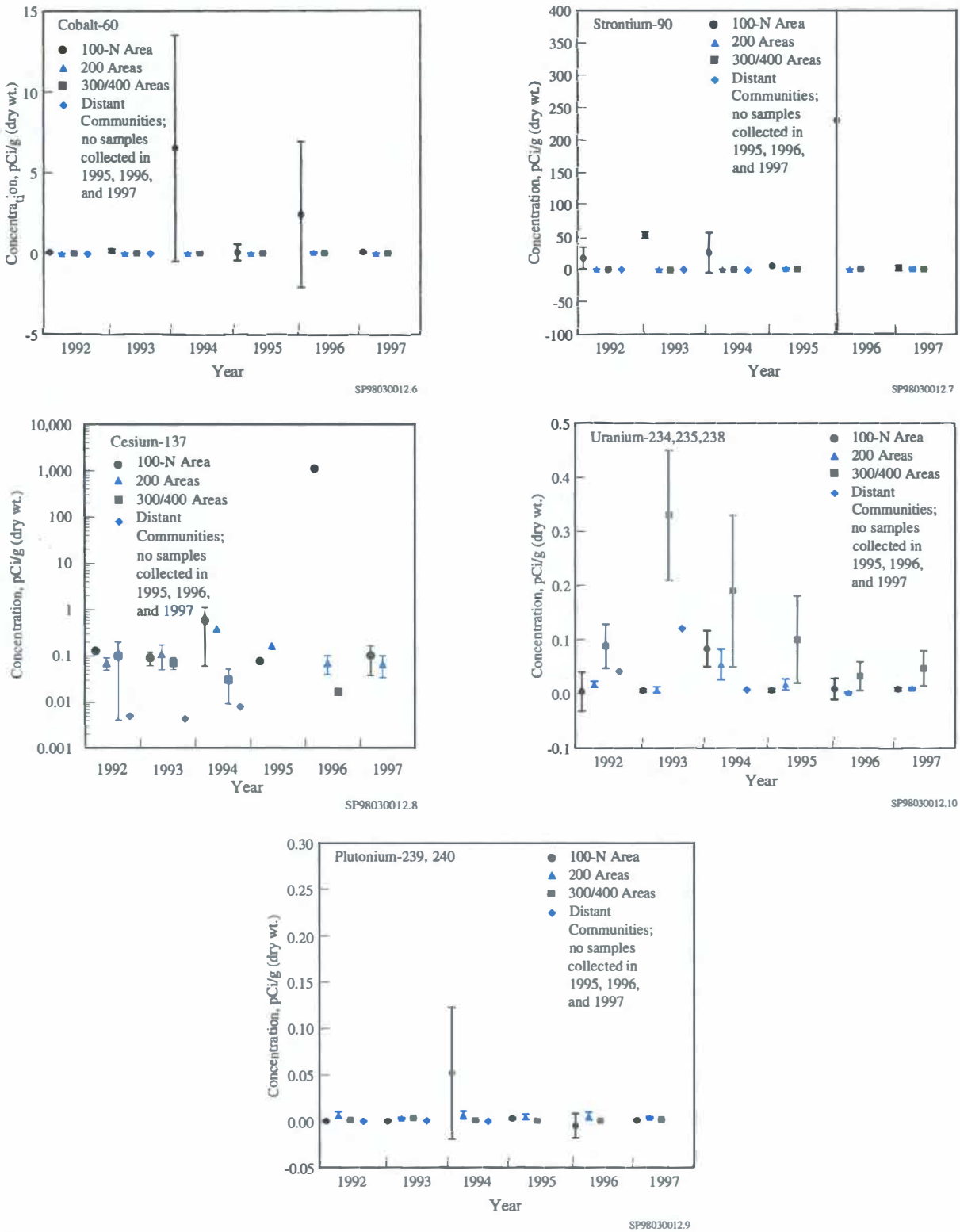



**Figure 3.2.3.** Average Concentrations (±2 standard error of the mean) of Selected Radionuclides in Near-Facility Vegetation Samples Compared to Those in Distant Communities, 1992 Through 1997. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols. The 1994, 1995, 1996, and 1997 100 Areas data include the 100-N Area only. The 1997 cesium-137 data point for the 300/400 Areas is less than zero and cannot be plotted on a log scale.

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 1997, 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 than levels measured in 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 recorded in the 400 Area were at or near those measured offsite.

## 3.2.6 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.

### 3.2.6.1 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 WMNW-CM-4.

**Results of Radiological Field Measurements**

***Radiation Surveys.*** A hand-held micro-rem meter was used to survey points along the 100-N Area 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 overrespond to low-energy gamma radiation. Since 1995, the micro-rem meter has been used to provide a more accurate measurement of the dose rate. Figure 3.2.4 shows the overall shape of the curve for 1997, which indicates that N Springs shoreline areas with the highest dose rate are, as in the past, juxtapositional with the 1301-N Liquid Waste Disposal Facility.

**Thermoluminescent Dosimeters**

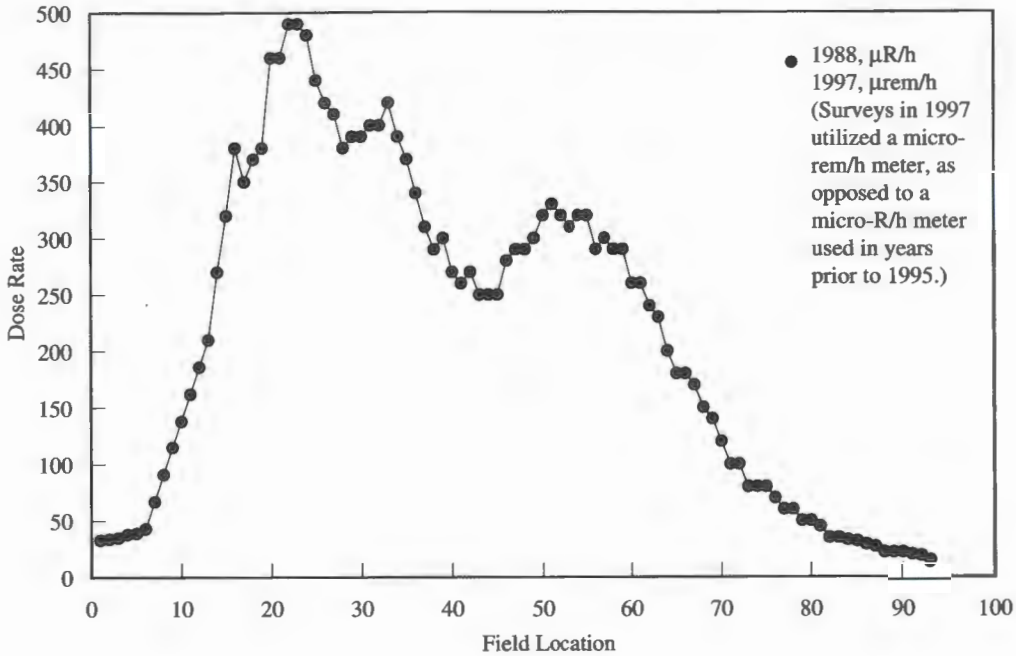
***100-B,C Area.*** Four new thermoluminescent dosimeter monitoring sites were established in this area during the fourth quarter of 1997 to evaluate environmental restoration activities at the 116-B-11 and 116-C-1 Liquid Waste Disposal Facilities. Because only 27 days of data were collected at these sites during 1997, the thermoluminescent dosimeter results were extrapolated to 1 year, resulting in an average of 93 mrem/yr, which is comparable to offsite ambient background levels. Table 3.2.9 summarizes the 1997 results.

***100-D,DR Area.*** This is the second year that thermoluminescent dosimeters have been placed in this area to evaluate environmental restoration activities at the 116-D-7 and 116-DR-9 Liquid Waste Disposal Facilities. Dose rates measured at these locations were equal to the results of 1996, with an average of 88 mrem/yr, which is comparable to offsite ambient background levels (see Table 3.2.9).

***100-K Area.*** This is the fifth year that thermoluminescent dosimeters have been placed in this 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 30 times greater than the overall 100-K Area average) because of their proximity to radioactive waste storage areas or stored radioactive rail equipment.

***100-N Area.*** The 1997 thermoluminescent dosimeter results (see Table 3.2.9) 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. While the results for these two facilities were noticeably higher than those for other 100-N Area thermoluminescent dosimeter locations, they were approximately 17% lower than dose levels measured at these locations in 1996. Overall, dose rates measured at all locations in the 100-N Area in 1997 were approximately 15% lower than those measured in 1996.

***200/600 Areas.*** The highest dose rates were measured near waste handling facilities such as tank farms in the 200 Areas. The highest dose rate was measured at the A Tank Farm in the 200-East Area. The average annual dose rate measured in 1997 (110 mrem/yr) was 8% lower than the 1996 measurement (see Table 3.2.9).



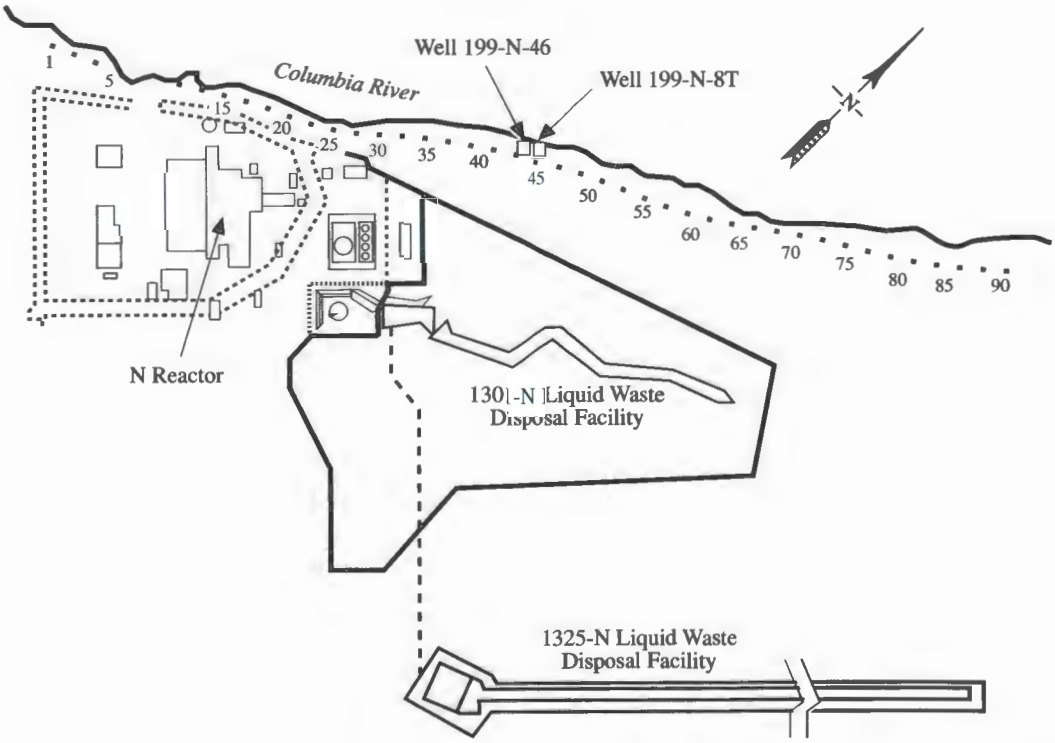




**Figure 3.2.4**. Radiation Survey Measurements Along the 100-N Area Shoreline, 1988 and 1997

**Table 3.2.9**. Thermoluminescent Dosimeter Results for Waste Handling Facilities, 1996 and 1997, mrem/yr based on 24 h/d

| Area | No. of Locations, 1997 | 1997 Maximum | 1997 Mean | 1996 Maximum | 1996 Mean | % Change[a] |
|---|---|---|---|---|---|---|
| 100-B,C[b] | 4 | 96 | 93 | NA[c] | NA | NA |
| 100-D,DR | 5 | 91 | 88 | 92 | 88 | 0 |
| 100-K | 11 | 2,250 | 470 | 2,250 | 480 | -2 |
| 100-N | 22 | 7,700 | 1,250 | 9,200 | 1,500 | -15 |
| 200/600 | 63 | 350 | 110 | 500 | 120 | -8 |
| TWRS[b,d] | 10 | 81 | 78 | NA | NA | NA |
| ERDF[e] | 3 | 100 | 95 | 100 | 100 | -7 |
| 300 | 8 | 200 | 110 | 240 | 120 | -8 |
| 300 TEDF[f] | 6 | 87 | 82 | 87 | 85 | -4 |
| 400 | 7 | 88 | 86 | 92 | 83 | 3 |

(a) Numbers indicate a decrease (-) or increase from the 1996 mean.
(b) Thermoluminescent dosimeter network was established during the fourth quarter of 1997.
(c) NA = Not applicable.
(d) TWRS = Tank Waste Remediation System Phase I Demonstration Project.
(e) ERDF = Environmental Restoration Disposal Facility.
(f) TEDF = Treated Effluent Disposal Facility.

***Tank Waste Remediation System Phase I Demonstration Project***. Ten new thermoluminescent dosimeter locations were established around the perimeter of this project site during the fourth quarter of 1997 to collect preoperational monitoring data. Because only 67 days of data were collected at this site during 1997, the results were extrapolated to 1 year, resulting in an average of 78 mrem/yr, which is comparable to offsite ambient background levels.

***Environmental Restoration Disposal Facility***. This is the second year that thermoluminescent dosimeters have been placed at this facility to evaluate environmental restoration disposal activities. Dose rates measured were slightly lower than the results of 1996 analyses, with an average of 95 mrem/yr, which is comparable to offsite ambient background levels.

***300 Area/300 Area Treated Effluent Disposal Facility/400 Area***. Table 3.2.9 compares 1997 thermoluminescent dosimeter results to those of 1996 for these areas and facilities. The highest dose rates in the 300 Area were measured near the 340 Waste Handling Facility. The average dose rate measured in the 300 Area in 1997 was 110 mrem/yr, which is a decrease of 8% compared to the average dose rate of 120 mrem/yr measured in 1996. The average dose rate at the 300 Area Treated Effluent Disposal Facility in 1997 was 82 mrem/yr, which is an decrease of 4% compared to the average dose rate of 85 mrem/yr measured in 1996. The average dose rate measured in the 400 Area in 1997 was 86 mrem/yr, which is an increase of 3% compared to the average dose rate of 83 mrem/yr measured in 1996.

## 3.2.7 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 given in Table 3.2.10. Complete results for these investigations, including counting errors, and, where appropriate, field instrument and dose readings, are provided in HNF-EP-0573-6.

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 and no special characterization samples were collected in 1997.

### 3.2.7.1 Collection of Investigative Samples and Analytes of Interest

Investigative samples collected in 1997 included sludge, soil, vegetation (e.g., grass, tumbleweeds, rabbitbrush, sagebrush), insects (darkling beetles), reptiles (sagebrush lizards), a bird nest, mammal feces (e.g., mouse, rabbit, coyote), and mammals (e.g., deer mouse, Great Basin pocket mouse, cottontail rabbit). A summary of radioisotopic analyses was presented in Table 3.2.10.

Methods for collecting or otherwise obtaining investigative samples are described in WMNW-CM-4. Field monitoring was conducted to detect radioactivity in samples before they were submitted for analysis. Field monitoring results are expressed as counts per minute (counts/min) when a Geiger-Müeller detector is used or as millirad per hour (mrads/h) 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 picocuries per sample (pCi/sample). Maximum concentrations, rather than averages, are presented here.

### 3.2.7.2 Radiological Results for Investigative Samples

Investigative samples were collected where known or suspected radioactive contamination was present or to verify radiological conditions at project sites. In 1997, 30 samples were analyzed for radionuclides, and 27 showed measurable levels of contamination. Another 115 samples were collected during cleanup operations, and were disposed of without isotopic analysis, though field instrument readings were recorded. A detailed data summary of all known radioactive contamination incidents in the operations areas during 1997 is provided in HNF-EP-0573-6.

**Sludge**. In 1997, two samples of dried sludge were collected from the contaminated C-5 Tank in the 200-East Area to determine if the potential for flaking and dispersal by winds might require the surface to be stabilized. The analytical results from these samples showed that all radionuclide concentrations were below regulatory limits (see Table 3.2.10).

**Soil**. In 1997, no investigative soil samples were collected for radioisotopic analysis. There were 51 incidents of contaminated soil or specks found during cleanup operations were disposed of in low-level burial grounds without analysis. External radioactivity ranged from slightly above background (approximately 100 counts/min) to 38 mrads/h. The contaminated areas were posted or cleaned up.

In 1997, 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 control limits were posted as contamination areas.

**Vegetation**. In 1997, four tumbleweed samples, one rabbitbrush sample, and one grass sample were analyzed for radionuclide contaminants (see Table 3.2.10). The maximum radionuclide concentrations were in a tumbleweed sample from near the 221-U Building in the 200-West Area and consisted primarily of strontium-90 (250,000 pCi/g) and cesium-137 (1,800,000 pCi/g). The rabbitbrush sample from near T Tank Farm in the 200-West Area contained primarily strontium-90 (1,100 pCi/g) and cesium-137 (310 pCi/g). In addition, 40 instances of contaminated vegetation were recorded in the operational areas in 1997. 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 approximately 100 to >1,000,000 counts/min). During 1997, the numbers of contaminated vegetation (both samples and those disposed without analysis) exceeded those of the

**Table 3.2.10**. Investigative Samples Collected from Hanford Site Operational Areas, 1997

| Sample Type | Collection Area (No. of Samples) | Radionuclides | Maximum Concentration, pCi/g |
|---|---|---|---|
| Dried sludge | 200-East Area (2) | $^{60}Co$ | <14,000[a] |
| | | $^{90}Sr$ | <10,000[a] |
| | | $^{137}Cs$ | <15,000[a] |
| | | $^{152}Eu$ | <65,000[a] |
| | | $^{154}Eu$ | <45,000[a] |
| | | $^{155}Eu$ | <36,000[a] |
| | | $^{238}Pu$ | <18,000[a] |
| | | $^{239,240}Pu$ | <18,000[a] |
| | | $^{Total}U$ | 190 |
| Grass | 200-East Area (1) | $^{60}Co$ | <2.4[a] |
| | | $^{90}Sr$ | 1.3 |
| | | $^{137}Cs$ | <4.9[a] |
| | | $^{152}Eu$ | <11[a] |
| | | $^{154}Eu$ | <6.1[a] |
| | | $^{155}Eu$ | <8.3[a] |
| | | $^{238}Pu$ | <3.0[a] |
| | | $^{239,240}Pu$ | 3.9 |
| | | $^{Total}U$ | 870 |
| Rabbitbrush | 200-West Area (1) | $^{90}Sr$ | 1,100 |
| | | $^{137}Cs$ | 310 |
| Tumbleweeds | 200-East Area (2) | $^{90}Sr$ | 28 |
| | | $^{137}Cs$ | 150 |
| Tumbleweeds | 200-West Area (2) | $^{90}Sr$ | 250,000 |
| | | $^{137}Cs$ | 1,800,000 |
| Darkling beetle | 200-West Area (1) | $^{90}Sr$ | 180 |
| Sagebrush lizard | 200-East Area (1) | $^{90}Sr$ | 68 |
| | | $^{137}Cs$ | 33 |
| Bird nest | 200-West Area (1) | $^{90}Sr$ | 29 |
| | | $^{137}Cs$ | 370 |
| Mouse feces | 200-West Area (1) | $^{60}Co$ | 28,000 |
| | | $^{90}Sr$ | 170,000 |
| | | $^{137}Cs$ | 130,000 |
| | | $^{154}Eu$ | 26,000 |
| | | $^{155}Eu$ | 11,000 |
| | | $^{238}Pu$ | 8,100 |
| | | $^{239,240}Pu$ | 33,000 |
| | | $^{Total}U$ | 160,000 |
| Mouse nests | 200-East Area (2) | $^{90}Sr$ | 9,200 |
| | | $^{137}Cs$ | 860 |

**Table 3.2.10.** (contd)

| Sample Type | Collection Area (No. of Samples) | Radionuclides | Maximum Concentration, pCi/g |
|---|---|---|---|
| House mouse | 200-East Area (1) | $^{90}Sr$ | 160,000 |
| | | $^{137}Cs$ | 4,600 |
| Deer mice | 200-East Area (3) | $^{90}Sr$ | 590 |
| | | $^{137}Cs$ | 1,000 |
| Deer mice | 200-West Area (3) | $^{90}Sr$ | 92,000 |
| | | $^{137}Cs$ | 12,000 |
| Great Basin pocket mouse | 100-N Area (1) | $^{60}Co$ | 43 |
| | | $^{90}Sr$ | 150 |
| | | $^{137}Cs$ | 10 |
| Great Basin pocket mice | 200-East Area (2) | $^{90}Sr$ | 19,000 |
| | | $^{137}Cs$ | 260 |
| Great Basin pocket mouse | 600 Area (1) | $^{90}Sr$ | 220 |
| | | $^{137}Cs$ | 17 |
| Cottontail rabbit feces | 200-West Area (1) | $^{90}Sr$ | 4,400 |
| | | $^{137}Cs$ | 120 |
| Cottontail rabbit | 200-East Area (1) | $^{90}Sr$ | 7,200 |
| | | $^{137}Cs$ | 2,600 |
| | | $^{Total}U$ | 1,200 |
| Cottontail rabbits | 200-West Area (2) | $^{90}Sr$ | 5,000 |
| | | $^{137}Cs$ | 190 |
| Coyote feces | 200-West Area (1) | $^{90}Sr$ | 45 |
| | | $^{137}Cs$ | 710 |

(a) Below analytical detection limits.

previous year by a factor of four. This was primarily because of climatological conditions (i.e., increased frequency and quantity of precipitation), making the vegetation control program on the waste sites considerably less effective and resulting in more tumbleweed growth. The radioactivity levels and range of radionuclide concentrations were all within historical ranges (HNF-EP-0573-6). Historically, the greatest number of contaminated vegetation samples (42) were submitted for analyses in 1978 (WHC-MR-0418) but it is not recorded how many contaminated vegetation samples were disposed of without analysis that year.

**Wildlife.** Wildlife is collected either as part of an integrated pest management program designed to limit the exposure to animals potentially contaminated with radioactive material or as a result of finding radiologically contaminated wildlife-related material (e.g., feces, nests) during a radioactivity surveillance. Animals were collected directly from, or near, facilities to identify potential problems with preventive measures designed to deter animal intrusion. Radiological 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, still in a controlled area, 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.

In 1997, 22 wildlife and wildlife-related samples were submitted for analysis. All of these samples showed detectable levels of contamination (see Table 3.2.10). This compares to 37 contaminated samples (of 41 collected) that were analyzed in 1996, 22 contaminated samples (of 25 collected) that were analyzed in 1995, and 16 contaminated samples (of 27 collected) in 1994. The numbers of samples submitted depended on opportunity (i.e., resulting from the pest control activities at facilities) rather than exact numbers submitted from established sampling points. The maximum radionuclide concentrations in 1997 were all in mouse feces collected along railroad tracks east of 218-W-4B Burial Ground in the 200-West Area. The concentrations included cobalt-60 (28,000 pCi/g); strontium-90 (170,000 pCi/g); cesium-137 (130,000 pCi/g); europium-154 (26,000 pCi/g); europium-155 (11,000 pCi/g); plutonium-238 (8,100 pCi/g); plutonium-239,240 (33,000 pCi/g); and total uranium (160,000 pCi/g). A sample of three house mice from the 244-AR Vault in the 200-East Area had 160,000 pCi/g of strontium-90.

Contaminated animal samples, which were somewhat atypical for the special sample program, included darkling beetles with elevated strontium-90 levels (180 pCi/g) found inside the 272-S Building in the 200-West Area, and a sample of 12 sagebrush lizards containing low levels of strontium-90 (68 pCi/g) and cesium-137 (33 pCi/g) found in a contaminated cabinet outside the Plutonium-Uranium Extraction Plant in the 200-East Area (see Table 3.2.10).

Additionally, there were 8 cases of contaminated wildlife or related samples (e.g., nests, feces) found during cleanup operations that were not analyzed. The numbers of animals found to be contaminated with radioactive material, the radiation levels, and the range of radionuclide concentrations were within historical ranges (WHC-MR-0418).

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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 U.S. Department of Energy (DOE) environmental protection policies, support DOE environmental management decisions, and provide information to the public.

Sections 4.1 through 4.7 describe results of the Hanford Site surface environmental surveillance and drinking water surveillance projects for 1997 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/RL-91-50, Rev. 2). Radiological doses associated with the surveillance results are discussed in Section 5.0, "Potential Radiological Doses from 1997 Hanford Operations." The quality assurance and quality control programs developed for ensuring the value of surveillance data are described in Section 8.0, "Quality Assurance."

Many samples are collected and analyzed for the Hanford Site environmental surveillance program, and data obtained from the analytical laboratories are compiled in a large database. 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 1997* (PNNL-11796). The intent of these sections (Sections 4.1 through 4.7) is to provide current surveillance data, to compare 1997 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.

## 4.0.1 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 potential effects of these materials on the environment and the public. Samples of air, surface water, sediments, soil and natural vegetation, agricultural products, fish, and wildlife are collected. Analyses include the measurement of radionuclides at very low environmental concentrations and nonradiological chemicals, including metals and anions. In addition, ambient external radiation is measured.

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.

### 4.0.1.1 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/EH-0173T and include the following:

- determine compliance with applicable environmental quality standards and public exposure limits and applicable laws and regulations; the requirements of DOE Orders; 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 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/EH-0173T indicates that subsidiary objectives for surveillance should be considered. Subsidiary objectives applicable to the site include the following:

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

### 4.0.1.2 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 the Hanford Site 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 provides 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 (PNL-10714). 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 1997 pathway analysis was based on 1997 source-term data and on the comprehensive pathway and dose assessment methodology included in the Generation II (GENII) computer code (PNL-6584) used for estimating radiation doses to the public from Hanford Site operations. The CRITRII computer code (PNL-8150) 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). An exposure pathway is identified based on 1) examination of the types, location, and sources (contaminated soil, raw effluent) 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 Site releases and to document that contaminant levels were well below standards

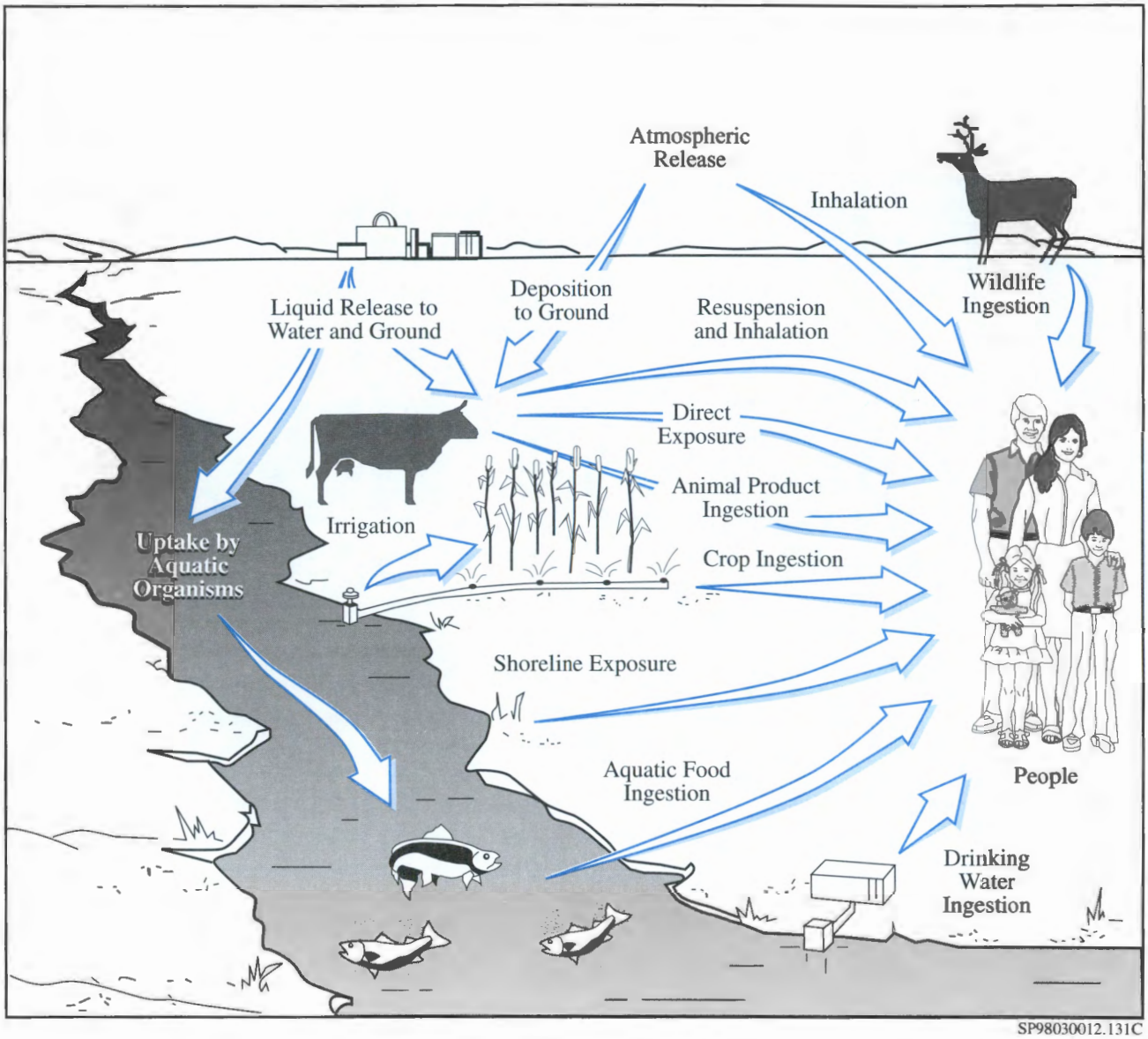


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**Figure 4.0.1**. Primary Exposure Pathways

established to protect public health. Table 4.0.1 summarizes the sample types and measurement locations in all three zones for 1997.

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 Site 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 Site 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 Site operations in recent years generally have been too small to be measured directly once dispersed in the offsite environment. For the measurable radionuclides, often it was not possible to distinguish levels resulting from worldwide fallout and natural

**Table 4.0.1.** Routine Environmental Surveillance Sample Types and Measurement Locations, 1997

| | | Sample Locations | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Columbia River | | |
| Type | Total Number | Onsite[a] | Site Perimeter[b] | Nearby[c] | Distant[c] | Upstream[c] | Hanford Reach[b] | Downstream[c] |
| Air | 39 | 20 | 9 | 8[d] | 2[e] | | | |
| Springs water | 8 | | | | | | 8 | |
| Springs sediment | 5 | | | | | | 5 | |
| Columbia River | 7 | | | | | 2 | 4 | 1 |
| Irrigation water | 1 | | 1 | | | | | |
| Drinking water | 6 | 6 | | | | | | |
| Columbia River sediments | 6 | | | | | 1 | 3 | 2 |
| Ponds | 3 | 3 | | | | | | |
| Foodstuffs | 16 | | | 12 | 4 | | | |
| Alfalfa | 3 | | | 2 | 1 | | | |
| Wildlife | 7 | 2 | | | | 1[f] | 4 | |
| Soil | 0 | | | | | | | |
| Vegetation | 0 | | | | | | | |
| TLDs[g] | 66 | 24 | 32[h] | 8[d] | 2[e] | | | |
| Shoreline surveys | 16 | | 16 | | | | | |
| Gamma measurements (PIC)[i] | 4 | | | 3[d] | 1[d] | | | |

(a) Surveillance zone 1.
(b) Surveillance zone 2.
(c) Surveillance zone 3.
(d) Community-operated environmental surveillance stations.
(e) Includes one community-operated environmental surveillance station.
(f) Sample collected from the Columbia River near the Vernita Bridge.
(g) TLDs = thermoluminescent dosimeters.
(h) Includes locations along the Columbia River.
(i) Pressurized ionization chamber.

sources from those associated with Hanford Site releases. Therefore, offsite doses in 1997 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* (PNNL-11464).

# 4.1 Air Surveillance

*B. M. Gillespie*

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 air surveillance program. A complete listing of all analytical results summarized in this section is reported separately (PNNL-11796). A detailed description of all radiological sampling and analytical techniques is provided in the environmental monitoring plan (DOE/RL-91-50, Rev. 2).

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

Airborne radionuclides were sampled at 39 continuously operating samplers: 20 on the Hanford Site, 9 near the site perimeter, 8 in nearby communities, and 2 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 7.4, "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 7.1, "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 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 (PNNL-11473). 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 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 Site emissions. The filters were then analyzed for gross beta radioactivity, and most filters were also analyzed for gross 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 (15.7 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.

Atmospheric water vapor was collected for tritium analysis at 19 locations by continuously passing air through

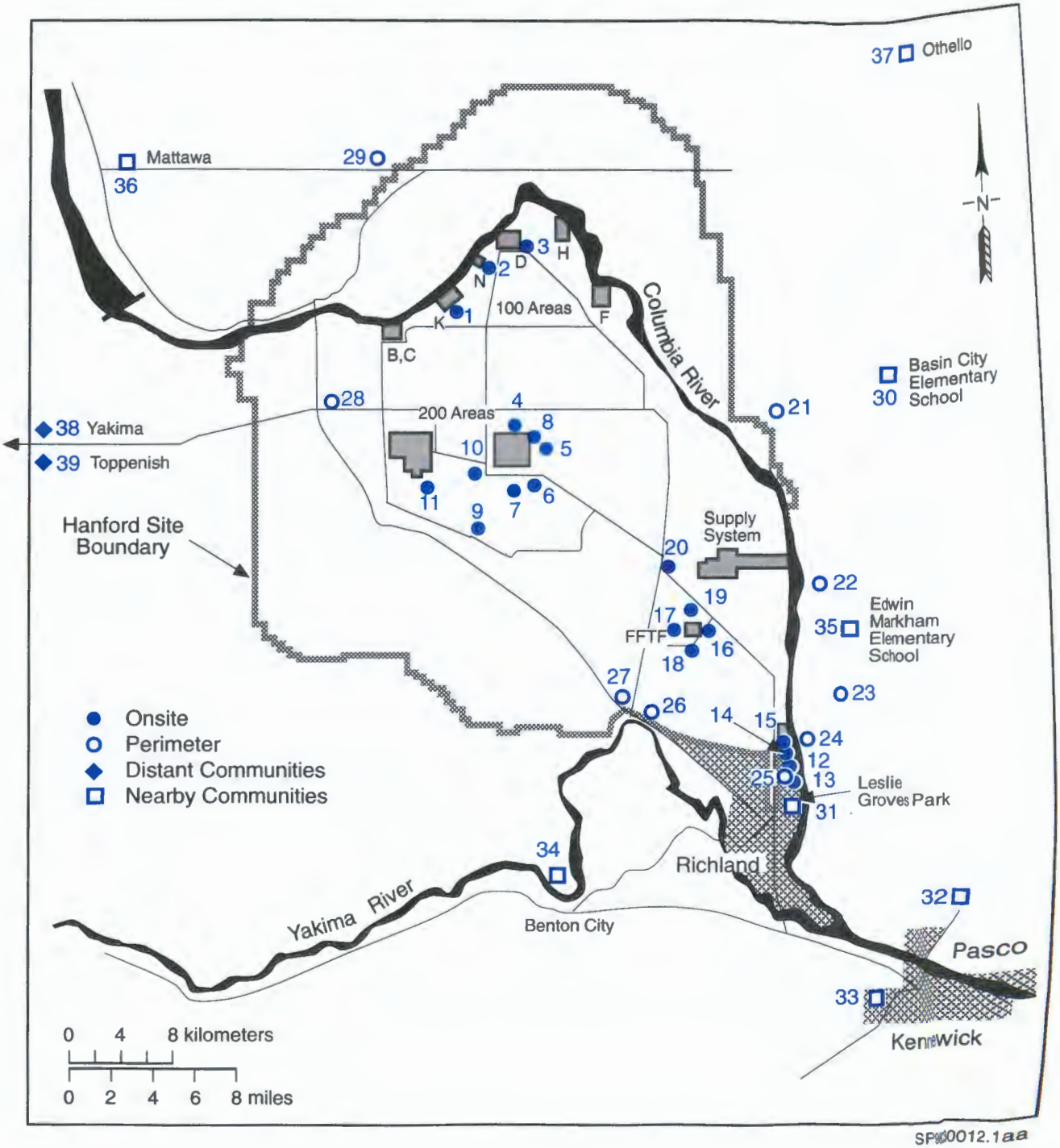


**Figure 4.1.1.** Air Sampling Locations, 1997 (see Table 4.1.1 for location names)

**Table 4.1.1.** Air Sampling Locations, Sample Composite Groups, and Analyses, 1997

| Map[a] Location | Sampling Location | Analytes[b] | Composite Group | Analytes[c] |
|---|---|---|---|---|
| **Onsite** | | | | |
| 1 | 100-K Area | Alpha, beta, $^{3}H$ | 100 Areas | Gamma, Sr, Pu |
| 2 | 100-N, 1325 Crib | Alpha, beta, $^{3}H$ | | |
| 3 | 100-D Area | Alpha, beta | | |
| 4 | N of 200 East | Beta | North of 200-East | Gamma - Annual |
| 5 | E of 200E | Alpha, beta | 200 E Area | Gamma, Sr, Pu, U |
| 6 | 200 ESE | Alpha, beta, $^{3}H$, $^{129}I$ | | |
| 7 | S of 200E | Alpha, beta | | |
| 8 | B Pond | Alpha, beta | B Pond | Gamma, Sr, Pu, U |
| 9 | Army Loop Camp | Alpha, beta | 200 West South East | Gamma, Sr, Pu, U |
| 10 | 200 Tel. Exchange | Alpha, beta, $^{3}H$ | | |
| 11 | 200 West SE | Alpha, beta | 200 West | Gamma, Sr, Pu, U |
| 12 | 300 Water intake | Beta | 300 Area | Gamma, Sr, Pu, U |
| 13 | 300 South Gate | Alpha, beta, $^{3}H$ | | |
| 14 | 300 Trench | Alpha, beta, $^{3}H$, | 300 NE | Sr, Pu, U |
| 15 | 300 NE | gamma - Quarterly | | |
| 16 | 400-East | Alpha, beta, $^{3}H$ | 400 Area | Gamma, Sr, Pu |
| 17 | 400-West | Alpha, beta | | |
| 18 | 400-South | Alpha, beta | | |
| 19 | 400-North | Alpha, beta | | |
| 20 | Wye Barricade | Alpha, beta | Wye Barricade | Gamma, Sr, Pu, U |
| **Perimeter** | | | | |
| 21 | Ringold Met. Tower | Alpha, beta, $^{3}H$, $^{129}I$ | Ringold Met. Tower | Gamma, Sr, Pu |
| 22 | W End of Fir Road | Alpha, beta | W End of Fir Road | Gamma, Sr, Pu, U |
| 23 | Dogwood Met. Tower | Alpha, beta, $^{3}H$ | Dogwood Met. Tower | Gamma, Sr, Pu, U |
| 24 | Byers Landing | Alpha, beta, $^{3}H$, $^{129}I$ | Byers Landing | Gamma, Sr, Pu, U |
| 25 | Battelle Complex | Beta | Battelle Complex | Gamma - Annual |
| 26 | Horn Rapids Substation | Alpha, beta | Prosser Barricade | Gamma, Sr, Pu, U |
| 27 | Prosser Barricade | $^{3}H$ | | |
| 28 | Yakima Barricade | Alpha, beta | Yakima Barricade | Gamma, Sr, Pu |
| 29 | Wahluke Slope | Alpha, beta, $^{3}H$ | 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] | Alpha, beta, $^{3}H$ | Basin City Elem. School | Gamma, Sr, Pu, U |
| 31 | Richland[d] | Alpha, beta, $^{3}H$ | Leslie Groves Park | Gamma, Sr, Pu, U |
| 32 | Pasco[d] | Beta | Tri-Cities | Gamma, Sr, Pu |
| 33 | Kennewick[d] | Alpha, beta | | |
| 34 | Benton City[d] | Beta | Benton City | Gamma - Annual |
| 35 | North Franklin County[d] | Alpha, beta, $^{3}H$ | 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 | Yakima | Alpha, beta, $^{3}H$, $^{129}I$ | Yakima | Gamma, Sr, Pu, U |
| 39 | Toppenish[d] (Heritage College) | Alpha, beta, $^{3}H$ | Toppenish | Gamma, Sr, Pu, U |

(a) See Figure 4.1.1.
(b) Alpha (gross) and beta (gross) 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]); strontium-90, plutonium-isotopic, and uranium-isotopic analyses are performed on annual composite samples.
(d) A community-operated environmental surveillance station.

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 air samples were collected at nine community-operated environmental surveillance stations (see Section 7.4, "Community-Operated Environmental Surveillance Program") 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 Site environmental monitoring programs. The samples were submitted to the analytical laboratory and treated the same as all other submitted samples.

## 4.1.2 Radiological Results for Air Samples

Radiological air sampling results for onsite, site perimeter, nearby communities, and distant communities for gross alpha, gross beta, and specific radionuclides are summarized in Table 4.1.2.

A detectable value is defined in this section as a value reported above the 2-sigma total propagated analytical uncertainty for all analytes of interest except for gamma-emitting radioisotopes. A gamma-emitting radioisotope

**Table 4.1.2.** Airborne Radionuclide Concentrations in the Hanford Environs, 1997 Compared to Previous Years

| Radionuclide | Location Group[a] | 1997 No. of Samples | 1997 No. of Detections[b] | 1997 Maximum[c] | 1997 Average[d] | 1993-1996 No. of Samples | 1993-1996 No. of Detections[b] | 1993-1996 Maximum[c] | 1993-1996 Average[d] | Derived Concentration Guide[e] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | aCi/m³ | aCi/m³ | | | aCi/m³ | aCi/m³ | |
| Gross alpha | Onsite | 457 | 265 | 5,500 ± 1,260 | 520 ± 27 | 1,799 | 1,486 | 2,300 ± 620 | 500 ± 15 | |
| | Perimeter | 180 | 114 | 2,000 ± 1,010 | 550 ± 43 | 740 | 641 | 2,200 ± 620 | 530 ± 23 | |
| | Nearby communities | 104 | 64 | 1,460 ± 972 | 510 ± 56 | 415 | 365 | 1,800 ± 530 | 530 ± 28 | No Standard |
| | Distant communities | 50 | 32 | 2,340 ± 1,040 | 410 ± 81 | 231[f] | 178 | 4,800 ± 920 | 470 ± 61 | |
| | | | | pCi/m³ | pCi/m³ | | | pCi/m³ | pCi/m³ | pCi/m³ |
| Tritium | Onsite | 107 | 29 | 4.9 ± 2.0 | 0.68 ± 0.16 | 429 | 91 | 610 ± 52 | 5.0 ± 3.93 | |
| | Perimeter | 58 | 7 | 3.7 ± 5.8 | 0.48 ± 0.16 | 256 | 23 | 12 ± 22 | 0.9 ± 0.23 | |
| | Nearby communities | 38 | 5 | 2.1 ± 1.6 | 0.67 ± 0.18 | 157 | 16 | 120 ± 13 | 2.0 ± 1.61 | 100,000 |
| | Distant communities | 26 | 2 | 2.9 ± 3.4 | 0.64 ± 0.27 | 117 | 8 | 5.2 ± 5.0 | 0.60 ± 0.19 | |
| | | 1997 | | | | 1992-1996 | | | | |
| | | | | pCi/m³ | pCi/m³ | | | pCi/m³ | pCi/m³ | |
| Gross beta | Onsite | 506 | 506 | 0.050 ± 0.007 | 0.015 ± 0.001 | 2,464 | 2,460 | 0.13 ± 0.012 | 0.019 ± 0.00047 | |
| | Perimeter | 204 | 204 | 0.043 ± 0.006 | 0.015 ± 0.001 | 1,035 | 1,029 | 0.15 ± 0.014 | 0.019 ± 0.00077 | |
| | Nearby communities | 208 | 208 | 0.044 ± 0.005 | 0.017 ± 0.001 | 806 | 806 | 0.10 ± 0.010 | 0.019 ± 0.00082 | No Standard |
| | Distant communities | 50 | 50 | 0.037 ± 0.004 | 0.013 ± 0.002 | 286 | 286 | 0.12 ± 0.013 | 0.018 ± 0.0016 | |
| | | | | aCi/m³ | aCi/m³ | | | aCi/m³ | aCi/m³ | aCi/m³ |
| Strontium-90 | Onsite | 9 | 1 | 9.6 ± 11 | 2.15 ± 3.2 | 50 | 17 | 300 ± 96 | 25 ± 18 | |
| | Perimeter | 7 | 0 | 3.7 ± 9.4 | 0.350 ± 1.8 | 34 | 3 | 35 ± 11 | -3.4 ± 6.6 | |
| | Nearby communities | 4 | 0 | 7.2 ± 8.5 | 1.35 ± 4.3 | 20 | 2 | 16 ± 16 | -3.4 ± 6.2 | 9,000,000 |
| | Distant communities | 2 | 0 | -3.1 ± 16 | -5.28 ± 4.3 | 11 | 0 | 68 ± 120 | 3.0 ± 15 | |
| Iodine-129 | Onsite | 4 | 4 | 32 ± 2.9 | 23 ± 13 | 20 | 20 | 74 ± 7.2 | 41 ± 5.1 | |
| | Perimeter | 8 | 8 | 1.2 ± 0.057 | 0.65 ± 0.19 | 41 | 41 | 2.3 ± 0.28 | 1.2 ± 0.18 | |
| | Distant communities | 4 | 4 | 0.078 ± 0.008 | 0.043 ± 0.024 | 21 | 21 | 0.14 ± 0.02 | 0.067 ± 0.014 | 70,000,000 |
| Plutonium-238 | Onsite | 9 | 0 | 0.15 ± 0.26 | 0.017 ± 0.058 | 50 | 4 | 0.90 ± 0.54 | -0.12 ± 0.12 | |
| | Perimeter | 7 | 0 | 0.15 ± 0.28 | 0.021 ± 0.057 | 33 | 0 | 3.1 ± 4.1 | -0.020 ± 0.26 | |
| | Nearby communities | 4 | 0 | 0.27 ± 0.40 | 0.13 ± 0.10 | 20 | 1 | 0.76 ± 3.5 | -0.019 ± 0.18 | 30,000 |
| | Distant communities | 2 | 0 | 0.09 ± 0.64 | 0.005 ± 0.16 | 11 | 0 | 0.86 ± 3.5 | 0.10 ± 0.24 | |

## Table 4.1.2. (contd)

| Radionuclide | Location Group[a] | 1997 No. of Samples | 1997 No. of Detections[b] | 1997 Maximum[c] aCi/m³ | 1997 Average[d] aCi/m³ | 1992-1996 No. of Samples | 1992-1996 No. of Detections[b] | 1992-1996 Maximum[c] aCi/m³ | 1992-1996 Average[d] aCi/m³ | Derived Concentration Guide[e] aCi/m³ |
|---|---|---|---|---|---|---|---|---|---|---|
| Plutonium-239,240 | Onsite | 9 | 6 | 2.6 ± 0.82 | 0.76 ± 0.54 | 50 | 24 | 12 ± 2.5 | 1.8 ± 0.70 | |
| | Perimeter | 7 | 3 | 0.73 ± 0.60 | 0.33 ± 0.18 | 33 | 12 | 2.3 ± 0.92 | 0.59 ± 0.21 | |
| | Nearby communities | 4 | 2 | 0.67 ± 0.65 | 0.38 ± 0.20 | 20 | 9 | 1.8 ± 1.7 | 0.59 ± 0.36 | 20,000 |
| | Distant communities | 2 | 0 | -0.15 ± 0.43 | -0.22 ± 0.16 | 11 | 3 | 3.9 ± 1.3 | 0.65 ± 0.72 | |
| Uranium-234 | Onsite | 8 | 8 | 59 ± 14 | 30 ± 11 | 40 | 39 | 142 ± 208 | 23 ± 6.9 | |
| | Perimeter | 4 | 4 | 41 ± 8.3 | 31 ± 11 | 19 | 19 | 54 ± 18 | 26 ± 5.5 | |
| | Nearby communities | 3 | 3 | 31 ± 6.8 | 26 ± 6.0 | 15 | 15 | 37 ± 13 | 24 ± 4.1 | 90,000 |
| | Distant communities | 2 | 2 | 21 ± 5.6 | 21 ± 0.70 | 11 | 11 | 31 ± 10 | 20 ± 4.9 | |
| Uranium-235 | Onsite | 8 | 3 | 2.6 ± 2.7 | 0.95 ± 0.54 | 40 | 13 | 51 ± 129 | 2.1 ± 2.5 | |
| | Perimeter | 4 | 2 | 3.4 ± 2.1 | 1.2 ± 1.5 | 19 | 9 | 4.3 ± 4.8 | 1.3 ± 0.47 | |
| | Nearby communities | 3 | 3 | 1.6 ± 1.5 | 1.3 ± 0.42 | 15 | 6 | 4.3 ± 4.8 | 1.2 ± 0.6 | 100,000 |
| | Distant communities | 2 | 0 | 0.32 ± 1.1 | 0.15 ± 0.34 | 11 | 2 | 3.3 ± 4.0 | 0.85 ± 0.7 | |
| Uranium-238 | Onsite | 8 | 8 | 58 ± 14 | 28 ± 9.9 | 40 | 39 | 44 ± 12 | 17 ± 3.0 | |
| | Perimeter | 4 | 4 | 43 ± 8.6 | 29 ± 12 | 19 | 19 | 42 ± 16 | 24 ± 4.1 | |
| | Nearby communities | 3 | 3 | 34 ± 7.2 | 26 ± 9.2 | 15 | 15 | 36 ± 11 | 23 ± 4.0 | 100,000 |
| | Distant communities | 2 | 2 | 17 ± 5.1 | 17 ± 0.10 | 11 | 10 | 30 ± 7.5 | 17 ± 4.5 | |
| Cobalt-60 | Onsite | 41 | 0 | 680 ± 650 | 74 ± 88 | 193 | 31 | 880 ± 490 | 55 ± 35 | |
| | Perimeter | 29 | 0 | 500 ± 490 | 142 ± 92 | 142 | 13 | 740 ± 870 | 12 ± 42 | |
| | Nearby communities | 19 | 0 | 800 ± 560 | -10 ± 150 | 92 | 5 | 750 ± 440 | 16 ± 48 | 80,000,000 |
| | Distant communities | 8 | 0 | 640 ± 490 | 196 ± 190 | 47 | 7 | 680 ± 440 | 100 ± 75 | |
| Cesium-137 | Onsite | 41 | 0 | 430 ± 290 | 47 ± 61 | 193 | 23 | 570 ± 420 | 35 ± 39 | |
| | Perimeter | 29 | 0 | 660 ± 210 | -32 ± 110 | 142 | 10 | 650 ± 410 | 23 ± 35 | |
| | Nearby communities | 19 | 0 | 500 ± 480 | 54 ± 120 | 92 | 7 | 710 ± 330 | 47 ± 37 | 400,000,000 |
| | Distant communities | 8 | 0 | 370 ± 700 | -27 ± 230 | 47 | 2 | 390 ± 290 | 47 ± 53 | |

(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) 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]).

is detectable if the radionuclide library of the software determines an isotope concentration above the minimum detectable activity of a sample. 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 gross alpha radioactivity at the site perimeter was not elevated compared to the concentrations measured at distant stations (see Table 4.1.2) and was similar to values reported for 1993 through 1996 (Figure 4.1.2). The highest onsite gross alpha radioactivity concentration was in the 200 West South East sampling site (location 11 on Figure 4.1.1).

Tritium concentrations measured in 1997 were similar to values reported for 1993 through 1996 (see Table 4.1.2) and did not show the highly elevated concentrations and widely variable results reported for 1992 (Section 4.2 in PNL-8682). The 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 1997, only 43 of the 229 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 (0.48 ± 0.16 pCi/m$^3$) was significantly lower (log transformed, two-tailed t-test, 5% significance level) than the annual average value at the distant locations (0.64 ± 0.27 pCi/m$^3$). The annual average tritium concentration at the site perimeter in 1997 was less than 0.0005% of the 100,000-pCi/m$^3$ DOE derived concentration guide (DOE Order 5400.5).

Gross beta concentrations in air for 1997 (Figure 4.1.3) peaked during the winter, repeating a pattern of natural annual radioactivity fluctuations (Eisenbud 1987). The average gross beta concentration was slightly higher at the site perimeter than 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.

Only one of the 22 strontium-90 results for air samples for 1997 was above the detection limit (see Table 4.1.2). The nominal detection limit of the 22 sample results is 8 aCi/m$^3$. The one detected concentration (9.3 ± 6.3 aCi/m$^3$) was determined for the 200-East Area composite sample (locations 5, 6, and 7 on Figure 4.1.1), and this concentration is 0.0001% of the 9,000,000-aCi/m$^3$ 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 1997 (see Figure 4.1.1). Onsite concentrations in 1997 were elevated compared to those measured at the site perimeter, and perimeter concentrations were higher than those measured at Yakima, the distant location (Figure 4.1.4 and see 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 1992 through 1997 (see 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 1997 (0.65 ± 0.19 aCi/m$^3$) was less than 0.000001% of the 70,000,000-aCi/m$^3$ derived concentration guide.

Plutonium-238 was not detected in any of the 22 air samples for 1997 (nominal detection limit of 0.1 aCi/m$^3$). The plutonium-238 nominal detection limit represents 0.0003% 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 0.33 ± 0.18 aCi/m$^3$, which is less than 0.002% of the 20,000-aCi/m$^3$ derived concentration guide. The annual average air concentration was higher for the site perimeter locations than the distant locations (0.11 ± 0.11 aCi/m$^3$) and was statistically significant (log transformed, two-tailed t-test, 5% significance level), indicating a Hanford influence. The maximum Hanford Site plutonium-239,240 air concentration (2.6 ± 0.82 aCi/m$^3$) was determined for the 200-West Area composite sample (location 11 on Figure 4.1.1). This represents less than 0.02% of the 20,000-aCi/m$^3$ derived concentration guide.

Average uranium isotopic concentrations (uranium-234, uranium-235, and uranium-238) in airborne particulate matter in 1997 were similar on the site, at the site perimeter, and at distant communities (see Table 4.1.2 and

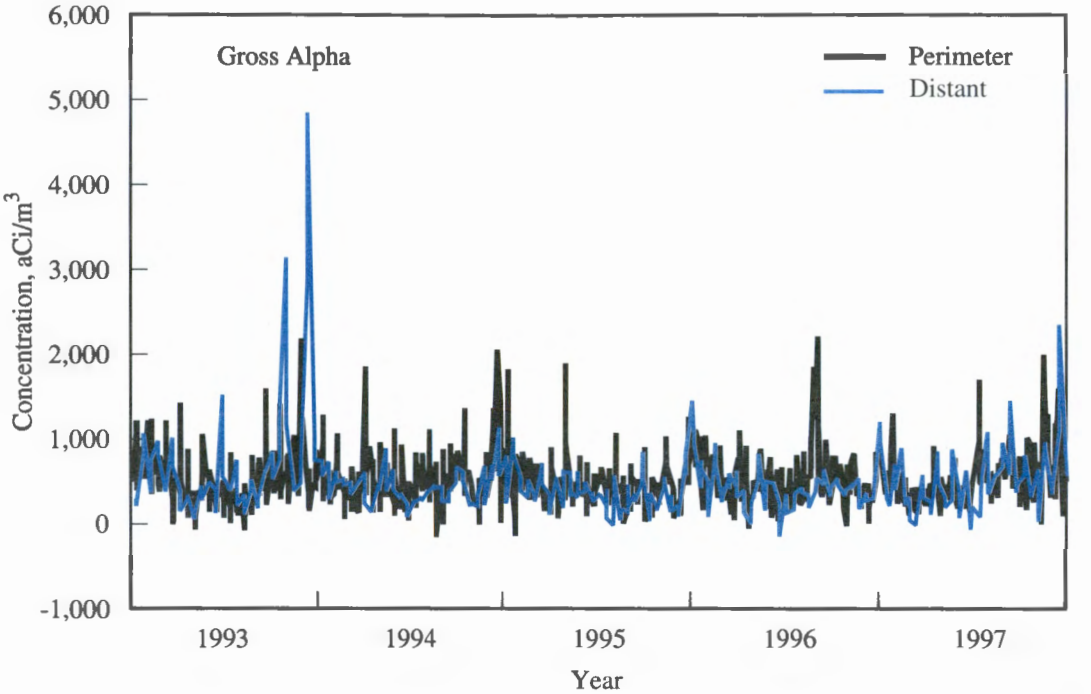


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**Figure 4.1.2**. Gross Alpha in Airborne Particulate Samples, 1993 Through 1997

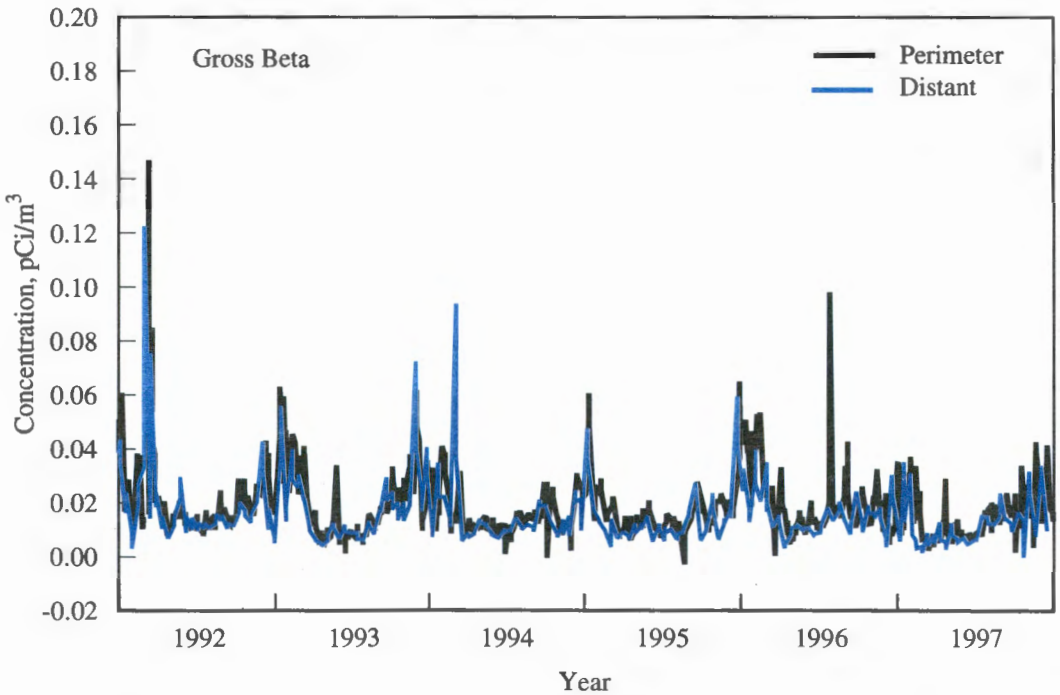


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**Figure 4.1.3**. Gross Beta in Airborne Particulate Samples, 1992 Through 1997

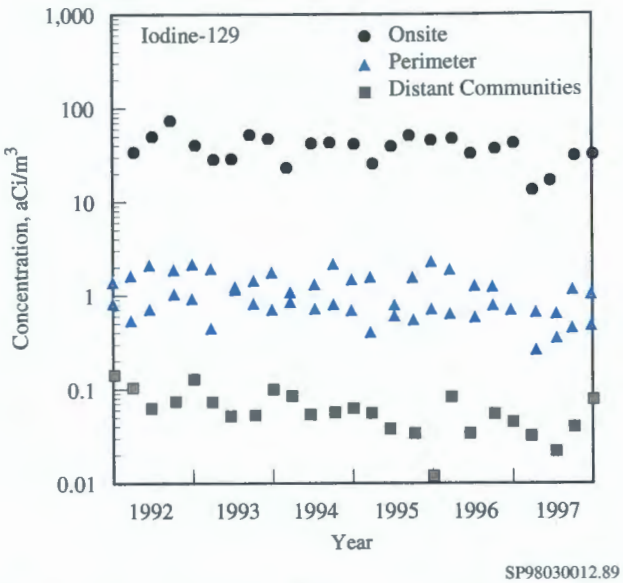


**Figure 4.1.4**. Iodine-129 Concentrations in Air, 1992 Through 1997

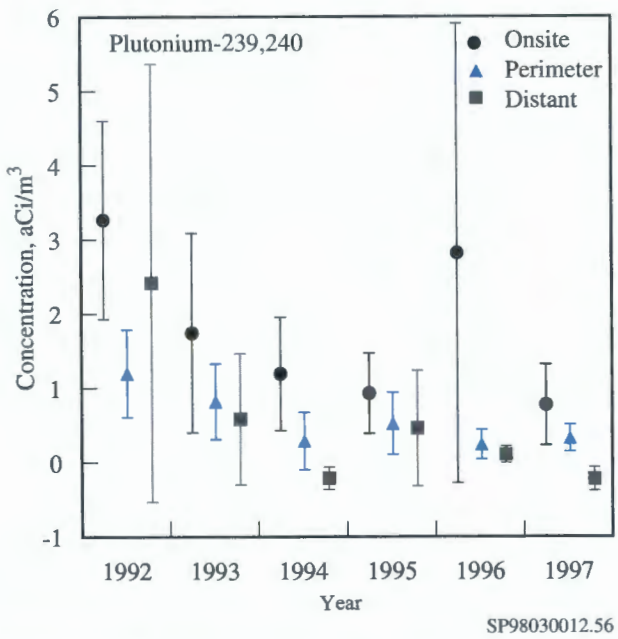


**Figure 4.1.5**. Annual Average Plutonium-239,240 Concentrations (±2 standard error of the mean) in Air, 1992 Through 1997

Figure 4.1.6). The 1997 annual average concentration of uranium-238 for the site perimeter was 29 ± 12 aCi/m³, which was 0.03% of the 100,000-aCi/m³ derived concentration guide.

Samples were analyzed quarterly, and at some locations annually, by gamma 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 spectroscopy. Of the 97 samples analyzed by gamma spectroscopy, none of the samples had concentrations above the minimum detectable activity for the sample for that isotope. The cobalt-60 and cesium-137 results for 1997 samples are included in Table 4.1.2. Even the maximum individual measurements for these radionuclides (800 ± 560 and 660 ± 210 aCi/m³, respectively) were less than 0.001% of their derived concentration guides.

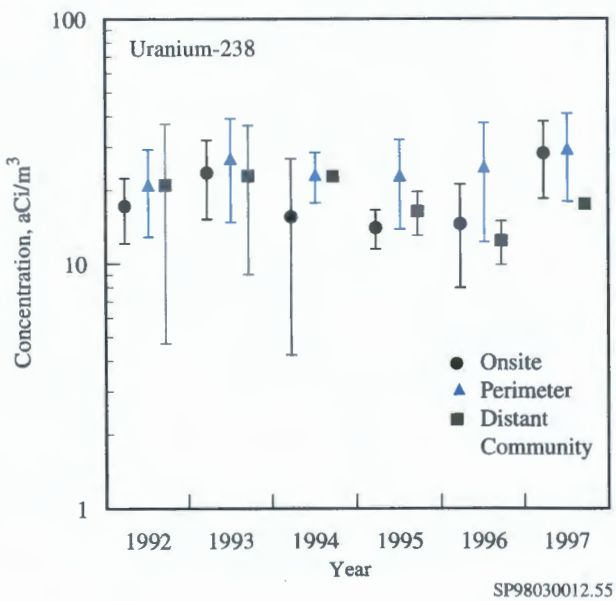


**Figure 4.1.6**. Annual Average Uranium-238 Concentrations (±2 standard error of the mean) in Air, 1992 Through 1997

# 4.2 Surface Water and Sediment Surveillance

*G. W. Patton*

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 surveillance is conducted for 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 1997. 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 in PNNL-11796.

## 4.2.1 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 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 river downstream of the site 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 670,000 km$^2$ (260,000 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 the nearest upstream dam and McNary Dam is the nearest downstream dam 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, Washington. 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 average flows of the Columbia River below Priest Rapids Dam are nearly 3,400 m$^3$/s (120,000 ft$^3$/s) (WA-94-1). In 1997, the Columbia River had exceptionally high flow; the average daily flow rate below Priest Rapids Dam was 4,790 m$^3$/s (169,000 ft$^3$/s). The peak monthly average flow rate occurred during June (9,150 m$^3$/s [323,000 ft$^3$/s]) (Figure 4.2.2). The lowest monthly average flow rate occurred during November (2,970 m$^3$/s [105,000 ft$^3$/s]). Daily flow rates varied from 1,870 to 11,600 m$^3$/s (66,200 to 410,000 ft$^3$/s) during 1997. 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 (Section 3.3.7 in PNL-10698). Seasonal changes of approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are approximately half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam (PNL-8580) 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 permitted direct discharges of liquid effluents from Hanford facilities, contaminants in groundwater from past discharges to the ground are known to seep into the river (DOE/RL-92-12, PNL-5289, PNL-7500, WHC-SD-EN-TI-006). Effluents from each direct discharge point are routinely monitored and reported by the responsible operating contractor; these were summarized in Section 3.1, "Facility Effluent Monitoring." Direct discharges are identified and regulated for

**Table 4.2.1.** Surface-Water Surveillance, 1997

| Location | Sample Type | Frequency[a] | Analyses |
|---|---|---|---|
| **Columbia River - Radiological** | | | |
| Priest Rapids Dam and Richland Pumphouse | Cumulative | M Comp[b] | Alpha, beta, lo $^{3}H$,[c] gamma scan, $^{90}Sr$, $^{99}Tc$, U[d] |
| | Particulate (filter) | Q Cont [e] | Gamma scan, Pu[f] |
| | Soluble (resin) | Q Cont | Gamma scan, $^{129}I$, Pu |
| Vernita Bridge and Richland Pumphouse | Grab (transects) | Q | lo $^{3}H$, $^{90}Sr$, U |
| 100-F, 100-N, 300, and old Hanford Townsite | Grab (transects) | A | lo $^{3}H$, $^{90}Sr$, U |
| **Columbia River - Nonradiological** | | | |
| Vernita and Richland Pumphouse[g] | Grab | Q | NASQAN, temperature, dissolved oxygen, turbidity, pH, alkalinity, anions, suspended solids, dissolved solids, specific conductance, hardness (as $CaCO_3$), Ca, P, Cr, Mg, N-Kjeldahl, Fe, $NH_3$, $NO_3 + NO_2$ |
| | Grab (transects) | Q | ICP[h] metals, anions |
| | Grab (transects) | A | Cyanide ($CN^-$) |
| 100-F, 100-N, 300, and old Hanford Townsite | Grab (transects) | A | ICP metals, anions |
| **Onsite Ponds** | | | |
| West Lake | Grab | Q | Alpha, beta, $^{3}H$, $^{90}Sr$, $^{99}Tc$, U, gamma scan |
| B Pond (216-B-3C) | | 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-H Area | Grab | A | Alpha, beta, $^{3}H$, $^{90}Sr$, $^{99}Tc$, U, gamma scan, ICP metals, anions |
| 100-B Area | Grab | A | Alpha, beta, $^{3}H$, $^{90}Sr$, $^{99}Tc$, gamma scan, ICP metals, anions |
| 100-D, 100-K, and 100-N Areas | Grab | A | Alpha, beta, $^{3}H$, $^{90}Sr$, gamma scan, ICP metals, anions |
| Old Hanford Townsite and 300 Area | Grab | A | Alpha, beta, $^{3}H$, $^{129}I$, $^{90}Sr$, $^{99}Tc$, U, gamma scan, ICP metals, anions |

(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 (10-pCi/L detection limit), which includes an electrolytic preconcentration.
(d) U = isotopic uranium-234,235,238.
(e) Q Cont = river water was sampled for 2 weeks by continuous flow through a filter and resin column and multiple samples were composited quarterly for analysis.
(f) Pu = isotopic plutonium-238 and -239,240.
(g) Numerous water quality analyses are performed by the U.S. Geological Survey in conjunction with the National Stream Quality Accounting Network (NASQAN) Program.
(h) ICP = inductively coupled plasma analysis method.
(i) Three samples during irrigation season.

**Table 4.2.2.** Sediment Surveillance, 1997

| Location[a] | Frequency | Analyses |
|---|---|---|
| **River** | | All river sediment analyses included gamma scan, $^{90}Sr$, U, Pu, ICP metals, SEM/AVS[f] |
| Priest Rapids Dam:<br>Grant County shore<br>1/3 from Grant County shore<br>2/3 from Grant County shore<br>Yakima County shore | A | |
| White Bluffs Slough | A | |
| 100-F Slough | A | |
| Hanford Slough | A | |
| Richland | A | |
| McNary Dam:<br>Oregon shore<br>1/3 from Oregon shore<br>2/3 from Oregon shore<br>Washington shore | A[b] | |
| **Springs** | | All springs sediment analyses included gamma scan, $^{90}Sr$, U, ICP metals |
| 100-B Area | A | |
| 100-K Area | A | |
| 100-N Area Spring 8-13 | A | |
| 100-F Area | A | |
| Old Hanford Townsite Springs | A | |
| 300 Area Spring 42-2 | A | |

(a) See Figure 4.2.1.
(b) A = annually.
(c) U = uranium-235 and -238 analyzed by low-energy photon analysis.
(d) Pu = isotopic plutonium-238 and -239,240.
(e) ICP = inductively coupled plasma analysis method.
(f) SEM/AVS = simultaneously extracted metals and acid volatile sulfide.

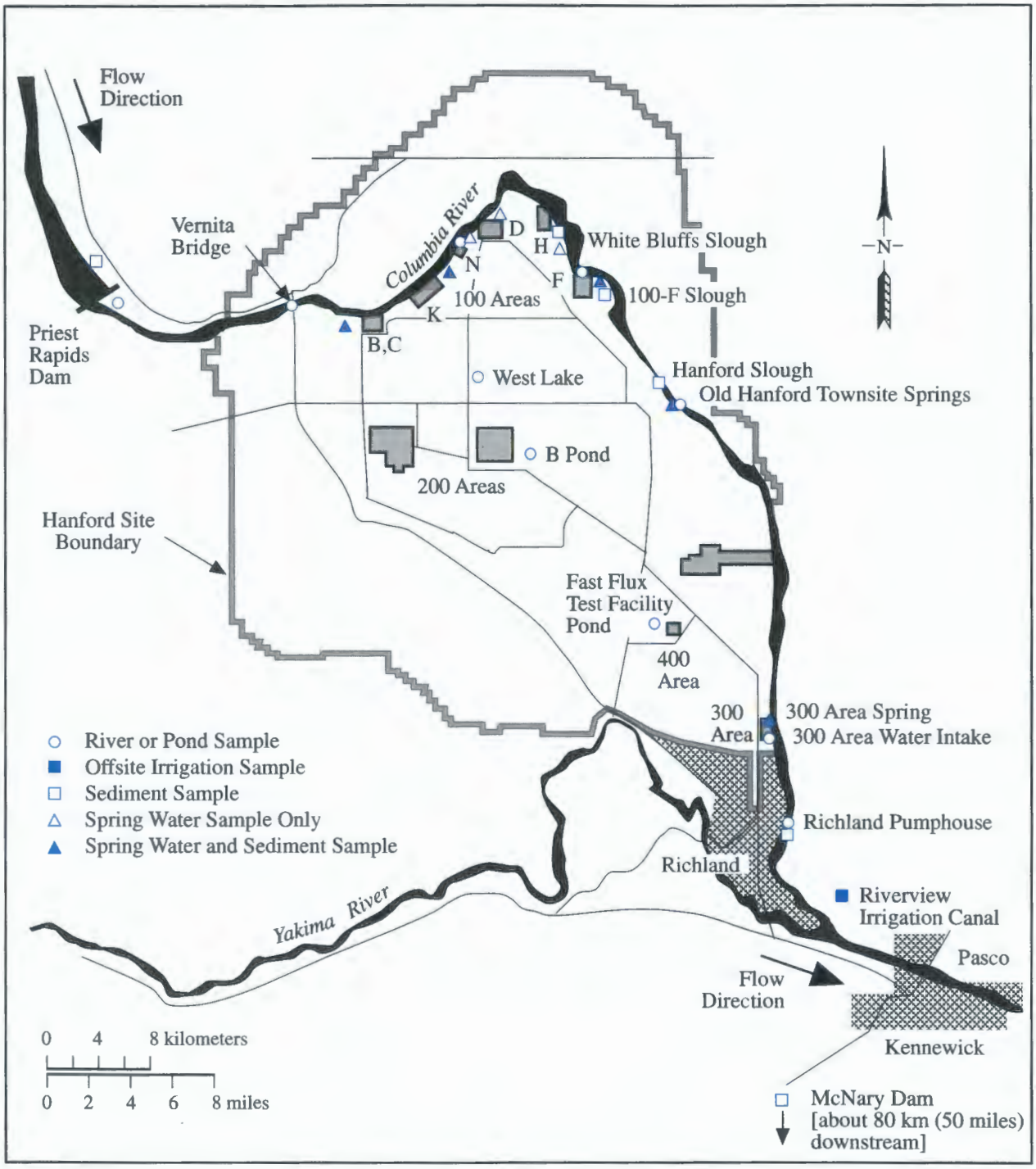


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**Figure 4.2.1**. Water and Sediment Sampling Locations, 1997

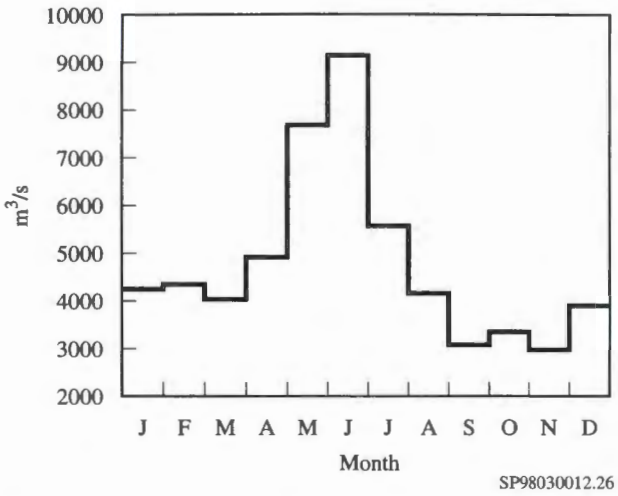


**Figure 4.2.2**. Mean Monthly Columbia River Flow Rates, 1997

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 the Hanford Site were 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 (Washington Administrative Code [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).

## 4.2.1.1 Collection of River Water Samples and Analytes of Interest

Samples of Columbia River water were collected throughout 1997 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 Columbia River water withdrawal for a municipal drinking water supply.

The fixed-location monitoring stations at Priest Rapids Dam and the Richland Pumphouse consisted of both an automated sampler and a continuous flow system. Using the automated sampler, unfiltered samples of Columbia River water (cumulative samples) were collected hourly and composited monthly for radiological analyses (see Table 4.2.1). Using the continuous flow system, particulate and soluble fractions of selected Columbia River water constituents were collected by passing water through a filter and then through a resin column. Filter and resin samples were exchanged approximately every 14 days and were combined into quarterly composite samples for radiological analyses. The river sampling locations and the methods used for sample collection are discussed in detail in DOE/RL-91-50, Rev. 2.

Analytes of interest in water samples collected from Priest Rapids Dam and the Richland Pumphouse included gross alpha, gross beta, selected gamma emitters, tritium, strontium-90, technetium-99, iodine-129, uranium-234, 235,238, plutonium-238, and plutonium-239,240. Gross alpha and beta measurements are indicators of the general radiological quality of the river and provide an early indication of change. Gamma scans provide the ability to detect numerous specific radionuclides (see Appendix E). Sensitive radiochemical analyses were used to determine the concentrations of tritium, strontium-90, technetium-99, iodine-129, uranium-234,235,238, 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 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 (PNL-8531). That study concluded that, under certain flow conditions, contaminants entering the river from the Hanford Site 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 system at the Richland Pumphouse. The Vernita Bridge and the Richland Pumphouse transects were sampled quarterly during 1997. Annual transect sampling was conducted at the 100-F Area, 100-N Area, Old Hanford Townsite, and 300 Area locations.

Columbia River transect water samples collected in 1997 were analyzed for both radiological and chemical contaminants (see Table 4.2.1). Metals and anions (listed in DOE/RL-93-94, Rev. 1), 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/RL-92-67, PNL-8073, PNL-8654, PNL-10400, PNL-10535). 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 1997, 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 (Appendix A, Table A.4). Sample analyses were performed at the U.S. Geological Survey laboratory in Denver, Colorado for numerous physical and chemical constituents.

## 4.2.1.2 Radiological Results for Columbia River Water Samples

**Fixed Location Sampling**. Results of the radiological analyses of Columbia River water samples collected at Priest Rapids Dam and Richland Pumphouse during 1997 are reported in PNNL-11796 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 1997 and during the previous 5 years. All radiological contaminant concentrations measured in Columbia River water in 1997 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 during 1997 included tritium, strontium-90, iodine-129, uranium-234,238, and plutonium-239,240. The concentrations of all other measured radionuclides were below detection limits 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 Site effluents.

Figures 4.2.3 and 4.2.4 illustrate the average annual gross alpha and gross beta concentrations, respectively, at Priest Rapids Dam and Richland Pumphouse during the past 6 years. The 1997 average gross alpha and gross beta concentrations were similar to those observed during recent years. Monthly concentrations measured at the Richland Pumphouse in 1997 were not statistically different (unless otherwise noted in this section, the statistical test for difference are 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 1997 were less than 5% of their respective ambient surface-water quality criteria levels of 15 and 50 pCi/L, respectively (WAC 246-290).

Figure 4.2.5 compares the annual average tritium concentrations at Priest Rapids Dam and Richland Pumphouse from 1992 through 1997. The general decline in tritium concentrations in river water remains evident at both locations. Statistical analysis indicated that monthly tritium concentrations in river water at the Richland Pumphouse were higher than those at Priest Rapids Dam.

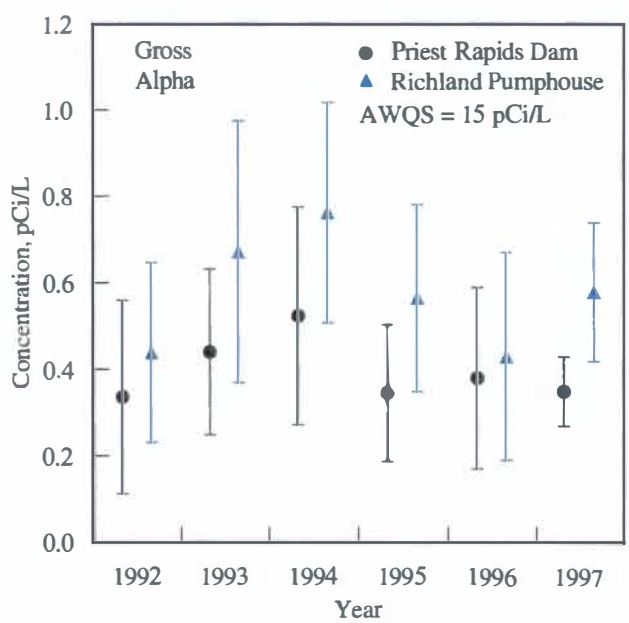


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**Figure 4.2.3**. Annual Average Gross Alpha Concentrations (±2 standard error of the mean) in Columbia River Water, 1992 Through 1997 (AWQS = ambient water quality standard)

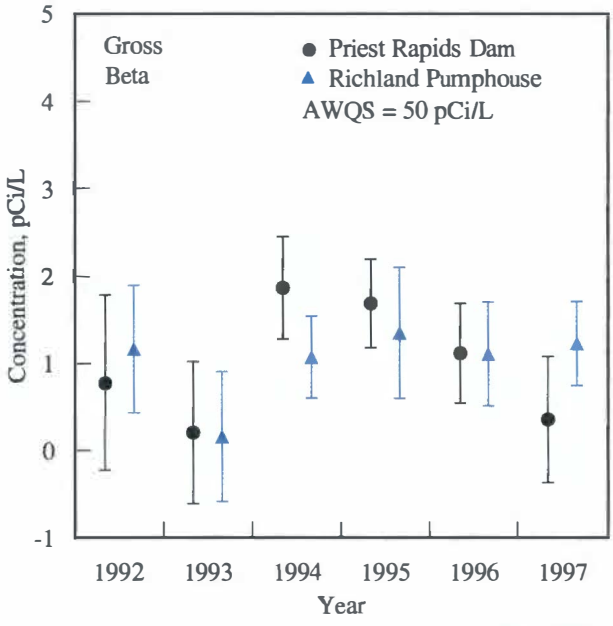


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**Figure 4.2.4**. Annual Average Gross Beta Concentrations (±2 standard error of the mean) in Columbia River Water, 1992 Through 1997 (AWQS = ambient water quality standard)

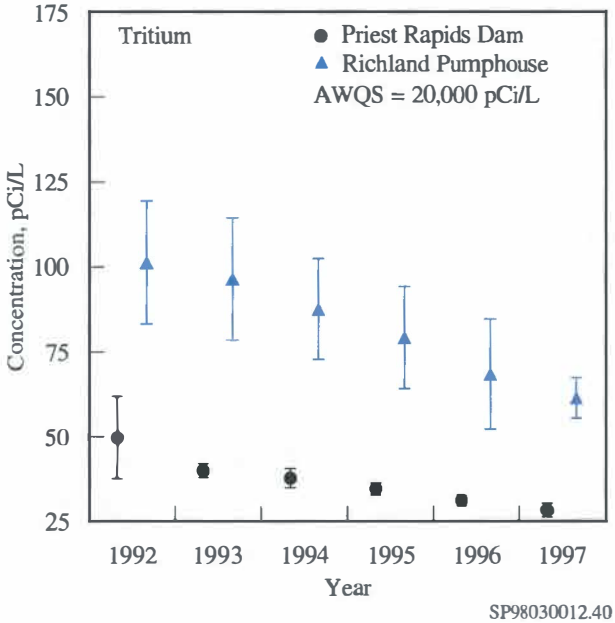


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**Figure 4.2.5**. Annual Average Tritium Concentrations (±2 standard error of the mean) in Columbia River Water, 1992 Through 1997 (AWQS = ambient water quality standard)

However, 1997 average tritium concentrations in Columbia River water collected at the Richland Pumphouse were only 0.31% of the 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 6.1, "Hanford Groundwater Monitoring Project"). 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 (PNL-8531). 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 1997 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.

The annual average strontium-90 concentrations in Columbia River water collected from Priest Rapids Dam and Richland Pumphouse from 1992 through 1997 are presented in Figure 4.2.6. Concentrations observed in 1997 were similar to those observed previously. Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Areas (Chapter 5.0 in PNL-10698). The highest strontium-90 concentrations in groundwater onsite that have been found are the result of past discharges to the 100-N Area liquid waste disposal facilities. Despite the Hanford Site source, the differences between monthly strontium-90 concentrations at Priest Rapids Dam and Richland Pumphouse in 1997 were not statistically different. Average strontium-90 concentrations in Columbia River water at the Richland Pumphouse were 1.0% of the 8-pCi/L ambient surface-water quality criteria level (WAC 246-290).

Annual average total uranium concentrations (i.e., the sum of uranium-234,235,238 concentrations) at Priest Rapids Dam and Richland Pumphouse for 1992 through 1997 are shown in Figure 4.2.7. The large error associated with

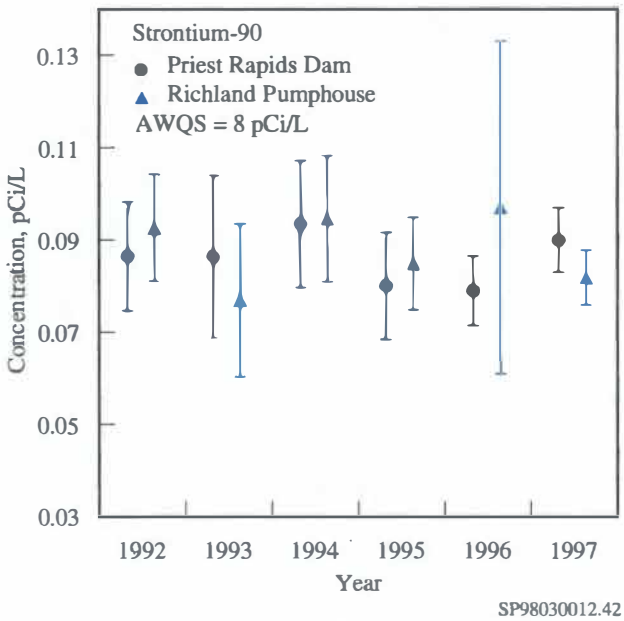


**Figure 4.2.6**. Annual Average Strontium-90 Concentrations (±2 standard error of the mean) in Columbia River Water, 1992 Through 1997 (AWQS = ambient water quality standard)

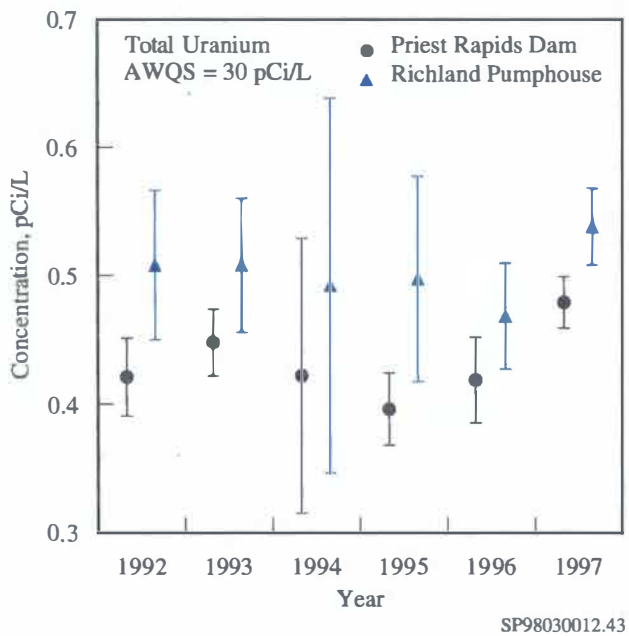


**Figure 4.2.7**. Annual Average Total Uranium Concentrations (±2 standard error of the mean) in Columbia River Water, 1992 Through 1997 (AWQS = ambient water quality standard)

1994 results was attributed to an unusually low concentration found in the December sample at each location. Total uranium concentrations observed in 1997 were similar to those observed during recent years. Monthly total uranium concentrations measured at the Richland Pumphouse in 1997 were statistically higher than those measured at Priest Rapids Dam. 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 6.1, "Hanford Groundwater Monitoring Project") and has been detected at elevated levels in riverbank springs in this area (see Section 4.2.3, "Riverbank Springs Water"). Naturally occurring uranium is also known to enter the river across from the Hanford Site via irrigation return water and groundwater seepage associated with extensive irrigation north and east of the Columbia River (PNL-7500). There are currently no ambient surface-water quality criteria levels directly applicable to uranium. However, total uranium concentrations in the river during 1997 were well below the proposed U.S. Environmental Protection Agency (EPA) drinking water standard of 20 µg/L (30 pCi/L; EPA 822-R-96-001).

The annual average iodine-129 concentrations for Priest Rapids Dam and Richland Pumphouse for 1992 through 1997 are presented in Figure 4.2.8. Only one quarterly

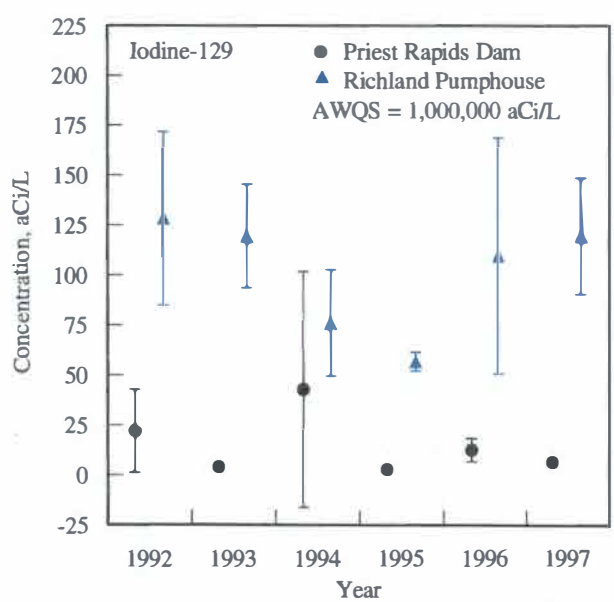


**Figure 4.2.8**. Annual Average Iodine-129 Concentrations (±2 standard error of the mean) in Columbia River Water, 1992 Through 1997 (AWQS = ambient water quality standard)

iodine-129 result was available for the Richland Pumphouse during 1995 because of construction activities at the structure. The average concentration of iodine-129 in Columbia River water at the Richland Pumphouse was extremely low during 1997 (0.011% of the ambient surface-water quality criteria level of 1 pCi/L [1,000,000 aCi/L] [WAC 246-290]) 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 6.1, "Hanford Groundwater Monitoring Project"). 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 statistically higher than those at Priest Rapids Dam.

During 1997, average plutonium-239,240 concentrations at Priest Rapids Dam and Richland Pumphouse were 79 ± 48 and 81 ± 48 aCi/L, respectively. For both locations, plutonium was detected only for the particulate fraction of the continuous water sample (i.e., detected on the filters but not detected on the resin column). No ambient surface-water quality criteria levels exist for 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 the 4-mrem dose equivalent used to develop the drinking water standards and ambient surface-water quality criteria levels, 1,200,000 aCi/L would be the relevant guideline for plutonium-239,240. There was no statistical difference in concentrations at Priest Rapids Dam and Richland Pumphouse.

**River Transect Sampling**. 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 1997 are presented in Appendix A (Table A.3) and PNNL-11796. Constituents that were consistently detected 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 August 1997 are depicted in Figure 4.2.9. The results 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 tritium concentrations observed in 1997 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 (Chapter 5.0 in PNL-10698). Slightly elevated levels of tritium were also evident near the Hanford Site shoreline at the 100-N Area, 300 Area , and Richland Pumphouse. The presence of a tritium concentration gradient in the Columbia River at the Richland Pumphouse supports previous conclusions made in HW-73672 and PNL-8531 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 (i.e., overestimate) of the fixed-location monitoring station.

Strontium-90 concentrations in 1997 transect samples were fairly uniform across the width of the river and varied little between transects. The mean concentration of strontium-90 found during transect sampling at the Richland Pumphouse was similar to that measured in monthly composite 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 in 1997 were elevated along the Franklin County shoreline of the 300 Area and Richland Pumphouse transects. The highest total uranium concentration was measured near the Franklin County shoreline of the 300 Area transect and likely resulted from groundwater seepage and water from irrigation return canals on the east side of the river that contained naturally occurring uranium (PNL-7500). The mean concentration of total uranium across the Richland Pumphouse transect was similar to that measured in monthly composited samples from the pumphouse.

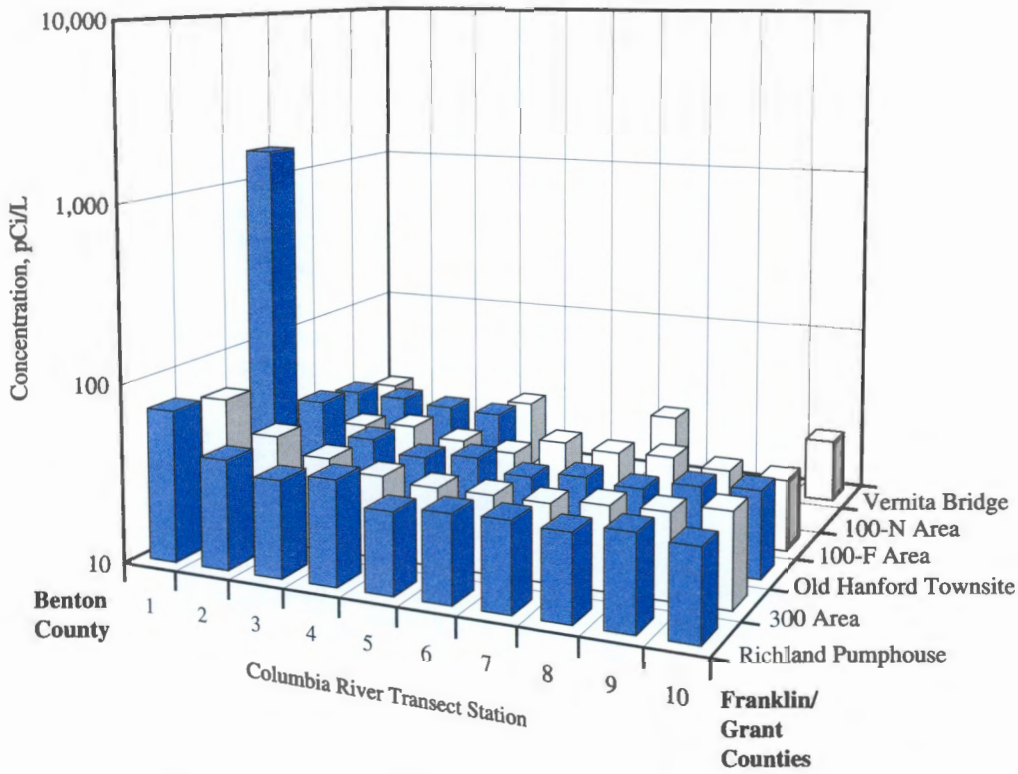


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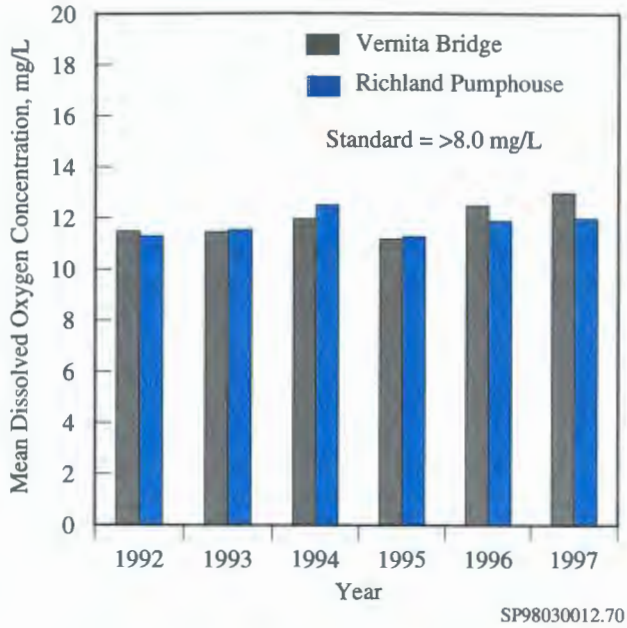
**Figure 4.2.9**. Tritium Concentrations in Water Samples from Columbia River Transects, August 1997

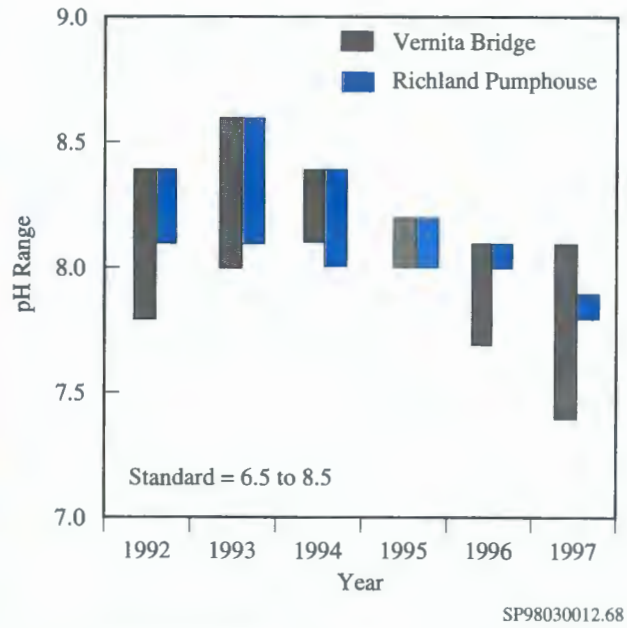
## 4.2.1.3 Nonradiological Results for Columbia River Water Samples

The Pacific Northwest National Laboratory and the U.S. Geological Survey compiled nonradiological water quality data during 1997. 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 (PNL-7500).

**U.S. Geological Survey**. Figure 4.2.10 shows the Vernita Bridge and Richland Pumphouse U.S. Geological Survey results for 1992 through 1997 (1997 results are preliminary) 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 PNNL-11796 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 1997 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. During 1997, there was no indication of any deterioration of water quality resulting from site operations along the Hanford Reach of the Columbia River (see Appendix C, Table C.1).

**River Transect Samples**. Results of nonradiological sampling conducted by Pacific Northwest National Laboratory along transects of the Columbia River in 1997 at Vernita Bridge, 100-F Area, 100-N Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse are provided in PNNL-11796. The concentrations of metals and anions observed in river water in 1997 were similar to those observed in the past. Several metals and anions were detected in Columbia River transect samples both upstream and downstream of the Hanford Site. Arsenic, antimony, cadmium, chromium, lead, nickel, thallium, and zinc were detected in the majority of samples, with similar levels at most locations. Beryllium, selenium, and silver were only occasionally detected. Nitrate concentrations were slightly elevated along the Benton County shoreline for the 300 Area and Old Hanford Townsite



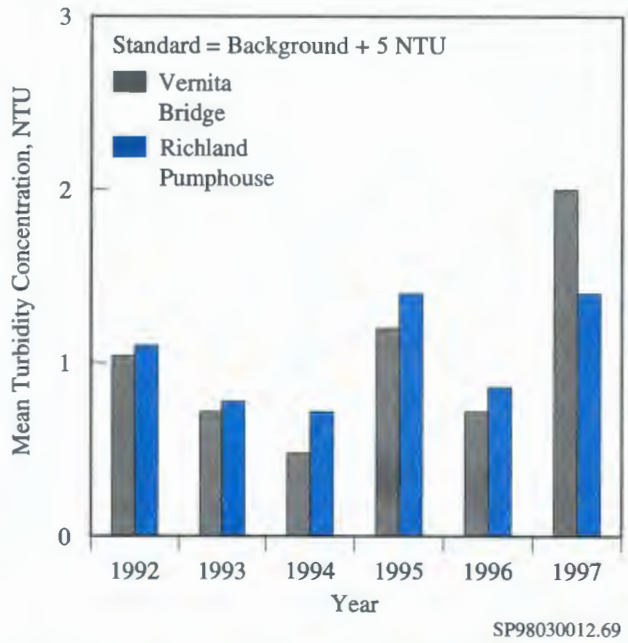




**Figure 4.2.10**. U.S. Geological Survey Columbia River Water Quality Measurements, 1992 Through 1997 (1997 results are preliminary; NTU = nephelometric turbidity unit)

transects. Nitrate, sulfate, and chloride concentrations were slightly elevated along the Franklin County shoreline of the 300 Area and Richland Pumphouse transects and likely resulted from groundwater seepage associated with extensive irrigation north and east of the Columbia River. Nitrate contamination of some Franklin County groundwater has been documented by the U.S. Geological Survey (1995) and is associated with high fertilizer and water usage. Numerous wells in western Franklin County exceed the EPA maximum contaminant level for nitrate (40 CFR 141). Nitrate, sulfate, and chloride results were slightly higher for average quarterly concentrations at the Richland Pumphouse transect compared to the Vernita Bridge transect.

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 48 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 the Richland Pumphouse over the past 6 years. The total hardness reported by the U.S. Geological Survey at those locations from 1992 through 1997 ranged from 48 to 77 mg/L as $CaCO_3$. All metal and anion concentrations in river water were less than the ambient surface-water quality criteria levels for both acute and chronic toxicity levels (see Appendix C, Table C.3). Arsenic concentrations exceeded EPA standards; however, similar concentrations were found at Vernita Bridge and Richland Pumphouse (see Appendix C, Table C.3).

## 4.2.2 Columbia River Sediments

Sediments in the Columbia River contain low concentrations of radionuclides and metals of Hanford Site origin as well as radionuclides from nuclear weapons testing fallout (Beasley et al. 1981, BNWL-2305, PNL-8148, PNL-10535). Potential public exposures are well below the level at which routine surveillance of Columbia River sediments is required (PNL-3127, 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/EH-0173T). As a result of past operations at the Hanford Site, 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/RL-91-50, Rev. 2).

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 permit-regulated liquid effluent discharges (see Section 3.1, "Facility Effluent Monitoring") and via contaminated groundwater seepage (DOE/EIS-0119F, PNL-5289, PNL-7500, WHC-SD-EN-TI-006).

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 (PNL-10535). 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).

### 4.2.2.1 Collection of Sediment Samples and Analytes of Interest

During 1997, 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 springs locations that are periodically inundated (see Figure 4.2.1 and Table 4.2.2). Samples were collected upstream of Hanford Site facilities above Priest

Rapids Dam (the nearest upstream impoundment) to provide background data from an area unaffected by site operations. Samples were collected downstream of the Hanford Site 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 Site 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-$cm^2$ (36.4 $in^2$ opening. Samples of periodically inundated river sediment, herein referred to as riverbank springs sediment, were collected using a large plastic spoon, immediately following the collection of riverbank springs water samples. Sampling methods are discussed in detail in DOE/RL-91-50, Rev. 2. All sediment samples were analyzed for gamma emitters (see Appendix E), strontium-90, uranium-235, uranium-238, and metals (DOE/RL-91-50, Rev. 2). River sediment samples were also analyzed for plutonium-238, plutonium-239,240, and simultaneously extracted metals/acid volatile sulfide. 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.

### 4.2.2.2 Radiological Results for River Sediment Samples

Results of the radiological analyses on river sediment samples collected during 1997 are reported in PNNL-11796 and summarized in Appendix A (Table A.5). Radionuclides consistently detected in river sediment adjacent and downstream of the Hanford Site during 1997 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 below detection limits for most samples. Strontium-90 and plutonium-239,240 exist in worldwide fallout, as well as in effluents from Hanford Site facilities. Uranium occurs naturally in the environment in addition to being present in Hanford Site 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 822-R-96-001).

Radionuclide concentrations reported in river sediment in 1997 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 1992 through 1997 are presented in Figure 4.2.11. Sampling areas include stations at Priest Rapids and McNary Dams as well as the Hanford Reach stations (White Bluffs, 100-F Area, Hanford Sloughs, and Richland Pumphouse). Strontium-90 was the only radionuclide to exhibit consistently higher median concentrations at McNary Dam from 1992 through 1997. The rank of all other radionuclide concentrations by sampling area varied from year to year. No other radionuclides measured in 1997 exhibited appreciable differences in concentrations between locations.

### 4.2.2.3 Radiological Results for Riverbank Springs Sediment Samples

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

Radiological results for riverbank springs sediment collected in 1997 are presented in PNNL-11796 and are summarized in Appendix A (Table A.5). Results were similar to those observed for previous years, with the

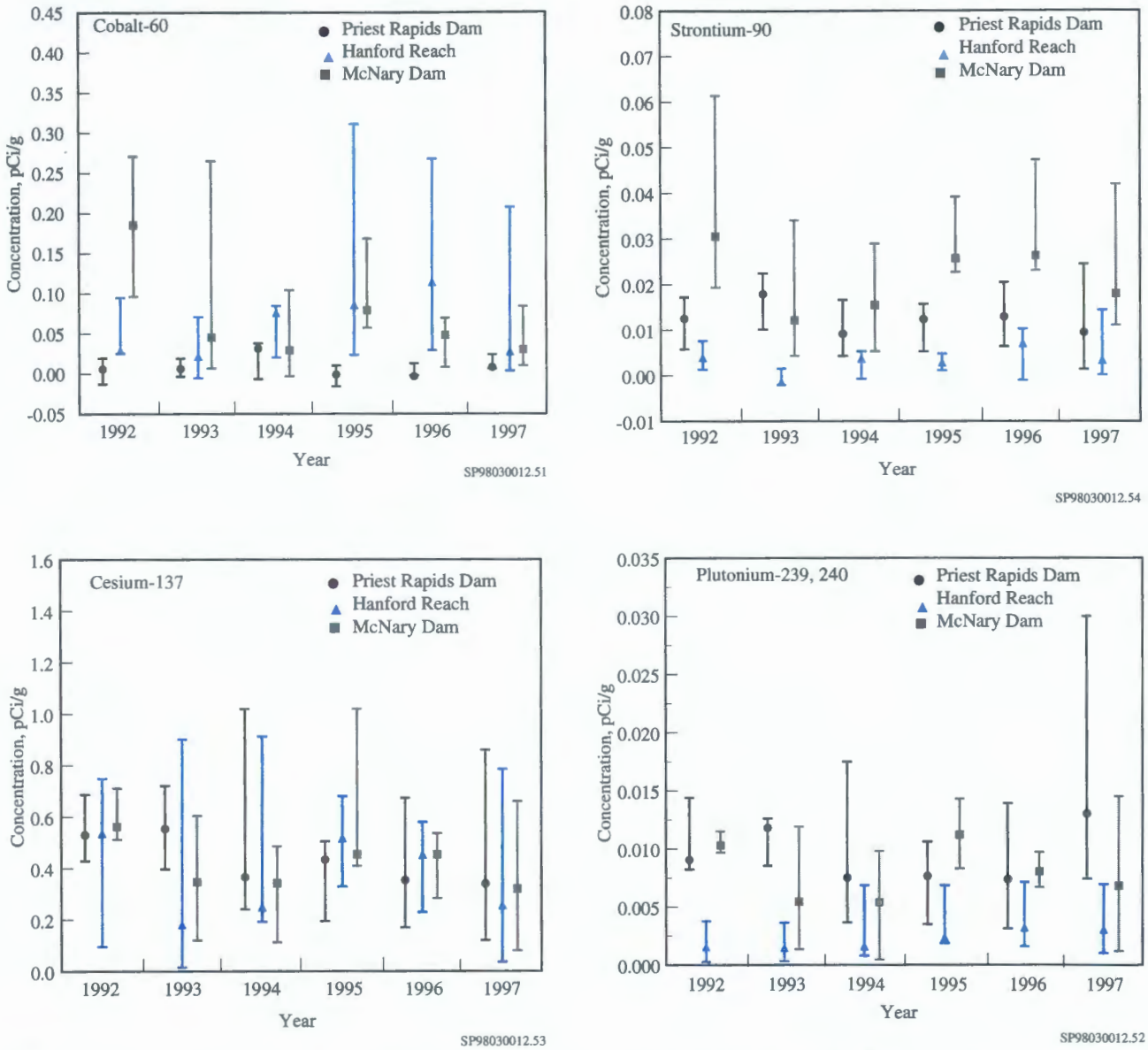



**Figure 4.2.11**. Minimum, Median, and Maximum Concentrations of Selected Radionuclides Measured in Columbia River Sediments, 1992 Through 1997

exception of total uranium in 300 Area spring sediment that did not show the elevated concentrations reported in 1995. Radionuclide concentrations in riverbank springs sediment were similar to those observed in river sediment in 1997.

## 4.2.2.4 Nonradiological Results for Columbia River Sediment Samples

Metal concentrations (total metals, reported on a dry weight basis) observed in Columbia River sediment in 1997 are reported in PNNL-11796 and are summarized in Appendix A (Table A.6). Detectable amounts of most metals were found in all Columbia River sediment samples. Overall median concentrations of most metals were similar for most samples (Figure 4.2.12). The maximum and highest median concentrations of chromium were found in riverbank springs sediment.

In 1997, the Columbia River sediment was also analyzed for simultaneously extracted metals/acid volatile sulfide (SEM/AVS). This analysis involves a cold acid extraction of the sediments followed by analysis for sulfide and

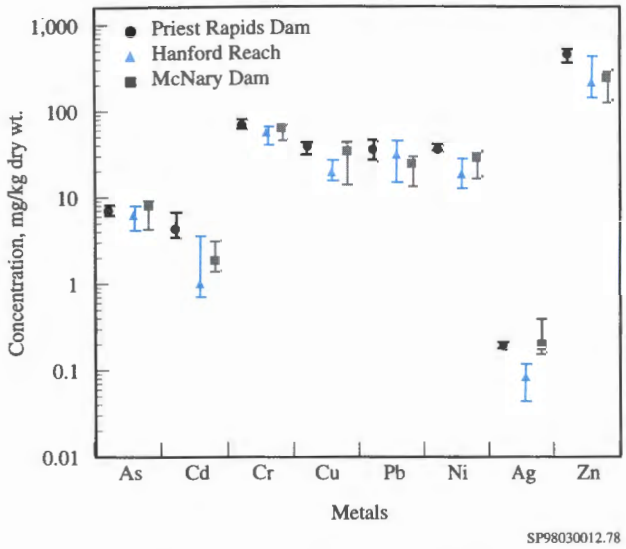



**Figure 4.2.12**. Minimum, Median, and Maximum Concentrations of Selected Metals Measured in Columbia River Sediments, 1997

metals. The SEM/AVS ratios are typically a better indicator of sediment toxicity than total metal concentrations (DeWitt et al. 1996, Hansen et al. 1996). Acid volatile sulfide is usually the dominant binding phase for metals in sediment, and metal sulfide precipitates can form that are very insoluble in sediment porewater. When the amount of acid volatile sulfide exceeds the amount of the metals (i.e., the SEM/AVS molar ratio is below 1), the metal concentration in the porewater will be low because of the limited solubility of the metal sulfide. Acid volatile sulfide ranged from 1.2 to 21 µmole/g and SEM/AVS ratios were 0.0086 to 0.20 for copper and 0.21 to 1.4 for zinc. The SEM/AVS ratios for mercury, cadmium, nickel, and lead were all below 0.05.

## 4.2.3 Riverbank Springs Water

The Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site (Chapter 2.0 in PNL-10698). Groundwater provides a means for transporting Hanford-associated contaminants, which have leached into groundwater from past waste disposal practices, to the Columbia River (DOE/RL-92-12, PNL-5289, PNL-7500, WHC-SD-EN-TI-006). 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 Site operations began during World War II (Jenkins 1922). In 1984, researchers walked the 66-km (41-mi) stretch of Benton County shoreline of the Hanford Reach in 1983 and identified 115 springs (PNL-5289). 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 to the ground from Hanford Site operations. In recent years, it has become increasingly difficult to locate riverbank springs in the 100-N Area.

The presence of riverbank springs also varies with river stage. Groundwater levels in the 100 and 300 Areas are heavily influenced by river stage fluctuations (see Section 6.1, "Hanford Groundwater Monitoring Project"). 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 $m^3/d$ (2,350,000 $ft^3/d$).[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. It should be noted that not all of the groundwater discharged to the river contains contaminants originating from Hanford Site operations. Riverbank springs studies conducted in 1983 (PNL-5289) and in 1988 (PNL-7500) 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.

### 4.2.3.1 Riverbank Springs Water Samples and Analytes of Interest

Routine monitoring of selected riverbank springs was initiated in 1988 at the 100-N Area, Old Hanford Townsite, and 300 Area. Monitoring was expanded in 1993 to include riverbank springs in the 100-B, 100-D, 100-H, and 100-K Areas. A 100-F Area riverbank spring was added in 1994. The locations of all riverbank springs sampled in 1997 are identified in Figure 4.2.1. Sample collection methods are described in DOE/RL-91-50, Rev. 2. 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 when river flows are low, typically August through September.

For 1997, high Columbia River flows delayed sample collections until late October and November. The 100-H Area spring was under water during all sampling attempts in 1997, so an alternate spring was sampled approximately 150 m (500 ft) downriver. Samples from riverbank springs collected during 1997 were analyzed for gamma-emitting radionuclides, gross alpha, gross beta, and tritium. Samples from selected springs were analyzed for strontium-90, technetium-99, iodine-129, and uranium-234,235,238. Samples were also analyzed for metals and anions. All analyses were conducted on unfiltered samples.

### 4.2.3.2 Results for Riverbank Springs Water

Hanford-origin contaminants continued to be detected in riverbank springs water entering the Columbia River along the Hanford Site during 1997. The locations and extent of contaminated discharges were consistent with recent groundwater surveys. Tritium, strontium-90, technetium-99, iodine-129, uranium-234,235,238, metals (antimony, arsenic, cadmium, copper, lead, nickel, selenium, thallium, zinc, and occasionally silver), and anions (chloride, fluoride, nitrate, and sulfate) were detected in spring water. The contaminant concentrations in spring water are typically lower than those found in near-shore groundwater wells because of bank storage effects.

Results of radiological and chemical analyses conducted on riverbank springs samples in 1997 are documented in PNNL-11796. Radiological results obtained in 1997 are summarized in Appendix A (Table A.7) and compared to those reported in 1992 through 1996. 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.

### 4.2.3.3 Radiological Results for Riverbank Springs Water Samples

All radiological contaminant concentrations measured in riverbank springs in 1997 were less than the DOE derived concentration guides, except for strontium-90 at the 100-N Area where one spring was nearly 10 times the standard (DOE Order 5400.5; see Appendix C, Table C.5). However, the DOE derived concentration guide uses an annual consumption scenario that is not possible at this location because the spring is typically under water. Strontium-90 concentrations at the 100-N Area riverbank spring exceeded the ambient surface-water quality criteria levels (WAC-246-290). Tritium concentrations in riverbank springs water at the Old Hanford Townsite exceeded the ambient surface-water quality criteria levels (WAC 246-290; see Appendix C, Table C.1) and were close to the criteria levels in springs at the 100-N and 100-B Areas. There are no ambient surface-water quality criteria levels directly applicable to uranium. However, total uranium concentrations exceeded the site-specific

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

proposed EPA drinking water standard (EPA 822-R-96-001) in the 300 Area (see Appendix C, Table C.2). The gross alpha concentration exceeded the ambient surface-water quality criteria level (WAC 246-290) in riverbank spring water at the 300 Area, which is consistent with the elevated uranium levels. All other radionuclide concentrations in 300 Area spring water were less than ambient surface-water quality criteria levels. Gross beta concentrations in riverbank springs water were elevated at the 100-H Area, 100-N Area, and Old Hanford Townsite, but were below surface-water quality criteria levels at all locations. The range of concentrations of selected radionuclides measured in riverbank springs water from 1992 through 1997 is presented in Table 4.2.3.

Tritium concentrations varied widely with location. The highest tritium concentration detected in riverbank springs water was at the Old Hanford Townsite (56,000 ± 4,200 pCi/L), followed by the 100-N Area (19,000 ± 1,500 pCi/L), 100-B Area (11,000 ± 910 pCi/L), and 300 Area (7,900 ± 680 pCi/L). The ambient surface-water quality criteria level for tritium is 20,000 pCi/L (WAC 246-290). Tritium concentrations in all riverbank springs water samples were elevated compared to the 1997 average Columbia River concentrations at Priest Rapids Dam (28 ± 2.3 pCi/L).

Samples from riverbank springs in the 100-B Area, 100-H Area, 300 Area, and Old Hanford Townsite were analyzed for technetium-99. The highest technetium-99 concentration was found in water from the Old Hanford Townsite spring (43 ± 5.1 pCi/L), in agreement with the observed beta activity.

Iodine-129 was detected in the Old Hanford Townsite and 300 Area riverbank springs; the highest concentration was found in water from the Old Hanford Townsite spring (0.14 ± 0.0081 pCi/L). This value was elevated compared to the 1997 average concentration measured at Priest Rapids Dam (0.0000072 ± 0.0000012 pCi/L) but was below the 1-pCi/L surface-water quality criteria level (see Appendix C, Table C.2).

Uranium was found in all riverbank springs samples in 1997, and the highest concentration was found for the 300 Area spring (53 ± 5.6 pCi/L), which is downgradient from the retired 300 Area process trenches. The 300 Area spring had elevated concentrations of gross alpha activity, which paralleled that of uranium.

Samples were analyzed for strontium-90 from riverbank springs in the 100-B, 100-D, 100-F, 100-H, 100-K, and 100-N Areas. The ambient surface-water quality criteria level of 8 pCi/L for strontium-90 was exceeded at 100-N Area (9,900 ± 1,800 pCi/L) and 100-H Area (17 ± 3.1 pCi/L). Beta activity paralleled that of strontium-90 at the 100-N and 100-H Areas. Results are consistent with those found in previous years.

Riverbank seepage in the 100-N Area has been monitored for contaminants by sampling from either the 199-N-8T monitoring well, which is located close to the river, the 199-N-46 monitoring well (caisson), which is slightly inland from well 199-N-8T (see Figure 3.2.4), or riverbank springs. In 1992, the sample was collected from well 199-N-46. From 1993 to 1997, 100-N Area seepage samples were collected from riverbank springs. Sampling in this manner is consistent with the sampling protocol at other riverbank springs. For 1993 to 1996, there was no visible riverbank spring directly adjacent to wells 199-N-8T or 199-N-46 during the sampling period. The 100-N Area riverbank spring samples were instead collected from the nearest visible downstream riverbank spring. In 1997, a sample was collected from the riverbank spring directly adjacent to well 199-N-8T and also from the riverbank spring sampled from 1993 to 1996. Contaminant concentrations measured in the water from the two riverbank springs locations were distinctly different (Table 4.2.4). The concentrations of strontium-90 and gross beta were considerably higher in the spring directly adjacent to well 199-N-8T and were similar to the 1992 groundwater samples from well 199-N-46. Tritium concentrations in riverbank springs water were elevated at both locations and were similar to those found in previous years (see Table 3.2.5). Tritium and strontium-90 were the only contaminants detected at the 100-N Area riverbank spring in 1997. The maximum tritium and strontium-90 concentrations were 0.95 and 1,200 times the ambient surface-water quality criteria levels, respectively (WAC 246-290; see Appendix C, Table C.3). The results for the 100-N Area riverbank spring samples are of the same magnitude as those reported in Section 3.2, "Near-Facility Environmental Monitoring," Table 3.2.5.

Concentrations of selected radionuclides in riverbank springs water near the Old Hanford Townsite from 1992 through 1997 are provided in Figure 4.2.13. Gross beta and technetium-99 concentrations in 1997 were similar to those observed since 1994 and were slightly lower than those observed prior to 1994. The 1997 tritium concentration was slightly higher than in recent years but well below values reported for 1992 and 1993. Annual fluctuations in these tritium concentrations may reflect

**Table 4.2.3.** Range of Radiological Data for Riverbank Springs, 1992 Through 1997

| Spring Location | No. of Samples | Concentration, pCi/L | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Gross Alpha | Gross Beta | Iodine-129 | Strontium-90 | Technetium-99 | Tritium | Total Uranium |
| 100-B | 7 | 1.1 - 3.5 | 6.5 - 38 | NS[a] | -0.11 - 0.072 | 5.8 - 25 | 11,000 - 24,000 | NS |
| 100-K | 4 | 0.56 - 1.6 | 1.4 - 3.6 | NS | -0.031 - 0.59 | -0.031 - 0.8 | 110 - 20,000 | NS |
| 100-N Spring 8-13 | 6 | 0.043 - 8.1 | 1.5 - 8.8 | NS | -0.010 - 0.59 | NS | 12,000 - 31,000 | NS |
| 100-N Spring (below well 199-N-8T | 1 | 2.8 | 16,000 | NS | 9,900 | NS | 14,000 | NS |
| 100-D | 8 | 0.27 - 2.9 | 2.1 - 21 | NS | 0.069 - 9.4 | NS | 87 - 13,000 | NS |
| 100-H | 6 | 2.4 - 4.6 | 33 - 69 | NS | 12 - 25 | 18 - 140 | 430 - 1,200 | 0.52 - 2.7 |
| 100-F | 4 | 2.6 - 41 | -4.6 - 65 | NS | -0.03 - 0.099 | NS | 620 - 1,800 | 3.4 - 9.2 |
| Hanford Spring 28-2 | 8 | 0.10 - 4.9 | 4.8 - 95 | 0.044 - 0.22 | NS | 2.0 - 130 | 6,300 - 170,000 | 1.6 - 4.6[b] |
| 300 Area Spring 42-2 | 8 | 13 - 110 | 3.3 - 29 | 0.0019 - 0.0055[c] | NS | 0.50 - 14[b] | 1,300 - 12,000 | 24 - 130 |
| Ambient surface-water quality criteria level | | 15[d,e] | 50[d] | 1[f] | 8[d] | 900[f] | 20,000[d] | 20[f] |

(a) No sample.
(b) Seven samples analyzed.
(c) Five samples analyzed.
(d) WAC 246-290 and 40 CFR 141.
(e) Ambient surface-water quality criteria level for gross alpha excludes uranium contribution.
(f) Proposed standard (EPA 822-R-96-001).

**Table 4.2.4.** Selected Radionuclide Concentrations in 100-N Area Riverbank Springs Water, 1992 Through 1997

| | Concentration, pCi/L[a] | | |
|---|---|---|---|
| Year | Tritium | Gross beta | Strontium-90 |
| 1992[b] | 4,900 ± 500 | 24,000 ± 1,700 | 11,000 ± 2,000 |
| 1993[c] | | | |
| Min | 28,000 ± 2,200 | 2.4 ± 3.2 | -0.010 ± 0.22 |
| Max | 29,000 ± 2,300 | 4.5 ± 3.3 | 0.020 ± 0.26 |
| 1994[c] | 31,000 ± 2,400 | 8.8 ± 2.3 | 0.13 ± 0.11 |
| 1995[c] | 12,000 ± 970 | 1.5 ± 1.5 | 0.079 ± 0.10 |
| 1996[c] | 17,000 ± 1,300 | 4.5 ± 1.8 | 0.053 ± 0.048 |
| 1997[c] | 19,000 ± 1,500 | 3.5 ± 1.6 | 0.59 ± 0.13 |
| 1997[d] | 14,000 ± 1,100 | 16,000 ± 1,400 | 9,900 ± 1,800 |

(a) Concentrations are ±2 total propagated analytical uncertainty.
(b) Sample collected from well 199-N-46 (see Figure 3.2.4).
(c) Sample collected from riverbank spring downstream of well 199-N-8T (100-N Area spring 8-13).
(d) Samples collected from spring below well 199-N-8T (see Figure 3.2.5).

the influence of bank storage during the sampling period. Tritium and technetium-99 concentrations detected in Old Hanford Townsite riverbank springs water in 1997 were 280% and 4.8% of their respective ambient surface-water quality criteria levels (WAC 246-290; see Appendix C, Table C.3). The iodine-129 concentration measured in the Old Hanford Townsite riverbank springs water for 1997 was 14% of the ambient surface-water quality criteria level (WAC 246-290; see Appendix C, Table C.3).

Figure 4.2.14 depicts the concentrations of selected radionuclides in the 300 Area riverbank springs from 1992 through 1997. Results in 1997 were similar to those observed previously. The elevated tritium concentrations measured in the 300 Area riverbank springs are indicators of the contaminated groundwater plume emanating from the 200 Areas (Section 5.9 in PNL-10698). 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 springs water in 1997 were 40%, 0.98%, and 0.55% of their respective ambient surface-water quality criteria levels (WAC 246-290; see Appendix C, Table C.3). The highest total uranium concentrations in riverbank springs water from 1992 through 1997 were found in the 300 Area riverbank springs, with the 1997 concentration four times higher than the proposed site-specific EPA drinking water standard (13.4 pCi/L [EPA 822-R-96-001]; 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. Gross alpha and gross beta concentrations in the 300 Area riverbank springs water from 1992 through 1997 parallel that of uranium and are likely associated with its presence.

## 4.2.3.4 Nonradiological Results for Riverbank Springs Water Samples

The range of concentrations of selected chemical compounds measured in riverbank springs water in 1993 through 1997 are presented in Table 4.2.5. For most locations, the 1997 nonradiological sample results were slightly lower than those previously reported. This may be the result of increased bank storage during an extremely high water year for the Columbia River. The 1997 nitrate concentrations at all spring locations were the lowest reported since 1993, except for the 100-D Area spring that was within the previous range of values. Nitrate concentrations were highest in the 100-F and 100-H Area springs. Chromium concentrations were highest in the 100-D, 100-F, and 100-H Areas' riverbank springs. Hanford groundwater monitoring results for 1997 indicated similar nonradiological contaminants in shoreline areas (see Section 6.1, "Hanford Groundwater Monitoring Project").

The 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). For comparison purposes, spring water criteria were calculated using the same 48-mg $CaCO_3$/L hardness given in Table C.3. The 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/RL-91-50, Rev. 2). The standards are instead used as a point of reference. Metal concentrations measured in riverbank springs from the Hanford Site shoreline in 1997 were below ambient surface-water acute toxicity levels (WAC 173-201A), except for chromium concentrations in 100-D and 100-H Areas riverbank springs (see Appendix C, Table C.3). Spring water from the 100-B, 100-D, 100-F, and 100-H Areas exceeded the chronic toxicity standard for chromium (see Appendix C, Table C.3). Lead concentrations were above the chronic toxicity standard in the 100-F and 100-K Areas (see Appendix C,

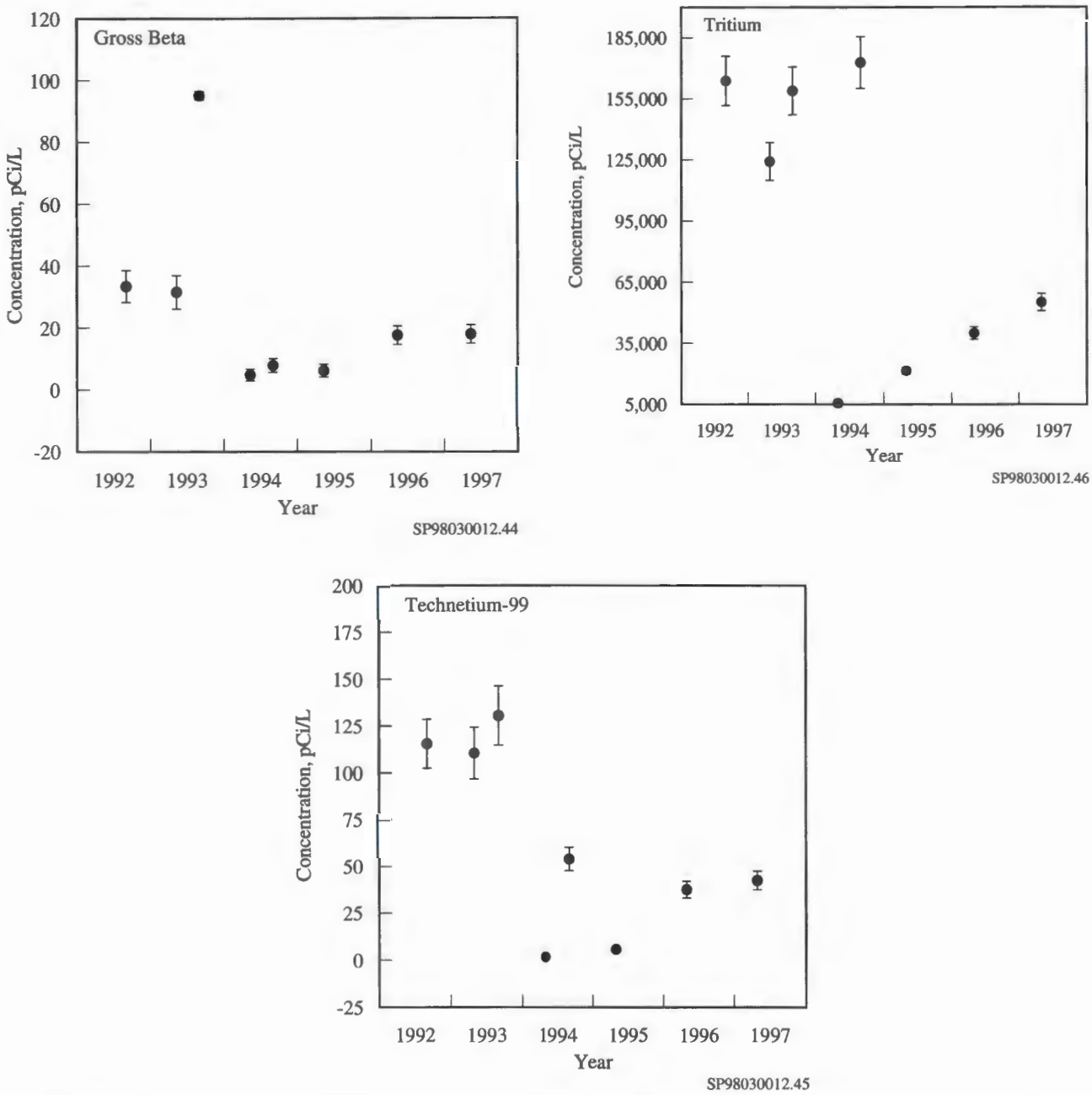



**Figure 4.2.13**. Concentrations (results ±2 total propagated analytical uncertainty) of Constituents of Interest in Riverbank Springs Water Near the Old Hanford Townsite, 1992 Through 1997. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

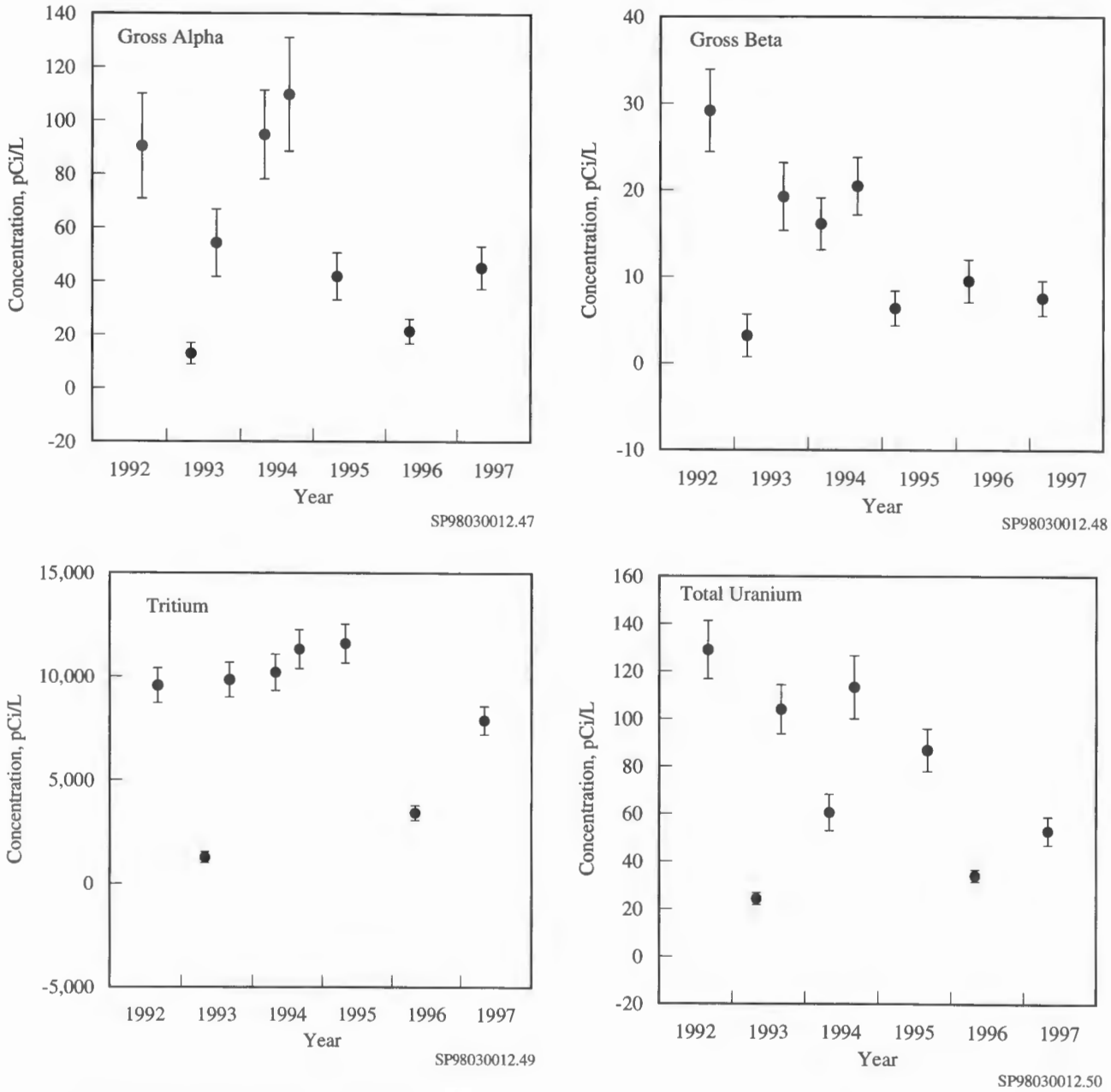



**Figure 4.2.14**. Concentrations (results ±2 total propagated analytical uncertainty) of Constituents of Interest in 300 Area Riverbank Spring Water, 1992 Through 1997

**Table 4.2.5.** Concentration Ranges of Selected Nonradiological Compounds in Riverbank Springs, 1993 Through 1997

| | Ambient Surface-Water Quality Criteria Level, µg/L | Concentration, µg/L | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 100-B Area | 100-K Area | 100-N Area[a] | 100-D Area | 100-H Area | 100-F Area | Old Hanford Townsite | 300 Area |
| No. of Samples | | 5 | 2 | 4 | 6 | 4 | 4 | 5 | 4 |
| **Metals** | | | | | | | | | |
| Antimony[b] | | 0.24 | 0.42 | 0.24 | 0.36 | 0.31 | 0.17 | 0.42 | 0.28 |
| Arsenic[b] | 190 | 1.3 | 1.2 | 2.5 | 1.0 | 0.90 | 2.2 | 3.2 | 1.3 |
| Cadmium | [c] | 0.031 - 0.72 | 0.067 - 2.0 | ND[d] - 0.038 | ND - 0.035 | ND - 0.033 | 0.10 - 4.8 | ND | ND - 0.055 |
| Chromium | [c] | 13 - 25 | 1.7 - 66 | ND - 45 | ND - 400 | 18 - 55 | 6.0 - 99 | ND - 2.5 | ND - 6.4 |
| Copper | [c] | ND - 0.36 | 1.1 - 37 | ND - 30 | ND - 6.4 | ND - 4.7 | ND - 85 | ND - 5.4 | ND - 14 |
| Lead[b] | [c] | 0.90 | 2.5 | 0.35 | 0.41 | 0.37 | 1.9 | 0.22 | 0.95 |
| Nickel | [c] | ND - 8.1 | ND - 0.83 | ND - 25 | ND - 26 | ND - 1.1 | ND - 31 | ND - 22 | ND - 1.3 |
| Selenium[b] | 5 | 2.9 | 0.89 | 0.58 | 1.0 | 0.96 | 3.0 | 1.8 | 2.8 |
| Thallium[b] | [c] | 0.0088 | 0.047 | 0.023 | 0.072 | 0.044 | 0.025 | 0.035 | 0.045 |
| Zinc | [c] | ND - 45 | 4.7 - 410 | 1.2 - 460 | 1.3 - 18 | 1.7 - 15 | 6.0 - 910 | 0.66 - 32 | 4.0 - 100 |
| **Anions** | | | | | | | | | |
| Nitrate | | 4,000 - 11,000 | 320 - 15,000 | 3,100 - 15,000 | 1,000 - 46,000 | 5,800 - 47,000 | 9,000 - 33,000 | 1,800 - 40,000 | 4,000 - 23,000 |

(a) Sample collected from riverbank spring downstream of well 199-N-8T (see Table 4.2.4).
(b) 1997 value only (n=1).
(c) Ambient surface-water quality criteria level is hardness-dependent (WAC 173-201A-040; see Appendix C, Table C.3).
(d) ND indicates result was less than the minimum detection level.

Table C.3). The riverbank spring near the 100-F Area had the highest nitrate concentration; however, nitrate concentrations at all spring water locations were below the drinking water standards (see Appendix C, Table C.2).

## 4.2.4 Onsite Pond Water

Three onsite ponds (see Figure 4.2.1), located near operational areas, were sampled periodically during 1997. B Pond near the 200-East Area was constructed 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. B Pond was 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. The 216-B-3C Expansion Pond was decommissioned in late 1997. The Fast Flux Test Facility Pond near the 400 Area was excavated in 1978 for the disposal of cooling and sanitary water from various facilities in the 400 Area. Sanitary water is now piped to the Washington Public Power Supply System treatment facility, and the pond has been drained and backfilled. Fast Flux Test Facility pond samples are currently collected from a pond (located just east of the 1978 pond) that is a disposal site for process water (primarily cooling tower water). West Lake, the only naturally occurring pond onsite, is located north of the 200-East Area (ARH-CD-775). West Lake has not received direct effluent discharges from site facilities but is influenced by changing water table elevation.

The site management and integration contractor is responsible for monitoring effluents discharged to the ponds. Although the ponds are inaccessible to the public and did not constitute a direct offsite environmental impact during 1997, they were accessible to migratory waterfowl, thus creating a potential biological pathway for the dispersion of contaminants (PNL-10174). Periodic sampling of the ponds also provided an independent check on effluent control and monitoring systems.

### 4.2.4.1 Collection of Pond Water Samples and Analytes of Interest

In 1997, grab samples were collected quarterly from B Pond (i.e., 216-B-3C Expansion Pond), Fast Flux Test Facility Pond, and West Lake. Unfiltered aliquots of all samples were analyzed for gross alpha and gross 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, and uranium-234,235,238. 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 to the public.

### 4.2.4.2 Radiological Results for Pond Water Samples

Analytical results from pond samples collected during 1997 are reported in PNNL-11796. With the exceptions of uranium-234 and uranium-238 in the July sample from West Lake, radionuclide concentrations in onsite pond water were less than the DOE derived concentration guides (DOE Order 5400.5; see Appendix C, Table C.5). Median concentrations of gross beta and total uranium exceeded the ambient surface-water quality criteria level in West Lake. The median concentrations of all other radionuclides were below ambient surface-water quality criteria levels (WAC 246-290; see Appendix C, Table C.2).

Annual concentrations of selected radionuclides in B Pond water for the years 1992 through 1997 are shown in Figure 4.2.15. B Pond samples in 1997 were collected from the 216-B-3C Expansion Pond until July when it was drained and decommissioned. Median concentrations of gross alpha, gross beta, tritium, and strontium-90 in 1997 were 2.0%, 3.0%, 0.85%, and 1.3% of ambient surface-water quality criteria levels, respectively (WAC 246-290). 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 gross beta and tritium concentrations in Fast Flux Test Facility Pond water from 1992 through 1997. 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 was much higher than that observed previously. During this time, emergency 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 well 499-S0-7 is most likely responsible for the high levels of tritium observed in July 1995. Median concentrations of gross beta and tritium in Fast Flux Test Facility Pond water during 1997 were 28% and 21% of their respective ambient surface-water quality

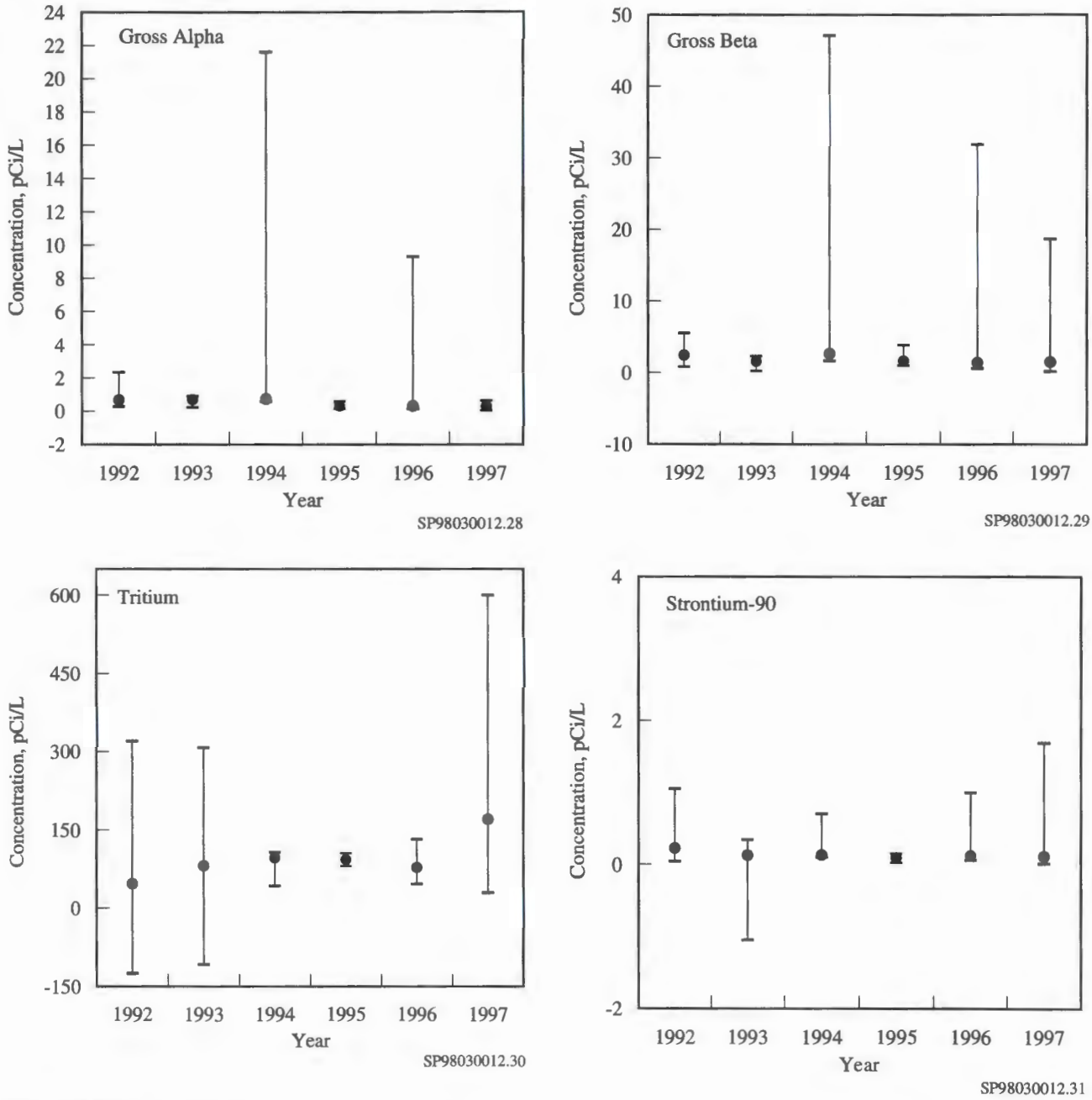
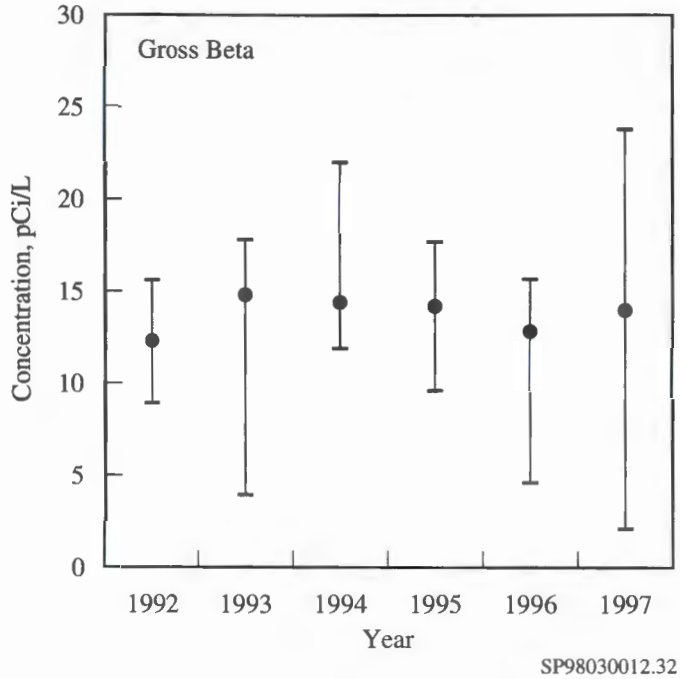



**Figure 4.2.15**. Minimum, Median, and Maximum Concentrations of Selected Radionuclides in B Pond Water, 1992 Through 1997



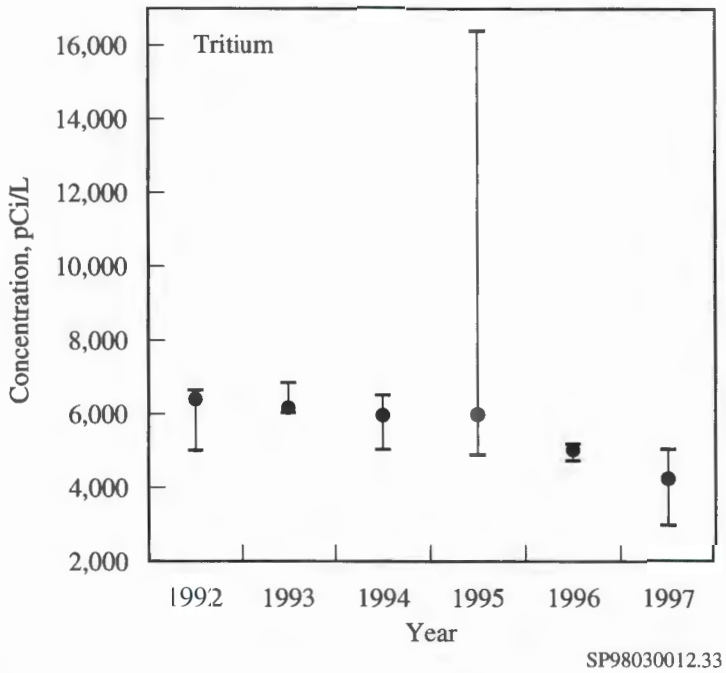




**Figure 4.2.16**. Minimum, Median, and Maximum Gross Beta and Tritium Concentrations in Fast Flux Test Facility Pond Water, 1992 Through 1997

criteria levels (WAC 246-290). The concentrations of all other measured contaminants in this pond water were below detection limits.

The annual concentrations of selected radionuclides from 1992 through 1997 in West Lake water are shown in Figure 4.2.17. Median radionuclide concentrations in West Lake during 1997 were similar to those observed in the past. The gross alpha and gross beta concentrations in West Lake water are believed to result from high concentrations of naturally occurring uranium in the surrounding soils (BNWL-1979, PNL-7662). Annual median total uranium concentrations have remained stable over the last 6 years but the range in concentrations is large. The highest concentrations measured in 1997 were in summer and fall when the water level in the pond was low. It is thought that the relatively large concentration of suspended sediment in the samples is causing the elevated results. Similar total uranium concentrations were reported in PNNL-7662 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 of U Pond in 1984 and the shutdown of production facilities (see Section 6.1, "Hanford Groundwater Monitoring Project"). As a result, the water level in West Lake has dropped. Median concentrations of tritium, strontium-90, and technetium-99 in West Lake in 1997 were 1.6%, 49%, and 0.52%, respectively, of the ambient surface-water quality criteria levels (WAC 246-290) and reflected local groundwater concentrations. The concentrations of all other measured radionuclides were rarely above detection limits, except for naturally occurring potassium-40.

## 4.2.5 Offsite Water

During 1997, water samples were collected from an irrigation canal across the Columbia River and downstream from the Hanford Site that receives water pumped from the Columbia River. As a result of public concern about the potential for Hanford-associated contaminants in offsite water, sampling was conducted to document the levels of radionuclides in water used by the public. Consumption of vegetation irrigated with Columbia River water downstream of the site has been identified as one of the primary pathways contributing to the potential dose to the hypothetical maximally exposed individual and any other member of the public (see Section 5.0, "Potential Radiological Doses from 1997 Hanford Operations").

### 4.2.5.1 Collection, Analysis, and Results for Irrigation Canal Water

Water in the Riverview irrigation canal was sampled three times in 1997 during the irrigation season. Unfiltered samples of the canal water were analyzed for gross alpha, gross beta, gamma emitters, tritium, strontium-90, and uranium-234,235,238. Results are presented in PNNL-11796. In 1997, radionuclide concentrations measured in this canal's water were 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 (DOE Order 5400.5, WAC 246-290). The concentrations of strontium-90 in the irrigation water during 1997 ranged from $0.052 \pm 0.031$ to $0.080 \pm 0.042$ pCi/L and were similar to those reported for the Columbia River at Priest Rapids Dam and the Richland Pumphouse (see Section 4.2.1, "Columbia River Water").

### 4.2.5.2 Pacific Northwest National Laboratory and Washington State Department of Health Survey of Contaminants in the Near-Shore Environment at the 100-N Area

In September 1997, Pacific Northwest National Laboratory and the Washington State Department of Health cooperated in a special study of the 100-N Area near-shore springs. Environmental samples were collected to study radiological and chemical contaminants, with each entity analyzing a portion of the samples. Near-shore samples of water, river sediment, a riverbank spring, periphyton, milfoil, flying insects, clams, fish, and reed canary grass were collected. Results of this study are scheduled to be published in a joint Pacific Northwest National Laboratory/Washington State Department of Health report sometime in 1998. The results for the samples analyzed by Pacific Northwest National Laboratory are given in PNNL-11796.

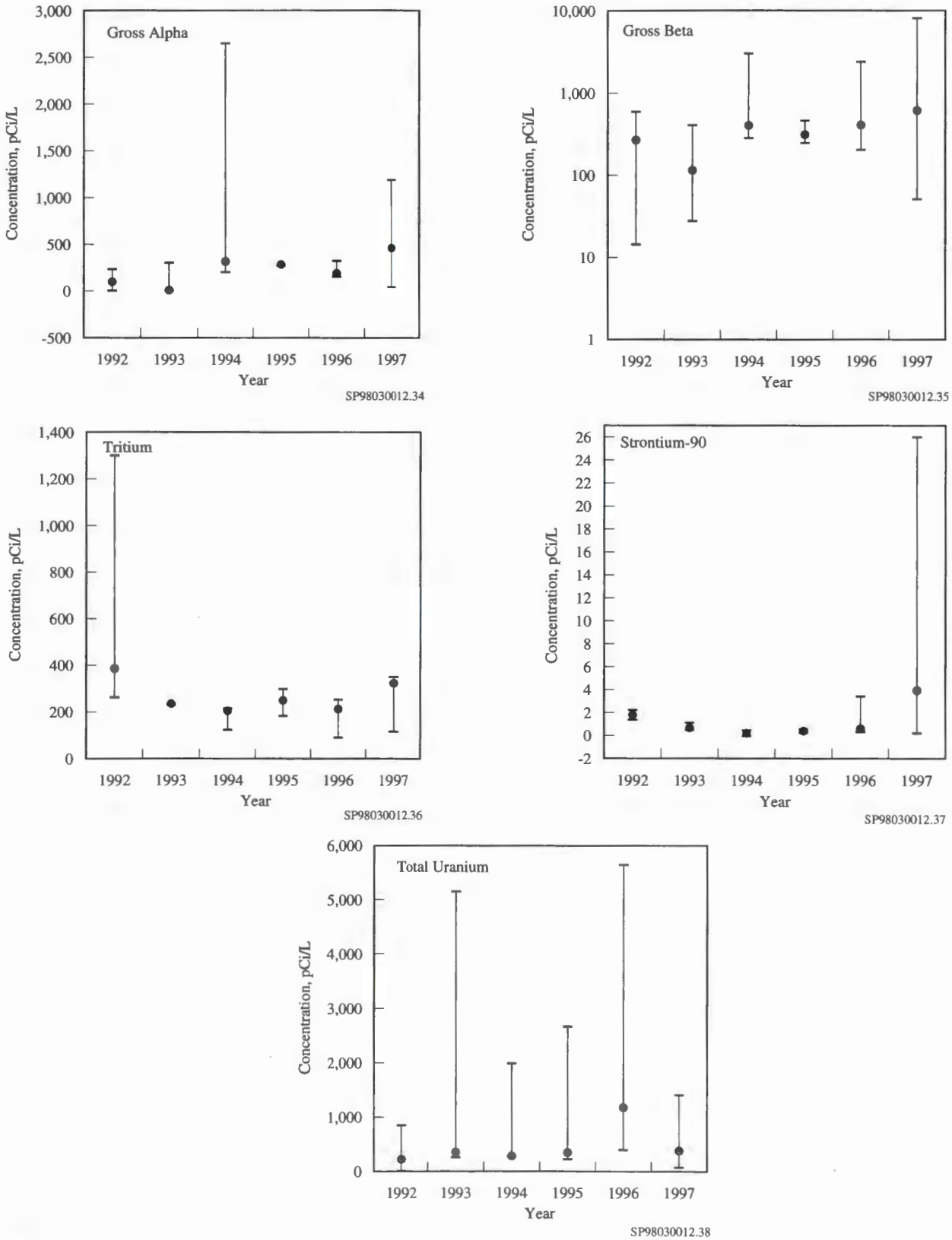



**Figure 4.2.17**. Minimum, Median, and Maximum Concentrations of Selected Radionuclides in West Lake Water, 1992 Through 1997

# 4.3 Hanford Site Drinking Water Surveillance

*R. W. Hanf, L. M. Kelly, and R. G. Gant*

The primary purpose of Hanford Site drinking water surveillance is to verify the quality of the site's drinking water. This is achieved by the routine collection and analysis of drinking water samples and the comparison of the resulting data with established drinking water standards and guidelines (WAC 246-290, 40 CFR 141, EPA-570/9-76-003, EPA 822-R-96-001; see Appendix C, Tables C.2 and C.5). In 1997, most radiological surveillance of DOE-owned drinking water systems on the site was conducted by Pacific Northwest National Laboratory for DynCorp Tri-Cities Services, Inc. In addition, DE&S Hanford, Inc. collected radiological data for a single system in the 100-K Area (Table 4.3.1). Chemical and microbiological monitoring of all onsite DOE-owned drinking water systems was conducted by DynCorp Tri-Cities Services, Inc.

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. WAC 246-290 requires that all drinking water analytical results be reported routinely to the Washington State Department of Health. In previous years, this was accomplished at the Hanford Site by the issuance of an annual report produced by the Hanford Environmental Health Foundation (e.g., HEHF-95, HEHF-96). In recent years, summary and individual radiological results have been reported to the state through this annual Hanford Site environmental report and through a supplemental data compilation (PNNL-11796). Nonradiological data have been reported to the state by DynCorp Tri-Cities Services, Inc. and have not been published.

## 4.3.1 Radiological Monitoring of Hanford Site Drinking Water Systems

Drinking water is supplied to DOE facilities on the site by 12 DOE-owned, contractor-operated, water treatment systems (see Table 4.3.1) and one system owned and operated by the city of Richland. Ten of these systems (including Richland's system) use water from the Columbia River. Three systems use groundwater from beneath the site. 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. Water from Richland's system is not monitored through the site drinking water surveillance project; however, Pacific Northwest National Laboratory routinely collects water samples from the Columbia River at the Richland Pumphouse, which is the city of Richland's drinking water intake. The analytical results (radiological) for these samples of untreated river water can be found in Appendix A (Table A.2).

In 1997, radionuclide concentrations in onsite drinking water were monitored at the seven facilities shown in Figure 4.3.1, which represent the principal water supply facilities for the site's DOE-owned drinking water treatment systems. The 100-B Area pumphouse continued to serve as the primary Columbia River pumping station for many areas on the site (100-N Area, 200-East and 200-West Areas, 251 Building, and 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 181-KE Pumphouse. The 300 Area obtains its water via the 312 Pumphouse or the city of Richland. The Yakima Barricade, Patrol Training Academy, and 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-S0-8 (P-14) serving as the emergency supply. Well 499-S0-8 was used 6 times during 1997 (in January for 24.9 h, February for 53.5 h, April for 22.9 h, May for 19.7 h, June for 26.7 h, and July for 14.7 h). Well 499-SO-7 (P-15) continued to function as

**Table 4.3.1**. DOE-Owned Drinking Water Systems on the Hanford Site, 1997

| 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. Operated by DynCorp Tri-Cities Services, Inc. |
| 100-K/00177J | Columbia River via 181-K Pumphouse | Filtered and chlorinated at 183-KE. 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 well 499-S1-8J (P-16); well 499-S0-8 (P-14) is the emergency supply, well 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 Pump-house or city of Richland | Filtered and chlorinated at 315 Building. Operated by DynCorp Tri-Cities Services, Inc. |

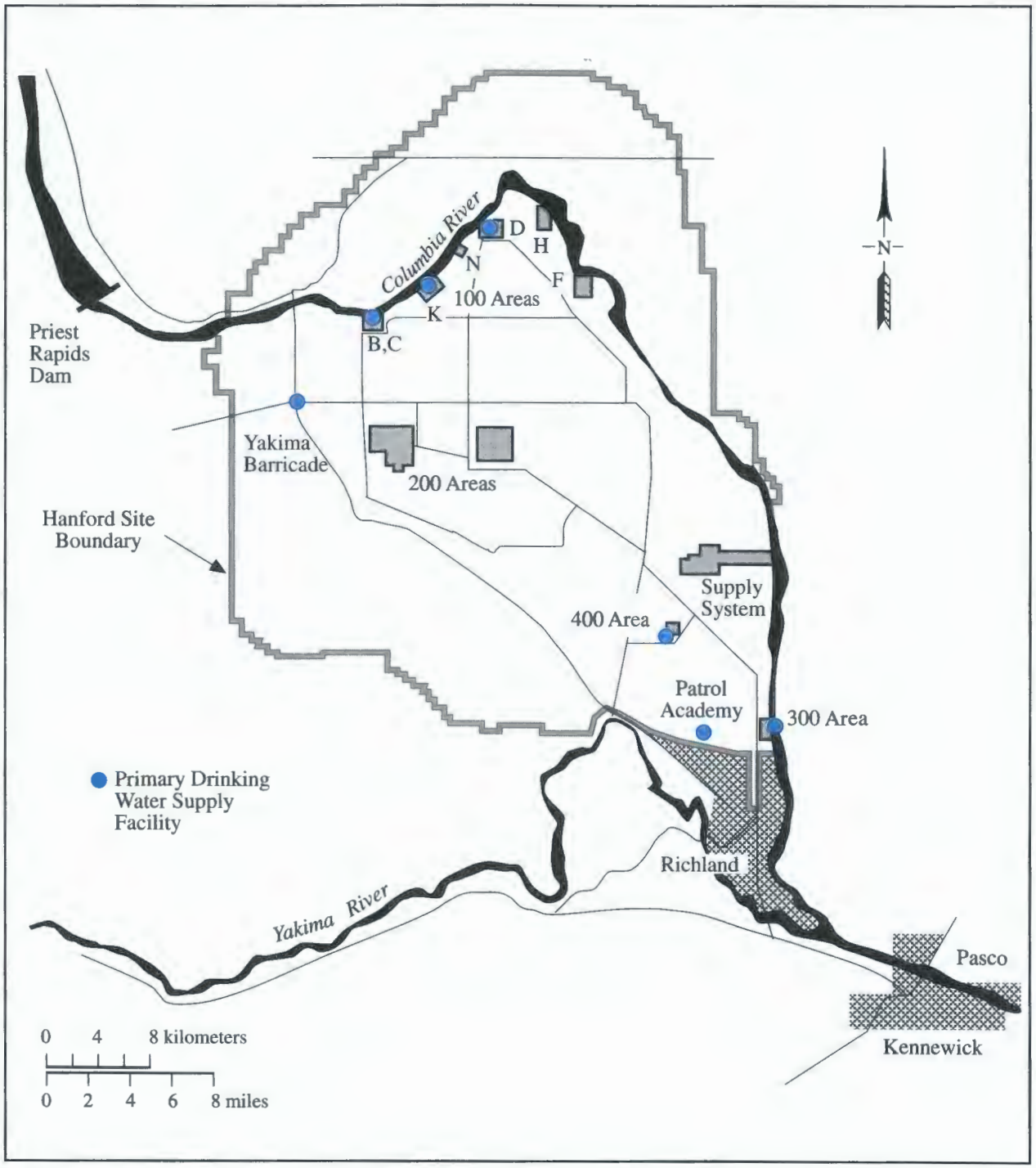



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**Figure 4.3.1.** Hanford Site Primary Drinking Water Supply Facilities, 1997

the dire emergency supply but was not used as a source of drinking water in 1997. In addition to supplying drinking water, these three wells are also important for maintaining fire suppression capabilities within the 400 Area.

## 4.3.2 Collection of Drinking Water Samples and Analytes of Interest

Pacific Northwest National Laboratory collected samples according to a schedule established at the beginning of the calendar year (PNNL-11464). A majority of the samples were collected and analyzed quarterly. The 300 Area samples were collected monthly and composited for quarterly analysis. The Yakima Barricade and Patrol Training Academy samples were collected quarterly and composited for annual analysis. Well water samples from the 400 Area were collected and analyzed monthly. Samples from most locations were grab samples of treated water collected at the tap. The 300 Area samples were cumulative raw river water samples collected at the water supply pumphouse before any treatment. Tap water samples obtained from the Patrol Training Academy in January, April, July, and October, and the 400 Area in April were cosampled with the Washington State Department of Health. The analytical results from the state's samples help to verify the quality of the drinking water data reported herein and in PNNL-11796.

All 1997 drinking water samples were analyzed for gross alpha, gross beta, tritium, and strontium-90. Additionally, samples from the 300 Area were analyzed for uranium and technetium, and concentrations of plutonium and americium were monitored in water from the 100-K Area. The 100-K Area and 300 Area samples were also analyzed by gamma spectrometry.

Gross alpha and gross beta measurements provided a general indication of radioactive contamination. Gamma spectrometry was used to detect numerous specific radionuclides (see Appendix E). Radiochemical analyses were used to determine the concentrations of other specific radionuclides.

## 4.3.3 Radiological Results for Hanford Site Drinking Water

Results for radiological monitoring of Hanford Site drinking water during 1997 are summarized in Table 4.3.2. Concentrations of gross alpha, gross beta, tritium, strontium-90, and total 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 the 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 mrem/yr. If both tritium and strontium-90 are present, the sum of their annual dose equivalent to bone marrow must not exceed 4 mrem. Compliance with this standard may be assumed if the annual average concentration for each of gross alpha, gross beta, tritium, and strontium-90 are less than 50, 15, 20,000, and 8 pCi/L, respectively (40 CFR 141 and WAC 246-290). All DOE-owned drinking water systems on the Hanford Site were in compliance with Washington State and EPA annual average radiological drinking water standards in 1997, and results were similar to those observed in recent years (Section 4.3 in PNNL-11139 and PNNL-11472).

Concentrations of uranium, plutonium, americium, and radionuclides measured by gamma spectrometry at selected locations (see PNNL-11796) were all below drinking water standards.

Raw water samples from all three 400 Area drinking water wells were collected and analyzed monthly by the site Ground-Water Monitoring Program. Results from these samples show that tritium levels continued to be lowest in well 499-S0-8J and highest in well 499-S0-7 (Table 4.3.3, Figure 4.3.2).

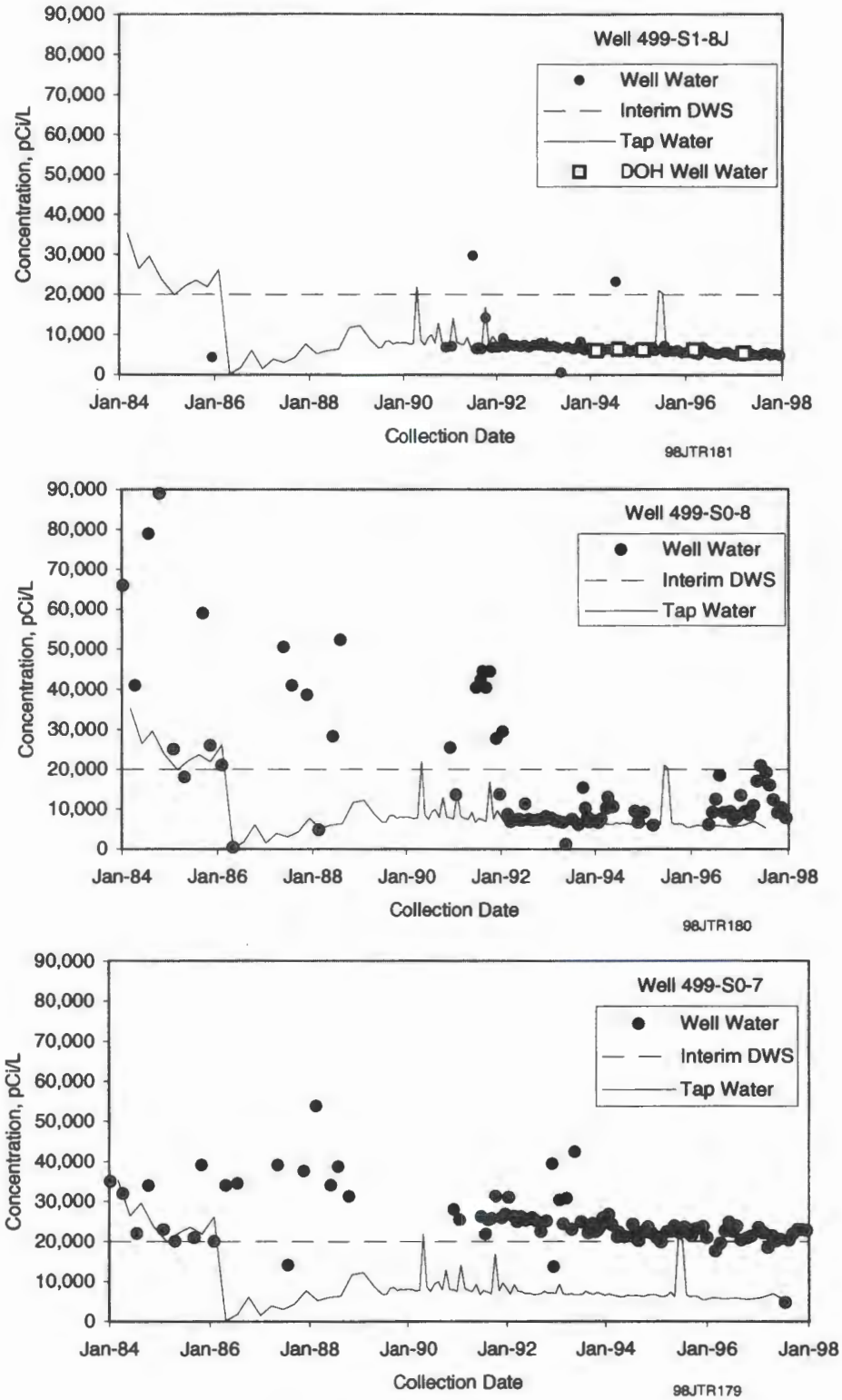


**Figure 4.3.2.** Tritium Concentrations in Drinking Water from Three Wells in the 400 Area, 1984 Through 1997 (DOH = Washington State Department of Health, DWS = Drinking Water Standard

**Table 4.3.2.** Selected Radiological Constituents in Hanford Site Drinking Water, 1997 Annual Average Concentrations (pCi/L)[a]

| System | No. of Samples | Gross Alpha | Gross Beta | Tritium | Strontium-90 | Total Uranium |
|---|---|---|---|---|---|---|
| 100-B Area | 4[b] | 0.55 ± 0.55 | 1.39 ± 0.76 | 83.83 ± 30.20 | 0.11 ± 0.03 | NM[c] |
| 100-D Area | 4[b] | 0.47 ± 0.27 | 2.43 ± 0.25 | 48.28 ± 70.58 | 0.11 ± 0.03 | NM |
| 100-K Area | 4[b] | 0.04 ± 0.23 | -0.77 ± 2.96 | 22.85 ± 30.63 | 0.03 ± 0.07 | NM |
| 300 Area | 4[d] | 1.41 ± 0.45 | 1.62 ± 1.11 | 340.53 ± 362.74 | 0.09 ± 0.03 | 1.71 ± 1.02 |
| 400 Area | 4[b] | 0.26 ± 0.53 | 8.47 ± 1.18 | 5,760 ± 882 | 0.03 ± 0.05 | NM |
| Yakima Barricade | 1[e] | 0.83 | 7.33 | 13.6 | 0.02 | NM |
| Patrol Academy | 1[e] | 0.35 | 6.25 | 19.3 | 0.02 | NM |
| Standards[f] | | 15[f,g] | 50[g,h] | 20,000[g,i] | 8[f,g] | |

(a) Average value ±2 standard error of the calculated mean.
(b) Grab samples collected and analyzed quarterly.
(c) NM = Not measured.
(d) Cumulative sample, collected monthly and composited for quarterly analysis.
(e) Grab sample, collected quarterly and composited for annual analysis.
(f) WAC 246-290.
(g) 40 CFR 141.
(h) Equivalent to 4 mrem/yr standard.
(i) Concentration assumed to yield an annual dose of 4 mrem/yr.

**Table 4.3.3.** Tritium Concentrations (pCi/L) in 400 Area Drinking Water Wells, 1997[a]

| Sampling Date | Well 499-S1-8J (P-16)[b] | Well 499-S0-8 (P-15)[c] | Well 499-S0-7 (P-14)[d] |
|---|---|---|---|
| January 10, 1997 | 4,730 ± 526 | 23,500 ± 1,890 | 13,400 ± 1,150 |
| February 14, 1997 | 5,550 ± 610 | 22,100 ± 1,810 | 9,310 ± 880 |
| March 18, 1997 | 4,600 ± 511 | 18,400 ± 1,510 | 8,500 ± 792 |
| April 17, 1997 | 5,470 ± 590 | 21,500 ± 1,750 | 10,900 ± 987 |
| May 14, 1997 | 4,920 ± 553 | 20,000 ± 1,650 | 17,000 ± 1,430 |
| June 10, 1997 | 4,870 ± 554 | 20,600 ± 1,690 | 20,900 ± 1,710 |
| July 21, 1997 | 4,790 ± 555 | 4,690 ± 550 | 19,200 ± 1,600 |
| August 15, 1997 | 5,210 ± 580 | 20,300 ± 1,670 | 16,000 ± 1,360 |
| September 12, 1997 | 5,360 ± 581 | 21,900 ± 1,780 | 12,300 ± 1,080 |
| October 17, 1997 | 4,820 ± 551[e] | 23,100 ± 1,860 | 9,020 ± 836 |
| November 13, 1997 | 5,090 ± 551 | 23,000 ± 1,850 | 10,300 ± 929 |
| December 18, 1997 | 4,740 ± 537 | 22,800 ± 1,850 | 7,740 ± 754 |

(a) Reported concentration ±2 total propagated analytical error.
(b) Drinking water well.
**(c) Dire emergency supply well.**
**(d) Emergency supply well.**
**(e) Sample collected on October 10, 1997.**

# 4.4 Food and Farm Product Surveillance

*T. M. Poston*

Alfalfa and foodstuffs, including milk, vegetables, fruits, and wine, were collected in 1997 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 the Hanford Site 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. Alfalfa was sampled because it is a primary feed commodity for dairy and beef cattle.

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 the Hanford Site 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 emphasis on the cleanup mission of the site. Specific details of the 1997 food and farm product sampling design, including sampling locations and radionuclides analyzed, are reported in DOE/RL-91-50, Rev. 2 and PNNL-11464 and are summarized in Table 4.4.1.

Gamma scans (cobalt-60, cesium-137, 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. Results for fruits and vegetables are reported in picocuries per gram wet weight. Results for alfalfa are reported in picocuries per gram dry 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 from site facilities are released to the atmosphere and to the Columbia River via riverbank springs. Strontium-90 from Hanford is released to the Columbia River through riverbank 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). This 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. Results, counting, and total propagated analytical uncertainty not given in this report may be found in PNNL-11796.

## 4.4.1 Collection of Milk Samples and Analytes of Interest

Composite samples of raw, whole milk were collected in 1997 from three East Wahluke and three Sagemoor dairy farms. These sampling areas are located near the site perimeter in the prevailingly downwind direction (see Figure 4.4.1). Milk samples were also collected from a Sunnyside 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 to humans. Gamma scans and strontium-90 analyses were

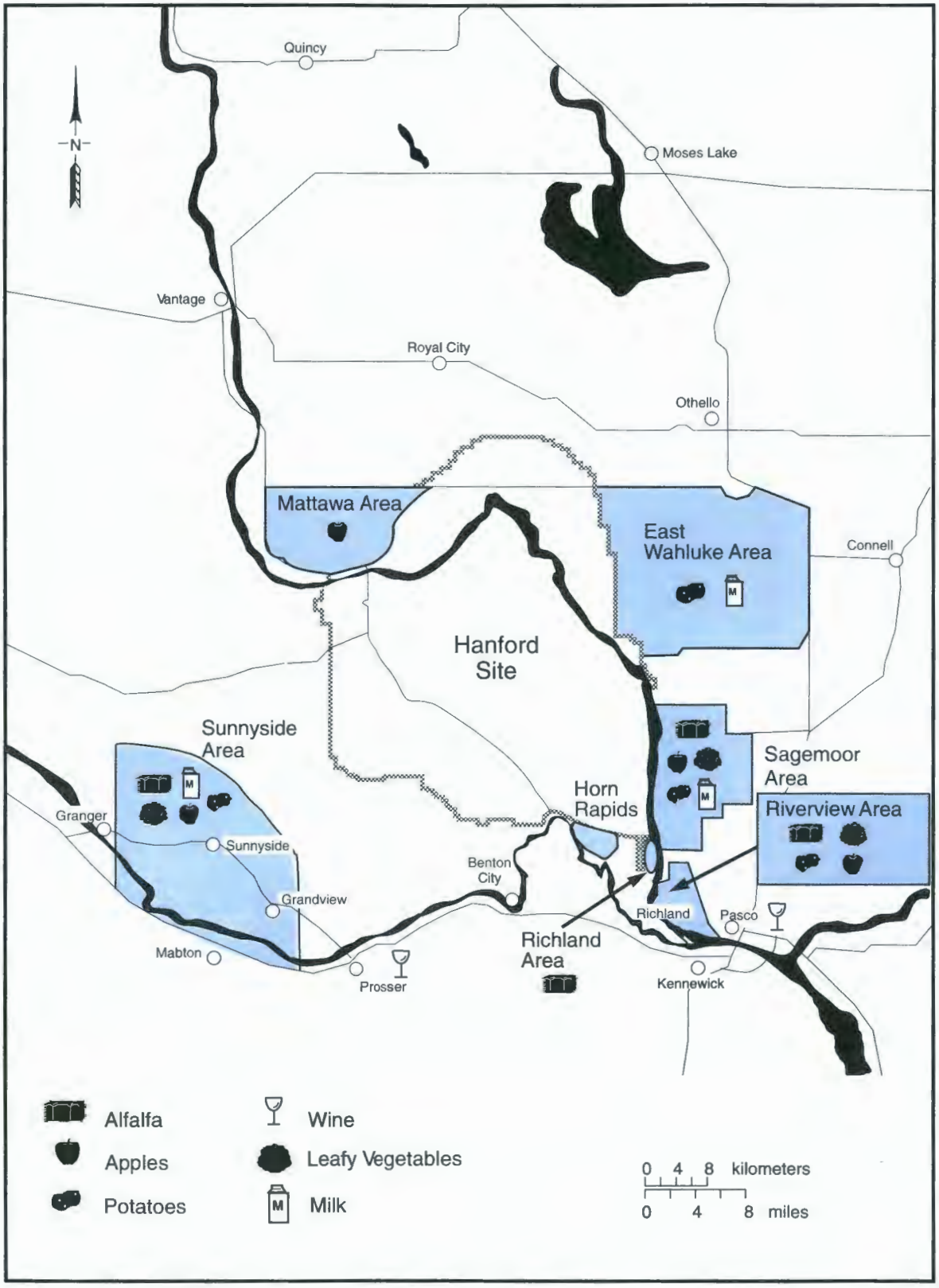


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**Figure 4.4.1**. Food and Farm Product Sampling Locations, 1997

**Table 4.4.1.** Locations, Sampling Frequencies, and Analyses Performed for Routinely Sampled Food and Farm Products, 1997[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 |
| Alfalfa | 1 | 3 | BA | 0 | 4 | 4 | 0 |

(a) Products may include multiple varieties for each category.
(b) Q = quarterly, SA = semiannually, A = annually, BA = biannually.

conducted quarterly, and iodine-129 analyses were conducted on two semiannual composite samples.

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 the sampling area in which the dairy farm is located. 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, levels of radioactivity in hay or alfalfa grown in some distant, rainy locations and purchased by local dairies may contribute more radioactivity to milk than 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 milk products; however, measured levels in milk are usually near levels considered to be background.

## 4.4.1.1 Radiological Results for Milk Samples

Strontium-90 was measured in 8 of 12 (67%) milk samples analyzed in 1997, with no apparent differences between upwind and downwind locations. Concentrations of strontium-90 remain near the nominal detection limit (0.7 pCi/L) and have been relatively constant over the past 6 years (Figure 4.4.2). The maximum observed concentration of strontium-90 in milk in 1997 was 2.1 ± 0.59 pCi/L in a Sunnyside sample. 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).

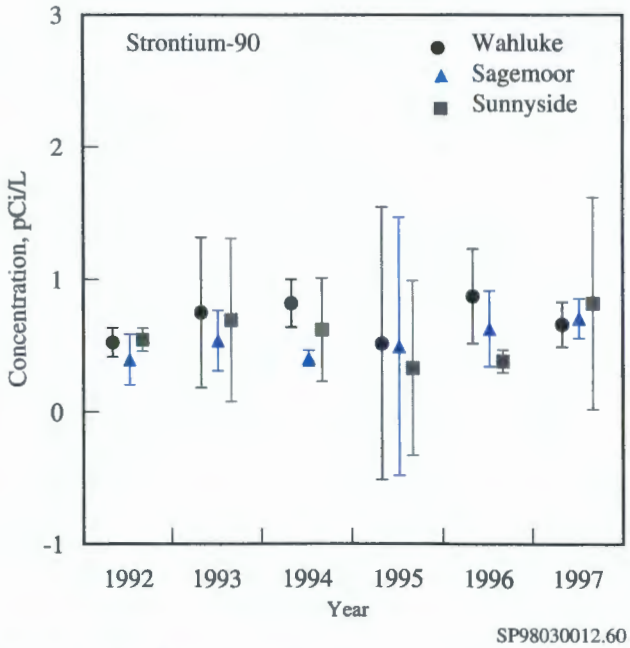


**Figure 4.4.2.** Mean Strontium-90 Concentrations (±2 standard error of the mean) in Milk, 1992 Through 1997

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 Sagemoor and East Wahluke have persisted at levels two to four times greater than levels measured upwind in Sunnyside (Figure 4.4.3). Iodine-129 concentrations have been declining with the end of nuclear production activities onsite. Iodine-129 contributes less than 1% of the dose to the maximally exposed individual through the consumption of dairy products (Section 5.0, "Potential Radiological Doses from 1997 Hanford Operations"). The maximum observed concentration of iodine-129 in milk in 1997 was 0.0006 ± 0.0001 pCi/L in a sample collected from Sagemoor. While there is no iodine-129 standard for milk, the drinking water standard is 1 pCi/L (EPA-570/9-76-003).

None of the 12 milk samples collected and analyzed in 1997 contained detectable concentrations of cesium-137 (<3.2 pCi/L). While there is no cesium-137 standard for milk, the drinking water standard is 200 pCi/L (EPA-570/9-76-003). Additionally, no other manmade gamma emitters were detectable in milk (PNNL-11796).

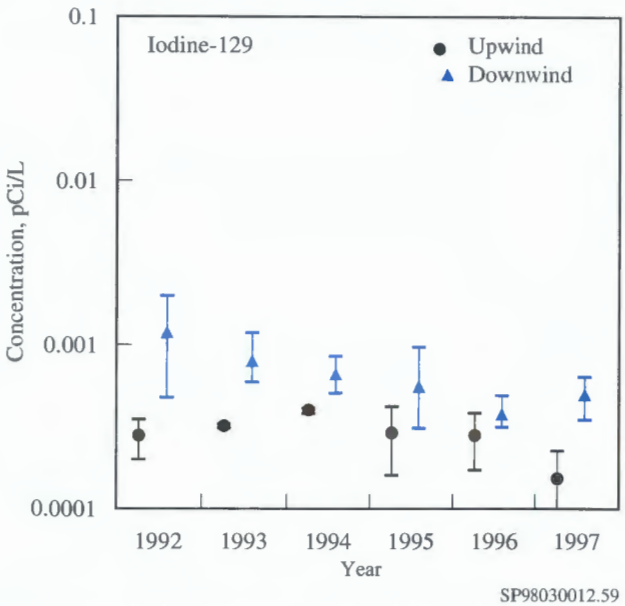


**Figure 4.4.3**. Minimum, Mean, and Maximum Iodine-129 Concentrations in Milk, 1992 Through 1997

## 4.4.2 Collection of Vegetable Samples and Analytes of Interest

Samples of leafy vegetables (i.e., cabbage, broccoli, beet tops, turnip greens) and potatoes were obtained during the summer from gardens and farms located within selected sampling areas (see Figure 4.4.1). Leafy vegetables are sampled because of the potential deposition of airborne contaminants. Riverview, Horn Rapids, and Richland are sampled because of 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.

### 4.4.2.1 Radiological Results for Vegetable Samples

Measurements of gamma emitters in potatoes and leafy vegetable samples were all less than their respective detection limits (0.02 pCi/g) and are consistent with results in recent years (see PNNL-11796). Strontium-90 was detected in one leafy vegetable sample collected from Riverview (0.034 ± 0.008 pCi/g) and in one potato sample collected at Horn Rapids (0.010 ± 0.005 pCi/g); strontium-90 levels in all other potato samples were below detection (<0.010 pCi/g).

## 4.4.3 Collection of Fruit Samples and Analytes of Interest

Apples were collected during harvest from the areas shown in Figure 4.4.1. All apple samples were analyzed for gamma-emitting radionuclides and strontium-90.

### 4.4.3.1 Radiological Results for Fruit Samples

Measurable levels of strontium-90, cesium-137 and other manmade radionuclides were not detected in apples in

1997. These results are consistent with measurements in grapes, apples, and melons over recent years (PNL-8683, PNL-9824, PNL-10575, PNNL-11140, PNNL-11473). Nominal levels of detection were 0.01 pCi/g wet weight for cesium-137 and 0.003 pCi/g wet weight for strontium-90.

## 4.4.4 Collection of Wine Samples and Analytes of Interest

Locally produced red and white wines (1997 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 location. Samples were analyzed for gamma emitters and for low-level tritium with the electrolytic enrichment method (DOE/RL-91-50, Rev. 2).

### 4.4.4.1 Radiological Results for Wine Samples

Gamma spectroscopy did not indicate the presence of cesium-137 or any other manmade gamma emitters in any of the 1997 wine samples. The nominal detection limit for cesium-137 in wine is approximately 3 pCi/L.

Concentrations of tritium in 1997 wine samples ranged from 19.4 to 34.4 pCi/L of distillate (Figure 4.4.4). There was generally no difference between the variety of wine or locations sampled. 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.

## 4.4.5 Collection of Alfalfa Samples and Analytes of Interest

Alfalfa samples were collected from the locations identified in Figure 4.4.1. Columbia River water withdrawn

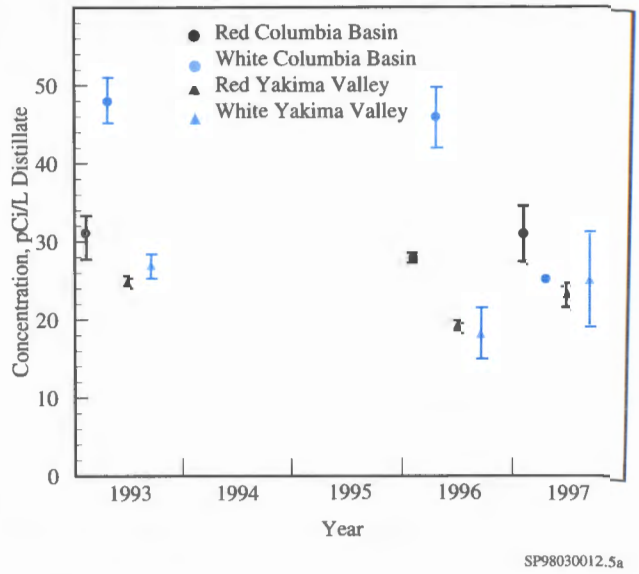


**Figure 4.4.4.** Minimum, Mean, and Maximum Tritium Concentrations in Wine Samples Collected in 1993, 1996, and 1997

downstream of the Hanford Site is used in Richland and Riverview for irrigation. Sagemoor and Sunnyside use other sources of irrigation water. Samples were analyzed for gamma-emitting radionuclides and strontium-90.

### 4.4.5.1 Radiological Results for Alfalfa Samples

From 1988 through 1994, alfalfa grown in locations irrigated with Columbia River water withdrawn downstream from the Hanford Site (Riverview, Richland, and Horn Rapids) contained slightly higher concentrations of strontium-90 relative to other locations (Poston et al. 1998). Further, mean strontium-90 concentrations in samples collected in 1995 and 1997 from locations irrigated with Columbia River water were higher than concentrations found in samples collected from locations using other sources of irrigation water. These differences in concentrations, however, are not statistically significant ($p = 0.191$) for either year (Figure 4.4.5). The concentrations of strontium-90 collected from all locations in 1997 were low and difficult to separate from the influence of historic fallout from atmospheric weapons testing. Cesium-137 and other manmade gamma-emitting radionuclides were not detected in any alfalfa sample collected in 1997.

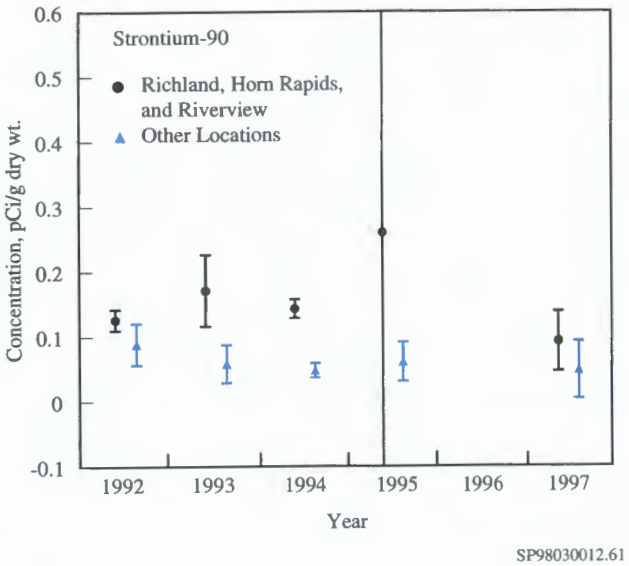


**Figure 4.4.5**. Mean Strontium-90 Concentrations (±2 standard error of the mean) in Alfalfa Routinely Collected, 1992 Through 1997. Samples were not collected in 1996.

# 4.5 Fish and Wildlife Surveillance

*T. M. Poston, M. L. Blanton, and G. W. Patton*

Contaminants in fish and wildlife 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 contaminants might be harvested for food and may potentially contribute to offsite public exposure. 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 1997 can be found in DOE/RL-91-50, Rev. 2.

Routine background sampling is conducted approximately every 5 years at locations believed to be unaffected by Hanford releases. Additional background data also may be collected during special studies.

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 the Hanford Site, strontium-90 and cesium-137 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 (14 to 600 d). 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%) (PNL-8817).

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 (<200 d in muscle; <20 d in the gastrointestinal tract), 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.

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. Results and propagated uncertainties for all results may be found in PNNL-11796.

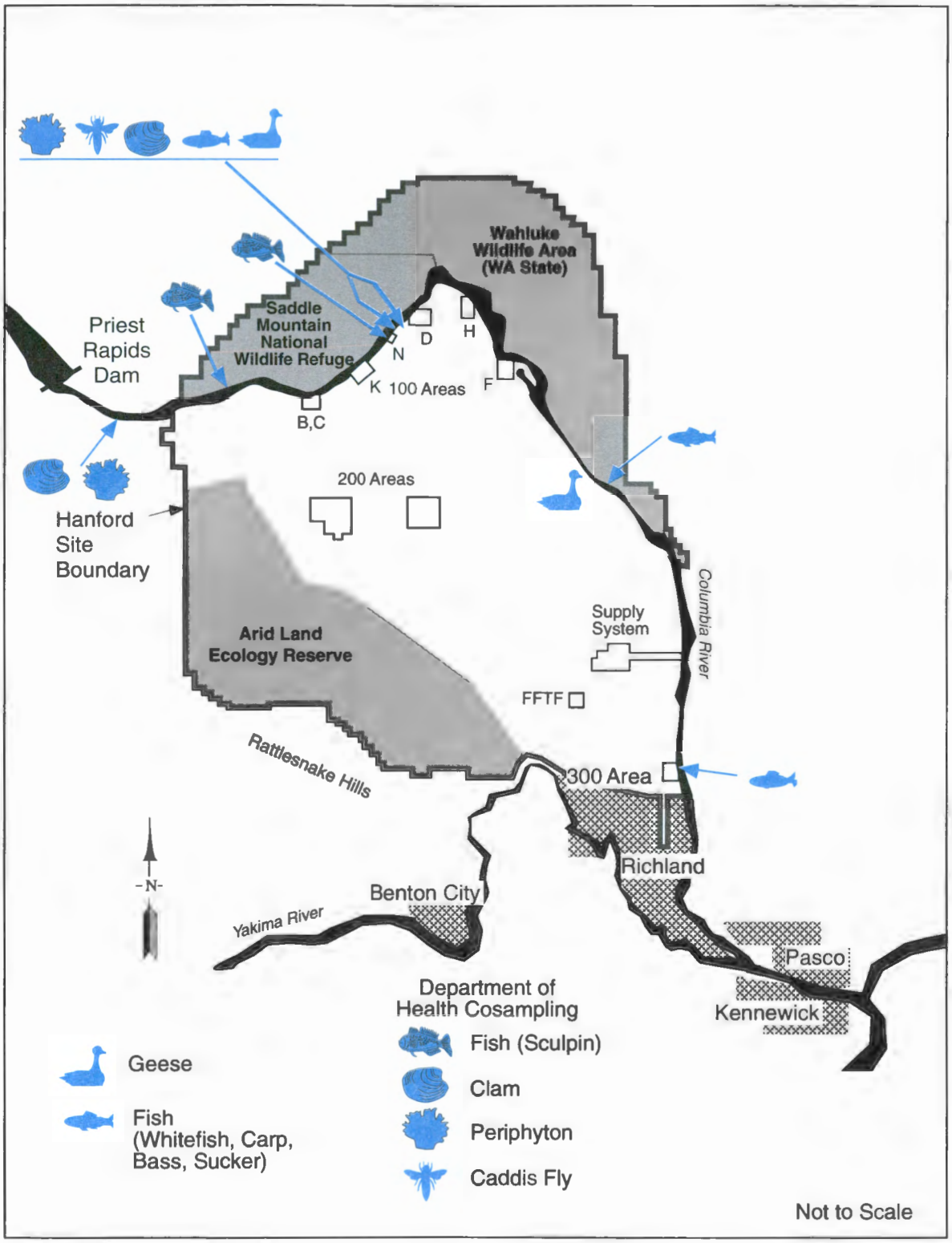


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**Figure 4.5.1**. Fish and Wildlife Sampling Locations, 1997

**Table 4.5.1.** Locations, Species, and Contaminants Sampled for Fish and Wildlife, 1997

| Medium | No. of Species | Offsite Locations | Onsite Locations | Contaminants Sampled/No. of Locations | | |
|---|---|---|---|---|---|---|
| | | | | Gamma | Strontium-90 | Metals |
| Fish (Whitefish, bass, carp, suckers, sculpins) | 5 | 1[a] | 4 | 1 | 1 | 4 |
| Geese | 1 | 0 | 2 | 2 | 2 | 0 |
| Rabbits | 0[b] | 0 | 0 | 0 | 0 | 0 |

(a) Background samples of sculpins collected near Vernita Bridge.
(b) Rabbit sampling suspended because of low jackrabbit populations.

## 4.5.1 Collection of Fish Samples and Analytes of Interest

In 1997, whitefish were collected from the Columbia River (i.e., that section of the river that includes the 100-N through 100-D Areas). Electrofishing near the 300 Area did not yield any whitefish. Results for whitefish collected in 1997 are compared to background fish collected in the Wenatchee River in 1995. Sculpins were also collected near the 100-N Area and from an upriver site near the Vernita Bridge as part of a collaborative study with the Washington State Department of Health. Sculpins are bottom-dwelling fish that are believed to reside in small home ranges. Consequently, they may be better indicators of localized contamination. Composite whole body samples (less liver) of sculpins were analyzed for gamma emitters and strontium-90.

Liver and kidney tissues were sampled from smallmouth bass, suckers, and carp collected near the 300 Area, Old Hanford Townsite, and the 100-N to 100-D Areas in August 1997. These samples were analyzed for metals. In addition to these samples, composite liver samples from sculpins were also collected at 100-N and the Vernita Bridge for metals analysis.

Bass, carp, suckers, and whitefish are very mobile, and the length of time they reside at any given sampling location is unknown. This mobility may explain why analytical results for these four species of fish generally are variable.

Fillets and the eviscerated remains (offal) were analyzed for contaminants. All analytical data for 1997 samples are listed in PNNL-11796.

## 4.5.2 Radiological Results for Fish Samples

### 4.5.2.1 Whitefish

**Muscle**. In 1997, muscle samples were analyzed with gamma spectrometry for cesium-137 and other gamma-emitting radionuclides (see Appendix E). Cesium-137 was detected in one of four whitefish fillet samples collected ($0.03 \pm 0.02$ pCi/g) in 1997. The 1997 results were similar to the results obtained over the preceding 5 years (Table 4.5.2).

Offal. Strontium-90 was found in 1 of 3 whitefish offal samples analyzed in 1997. Mean concentrations of strontium-90 in offal in 1997 were lower than had been observed in the preceding 5 years, and were lower than levels observed in the background samples collected from the Wenatchee River in 1995.

Overall, radionuclide concentrations in Hanford Reach whitefish were similar to the levels observed in background whitefish. The associated dose from the hypothetical consumption of whitefish is found in Section 5.0, "Potential Radiological Doses from 1997 Hanford Operations."

**Table 4.5.2.** Concentrations of Selected Radionuclides in Whitefish, 1997 Compared to Previous 5 Years

| Location | 1997 Maximum,[a] pCi/g wet wt. | 1997 Mean,[b] pCi/g wet wt. | 1997 No. Less Than Detection[c] | 1992-1996 Maximum,[a] pCi/g wet wt. | 1992-1996 Mean,[b] pCi/g wet wt. | 1992-1996 No. Less Than Detection[c] |
|---|---|---|---|---|---|---|
| **Cesium-137 in Muscle** | | | | | | |
| 100-N through 100-D Areas | 0.03 ± 0.02 | 0.01 ± 0.02 | 3 of 4 | 0.17 ± 0.04 | 0.03 ± 0.01 | 26 of 38 |
| Wenatchee River | NS[d] | NS | | 0.00 ± 0.01 | 0.004 ± 0.003 | 4 of 7 |
| **Strontium-90 in Offal** | | | | | | |
| 100-N through 100-D Areas | 0.033 ± 0.004 | 0.011 ± 0.022 | 2 of 3 | 0.46 ± 0.006 | 0.034 ± 0.028 | 1 of 33 |
| Wenatchee River | NS | NS | | 0.071 ± 0.018 | 0.049 ± 0.010 | 0 of 6 |

(a) Maximum is ± total propagated analytical uncertainty (2-sigma).
(b) Result is ±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.

### 4.5.2.2 Sculpins

Gamma emitters (nominal detection limit of 0.05 pCi/g) were not detected in composited sculpin samples from the 100-N shoreline or in samples collected from the upstream background location near the Vernita Bridge. The 100-N composite sample contained 0.75 ± 0.15 pCi/g strontium-90 compared to the upstream control concentration of 0.015 ± 0.009 pCi/g. Sculpins have disproportionately larger skulls than other fish routinely sampled in the Hanford Reach. The relatively larger skull in sculpins may influence the higher concentrations of strontium-90 observed in whole body samples of this species. The higher concentration found in the 100-N sample is attributed to the species small home range and greater potential exposure to 100-N groundwater seepage.

## 4.5.3 Wildlife Sampling

Wildlife scheduled for collection in 1997 for radioactive constituents included rabbits and geese. Jackrabbit populations statewide are down, and observations of site pest management and wildlife management staff indicated that the Hanford Site rabbit population was greatly depressed in 1997. Attempts to collect rabbits did not result in any sightings and rabbit collections were suspended. Collections of geese were successful for all locations. Data from all 1997 samples are given in PNNL-11796.

### 4.5.3.1 Collection of Goose Samples and Analytes of Interest

Resident Canada geese were collected from the 100-N through 100-D Areas and the Old Hanford Townsite in the summer of 1997. Radionuclide concentrations in these samples were compared to samples collected from the same locations in 1995.

### 4.5.3.2 Radiological Results for Goose Samples

**Muscle**. Cesium-137 was detected in 2 of 10 Canada goose muscle samples collected in 1997 (Table 4.5.3). Concentrations were close to the detection limit of 0.02 pCi/g and were similar to concentrations observed in 1995. Strontium-90 was measured in 2 of 10 muscle samples at levels very close to the detection limit of 0.005 pCi/g.

**Bone**. Strontium-90 was measured in 8 of 10 bone samples collected onsite in 1997. The mean concentrations

**Table 4.5.3.** Concentrations of Selected Radionuclides in Canada Geese, 1997 Compared to 1995

| Location/Tissue (Radionuclide) | 1997 Maximum, pCi/g[a] | 1997 Mean, pCi/g[b] | 1997 No. Less Than Detection[c] | 1995 Maximum, pCi/g[a] | 1995 Mean, pCi/g[b] | 1995 No. Less Than Detection[c] |
|---|---|---|---|---|---|---|
| **100-N through 100-D Areas** | | | | | | |
| Bone ($^{90}Sr$) | 0.15 ± 0.043 | 0.091 ± 0.040 | 0 of 5 | 0.717 ± 0.164 | 0.313 ± 0.284 | 0 of 5 |
| Muscle ($^{90}Sr$) | 0.005 ± 0.004 | 0.004 ± 0.001 | 4 of 5 | 0.002 ± 0.002 | 0.000 ± 0.001 | 5 of 5 |
| Muscle ($^{137}Cs$) | 0.04 ± 0.02 | 0.02 ± 0.02 | 3 of 5 | 0.01 ± 0.01 | 0.01 ± 0.00 | 5 of 5 |
| **Old Hanford Townsite** | | | | | | |
| Bone ($^{90}Sr$) | 0.15 ± 0.048 | 0.066 ± 0.046 | 2 of 5 | 0.439 ± 0.112 | 0.220 ± 0.141 | 0 of 5 |
| Muscle ($^{90}Sr$) | 0.010 ± 0.006 | 0.004 ± 0.004 | 4 of 5 | 0.001 ± 0.003 | 0.000 ± 0.001 | 5 of 5 |
| Muscle ($^{137}Cs$) | 0.02 ± 0.02 | 0.00 ± 0.01 | 5 of 5 | 0.01 ± 0.01 | 0.00 ± 0.01 | 5 of 5 |

(a) Maximum is ±2 total propagated analytical uncertainty (2-sigma).
(b) Result is ±2 standard error of the mean.
(c) Number of samples with values less than the detection limit out of number of samples analyzed.

of strontium-90 in bone samples collected from both locations were generally lower than concentrations observed in 1995 (see Table 4.5.3).

## 4.5.4 Nonradiological Results for Fish and Other Aquatic Organisms

Fish and several other aquatic organisms were collected from the Hanford Reach in 1997 as part of ongoing efforts to better understand the distribution and significance of metals. Fish kidney and liver samples were analyzed for metals. Other aquatic organisms including periphyton (assemblages of sponges, sessile algae, protozoans, and microinvertebrates found on cobble substrate), emergent adult caddis flies, and clams (soft tissue and shells) were also analyzed for metals. Samples were analyzed using two methods: cold vapor atomic adsorption spectrometry for the analysis of mercury and inductively coupled plasma emission spectrometry/mass spectrometry for the analysis of antimony, arsenic, cadmium, chromium, copper, nickel, lead, silver, selenium, thallium, and zinc. The metals data reported here represent an initial characterization effort to evaluate current concentrations of metals in Columbia River fish and aquatic biota.

### 4.5.4.1 Metals Analysis in Fish

Metals analysis was conducted on livers and kidneys collected from smallmouth bass, suckers, and carp. Five fish of each species were collected from the Columbia River adjacent to the 300 Area, Old Hanford Townsite, and 100-N through 100-D Areas.

Sculpins, which are considerably smaller than the other species, were collected near the 100-N Area and near the Vernita Bridge as part of a collaborative study with the Washington State Department of Health. Livers from these fish were used to prepare a composite sample from each study area.

### 4.5.4.2 Analytical Results

Metals data are summarized in tabular form in Appendix A (Tables A.8 and A.9). In recent years, chromium has been the focus of numerous site investigations and cleanup actions because it is known to enter the Columbia River in groundwater seeps along the Hanford shoreline. The chromium data for fish do not indicate any specific relationships between river location, tissues samples, or species (Figure 4.5.2). Concentrations of chromium ranged from less than detection (0.2 mg/g) to 1.2 mg/g dry weight in liver and kidney samples. Generally, liver and kidney concentrations were similar and there was no apparent

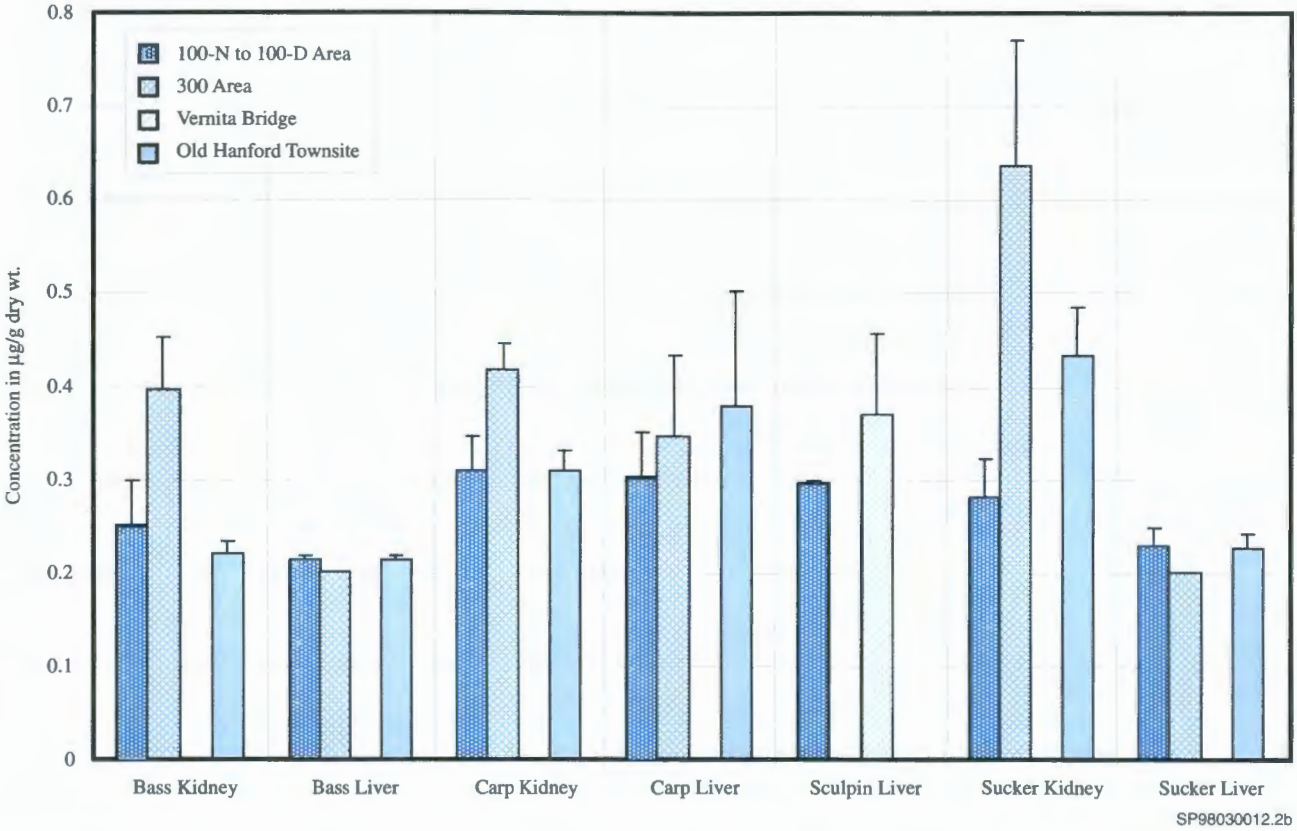


**Figure 4.5.2**. Chromium Concentrations (mean ±1 standard error of the mean) in Livers and Kidneys of Hanford Reach Fish, 1997

difference between species or locations sampled (see Figure 4.5.2). Carp appeared to be more prone to adsorption of metals than bass, suckers, and sculpins. The highest kidney concentrations of arsenic, cadmium, lead, thallium, and zinc were observed in carp. Additionally, the highest liver concentrations of copper and zinc were observed in carp. Zinc concentrations in carp liver and kidney samples exceeded concentrations in the comparable organs of bass, suckers, and sculpins by a factor of four or greater (Figure 4.5.3). Among bass, suckers, and sculpins, concentrations of other metals in liver and kidney samples were generally similar with no consistent and discernible distinction observed between the areas sampled (see Appendix A).

## 4.5.4.3 Metals Analysis in Other Aquatic Organisms

Periphyton, clams (shells and soft tissue), and emergent caddis flies were also sampled as part of the collaborative study with the Washington State Department of Health at 100-N Springs. Upstream control samples were collected between Priest Rapids Dam and Vernita Bridge on the Benton County side of the river. Obtaining enough caddis fly sample mass for analyses was difficult, and living clams were not found at the upstream control location.

## 4.5.4.4 Analytical Results

Chromium, copper, and zinc were found in the highest concentrations in the soft tissue of clams and in periphyton (Table 4.5.4). Beryllium and antimony were detected in periphyton samples, but were below detection in clam tissue. Overall, metals results are within the range of expected concentrations and are undergoing further evaluation with respect to fish, sediment, and water concentrations to gain a better understanding of trace metal distribution in the Columbia River ecosystem.

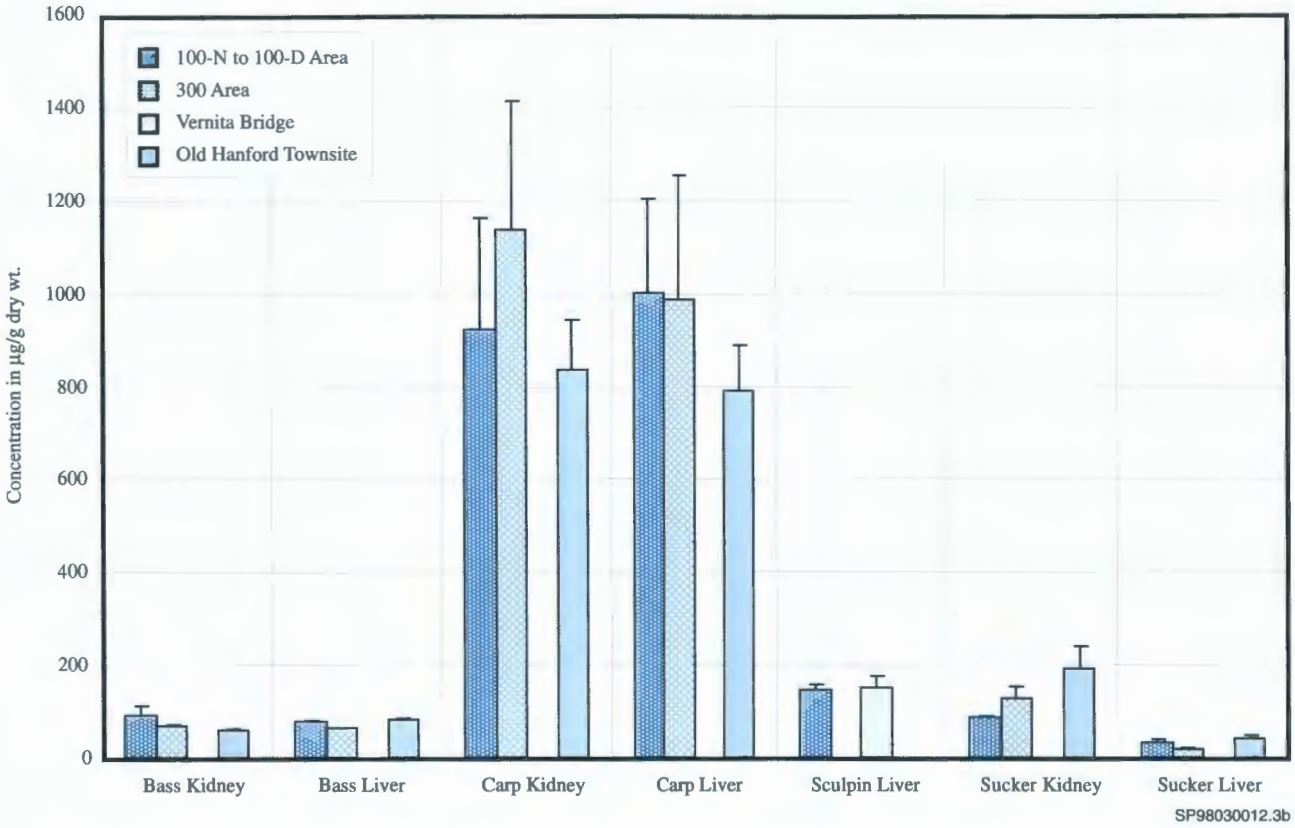


**Figure 4.5.3**. Zinc Concentrations (mean ±1 standard error of the mean) in Livers and Kidneys of Hanford Reach Fish, 1997

**Table 4.5.4**. Comparison of Metals Concentrations in Other Aquatic Organisms, 1997

| Organism | Sampling Location | No. of Samples | Data | Concentrations, µg/g dry wt. Antimony | Arsenic | Beryllium | Cadmium | Chromium | Copper | Lead |
|---|---|---|---|---|---|---|---|---|---|---|
| Caddis fly | | | | | | | | | | |
| Adult | 100-N Area | 2 | Mean | 0.10 | 0.97 | 0.15 | 0.89 | 0.57 | 31.0 | 0.87 |
| | | | Maximum | 0.19 | 1.0 | 0.15 | 0.75 | 0.73 | 33.0 | 1.2 |
| | | | Minimum | 0.015 | 0.93 | 0.15 | 0.62 | 0.41 | 29.0 | 0.53 |
| | Upstream of Vernita Bridge | 1 | Result | 0.054 | 1.2 | 0.15 | 0.91 | 0.52 | 35.0 | 1.5 |
| Larva | 100-N Area | 1 | Result | 0.015 | 3.7 | 0.49 | 2.5 | 12.7 | 27.0 | 12.0 |
| Clam muscle | 100-N Area | 2 | Mean | 0.015 | 10.004 | 0.15 | 4.025 | 11.503 | 56.86 | 1.733 |
| | | | Maximum | 0.015 | 15.74 | 0.15 | 5.557 | 19.8 | 92.26 | 2.998 |
| | | | Minimum | 0.015 | 4.268 | 0.15 | 2.493 | 3.206 | 21.46 | 0.468 |
| Clam shells | 100-N Area | 1 | Result | 0.019 | 0.11 | 0.15 | 0.066 | 0.25 | 3.016 | 0.206 |
| | Upstream of Vernita Bridge | 1 | Result | 0.015 | 0.505 | 0.15 | 0.325 | 1.912 | 9.847 | 2.693 |
| Periphyton | 100-N Area | 3 | Mean | 0.063 | 7.118 | 0.661 | 2.858 | 33.073 | 39.863 | 36.19 |
| | | | Maximum | 0.088 | 8.252 | 0.809 | 3.519 | 35.01 | 45.01 | 49.18 |
| | | | Minimum | 0.035 | 5.954 | 0.546 | 2.31 | 29.62 | 36.78 | 29.56 |
| | Upstream of Vernita Bridge | 1 | Result | 0.046 | 5.801 | 0.739 | 1.81 | 31.59 | 33.52 | 34.33 |
| | **Detection Limit** | | | **0.015** | **0.030** | **0.150** | **0.020** | **0.200** | **0.020** | **0.036** |

**Table 4.5.4.** (contd)

| Organism | Sampling Location | No. of Samples | Data | Concentrations, µg/g dry wt. Mercury | Nickel | Selenium | Silver | Thallium | Zinc |
|---|---|---|---|---|---|---|---|---|---|
| Caddis fly Adult | 100-N Area | 2 | Mean | 0.029 | 0.36 | 1.1 | 0.049 | 0.035 | 140 |
| | | | Maximum | 0.033 | 0.49 | 1.1 | 0.053 | 0.039 | 140 |
| | | | Minimum | 0.025 | 0.23 | 1.1 | 0.045 | 0.032 | 140 |
| | Upstream of Vernita Bridge | 1 | Result | 0.038 | 0.42 | 1.8 | 0.045 | 0.035 | 177 |
| Larva | 100-N Area | 1 | Result | 0.028 | 11.0 | 2.1 | 0.11 | 0.34 | 154 |
| Clam muscle | 100-N Area | 2 | Mean | 0.04 | 1.119 | 3.139 | 0.074 | 0.296 | 99.56 |
| | | | Maximum | 0.05 | 1.498 | 3.918 | 0.082 | 0.358 | 107.4 |
| | | | Minimum | 0.03 | 0.74 | 2.36 | 0.066 | 0.234 | 91.72 |
| Clam shells | 100-N Area | 1 | Result | 0.001 | 11.61 | 1 | 0.045 | 0.048 | 1.955 |
| | Upstream of Vernita Bridge | 1 | Result | 0.002 | 12.28 | 1 | 0.045 | 0.123 | 26.77 |
| Periphyton | 100-N Area | 3 | Mean | 0.074 | 26.703 | 1.36 | 0.15 | 0.491 | 228.767 |
| | | | Maximum | 0.089 | 28.65 | 1.448 | 0.189 | 0.633 | 259.6 |
| | | | Minimum | 0.057 | 25.07 | 1.194 | 0.121 | 0.401 | 210.4 |
| | Upstream of Vernita Bridge | 1 | Result | 0.041 | 26.08 | 1 | 0.139 | 0.498 | 259.1 |
| | **Detection Limit** | | | **0.001** | **0.020** | **1.0** | **0.045** | **0.005** | **0.150** |

# 4.6 Soil and Vegetation Surveillance

*T. M. Poston*

Soil surveillance provides information on long-term contamination trends and baseline environmental radionuclide concentrations in undisturbed locations (DOE/RL-91-50, Rev. 2). Surveillance of natural vegetation provides information on atmospheric deposition of radioactive materials in uncultivated areas and at onsite locations adjacent to potential sources of man-made radioactivity. Accordingly, concentrations of radionuclides in soil and natural vegetation provide a baseline against which unplanned releases can be compared.

Soil and natural vegetation samples have been collected on and around the Hanford Site for more than 50 years. Consequently, a large database exists that thoroughly documents onsite and offsite concentrations of man-made 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 at the site 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. Man-made radionuclides with short half-lives have decayed to stable isotopes and are no longer present. Moreover, radionuclide releases from the Hanford Site in recent years have been small, and therefore, baseline radionuclide concentrations have not changed appreciably for a number of years. Because only natural or man-made radionuclides with relatively long half-lives presently are found in soil and vegetation, sitewide environmental surveillance sampling of soil and vegetation can be less frequent. Routine surveillance of soil and vegetation was last conducted in 1994 (Section 4.6 in PNNL-10574). While no routine sampling of soil and vegetation was conducted onsite in 1997, special sampling of soil and natural vegetation was conducted in support of site cleanup activities, and a collaborative study was conducted with the Washington State Department of Health along the Columbia River shoreline at the 100-N Area.

Other soil and vegetation sampling by the management and integration contractor was conducted near active facility release points and waste sites on the site. Results are discussed in Section 3.2, "Near-Facility Environmental Monitoring."

## 4.6.1 300 Area and Franklin County Soil and Vegetation Sampling

In 1997, special soil and vegetation samples were collected in support of cleanup efforts in the 300-FF-1 Operable Unit north of the 300 Area. Samples were collected to the north, east, and west of the cleanup site. Five additional sampling locations were established on the Franklin County side of the Columbia River east and generally downwind of the 300 Area (Figure 4.6.1). Samples of natural vegetation (sagebrush and rabbitbrush) and soil were collected at each location.

Isotopic analyses indicated that uranium concentrations in the 300 Area and Franklin County soil in 1997 were similar. The 1997 samples were analyzed by alpha spectrometry. Samples collected in 1992, 1993, and 1994 were analyzed primarily by low-energy photon analysis. Alpha spectrometry generally will measure lower concentrations of uranium-235 than the low-energy photon method can detect. Also, low-energy photon analysis does not measure uranium-234. Concentrations of uranium reported for the 1992-1994 time period where analyzed predominately by the low-energy photon method.

### 4.6.1.1 Radionuclide Concentrations in Soil Samples

In 1997, soil samples were analyzed for gamma-emitting radionuclides, strontium-90, uranium-234, uranium-235, and uranium-238. These 1997 results were compared to soil results obtained from the same general areas around the 300 Area and in south Franklin County near the Columbia River between 1992 and 1994. In 1997,

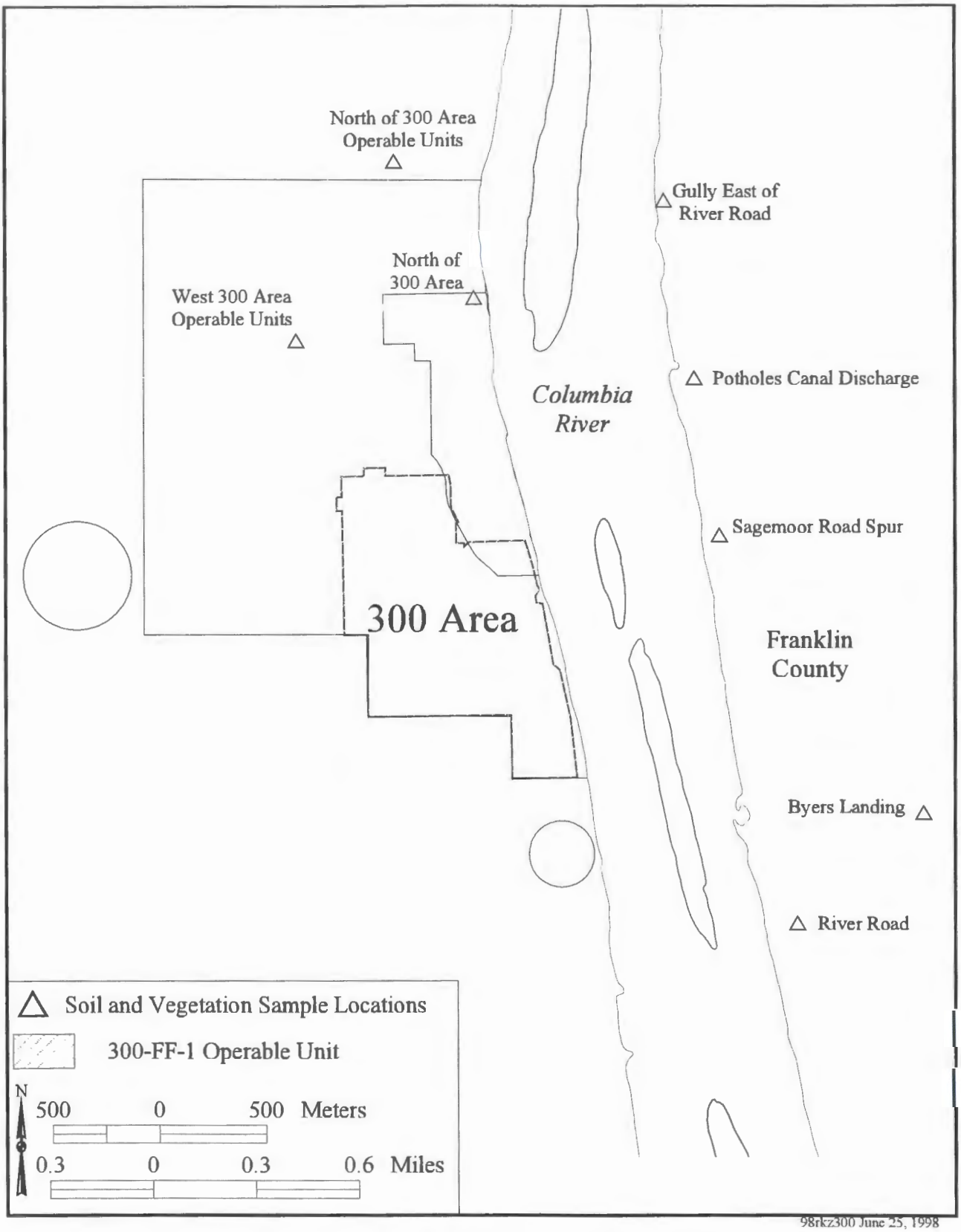


**Figure 4.6.1**. Soil and Vegetation Sampling Locations Associated with 300-FF-1 Operable Unit Cleanup, 1997

observed concentrations of strontium-90 and cesium-137 in soil were near detection limits, and while there appear to be differences in mean concentrations between Franklin County samples and 300 Area samples, the results from both locations are similar (Table 4.6.1). Similarly, there were no distinct differences between the 1997 results and results for 1992 through 1994. These results do not indicate any offsite dissemination of radionuclides from cleanup activities at the 300-FF-1 Operable Unit.

### 4.6.1.2 Radionuclide Concentrations in Vegetation Samples

Neither cesium-137 nor other man-made gamma-emitting radionuclides were detected in the special vegetation samples collected in 1997. Strontium-90 concentrations and uranium concentrations were similar in samples collected from north of the 300 Area and Franklin County (Table 4.6.2). There was a slight decrease in strontium-90 concentrations for 1997 results when compared to results of samples collected from earlier years. A mean (±2 standard error of the mean) strontium-90 concentration of 0.14 ± 0.10 pCi/g dry wt. in the 300 Area for the period 1983 through 1993 was reported in PNL-10728.

There were no significant differences in the concentrations of uranium-234, 238 in vegetation between the 300 Area samples and the Franklin County samples in 1997 (see Table 4.6.2). Uranium-235 concentrations were below detection limits at both locations. Comparisons of current data with past data, are difficult because different analytical methods were used from 1983 through 1993. Concentrations of uranium isotopes in vegetation do not indicate any consistent trend over the past 15 years in either the 300 Area or the Franklin County area. The mean uranium-238 concentration for the period 1983 through 1993 in Franklin County was 0.011 ± 0.008 pCi/g. This concentration compares favorably with the 0.013 ± 0.004 pCi/g value observed for the 1997 samples. These vegetation results do not indicate any offsite dissemination of radionuclides from 300-FF-1 Operable Unit cleanup activities.

## 4.6.2 Tree Sampling on the Hanford Site

During late July and early August 1997, three apricot trees and one quince tree growing on the Hanford Site were

**Table 4.6.1**. Radionuclides (pCi/g) in Soil Samples Collected from 300 Area and Franklin County

| | | 1997 | | | 1992-1994 | | |
|---|---|---|---|---|---|---|---|
| Radionuclide | Location | Maximum[a] | Mean[b] | No. Less Than Detection | Maximum[a] | Mean[b] | No. Less Than Detection |
| Cesium-137 | 300 Area | 0.61 ± 0.07 | 0.50 ± 0.20 | 0 of 3 | 0.56 ± 0.06 | 0.35 ± 0.70 | 0 of 5 |
| | Franklin County | 0.87 ± 0.04 | 0.30 ± 0.3 | 0 of 5 | 0.85 ± 0.09 | 0.34 ± 0.02 | 0 of 10 |
| Strontium-90 | 300 Area | 0.17 ± 0.03 | 0.140 ± 0.05 | 0 of 3 | 0.16 ± 0.04 | 0.10 ± 0.2 | 0 of 5 |
| | Franklin County | 0.15 ± 0.03 | 0.062 ± 0.05 | 0 of 5 | 0.15 ± 0.03 | 0.080 ± 0.02 | 0 of 10 |
| Uranium-234 | 300 Area | 0.34 ± 0.04 | 0.26 ± 0.09 | 0 of 3 | NA[c] | NA | 0 |
| | Franklin County | 0.42 ± 0.05 | 0.24 ± 0.09 | 0 of 5 | 0.88 ± 0.11 | 0.73 ± 0.1 | 0 of 7 |
| Uranium-235 | 300 Area | 0.019 ± 0.004 | 0.012 ± 0.008 | 0 of 3 | 0.17 ± 0.08 | 0.045 ± 0.09 | 3 of 5 |
| | Franklin County | 0.019 ± 0.004 | 0.011 ± 0.004 | 0 of 5 | 0.27 ± 0.15 | 0.013 ± 0.04 | 10 of 17 |
| Uranium-238 | 300 Area | 0.36 ± 0.04 | 0.26 ± 0.11 | 0 of 3 | 0.85 ± 0.03 | 0.62 ± 1.2 | 0 of 5 |
| | Franklin County | 0.44 ± 0.05 | 0.25 ± 0.10 | 0 of 5 | 1.1 ± 0.5 | 0.75 ± 0.09 | 1 of 17 |

(a) ± total propagated analytical uncertainty (2-sigma).
(b) ±2 standard error of the mean.
(c) Not available.

**Table 4.6.2.** Radionuclides (pCi/g) in Vegetation Samples Collected from 300 Area and Franklin County, 1997

| Radionuclide | Location | Maximum[a] | Mean[b] | No. Less Than Detection |
|---|---|---|---|---|
| Strontium-90 | 300 Area | 0.014 ± 0.004 | 0.010 ± 0.006 | 0 of 3 |
| | Franklin County | 0.037 ± 0.01 | 0.025 ± 0.01 | 0 of 5 |
| Uranium-234 | 300 Area | 0.022 ± 0.005 | 0.011 ± 0.01 | 0 of 3 |
| | Franklin County | 0.021 ± 0.006 | 0.014 ± 0.006 | 0 of 5 |
| Uranium-235 | 300 Area | < Detect[c] | < Detect | 3 of 3 |
| | Franklin County | < Detect | < Detect | 5 of 5 |
| Uranium-238 | 300 Area | 0.02 ± 0.005 | 0.009 ± 0.01 | 0 of 3 |
| | Franklin County | 0.019 ± 0.005 | 0.013 ± 0.004 | 0 of 5 |

(a) ± total propagated analytical uncertainty (2-sigma).
(b) ±2 standard error of the mean.
(c) Less than the detection limit.

sampled. Leaves were collected from two apricot trees located in the old orchards northeast of the 100-D Area, a third apricot tree located near the 100-F Area, and a quince tree growing in the Old Hanford Townsite (Figure 4.6.2). Originally, fruit and leaves were to be sampled; however, spring frost destroyed the tree blossoms and apricots were not produced. The quince tree was bearing fruit, and a sample of quince fruit was also collected with the leaves. Leaf samples from all trees were analyzed for gamma emitters, tritium, and strontium-90. Concentrations of tritium were measured with the electrolytic enrichment technique on water distilled from leaves (i.e., the method quantifies tritiated water, the principal form found in vegetation). The electrolytic enrichment method has a detection limit of approximately 10 to 15 pCi/L. The sample of quince fruit was analyzed for gamma emitters and strontium-90. All samples of leaves and fruit were also analyzed by inductively coupled plasma-mass (for trace metals) spectrometry and by cold vapor atomic adsorption spectrometry (for mercury).

## 4.6.2.1 Radionuclide Concentrations in Fruit Trees

No man-made gamma-emitting radionuclides (see Appendix E) were detected in any of the fruit or leaf samples collected near the 100-D Area, 100-F Area, or Old Hanford Townsite. Strontium-90 was measured in leaf samples from all three locations (Table 4.6.3), but was not detected in quince fruit obtained at the Old Hanford Townsite. From 1983 through 1993, concentrations of strontium-90 in native vegetation collected from the 600 Area ranged from 0.012 to 1.68 pCi/g dry wt. (PNL-10728). Concentrations of strontium-90 in fruit tree leaves were well within this range. The concentration in the 100-F Area apricot leaf sample (0.16 pCi/g) was equal to the reported mean (±2 standard error of the mean) for samples of vegetation shrub collected from the 600 Area (0.16 ± 0.10 pCi/g dry wt.).

Concentrations of tritium in apricot leaves collected adjacent to the 100-D Area indicated accumulation of low levels of tritium (500 to 620 pCi/L; Table 4.6.4). The apricot tree leaves at the 100-D Area were collected from an area within the 2,000-pCi/L plume contour for tritium in the unconfined aquifer, implying some contact with the unconfined aquifer (Section 4.8 in PNNL-11472). The apricot tree in the 100-F Area and the quince tree in the Old Hanford Townsite were just outside the 2,000-pCi/L tritium plume contour (see Figure 4.6.2). Concentrations of tritium in quince fruit should be comparable to levels observed in the distillate of leaves. The tritium concentration in leaves from the 100-F Area apricot

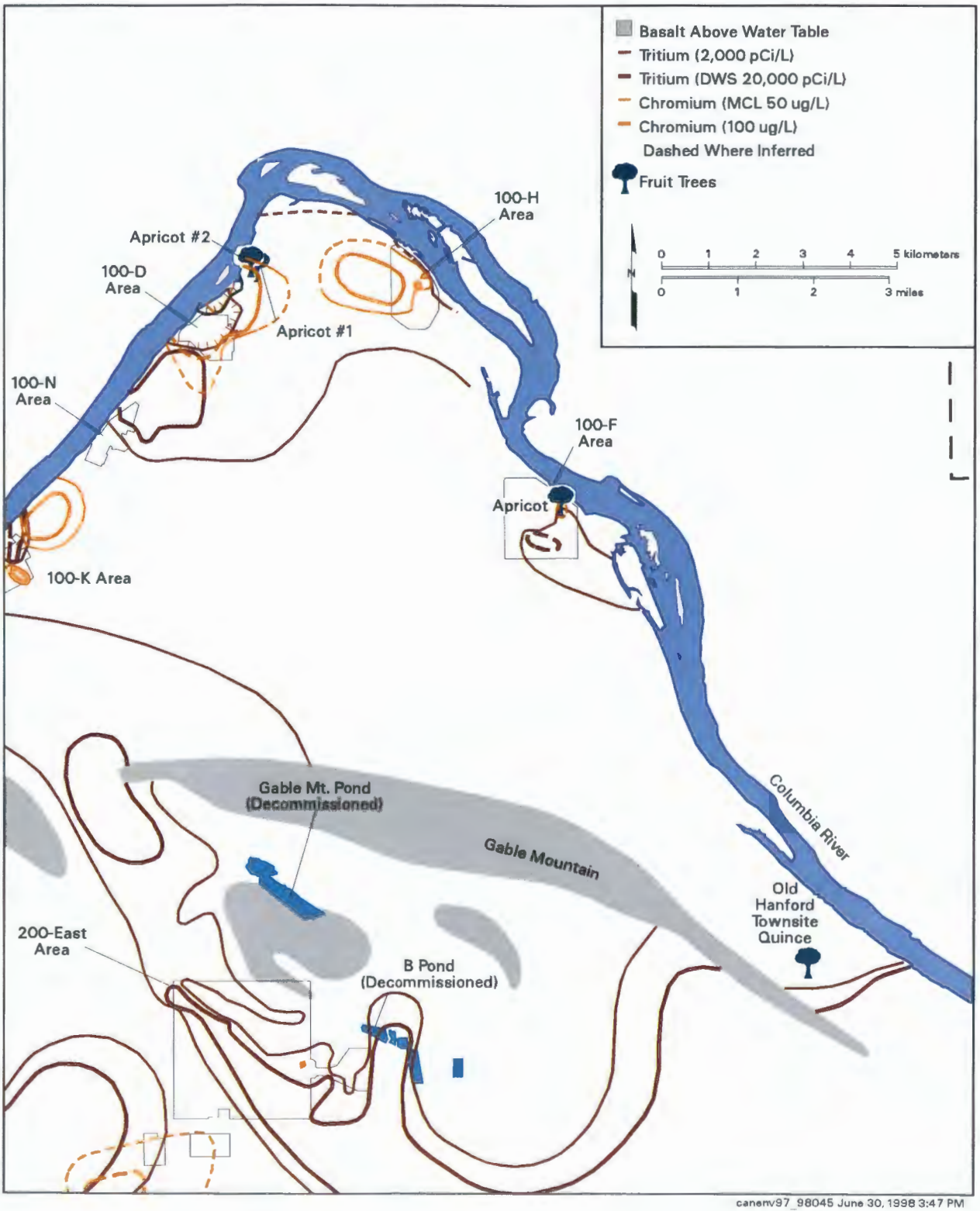


**Figure 4.6.2**. Fruit Tree Sampling Sites, 1997

**Table 4.6.3.** Strontium-90 in Fruit Tree Samples from Hanford Site, 1997

| Concentration, pCi/g[a] | Sample | Location |
|---|---|---|
| 0.004 ± 0.005 | Quince fruit | Old Hanford Townsite |
| 0.094 ± 0.02 | Quince leaves | Old Hanford Townsite |
| 0.015 ± 0.005 | Apricot leaves | 100-D Area |
| 0.011 ± 0.004 | Apricot leaves | 100-D Area |
| 0.16 ± 0.01 | Apricot leaves | 100-F Area |

(a) ±2 sigma total analytical error.

**Table 4.6.4.** Tritum in Fruit Tree Samples from Hanford Site, 1997

| Concentration, pCi/g[a] | Sample | Location |
|---|---|---|
| 15 ± 7.4 | Quince leaves | Old Hanford Townsite |
| 620 ± 57 | Apricot leaves | 100-D Area |
| 50 ± 47 | Apricot leaves | 100-D Area |
| 12.1 ± 7.2 | Apricot leaves | 100-F Area |

(a) ±2 sigma total analytical error.

tree and the Old Hanford Townsite quince tree is indicative of background levels and is lower than concentrations observed in Columbia River water.

## 4.6.2.2 Metals Concentrations in Hanford Trees

Table 4.6.5 presents the concentrations of metals measured in apricot and quince leaves and quince fruit collected in 1997. The last two columns in the table contain the range of background concentrations associated with each metal in vegetation and the levels in vegetation considered toxic (Kabata-Pendias and Pendias 1984). The background concentrations are based on a number of studies. They include concentrations reported for fruits, grains, and vegetables, but there were few data for fruit trees. Because of physiological differences, monocots (e.g., grasses) may accumulate different amounts of metals than dicots (e.g., legumes, forbs, deciduous trees). Consequently, the ranges reported are broad and provide a benchmark of natural background levels.

Antimony, beryllium, selenium, and silver were not detected in apricot leaves, quince leaves, or quince fruit, and the reported values are the analytical detection limits (see Table 4.6.5). Metals that were detected were within background ranges. None of the measured concentrations of metals fell within the range of concentrations that Kabata-Pendias and Pendias (1984) associate with toxic levels.

Chromium was detected in the 100-D Area apricot leaves at levels within the background range, but chromium was not detected in samples from the 100-F Area and in quince samples from the Old Hanford Townsite. The levels measured in 100-D Area apricot leaves were low and close to the detection limit. Both trees sampled from this area were growing in an area bounded by the 100- and 50-mg/L groundwater plume contours in the unconfined aquifer (see Figure 4.6.2). The maximum groundwater concentration of chromium at the 100-D Area was 727 mg/L in well 199-D5-14 (Section 4.8 in PNNL-11472). Cadmium, copper, and zinc concentrations also appeared elevated in the 100-D Area apricot leaves compared to the 100-F Area

**Table 4.6.5.** Metals (mg/kg dry wt.) in Fruit Trees Sampled from Hanford Site, 1997

| | Apricot Leaves | | | Quince | | | | |
|---|---|---|---|---|---|---|---|---|
| | 100-D Area (#1) | 100-D Area (#2) | 100-F Area | Fruit, Old Hanford Townsite | Leaves, Old Hanford Townsite | Detection Limit | Background Range[a] | Excessive or Toxic Range[a] |
| Antimony[b] | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 7-50 | 150 |
| Arsenic | 0.25 | 0.17 | 0.39 | 0.15 | 0.033 | 0.03 | 1-1.7 | 5-20 |
| Beryllium[b] | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | <1-7 | 10-50 |
| Cadmium | 0.15 | 0.21 | 0.097 | 0.053 | 0.079 | 0.02 | 0.05-0.2 | 5-30 |
| Chromium | 0.29 | 0.31 | 0.20 | 0.20 | 0.20 | 0.20 | 0.1-0.5 | 5-30 |
| Copper | 8.7 | 8.8 | 4.3 | 4.8 | 3.8 | 0.02 | 5-30 | 20-100 |
| Lead | 0.11 | 0.19 | 0.15 | 0.11 | 0.036 | 0.036 | 5-10 | 30-300 |
| Mercury | 0.020 | 0.021 | 0.017 | 0.022 | 0.002 | 0.001 | --[c] | 1-3 |
| Nickel | 0.84 | 1.1 | 0.79 | 0.95 | 0.13 | 0.020 | 0.1-5 | 10-100 |
| Selenium[b] | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.01-2 | 5-30 |
| Silver[b] | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.5 | 5-10 |
| Thallium | 0.005 | 0.02 | 0.005 | 0.005 | 0.006 | 0.005 | -- | 20 |
| Zinc | 13 | 17 | 9.8 | 5.9 | 3.1 | 0.15 | 27-150 | 100-400 |

(a) Taken from Kabata-Pendias and Pendias (1984). Excessive or toxic range is derived from studies where reported concentrations of metals in vegetation had arisen from elevated environmental exposures.
(b) All measured concentrations were less than the detection limit.
(c) No values reported.

apricot leaves and Old Hanford Townsite quince samples. These few data provide initial insight into the potential for metals contamination in trees; however, additional information would be required to provide a better characterization of the distribution of metals in this area.

## 4.6.3 Metals Analysis in Reed Canary Grass and Milfoil

Reed canary grass and milfoil (an aquatic plant) were also sampled as part of the collaborative study with the Washington State Department of Health at the 100-N Springs and analyzed for metals by the same methods used for tree leaves. One upstream control sample of each species was collected between Priest Rapids Dam and Vernita Bridge on the Benton County side of the river. Three samples of each species were collected at the 100-N Area. The samples collected provide baseline information about metals concentrations in riparian and aquatic plant species inhabiting the Columbia River and associated shoreline habitat.

### 4.6.3.1 Analytical Results

Concentrations of arsenic, cadmium, nickel, and zinc in milfoil were higher than concentrations of the same metals in reed canary grass (Table 4.6.6). Concentrations of other metals analyzed in both species were comparable. Concentrations of chromium, copper, lead, and silver in milfoil were markedly higher in the background sample compared to the 100-N Area samples. Concentrations of metals analyzed in reed canary grass did not show this spatial difference. Metals results are within the range of expected concentrations (see Table 4.6.5) and are undergoing further analysis with respect to fish, sediment, and water concentrations to better assess trace metal behavior in the Columbia River ecosystem.

**Table 4.6.6.** Concentrations of Trace Metals in Reed Canary Grass and Milfoil, 1997

| Organism | Sampling Location | No. of Samples | Data | Concentrations, mg/kg dry wt. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Antimony | Arsenic | Beryllium | Cadmium | Chromium | Copper | Lead |
| Reed canary grass | 100-N Area | 3 | Mean | 0.034 | 1.51 | 0.23 | 0.42 | 5.6 | 11.26 | 5.497 |
| | | | Maximum | 0.047 | 3.68 | 0.40 | 1.06 | 15.2 | 18.13 | 14.090 |
| | | | Minimum | 0.015 | 0.29 | 0.15 | 0.06 | 0.5 | 6.30 | 0.522 |
| | Vernita Bridge | 1 | Result | 0.015 | 1.60 | 0.16 | 0.41 | 4.4 | 12.73 | 8.896 |
| Milfoil | 100-N Area | 3 | Mean | 0.035 | 5.48 | 0.36 | 4.13 | 11.1 | 18.04 | 12.447 |
| | | | Maximum | 0.047 | 6.10 | 0.49 | 4.18 | 16.1 | 22.58 | 17.380 |
| | | | Minimum | 0.022 | 4.87 | 0.24 | 4.08 | 6.1 | 13.50 | 7.514 |
| | Vernita Bridge | 1 | Result | 0.040 | 8.10 | 1.07 | 3.15 | 29.9 | 33.61 | 47.830 |
| | | **Detection Limit** | | **0.015** | **0.030** | **0.150** | **0.020** | **0.200** | **0.020** | **0.036** |

| Organism | Sampling Location | No. of Samples | Data | Concentrations, mg/kg dry wt. | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Mercury | Nickel | Selenium | Silver | Zinc |
| Reed canary grass | 100-N Area | 3 | Mean | 0.019 | 4.95 | 1.00 | 0.053 | 104.37 |
| | | | Maximum | 0.033 | 11.71 | 1.00 | 0.069 | 152.90 |
| | | | Minimum | 0.010 | 1.04 | 1.00 | 0.045 | 49.00 |
| | Vernita Bridge | 1 | Result | 0.020 | 4.46 | 1.00 | 0.056 | 78.11 |
| Milfoil | 100-N Area | 3 | Mean | 0.028 | 10.85 | 1.03 | 0.07 | 209.75 |
| | | | Maximum | 0.038 | 15.23 | 1.05 | 0.094 | 241.50 |
| | | | Minimum | 0.018 | 6.47 | 1.00 | 0.045 | 178.00 |
| | Vernita Bridge | 1 | Result | 0.073 | 26.93 | 1.00 | 0.182 | 270.40 |
| | | **Detection Limit** | | **0.001** | **0.020** | **1.000** | **0.045** | **0.150** |

# 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). 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. Thermoluminescent dosimeters absorb and store energy of direct radiation within the thermoluminescent material. By heating the material under controlled laboratory conditions, this stored energy is released as light, which is measured and related to the amount of direct radiation. 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 sievert (Sv) is the SI equivalent of the rem.

$$D\ (\text{rad}) = X\ (R) * 1.0$$
$$H\ (\text{rem}) = D * N * Q$$

To convert to SI units of gray and sievert, divide rad and rem by 100, respectively.

In 1997, environmental external radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters and pressurized ionization chambers. Exposure rates measured by the pressurized ionization chambers are reported in units of microroentgens per hour. External radiation and surface contamination surveys at these locations were also performed with portable radiation survey instruments. This section describes how external radiation was measured, how surveys were performed, and gives the results of these measurements and surveys.

## 4.7.1 External Radiation Measurements

In 1995, the Harshaw 8800 series system replaced the former Hanford standard environmental dosimeter system. The new environmental dosimeter consists of two TLD-700 and two TLD-200 chips. This dosimeter also 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),

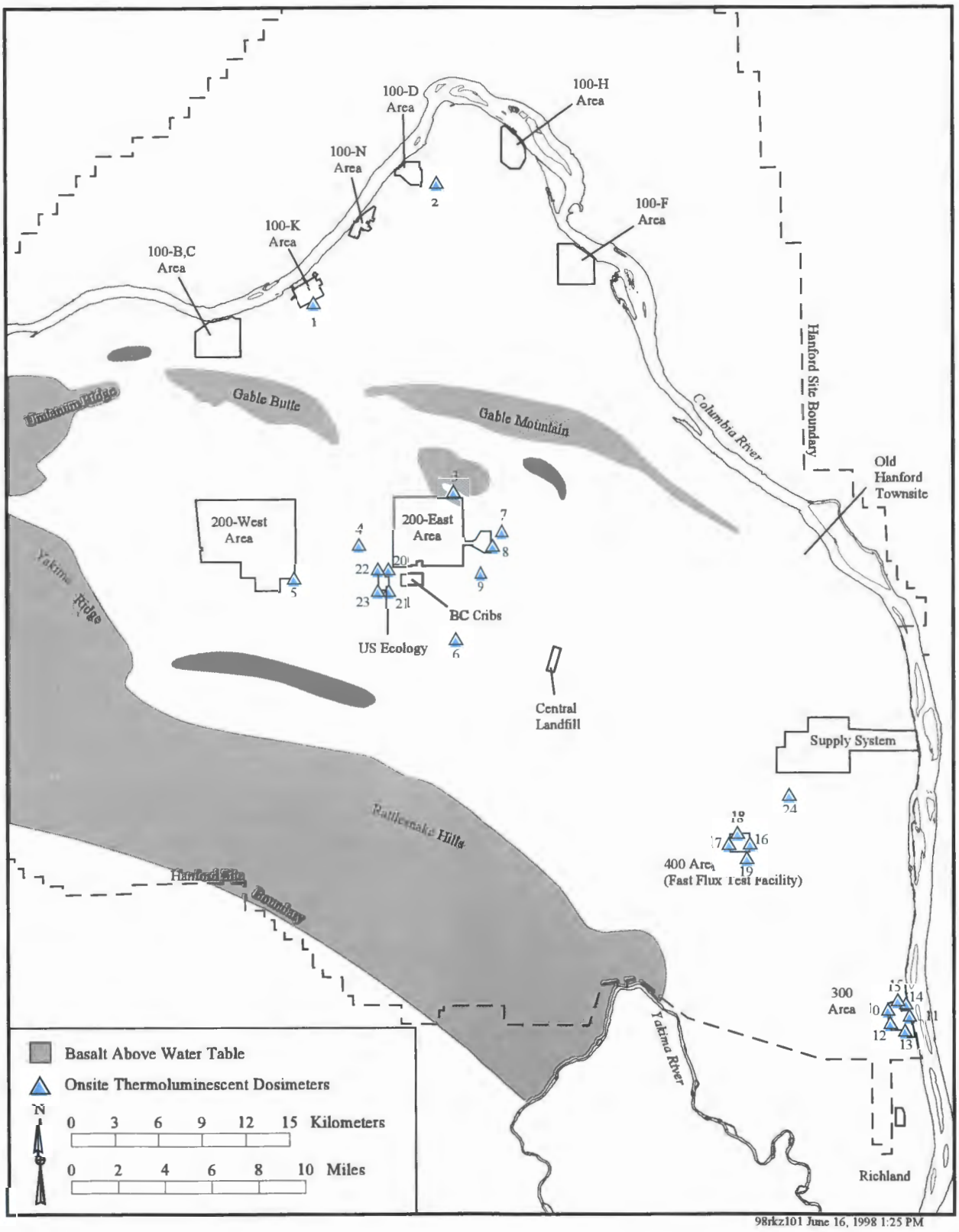


**Figure 4.7.1.** Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 1997

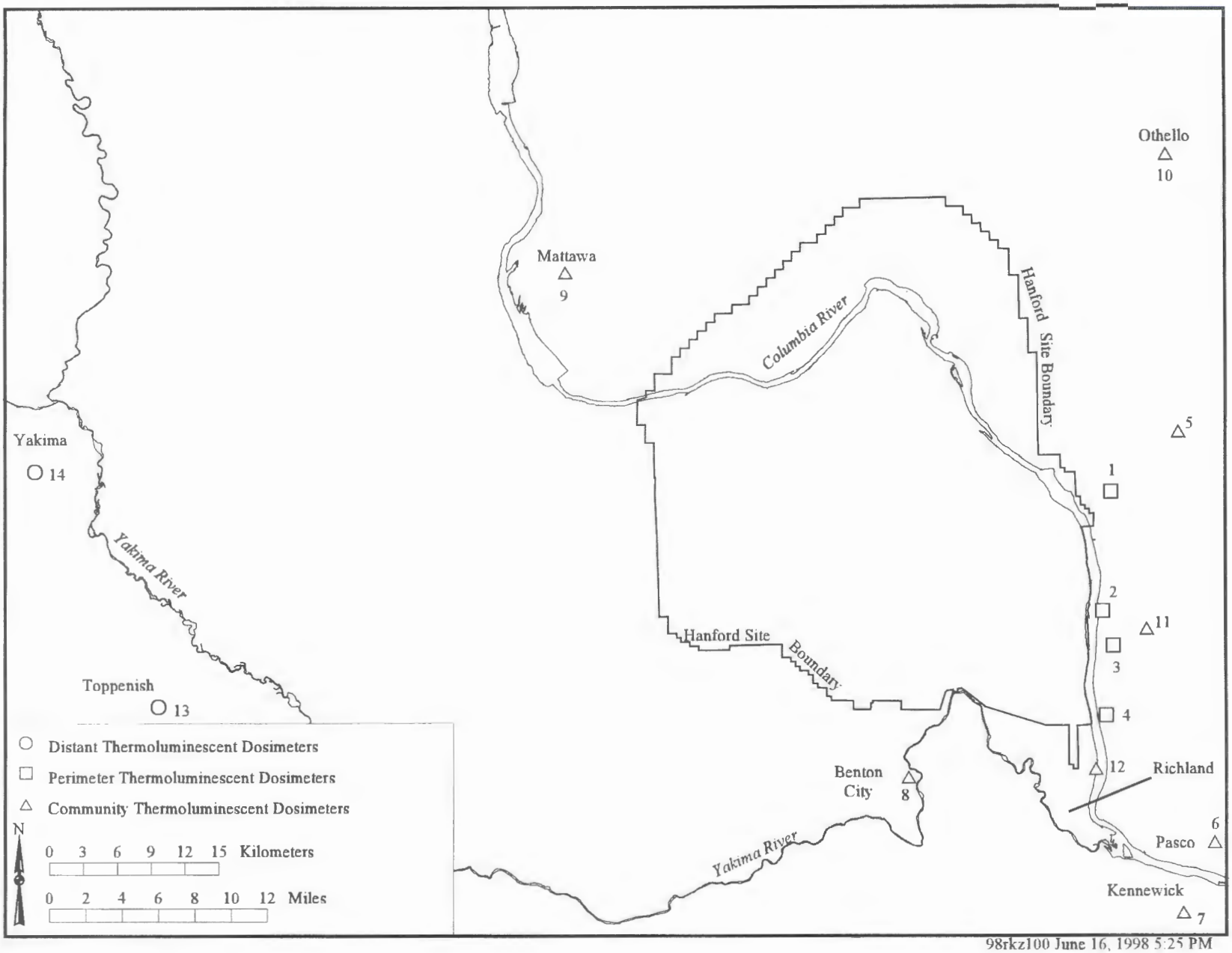


**Figure 4.7.2**. Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 1997

and 28 locations along 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 (in millirems per day) at each location were converted to annual dose equivalent rates (millirems per year) 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 Site 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 were 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. In March 1997, the number of thermoluminescent dosimeters along the rivershore was reduced to 24. The locations discontinued were just below the 100-N stack, on the opposite shore from the 100-D Area, near the old Hanford ferry landing, and on the north end of Wooded Island. Data collected from these locations prior to their elimination from the network are included in the data analysis.

## 4.7.2 External Radiation Results

Thermoluminescent dosimeter readings 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 1997 and the previous 5 years. External dose rates reported in Tables 4.7.1 through 4.7.3 include the maximum and mean 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.

The annual external radiation dose rates measured in 1997 were given in Table 4.7.1. The perimeter dose rate was 89 ± 10 mrem/yr, while in 1996, the mean was 88 ± 10 mrem/yr and the 5-year perimeter mean was 97 ± 5 mrem/yr. The mean background external radiation dose rate (at distant communities) in 1997 was 67 ± 1 mrem/yr compared to the 1996 background average of 71 ± 1 mrem/yr (Section 4.7 in PNNL-11472) and the 5-year mean background dose rate was 83 ± 7 mrem/yr. The background results may be biased low because the background dosimeters are located within fenced areas, for security reasons, and these areas are paved, which shields the dosimeters from some portion of the terrestrial component. The variation in dose 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 (PNL-7124), and changes in station locations. These changes include, but are not limited to, the discontinuation of thermoluminescent dosimeter locations or the moving of a station to avoid continual vandalism. Figure 4.7.4 graphically displays a comparison of dose rates between onsite, perimeter, and distant thermoluminescent dosimeter locations from 1992 through 1997.

Locations of the thermoluminescent dosimeters positioned along the Columbia River shoreline were shown in Figure 4.7.3, with Table 4.7.2 showing the measured dose rates for those 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 (PNL-3127). The maximum dose rate from the 100-N Area shoreline was 178 mrem/yr taken in the fourth quarter at the station located at the 100-N springs. The general public does not have legal access to the 100-N Area shoreline but does have access to the adjacent Columbia River. The dose implications associated with this access are discussed in Section 5.0, "Potential Radiological Doses from 1997 Hanford Operations."

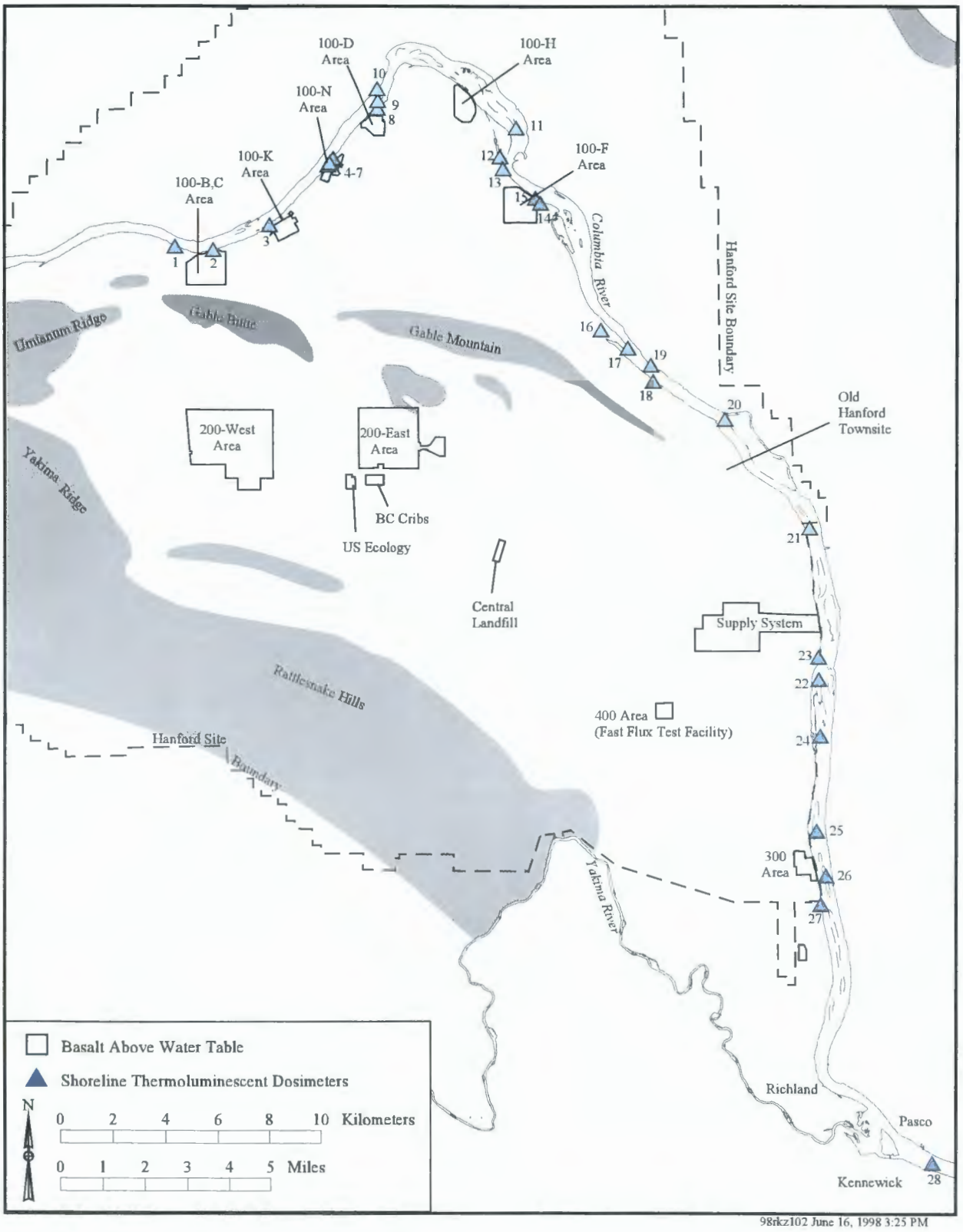


**Figure 4.7.3**. Thermoluminescent Dosimeter Locations and Station Numbers on the Columbia River, 1997

**Table 4.7.1.** Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations, 1997 Compared to Previous 5 Years

| | | 1997 | | 1992-1996 | | |
|---|---|---|---|---|---|---|
| Location | Map Location[b] | Maximum[c] | Mean[d] | No. of Samples | Maximum[c] | Mean[d] |
| Perimeter | 1 - 4 | 95 ± 3 | 89 ± 10 | 25 | 121 ± 8 | 97 ± 5 |
| Community | 5 - 12 | 86 ± 4 | 74 ± 9 | 37 | 106 ± 8 | 86 ± 4 |
| Distant | 13 - 14 | 68 ± 2 | 67 ± 1 | 11 | 100 ± 5 | 83 ± 7 |

(a) ±2 standard error of the mean.
(b) All station locations are shown on Figure 4.7.2.
(c) Maximum annual average dose rate for all locations within a given distance classification.
(d) Means computed by averaging annual means for each location within each distance classification.

**Table 4.7.2.** Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters Along the Hanford Reach of the Columbia River, 1997 Compared to Previous 5 Years

| | | 1997 | | 1992-1996 | | |
|---|---|---|---|---|---|---|
| Location | Map Location[b] | Maximum[c] | Mean[d] | No. of Samples | Maximum[c] | Mean[d] |
| Typical shoreline | 1 - 24 | 102 ± 1[e] | 85 ± 3 | 125 | 141 ± 11 | 100 ± 3 |
| 100-N Shoreline | 25 - 28 | 153 ± 31 | 121 ± 22 | 20 | 324 ± 39 | 189 ± 24 |
| All shoreline | 1 - 28 | 153 ± 31 | 90 ± 6 | 145 | 324 ± 39 | 113 ± 6 |

(a) ±2 standard error of the mean.
(b) All locations are shown on Figure 4.7.3.
(c) Maximum annual average dose rate for all locations within a given distance classification.
(d) Means computed by averaging the annual means for each location within each distance classification.
(e) Single quarter's data; error term is two times the counting error for that single measurement.

Table 4.7.3 summarized the results of 1997 measurements on the site, 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.

## 4.7.3 Radiation Survey Results

In 1997, 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 at the selected locations were comparable to levels observed

**Table 4.7.3.** Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters on the Hanford Site, 1997 Compared to Previous 5 Years

| | | 1997 | | 1992-1996 | | |
|---|---|---|---|---|---|---|
| Location | Map Location[b] | Maximum[c] | Mean[d] | No. of Samples | Maximum[c] | Mean[d] |
| 100 Areas | 1 - 2 | 86 ± 1 | 78 ± 16 | 12 | 108 ± 11 | 91 ± 7 |
| 200 Areas | 3 - 9 | 92 ± 6 | 86 ± 4 | 37 | 121 ± 10 | 97 ± 3 |
| 300 Area | 10 - 15 | 82 ± 2 | 80 ± 1 | 30 | 110 ± 18 | 92 ± 4 |
| 400 Area | 16 - 19 | 83 ± 6 | 81 ± 2 | 20 | 111 ± 18 | 94 ± 5 |
| 600 Area | 20 - 24 | 131 ± 26 | 94 ± 21 | 24 | 183 ± 16 | 110 ± 11 |
| Combined Onsite | 1 - 24 | 131 ± 26 | 85 ± 5 | 123 | 183 ± 16 | 97 ± 3 |

(a) ±2 standard error of the mean.
(b) All locations shown on Figure 4.7.1.
(c) Maximum annual average dose rate for all locations within a given area classification.
(d) Means computed by averaging the annual means for each location within each distance classification.

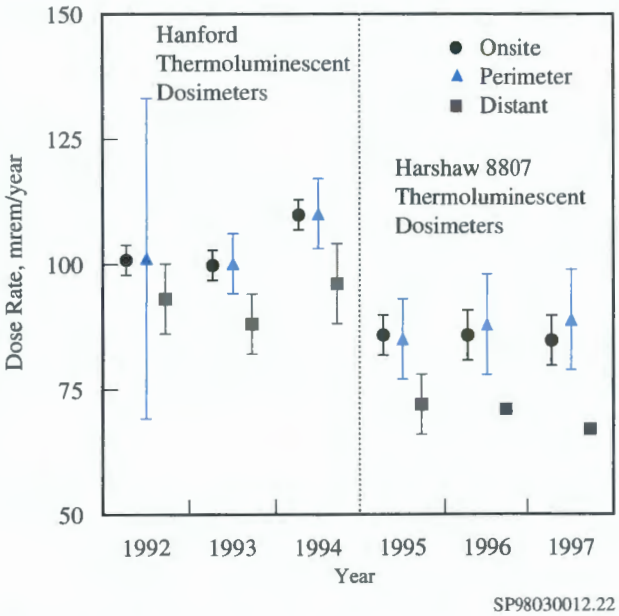


**Figure 4.7.4.** Annual Average Dose Rates (±2 standard error of the mean), 1992 Through 1997

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 7 to 30 mrem/h. The 30 mrem/h reading corresponded with the highest quarterly thermoluminescent dosimeter reading for the 100-N Trench location. Survey information is not included in the 1997 data volume (PNNL-11796), but is maintained in the Surface Environmental Surveillance Project files at Pacific Northwest National Laboratory and can be provided on written request.

## 4.7.3.1 Gamma Radiation Measurements

During 1997, gamma radiation levels in air were continuously monitored at four community-operated air monitoring stations (Section 7.4, "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. The data collected at each station each month are summarized in Table 4.7.4.

The measurements recorded at Basin City, Edwin Markham, and Leslie Groves Park during the year were similar and at background levels. The readings recorded at Heritage College were also within normal limits but were, on average, slightly lower than readings measured near the Hanford Site.

Monthly average exposure rates ranged from 6.9 mR/h at Heritage College in December to 8.7 mR/h at Edwin Markham during 7 months of the year (see Table 4.7.4). Average monthly readings at the stations near Hanford were consistently between 8.1 and 8.7 mR/h, and readings at Heritage College ranged between 6.9 and 8.1 mR/h. These dose rates were consistent with dose rates measured by the thermoluminescent dosimeters at these locations (Table 4.7.5).

**Table 4.7.4.** Average Exposure Rates Measured by Pressurized Ionization Chambers at Four Offsite Locations, 1997

| | Average Exposure Rate, μR/h[a](number of readings)[b], at Sampling Locations[c] | | | |
|---|---|---|---|---|
| Month | Leslie Groves Park[d] | Basin City[e] | Edwin Markham[e] | Toppenish[d] |
| January | 8.6 ± 0.024 (585) | 8.3 ± 0.013 (1,334) | 8.7 ± 0.017 (1,304) | 6.9 ± 0.019 (743) |
| February | 8.5 ± 0.020 (633) | 8.2 ± 0.011 (1,327) | 8.7 ± 0.011 (1,334) | 7.5 ± 0.011 (672) |
| March | 8.4 ± 0.018 (743) | 8.2 ± 0.008 (1,507) | 8.7 ± 0.009 (1,488) | 7.7 ± 0.014 (357) |
| April | 8.4 ± 0.015 (600) | 8.2 ± 0.009 (1,557) | 8.7 ± 0.009 (1,433) | 7.9 ± 0.014 (510) |
| May | 8.3 ± 0.015 (720) | 8.1 ± 0.014 (859) | 8.6 ± 0.010 (1,444) | 7.8 ± 0.014 (733) |
| June | 8.3 ± 0.011 (720) | 8.1 ± 0.006 (1,451) | 8.6 ± 0.007 (1,816) | 7.8 ± 0.010 (694) |
| July | 8.2 ± 0.016 (510) | 8.1 ± 0.008 (1,479) | 8.5 ± 0.010 (1,259) | 7.8 ± 0.014 (720) |
| August | 8.3 ± 0.021 (387) | 8.3 ± 0.007 (1,482) | 8.5 ± 0.013 (1,774) | 7.9 ± 0.012 (655) |
| September | 8.4 ± 0.020 (720) | ND[f] | 8.7 ± 0.018 (655) | 8.0 ± 0.016 (618) |
| October | 8.4 ± 0.020 (744) | 8.4 ± 0.016 (652) | 8.7 ± 0.010 (1,497) | 8.0 ± 0.020 (682) |
| November | 8.5 ± 0.041 (720) | ND | ND | 8.1 ± 0.025 (920) |
| December | 8.5 ± 0.036 (744) | 8.4 ± 0.024 (102) | ND | 8.1 ± 0.026 (744) |

(a) Averages are ±2 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) ND = No data collected; equipment or power problems.

**Table 4.7.5.** Quarterly Exposure Rates Measured by Thermoluminescent Dosimeters at Four Offsite Locations, 1997

| | Exposure Rate, μR/h[a], at Sampling Locations[b] | | | |
|---|---|---|---|---|
| Quarter Ending | Leslie Groves Park | Basin City | Edwin Markham | Toppenish |
| March | 9.3 ± 0.79 | 9.2 ± 0.00 | 9.1 ± 0.04 | 7.4 ± 0.13 |
| June | 8.3 ± 0.08 | NS[c] | 7.9 ± 0.13 | 7.8 ± 0.54[d] |
| September | NS | 9.3 ± 0.67 | 9.0 ± 0.58 | 7.8 ± 0.04 |
| December | 8.4 ± 0.04 | 8.8 ± 0.021 | 8.3 ± 0.04 | 7.8 ± 0.50 |

(a) ±2 standard deviations of the exposure rate.
(b) Sampling locations shown on Figure 4.1.1.
(c) NS = No sample; thermoluminescent dosimeters missing.
(d) Collected on July 1, 1997.

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# 5.0 Potential Radiological Doses from 1997 Hanford Operations

*E. J. Antonio and K. Rhoads*

During 1997, 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 wastewater 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. Dose calculation methodology is discussed in Appendix D. The radiological impacts of 1997 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 that may have acquired contamination from radionuclides onsite
- total 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 1997 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 Generation II (GENII) computer code Version 1.485 (PNL-6584) and Hanford Site-specific parameters listed in Appendix D and in PNNL-11796 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 1997, tritium, iodine-129, and uranium were found in the Columbia River downstream of Hanford at greater concentrations than predicted based on direct discharges from the 100 Areas. All other concentrations of radionuclides were lower than those predicted from known releases. Riverbank springs water, containing these radionuclides, is known to enter the river along the portion of shoreline extending from the Old Hanford Townsite downstream to the 300 Area (see Section 4.2, "Surface Water and Sediment Surveillance" and Section 6.1, "Hanford Groundwater Monitoring Project"). No direct discharges of radioactive materials from the 300 Area to the Columbia River were reported in 1997.

The estimated dose[a] to the maximally exposed offsite individual from Hanford operations in 1997 was

(a) Unless stated otherwise, the term "dose" in this section is the "total effective dose equivalent" (see Appendix B, "Glossary").

0.01 mrem (1 x $10^{-4}$ mSv) compared to 0.007 mrem (7 x $10^{-5}$ mSv) reported for 1996. The dose to the local population of 380,000 (PNL-7803) from 1997 operations was the same as reported for 1996, 0.2 person-rem (0.002 person-Sv) (Section 5.0 in PNNL-11472). The 1997 average dose to the population was approximately 0.0005 mrem (5 x $10^{-6}$ mSv) per person (the same as 1996). The current U.S. Department of Energy (DOE) radiological dose limit (DOE Order 5400.5) for an individual member of the public is 100 mrem/yr (1 mSv/yr) from all pathways, which includes the U.S. Environmental Protection Agency's (EPA) limit of 10 mrem/yr (0.1 mSv/yr) from airborne radionuclide emissions (40 CFR 61). The national average radiological dose from natural sources is approximately 300 mrem/yr (3 mSv/yr) (National Council on Radiation Protection 1987). Thus, 1997 Hanford emissions potentially contributed to the maximally exposed individual a dose equivalent to only 0.01% of the DOE dose limit, 0.1% of the EPA limit, or 0.003% 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%, 0.005%, 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.

## 5.0.1 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 a higher radiological dose. 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 highly unlikely to apply to any single individual.

The hypothetical 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: 1) the Ringold area, 26 km (16 mi) east of separations facilities in the 200 Areas and 2) the Riverview area across the river from Richland (Figure 5.0.1). The Ringold area 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 the Columbia River from the 300 Area has been considered. Because of the shift in site operations from strategic materials production to the current mission of developing waste treatment and disposal technologies and cleaning up contamination, the significance of the air emissions from the production facilities in the 200 Areas 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 below.

The Ringold area is situated to maximize air pathway exposures from emissions in 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 (discussed in Section 6.1, "Hanford Groundwater Monitoring Project"). 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 area 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

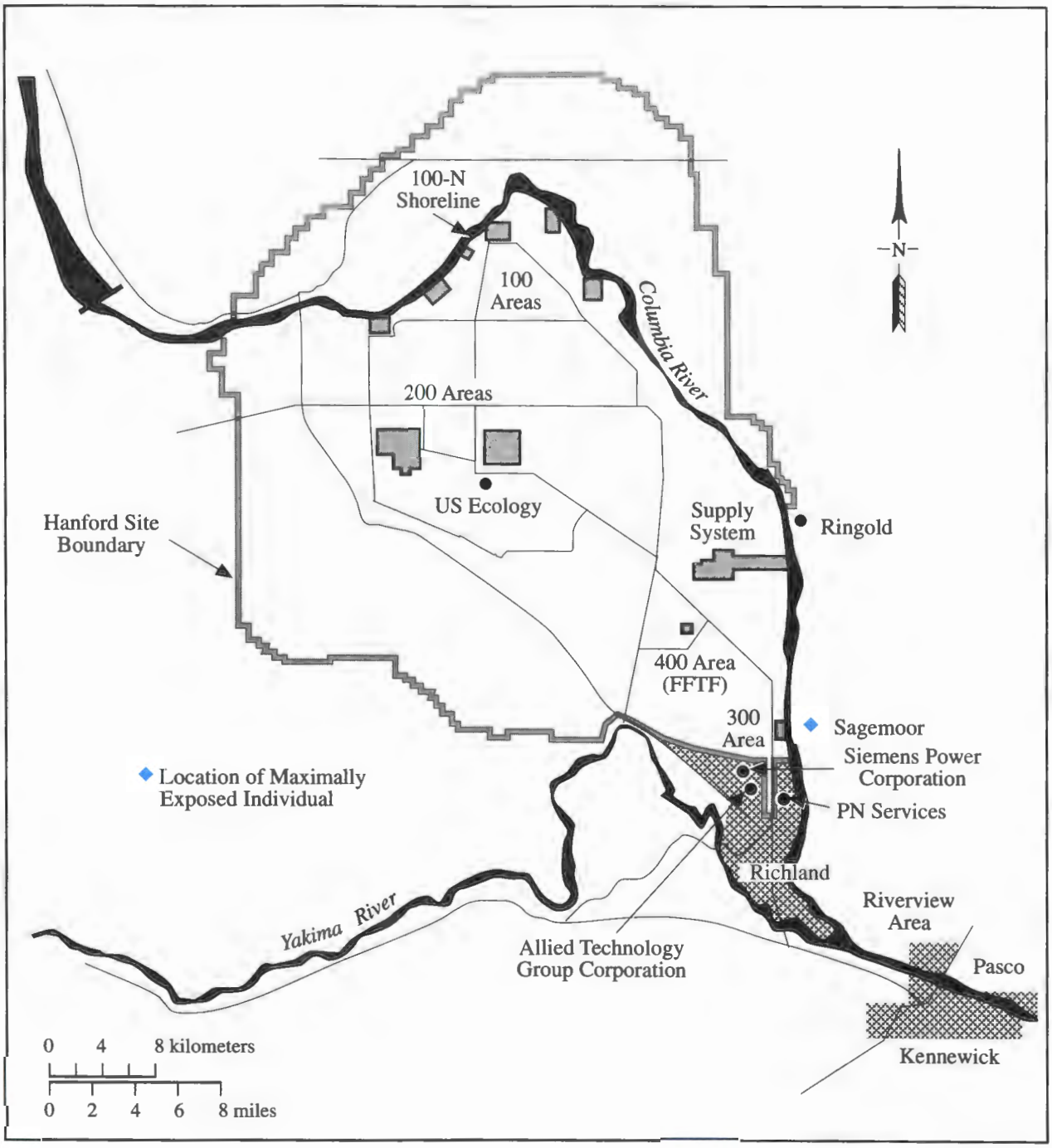


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**Figure 5.0.1**. Locations Important to Dose Calculations

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 of this individual from the air pathway is typically lower than exposure at Ringold because of the greater distance from the major onsite air 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 (EPS-87-367A). 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 1997 hypothetical maximally exposed individual at Sagemoor was calculated to have received a slightly higher dose (0.0152 mrem/yr) than the maximally exposed individual located at either Ringold (0.0125 mrem/yr) or Riverview (0.0146 mrem/yr). 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 hypothetical maximally exposed individual (at Sagemoor) in 1997 are summarized in Table 5.0.1. These values include the doses received from exposure to liquid and airborne effluents during 1997, as well as the future, or committed dose from radionuclides that were inhaled or ingested during 1997. As releases from facilities and the doses from these sources decrease, the contribution of diffuse sources such as wind-blown contaminated soil becomes relatively

**Table 5.0.1.** Dose to the Hypothetical Maximally Exposed Individual Residing at Sagemoor from 1997 Hanford Operations

| | | Operating Area Contribution Dose, mrem | | | | |
|---|---|---|---|---|---|---|
| Effluent | Pathway | 100 Areas | 200 Areas | 300 Area | 400 Area | Pathway Total |
| Air | External | $9.0 \times 10^{-9}$ | $5.4 \times 10^{-7}$ | $1.4 \times 10^{-4}$ | $1.5 \times 10^{-8}$ | $1.4 \times 10^{-4}$ |
| | Inhalation | $3.2 \times 10^{-6}$ | $1.2 \times 10^{-5}$ | $3.0 \times 10^{-3}$ | $2.0 \times 10^{-5}$ | $3.0 \times 10^{-3}$ |
| | Foods | $8.0 \times 10^{-8}$ | $1.2 \times 10^{-4}$ | $3.6 \times 10^{-5}$ | $5.6 \times 10^{-5}$ | $2.1 \times 10^{-4}$ |
| | Subtotal air | $3.3 \times 10^{-6}$ | $1.3 \times 10^{-4}$ | $3.2 \times 10^{-3}$ | $7.6 \times 10^{-5}$ | $3.4 \times 10^{-3}$ |
| Water | Recreation | $5.1 \times 10^{-7}$ | $4.2 \times 10^{-5}$ | 0.0[a] | 0.0 | $4.3 \times 10^{-5}$ |
| | Foods | $4.1 \times 10^{-4}$ | $3.8 \times 10^{-3}$ | 0.0 | 0.0 | $4.2 \times 10^{-3}$ |
| | Fish | $2.1 \times 10^{-4}$ | $2.8 \times 10^{-3}$ | 0.0 | 0.0 | $3.0 \times 10^{-3}$ |
| | Drinking water | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Subtotal water | $6.2 \times 10^{-4}$ | $6.6 \times 10^{-3}$ | 0.0 | 0.0 | $7.3 \times 10^{-3}$ |
| Combined total | | $6.2 \times 10^{-4}$ | $6.7 \times 10^{-3}$ | $3.2 \times 10^{-3}$ | $7.6 \times 10^{-5}$ | $1.1 \times 10^{-2}$ |

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

more significant. An upper estimate of the dose from diffuse sources is discussed in Section 5.0.3, "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 1997 was calculated to be 0.01 mrem ($1 \times 10^{-4}$ mSv) compared to 0.007 mrem ($7 \times 10^{-5}$ mSv) calculated for 1996. The primary pathways contributing to this dose (and the percentage of all pathways) were the following:

- inhalation of airborne radionuclides (27%), principally radon-220 (modeled as lead-212) released from the 300 Area, and tritium released from the 300 and 400 Areas
- consumption of food irrigated with Columbia River water or fish from the Columbia River containing radionuclides (77%), principally isotopes of uranium and tritium.

The DOE radiological dose limit for any member of the public from all routine DOE operations is 100 mrem/yr (1 mSv/yr) (DOE Order 5400.5). The dose calculated for the maximally exposed individual for 1997 was 0.01% 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 1997 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 1997, the hypothetical maximally exposed individual was located across the Columbia River from the 300 Area at Sagemoor.

## 5.0.2 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.

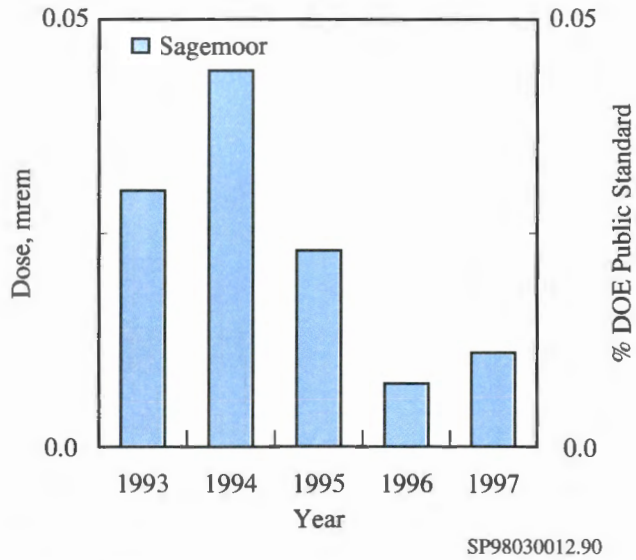


**Figure 5.0.2**. Calculated Dose to the Hypothetical Maximally Exposed Individual, 1993 Through 1997

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 radiological 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 in the 400 Area.

### 5.0.2.1 Maximum "Boundary" Dose Rate

The boundary radiological dose rate is the external radiological 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 radiological dose rates measured in the vicinity of the 100-N, 200, 300, and 400 Areas are described in Section 4.7, "External Radiation Surveillance." Results for the 200 Areas 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 approximately 100 m (330 ft) of the N Reactor and supporting facilities.

The dose rate at the location with the highest exposure rate along the 100-N Area shoreline during 1997 was 0.02 mrem/h (2 x $10^{-4}$ mSv/h), or approximately twice the average background dose rate of 0.01 mrem/h (1 x $10^{-4}$ mSv/h) normally observed at other shoreline locations. Therefore, for every hour someone spent at the 100-N Area shoreline during 1997, the external radiological dose received from Hanford operations would be approximately 0.01 mrem (1 x $10^{-4}$ mSv) above the natural background dose. If an individual spent 2 hours 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.

### 5.0.2.2 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 1997 migrated offsite, were hunted, and were eaten.

- The dose from eating 1 kg (2.2 lb) of whitefish fillets that contains the maximum concentrations of cobalt-60 (0.017 pCi/g) and cesium-137 (0.024 pCi/g) measured in a whitefish sample collected from the Hanford Reach of the Columbia River is estimated to be 2 x $10^{-3}$ mrem (2 x $10^{-5}$ mSv).

- The dose from eating 1 kg (2.2 lb) of Canada goose meat that contains the maximum concentrations of cobalt-60 (0.035 pCi/g), strontium-90 (0.00511 pCi/g), and cesium-137 (0.044 pCi/g) measured in a Canada goose sample collected onsite is estimated to be 4 x $10^{-3}$ mrem (4 x $10^{-5}$ mSv).

These are very low doses and do not exceed the maximally exposed individual hypothetical dose at Sagemoor. In fact, one person would have to consume 10 kg (22 lb) of whitefish fillets or 5 kg (11 lb) Canada goose meat, at the maximum concentrations measured in 1997, to receive a dose equal to the 1997 maximally exposed individual dose. 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 PNL-7539.

### 5.0.2.3 Fast Flux Test Facility Drinking Water

During 1997, groundwater was used as drinking water by workers at the Fast Flux Test Facility in the 400 Area. 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 1997 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 groundwater well concentrations, weighted for the amount of time each well was in use as the source for drinking water, 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) would be <0.09 mrem (<0.0009 mSv). Although the hypothetical Fast Flux Test Facility worker would receive approximately five times the dose as the 1997 offsite maximally exposed individual, the dose is well below the drinking water dose limit of 4 mrem for public drinking water supplies.

## 5.0.3 Comparison with Clean Air Act Standards

Limits for radiation dose to the public from airborne radionuclide emissions at 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 520/1-89-005). 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. Washington Administrative Code (WAC) 246-247 imposes requirements similar to those in 40 CFR 61, Subpart H, except that the 10-mrem/yr dose standard includes the dose resulting from radon emissions from other than naturally occurring sources. The following summarizes information that is provided in more detail in the 1997 air emissions report (DOE/RL-98-33), which addresses both EPA and Washington State regulations.

The 1997 air emissions from monitored Hanford Site facilities, including radon-220 and radon-222 releases from the 300 Area, resulted in a potential dose to a maximally exposed individual at Sagemoor of 0.0037 mrem ($3.7 \times 10^{-5}$ mSv), which represents less than 0.04% of the 10-mrem/yr standard. Of that total, radon emissions from the 327 Building contributed 0.0025 mrem ($2.5 \times 10^{-5}$ mSv), and nonradon emissions from all monitored stack sources contributed 0.0012 mrem ($1.2 \times 10^{-5}$ mSv). Therefore, the estimated annual dose from monitored stack releases at the Hanford Site during 1997 was well below the Clean Air Act standard. The Act requires the use of CAP-88 (EPA-402-B-92-001) or other EPA-approved models to demonstrate compliance with the standard, and the assumptions embodied in these codes differ slight 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 doses calculated for this report using the GENII code (0.0034 mrem, or $3.4 \times 10^{-5}$ 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, Washington State, 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 1997, the estimated dose from diffuse sources to the maximally exposed individual at Sagemoor was 0.022 mrem ($2.2 \times 10^{-4}$ mSv), which was greater than the estimated dose at that location from stack emissions (0.0037 mrem, or $3.7 \times 10^{-5}$ mSv). Doses at other locations around the Hanford Site perimeter ranged from 0.009 to 0.03 mrem ($9 \times 10^{-5}$ to $3 \times 10^{-4}$ mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1997 was well below the EPA standard.

## 5.0.4 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 1997 Hanford Site 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 1997, and remained unchanged from the 1996 population dose. The 80-km (50-mi) collective doses attributed to Hanford operations from 1992 through 1997 are compared in Figure 5.0.3. Primary pathways contributing to the 1997 population dose were the following:

- consumption of drinking water (62%) contaminated with radionuclides released to the Columbia River at Hanford, principally tritium
- consumption of foodstuffs (15%) contaminated with radionuclides released in gaseous effluents, primarily tritium from the 300 and 400 Areas and iodine-129 from the Plutonium-Uranium Extraction Plant stack
- inhalation of radionuclides (17%) that were released to the air, principally radon-220 (modeled as lead-212) and tritium emitted from the 300 Area stacks and the 400 Area.

**Table 5.0.2.** Dose to the Population from 1997 Hanford Operations

| Effluent | Pathway | Operating Area Contribution Dose, person-rem | | | | |
|---|---|---|---|---|---|---|
| | | 100 Areas | 200 Areas | 300 Area | 400 Area | Pathway Total |
| Air | External | $1.4 \times 10^{-6}$ | $4.9 \times 10^{-5}$ | $1.7 \times 10^{-3}$ | $5.0 \times 10^{-7}$ | $1.8 \times 10^{-3}$ |
| | Inhalation | $7.4 \times 10^{-4}$ | $1.7 \times 10^{-3}$ | $2.2 \times 10^{-2}$ | $1.0 \times 10^{-3}$ | $2.5 \times 10^{-2}$ |
| | Foods | $2.4 \times 10^{-5}$ | $1.5 \times 10^{-2}$ | $1.7 \times 10^{-3}$ | $4.8 \times 10^{-3}$ | $2.2 \times 10^{-2}$ |
| | Subtotal air | $7.7 \times 10^{-4}$ | $1.7 \times 10^{-2}$ | $2.5 \times 10^{-2}$ | $5.8 \times 10^{-3}$ | $4.9 \times 10^{-2}$ |
| Water | Recreation | $4.0 \times 10^{-6}$ | $2.4 \times 10^{-4}$ | 0.0[a] | 0.0 | $2.4 \times 10^{-4}$ |
| | Foods | $4.8 \times 10^{-4}$ | $4.1 \times 10^{-3}$ | 0.0 | 0.0 | $4.6 \times 10^{-3}$ |
| | Fish | $8.0 \times 10^{-5}$ | $1.1 \times 10^{-3}$ | 0.0 | 0.0 | $1.2 \times 10^{-3}$ |
| | Drinking water | $6.6 \times 10^{-4}$ | $9.1 \times 10^{-2}$ | 0.0 | 0.0 | $9.2 \times 10^{-2}$ |
| | Subtotal water | $1.2 \times 10^{-3}$ | $9.6 \times 10^{-2}$ | 0.0 | 0.0 | $9.8 \times 10^{-2}$ |
| Combined total | | $2.0 \times 10^{-3}$ | $1.1 \times 10^{-1}$ | $2.5 \times 10^{-2}$ | $5.8 \times 10^{-3}$ | $1.5 \times 10^{-1}$ |

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

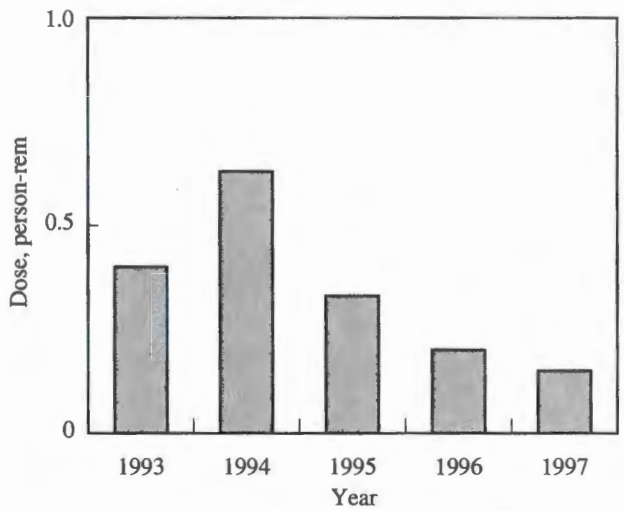


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**Figure 5.0.3.** Calculated Dose to the Population Within 80 km (50 mi) of the Hanford Site, 1993 Through 1997

The average per capita dose from 1997 Hanford Site operations based on a population of 380,000 within 80 km (50 mi) was 0.0005 mrem ($5 \times 10^{-6}$ mSv). To place this dose from Hanford activities into perspective, the estimate may be compared with doses from other routinely encountered sources of radiation such as natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural radionuclides in the body, and inhalation of naturally occurring radon. The national average radiological dose from these other sources is 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 1997 are a small percentage of the standards and of natural background.

## 5.0.5 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

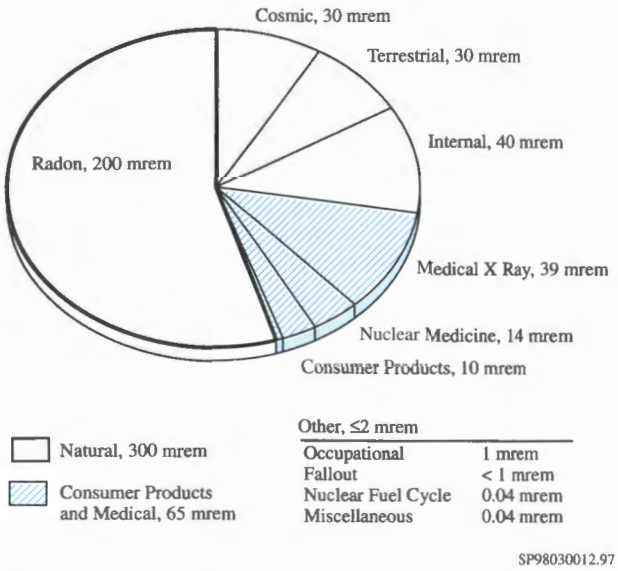


**Figure 5.0.4**. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection 1987)

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 gathered from these companies, it was conservatively estimated that the total 1997 individual dose from their combined activities is on the order of 0.05 mrem ($5 \times 10^{-4}$ mSv). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 1997 was well below any regulatory dose limit.

## 5.0.6 Hanford Public Radiological 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

**Table 5.0.3**. Summary of Doses to the Public in the Vicinity of the Hanford Site from Various Sources, 1997

| Source | Maximum Individual, mrem[a] | Population, person-rem[a] |
|---|---|---|
| All Hanford effluents | 0.011 | 0.2 |
| DOE limit | 100 | -- |
| Percent of DOE limit[b] | 0.011% | -- |
| Background radiation | 300 | 110,000 |
| Hanford dose percent of background | <0.01% | $2 \times 10^{-4}$% |
| Doses from gaseous effluents | 0.0034 | -- |
| EPA air standard[c] | 10 | -- |
| Percent of EPA standard | 0.034% | -- |

(a) To convert the dose values to mSv or person-Sv, divide by 100.
(b) DOE Order 5400.5.
(c) 40 CFR 61.

of these types of health effects at low doses (down to zero dose) is the same per unit dose as the same health effects observed at much higher doses (e.g., in atomic bomb victims, radium dial painters). This is also known as the linear no threshold hypothesis. Under these assumptions, even natural background radiation (which is hundreds of times greater than radiation from current Hanford 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 radiological doses. Some scientific studies have indicated that low radiological doses may cause beneficial effects (Sagan 1987). Because cancer and hereditary diseases in the general population may be caused by many sources (e.g., genetic defects, sunlight, chemicals, background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be conclusively proved. In developing Clean Air Act regulations, the EPA uses a probability value of approximately 4 per 10 million ($4 \times 10^{-7}$) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) (EPA 520/1-89-005). Additional data (National Research Council 1990) support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time.

Government agencies are trying to determine what level of risk is safe for members of the public exposed to pollutants from industrial activities (e.g., DOE facilities, nuclear power plants, chemical plants, 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 radiological 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 radiological doses to the risks of some activities encountered in everyday life. Table 5.0.5 lists some activities considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluents in 1997.

## 5.0.7 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 1997 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 animals collected from the river and onsite.

The animal receiving the highest potential dose from N Springs water was a duck consuming aquatic plants. The water flow of the N Springs is very low; no aquatic animal was observed to 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 4.2.4) after a 10-to-1 dilution by the river. Radiological doses were calculated for several different types of aquatic and riparian animals, using these extremely conservative assumptions and the CRITRII computer code (PNL-8150). 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 dose rate of 1.8 rad/d. This hypothetical dose rate exceeds by 80% the limit of 1 rad/d for native aquatic animal organisms established by DOE Order 5400.5. The intent of the DOE Order 5400.5 native aquatic animal organism dose limit is to protect the population of a species, not necessarily individual organisms. It is not possible for a population of ducks to live in this spring for an entire year. Another spring located along the 100-N shoreline, just downstream of N Springs, was also sampled in 1997. Making the same assumptions as above, the dose to the same hypothetical organisms was 0.11 mrad/d.

Doses were also estimated using the CRITRII code (PNL-8150) for aquatic and riparian organisms based on measured radionuclide concentrations in river water. The highest potential dose rate from all the radionuclides reaching the Columbia River from Hanford sources during 1997 was $9 \times 10^{-6}$ rad/d for a hypothetical muskrat

**Table 5.0.4**. Estimated Risk from Various Activities and Exposures[a]

| Activity or Exposure Per Year | Risk of Fatality |
|---|---|
| Smoking 1 pack of cigarettes per day (lung/heart/other diseases) | $3{,}600 \times 10^{-6}$ |
| Home accidents | $100 \times 10^{-6}$[b] |
| Taking contraceptive pills (side effects) | $20 \times 10^{-6}$ |
| Drinking 1 can of beer or 0.12 L (4 oz) of wine per day (liver cancer/cirrhosis) | $10 \times 10^{-6}$ |
| Firearms, sporting (accidents) | $10 \times 10^{-6}$[b] |
| Flying as an airline passenger (cross-country roundtrip--accidents) | $8 \times 10^{-6}$[b] |
| Eating approximately 54 g (4 tbsp) of peanut butter per day (liver cancer) | $8 \times 10^{-6}$ |
| Pleasure boating (accidents) | $6 \times 10^{-6}$[b] |
| Drinking chlorinated tap water (trace chloroform--cancer) | $3 \times 10^{-6}$ |
| Riding or driving in a passenger vehicle (483 km [300 mi]) | $2 \times 10^{-6}$[b] |
| Eating 41 kg (90 lb) of charcoal-broiled steaks (gastrointestinal tract cancer) | $1 \times 10^{-6}$ |
| Natural background radiation dose (300 mrem, 3 mSv) | 0 to $120 \times 10^{-6}$ |
| Flying as an airline passenger (cross-country roundtrip--radiation) | 0 to $5 \times 10^{-6}$ |
| Dose of 1 mrem (0.01 mSv) for 70 yr | 0 to $0.4 \times 10^{-6}$ |
| Dose to the maximally exposed individual living near Hanford in 1997 (0.01 mrem, $1 \times 10^{-4}$ mSv) | 0 to $0.004 \times 10^{-6}$ |

(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 0.02-mrem ($2 \times 10^{-4}$ mSv) Dose Calculated for the 1997 Maximally Exposed Individual

Driving or riding in a car 1.1 km (approximately 0.66 mi)
Smoking less than 1/100 of a cigarette
Flying 2.7 km (1.7 mi) on a commercial airliner
Eating approximately 4/5 tbsp of peanut butter
Eating one 0.18-kg (0.4-lb) charcoal-broiled steak
Drinking approximately 1 L (1.1 qt) of chlorinated tap water
Being exposed to natural background radiation for approximately 19 min in a typical terrestrial location
Drinking approximately 0.056 L (<2 oz) of beer or 0.02 L (0.6 oz) of wine

and a hypothetical duck, both of which consume contaminated vegetation. The radiological dose rate to individual animals collected onsite or from the Columbia River was calculated using the maximum concentrations of radionuclides measured in muscle. These doses ranged from $8 \times 10^{-6}$ rad/d for a whitefish to $2 \times 10^{-5}$ rad/d for a Canada goose. Neither the doses calculated based on river water concentrations nor the doses based on actual biota concentrations approach the dose limit set forth in DOE Order 5400.5.

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# 6.0 Groundwater and Vadose Zone Monitoring

## 6.0.1 Groundwater Monitoring

During 1996, groundwater monitoring activities at the Hanford Site were restructured into the Hanford Groundwater Monitoring Project. This project incorporates sitewide groundwater monitoring mandated by U.S. Department of Energy (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. The purpose of this section is to provide an overall summary of groundwater monitoring during 1997. Additional details concerning the Hanford Groundwater Monitoring Project are available in PNNL-11793.

### 6.0.1.1 Monitoring Objectives

Groundwater monitoring was conducted for the following:

- assess the impact of radiological and hazardous chemicals on groundwater as a result of Hanford Site operations
- provide an integrated assessment of groundwater quality on the Hanford Site
- evaluate potential offsite impacts from the groundwater pathway
- verify compliance with applicable environmental laws and regulations
- evaluate effectiveness of groundwater remediation activities
- identify new or existing groundwater quality problems.

Sitewide groundwater monitoring activities are designed to meet the project objectives stated in DOE Order 5400.1 and described above. The impacts of Hanford Site 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 Title 40, Code of Federal Regulations, Part 265 (40 CFR 265) and Washington Administrative Codes (WACs) 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 (40 CFR 300).

### 6.0.1.2 Monitoring Design

Various criteria were used to design groundwater monitoring. Specific chemicals and radionuclides analyzed at each monitoring well and their sampling frequencies were selected based on past waste disposal activities (PNL-6456, WHC-EP-0527-2) and on previous analysis results. Information on the location of potential contaminant sources and hydrogeology, including 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. Groundwater monitoring was designed to satisfy regulatory requirements.

Groundwater surveillance was conducted using established quality assurance plans (see Section 8.0, "Quality Assurance") and written procedures (WHC-CM-4-2).

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 Site operations (PNNL-11793) 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. Even though releases of waste to most disposal facilities have ceased, these wells will continue to be monitored as 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 1997, 3 of the site's 12 drinking water systems provided groundwater for human consumption on the Hanford Site. One system supplied water at the Fast Flux Test Facility, one supplied water to personnel at the Yakima Barricade guardhouse, and one was located at the Hanford Patrol Training Academy (see Section 4.3, "Hanford Site Drinking Water Surveillance"). Water supply wells used by the city of Richland are located near the Hanford Site'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.

To assess the impact of Hanford Site operations on groundwater quality, background conditions, or the quality of groundwater on the Hanford Site unaffected by operations, must be known. Data on the concentration of contaminants of concern in groundwater that existed before Hanford Site 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 Site operations, including upgradient locations, provide the best estimate of pre-Hanford groundwater quality. A summary of background conditions is tabulated in PNL-6886 and PNL-7120.

Groundwater 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.

Summary results for 1997 are discussed in Section 6.1, "Hanford Groundwater Monitoring Project."

## 6.0.2 Vadose Zone Monitoring

The vadose zone is defined as the area between the ground surface and the water table. This subsurface zone is also referred to as the unsaturated zone, zone of suspended water, or zone of aeration. The vadose zone functions as a transport pathway or storage area for water and other materials located between the soil surface and the groundwater aquifers. Historically, the vadose zone at the Hanford Site has been contaminated with large amounts of radioactive and nonradioactive materials through the intentional and unintentional discharge of liquid wastes to the soil column, the burial of contaminated solid wastes, and the deposition of airborne contaminants to the ground. Depending on the makeup of the soil, the geology of the area, the nature of the wastes, the amount of water or other fluids available to mobilize the contaminant, and other factors, contaminants can move downward and laterally through the soil column, can be chemically bound to soil particles (and immobilized), or can be contained by geologic formations.

Because of concerns of the impact of some vadose zone contaminants on the groundwater beneath the Hanford Site, and the potential for contaminated groundwater to reach the Columbia River, characterization efforts are under way to learn more about the nature and extent of vadose zone contamination. At Hanford, the primary method for investigating radiological contamination in the vadose zone consists of borehole logging (monitoring radiation levels in narrow shafts bored or drilled into the soil column). Borehole logging is being conducted in existing boreholes located in and around the 200 Areas single-shell tank farms and beneath former waste disposal facilities also in or near the 200 Areas. Additionally, soil-vapor extraction and monitoring are being conducted as part of an expedited response action in the 200-West Area to remove carbon tetrachloride from the vadose zone.

Results for the 1997 vadose zone monitoring program are discussed in Section 6.2, "Vadose Zone Characterization and Monitoring." Section 6.2 has been divided into vadose zone characterization activities in the 200 Areas tank farms and the vadose zone monitoring beneath former 200 Areas waste disposal facilities and carbon tetrachloride remediation work in the 200-West Area.

# 6.1 Hanford Groundwater Monitoring Project

*D. R. Newcomer, 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-RL-89-12, Rev. 2). 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 Hanford Federal Facility Agreement and Consent Order (also known as 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 and Regulatory Compliance Summary."

DOE prepared a *Plan and Schedule to Discontinue Disposal of Liquids Into the Soil Column at the Hanford Site* (DOE 1987), which includes an alternative for 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 the State-Approved Land Disposal Site north of the 200-West Area. The locations of these facilities are shown in Figures 1.0.2 and 6.1.1 and are discussed in detail in Section 2.3, "Activities, 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 <2.0 billion L (<530 million gal) in 1997. The locations of the effluent streams are shown in Figure 6.1.1. In 1997, approximately 51% of the liquid volume was discharged to B Pond, which ceased operating in August 1997, and approximately 45% was discharged 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 and DE&S Hanford, Inc., are summarized in Section 4.3, "Hanford Site Drinking Water Surveillance." The locations of wells completed in the unconfined aquifer that provide water for drinking, fire suppression, and cooling are shown in Figure 6.1.2.

## 6.1.1 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 (informal name) (Figure 6.1.3).

The Columbia River basalts were formed from lava that periodically erupted from volcanic fissures. The regional river system eroded the basalt and deposited sediments across the basalt surfaces between eruptions. Zones between the basalt flows and the sediments deposited as

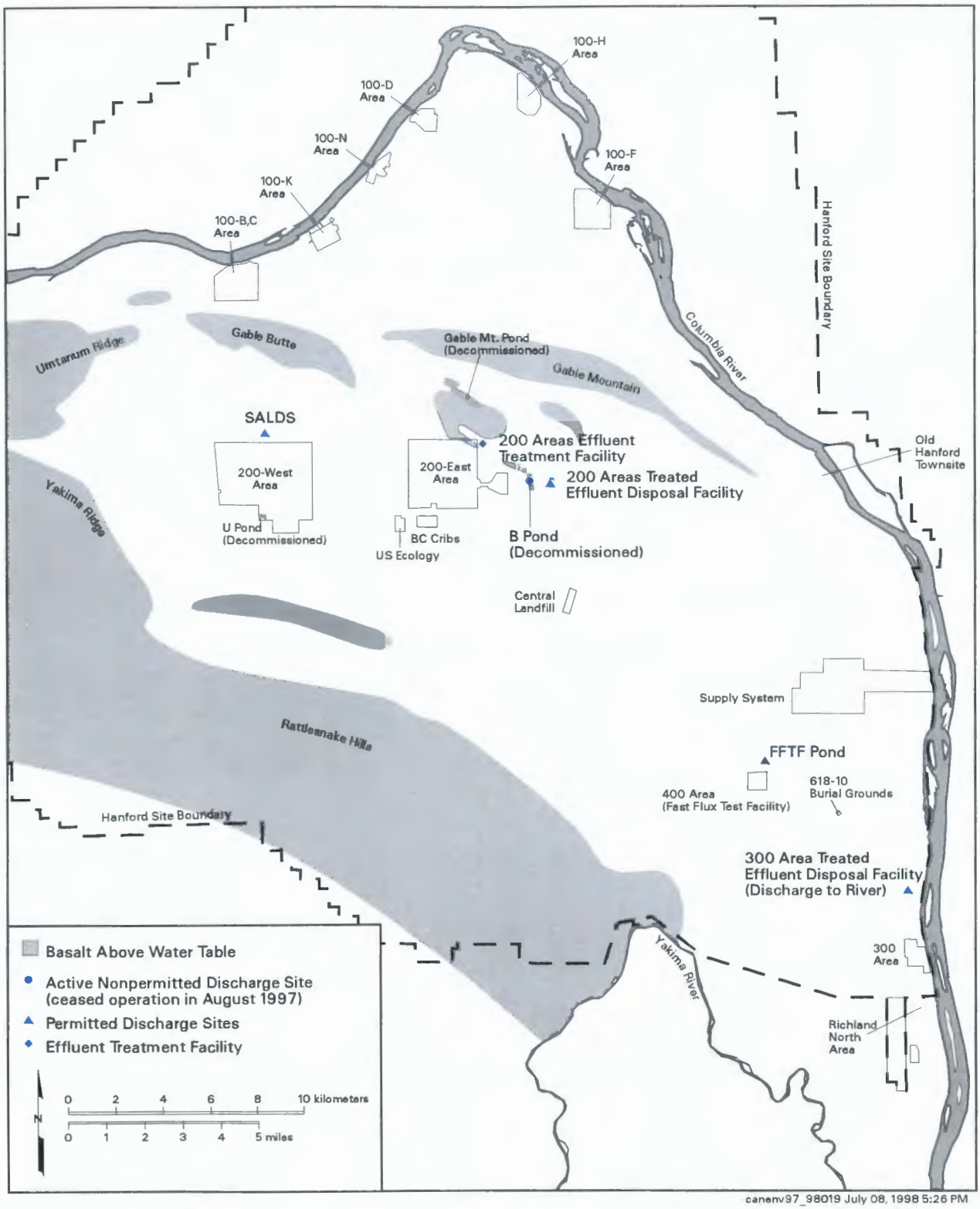



**Figure 6.1.1.** Disposal Facilities for the Major Liquid Waste Streams on the Hanford Site

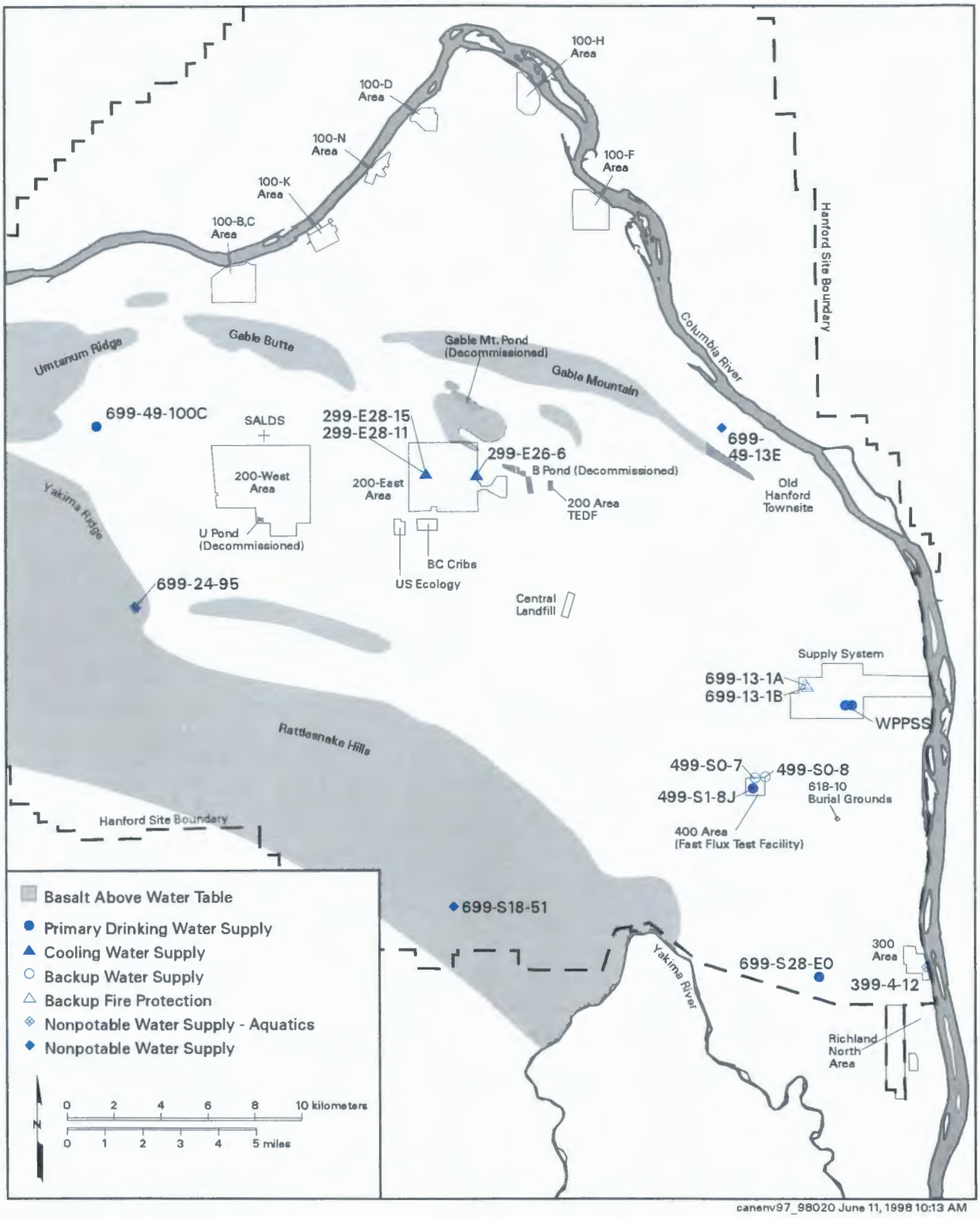



**Figure 6.1.2.** Water Supply Wells in the Unconfined Aquifer

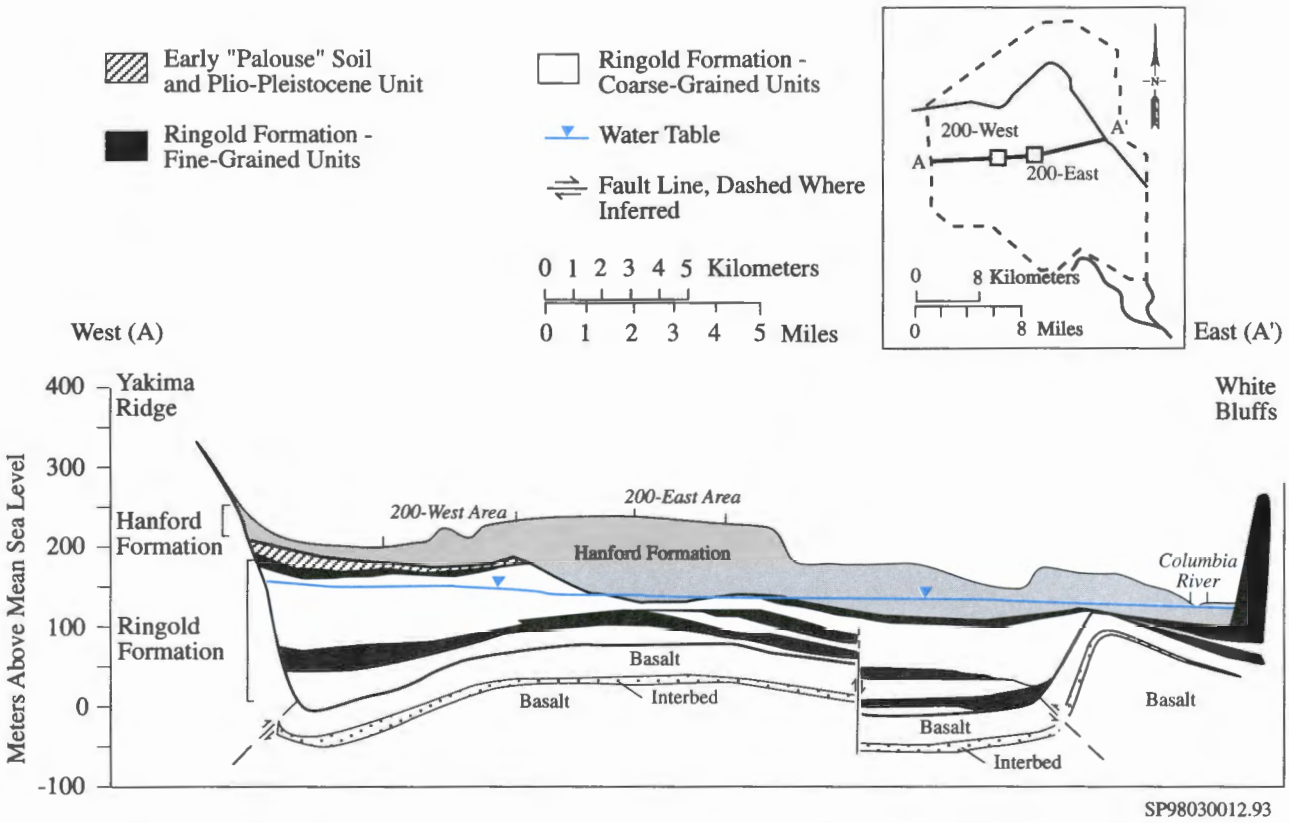



**Figure 6.1.3**. Geologic Cross Section of the Hanford Site

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, sand and gravel of the Ringold Formation were deposited in the central portion of the Pasco Basin by the ancestral Columbia River as it meandered back and forth across the relatively flat basalt surface. Following uplift of the basalts and overlying sediments, 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 recent geologic past. Fine sands and silts were deposited in slackwater 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 BHI-00184, DOE/RW-0164 (Vol. 1), PNNL-11793 (Section 3.1), WHC-MR-0391, WHC-SD-EN-TI-014, and WHC-SD-EN-TI-019.

## 6.1.2 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 the Hanford Site 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 wastewater 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, RHO-RE-ST-12 P, WHC-MR-0391). Additional information on the basalt-confined aquifer system can be found in PNL-10158 and PNL-10817.

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 6.1.4). 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 the lateral flow of groundwater where they rise above the water table (RHO-BWI-ST-5, p. II-116).

The water-table elevation contours shown in Figure 6.1.5 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. 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 6.1.6 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/RW-0164 (Vol. 2) and PNL-8337.

Recharge of water within the unconfined aquifer (RHO-ST-42) comes from several sources. Natural recharge occurs from infiltration of precipitation along the mountain fronts, runoff from intermittent streams such as Cold and Dry Creeks 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. Recharge from infiltration of precipitation is highly variable on the Hanford Site both spatially and temporarily. The rate of natural recharge depends primarily on soil texture, vegetation, and climate (Gee et al. 1992, PNL-10285), 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 to the west and south. Discharge of wastewater has caused the water table to rise over most of the Hanford Site. Local areas with elevated water tables are called groundwater mounds. Figure 6.1.7 shows the change in water-table elevations between 1944 and 1979, when the water table had stabilized over most of the site. Reduced wastewater discharge to the soil

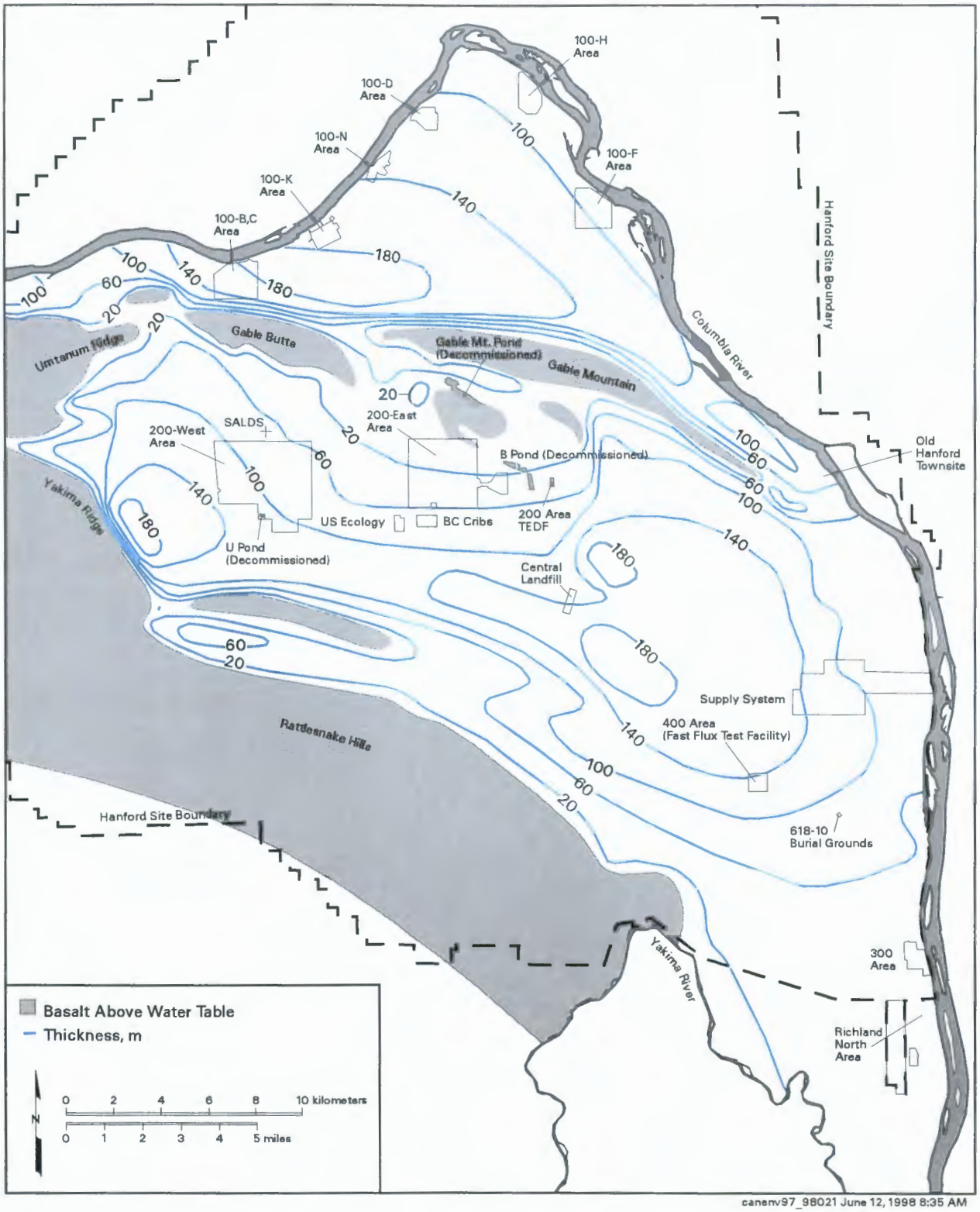



**Figure 6.1.4**. Saturated Thickness of the Unconfined Aquifer

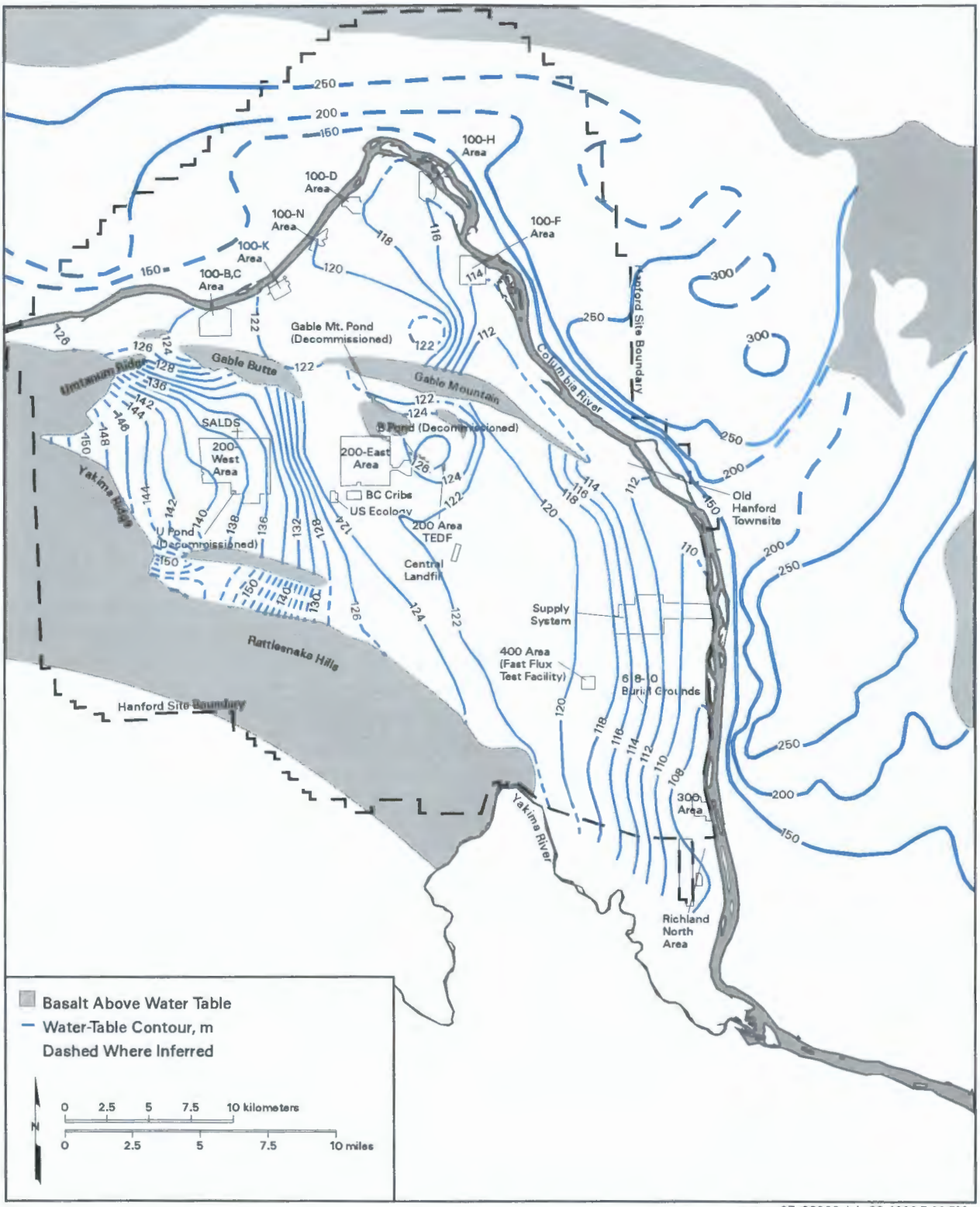



**Figure 6.1.5.** Water-Table Elevations for the Unconfined Aquifer at the Hanford Site and in Adjacent Areas East and North of the Columbia River, June 1997

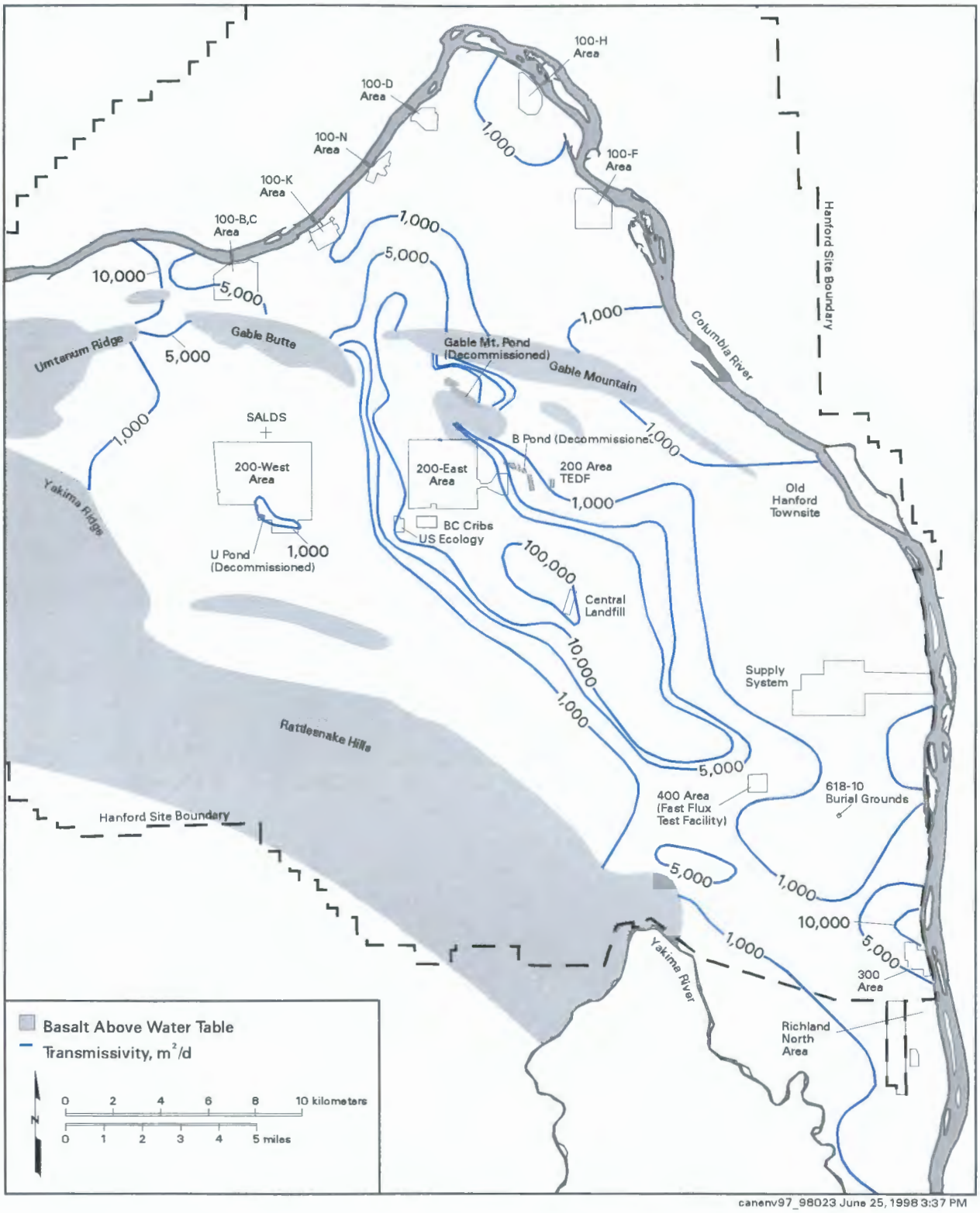



**Figure 6.1.6.** Transmissivity Distribution in the Unconfined Aquifer

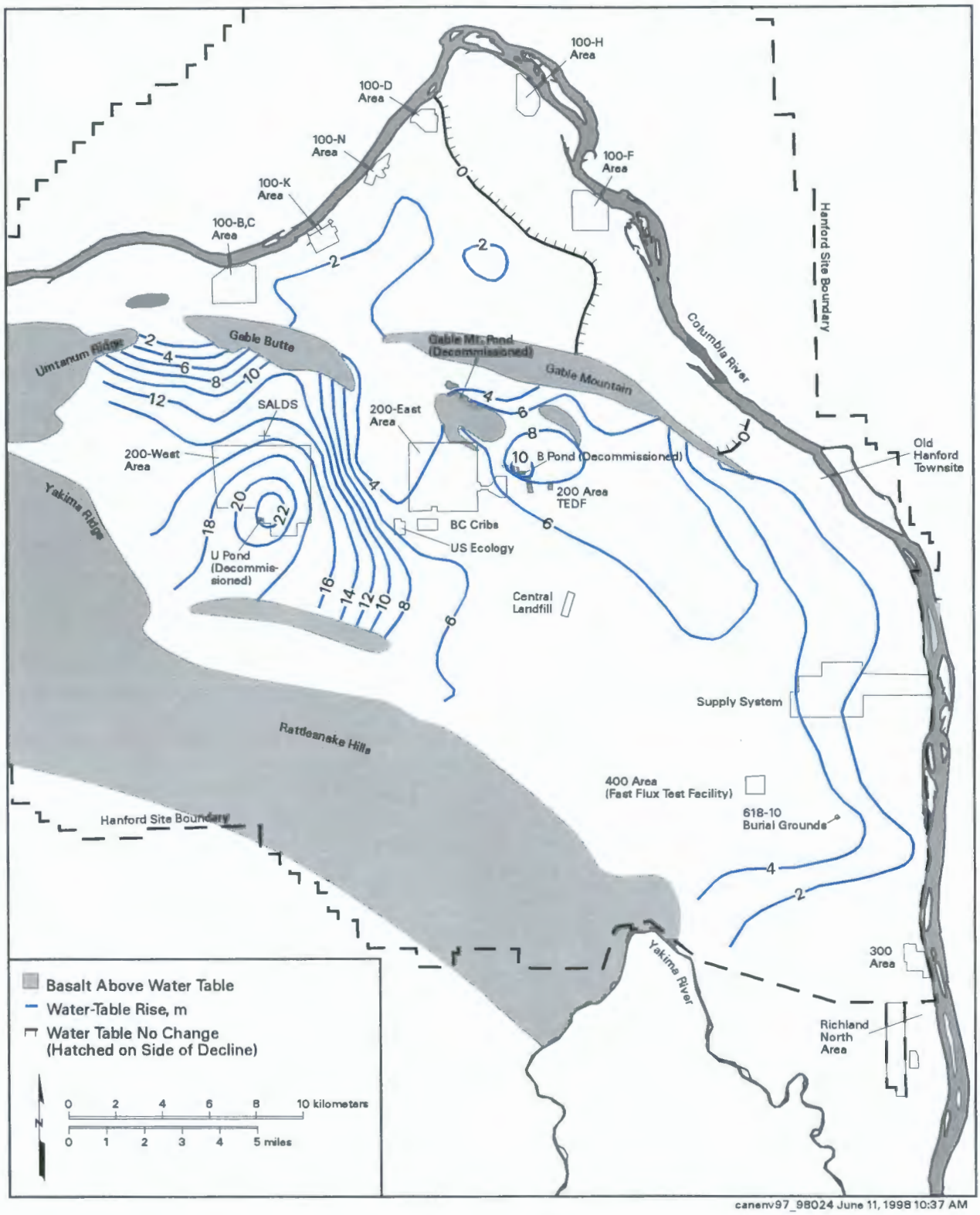



**Figure 6.1.7.** Change in Water-Table Elevations Between 1944 and 1979

column resulted in a decline in the water table over much of the Hanford Site. Figure 6.1.8 shows the decline between 1979 and 1995, when many waste streams were consolidated and wastewater discharge was reduced. The greatest decline in the water table occurred in the 200-West Area and is discussed below. The water table continues to decline over much of the Hanford Site, as illustrated by Figure 6.1.9, which shows the changes between 1996 and 1997.

Two major groundwater mounds formed in the vicinity of the 200-East and 200-West Areas in response to wastewater discharges. The first of these mounds was created by disposal at U Pond in the 200-West Area. After U Pond was decommissioned in 1984, the mound slowly dissipated and has become much less distinct over the last several years. However, the water table continues to decline in this area (see Figure 6.1.9). The second major mound was created by discharge to B Pond, east of the 200-East Area. The water-table elevation near B Pond increased to a maximum before 1990 and then decreased because of reduced discharge. After discharge to B Pond ceased in August 1997, the decline in the water-table elevation accelerated. The recent decline in the water-table elevation at B Pond is illustrated by the contours in Figure 6.1.9. 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 wastewater discharge. Consequently, the movement of groundwater and its associated constituents has also changed with time. Groundwater mounding related to wastewater discharges has also occurred in the 100 and 300 Areas; however, groundwater mounding in these areas is not as great as in the 200 Areas primarily because of lower discharge volumes.

In the 100 Areas, 300 Area, and other locations near the Columbia River, groundwater levels are influenced by river stage (PNL-9437). The Columbia River stage was unusually high throughout most of 1997, resulting in a rising water table near the river. This rise is illustrated in Figure 6.1.9 by the positive contours adjacent to the river. As a result of the rising water table near the river, water flowed from the river into the aquifer during much of the year.

## 6.1.3 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 movement of these contaminants at the Hanford Site are discussed below.

Most of the groundwater contamination at the Hanford Site resulted from discharge of wastewater from reactor operations, reactor fuel fabrication, and processing of spent reactor fuel. Table 6.1.1 lists the 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 wastewater 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 liquid organic chemicals 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.

Liquid effluents discharged to the ground at the Hanford Site 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

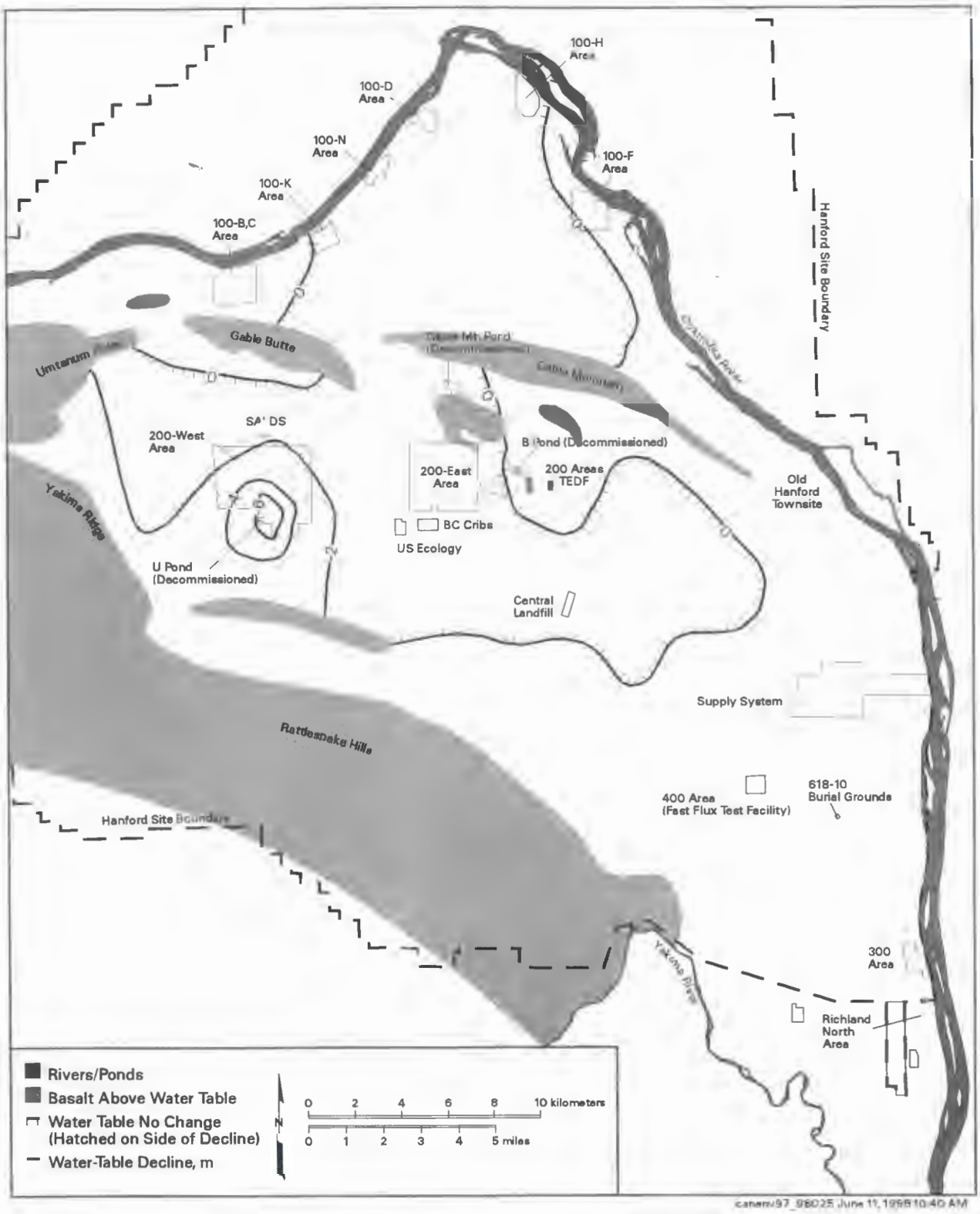



**Figure 6.1.8.** Change in Water-Table Elevations Between 1979 and 1995

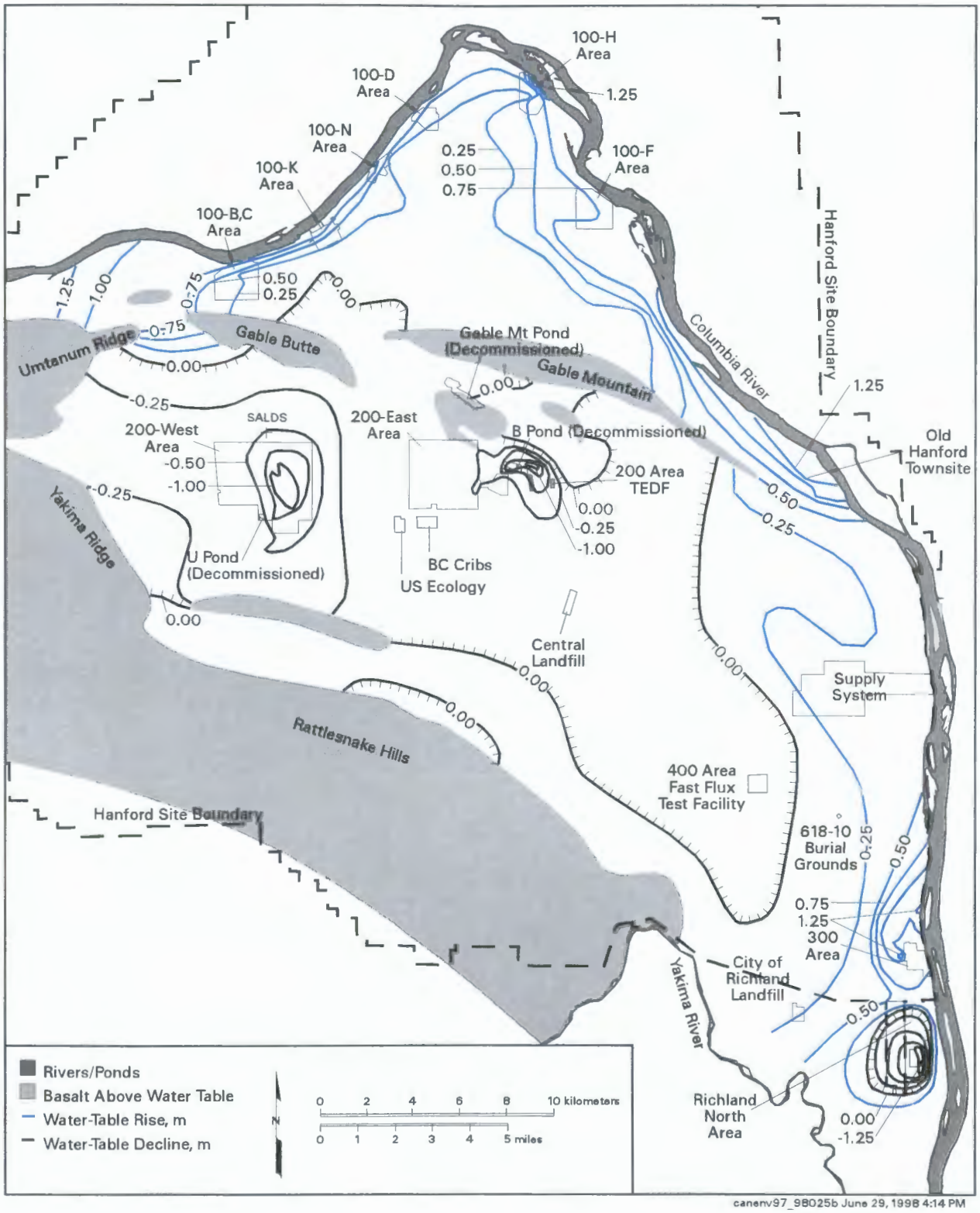



**Figure 6.1.9**. Change in Water-Table Elevations Between 1996 and 1997

**Table 6.1.1**. Chemical and Radiological Groundwater Contaminants and Their Link to Site Operations

| Constituents Generated | Areas | Facilities Type |
|---|---|---|
| Tritium, $^{60}Co$, $^{90}Sr$, $Cr^{6}$, $SO_4^{-2}$ | 100 | Reactor operations |
| Tritium, $^{90}Sr$, $^{99}Tc$, $^{129}I$, $^{137}Cs$, Pu, U, $CN^-$, $Cr^{6}$, $F^-$, $NO_3^-$ | 200 | Irradiated fuel processing |
| Pu, carbon tetrachloride, chloroform, $NO_3^-$ | 200 | Plutonium purification |
| $^{99}Tc$, U, $Cr^{6}$, trichloroethylene | 300 | Fuel fabrication |

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. As these dissolved constituents move with the groundwater, many radionuclides and chemicals adhere to sediment particle surfaces (adsorption) or diffuse into the particles (absorption). Dissolved constituents in groundwater tend to spread out by dispersion as the groundwater moves. Radionuclide concentrations are reduced by radioactive decay.

Outside the source areas (i.e., liquid disposal sites), 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.

## 6.1.4 Groundwater Modeling

Numerical modeling of groundwater flow and contaminant transport is performed to simulate future groundwater flow conditions and predict the migration of contaminants through the groundwater pathway. During 1997, a model was used to simulate future movement of selected contaminant plumes in the unconfined aquifer system. A groundwater flow model was also applied to illustrate the interaction between the unconfined aquifer and the Columbia River in the vicinity of the 100-N Area. The objective was to better understand the release of strontium-90 from the aquifer into the river. Other models were used in the design and evaluation of pump-and-treat activities aimed at remediation of contaminated groundwater in the 200-West Area. A brief description of these modeling efforts is provided here; additional details and results are presented in PNNL-11793 (Section 6.0) and PNNL-11801.

During the past several years, a three-dimensional flow and transport model has been under development. The objective of developing this model was to provide more accurate simulations of contaminant transport within the sitewide unconfined aquifer system. The model is based on the Coupled Fluid, Energy, and Solute Transport (CFEST) code (BMI/ONWI-660). During 1997, the model was updated to a new version of the CFEST code called CFEST-96. Information on the initial development of the three-dimensional CFEST model is available in PNL-10886. The model was used to simulate transient groundwater flow conditions through the year 2500 under assumed future recharge scenarios. The movements of existing tritium, strontium-90, technetium-99, iodine-129, and uranium plumes originating from the 200 Areas were predicted for this time period.

Future levels of tritium predicted by the sitewide model suggest that water supply wells in the 400 Area and emergency water supply wells in 200-East Area will continue to be impacted by the tritium plume originating from the 200-East Area for the next 10 to 20 years. Tritium levels in the upper part of the unconfined aquifer system in the 200-East and 400 Areas are expected to remain above 20,000 pCi/L until sometime between 2010 and 2020. Model results predicted that tritium now found in the 300 Area in excess of 2,000 pCi/L will not reach the North Richland well field, a municipal water supply south of the Hanford Site. The 200-East Area tritium plume was predicted to migrate primarily to discharge areas along

the Columbia River between the Old Hanford Townsite and the 300 Area over the next 90 to 100 years. A smaller plume will migrate northward to the Columbia River. The tritium plume from the 200-West Area was predicted to migrate beneath the 200-East Area as its concentration is reduced by dispersion and decay (half-life = 12.26 years).

Predictions of the iodine-129 plume indicated that it will migrate toward and discharge into the Columbia River over a period of about 570 years. During this period, iodine-129 concentrations predicted to discharge into the river will decline slightly by the process of dispersion. However, concentrations will not fall significantly below current levels because of the long half-life (16,000,000 years) of iodine-129. The technetium-99 and uranium plumes originating in the 200 Areas were predicted to continue migrating from source locations toward the Columbia River. Concentration levels of the simulated plumes will decline to below regulatory limits over a period of approximately 100 years because of plume dispersion. The strontium-90 plume in the 200-East Area will not migrate far from its current location because strontium-90 is sorbed by sediments. Concentrations will decline primarily because of radioactive decay (half-life = 28.8 years).

Modeling of groundwater interaction between the unconfined aquifer and the Columbia River in the vicinity of the 100-N Area was conducted as part of the evaluation of a proposed in situ treatment zone. The treatment zone would be placed in the aquifer close to the Columbia River and would contain a mineral, clinoptilolite, that reacts with strontium-90 and keeps it from migrating to the river. One of the uncertainties associated with this technology and other proposed remediation technologies at the 100-N Area is the effect of river stage fluctuations on groundwater movement near the river.

The Subsurface Transport Over Multiple Phases (STOMP) model (PNNL-11217) was used because of its ability to handle seepage face boundaries. The model simulated the interaction between the Columbia River and the unconfined aquifer in 1-h time steps for 4 weeks in October and early November. These 4 weeks were chosen because the Columbia River daily fluctuations are greatest during that time. Results of the simulation clearly demonstrate that variations in the level of the Columbia River have an impact on the near-river unconfined aquifer. Results also showed that bank storage is important in calculating total water movement from the aquifer into the river. In the model, the amount of water entering the river from bank storage was an order of magnitude greater than the net flux of groundwater from the aquifer into the river. For contaminants that are not sorbed, such as tritium and hexavalent chromium, water entering the aquifer from the river dilutes the concentration of these contaminants before they enter the river. However, for contaminants that are sorbed onto sediments, the flux of river water in and out of the sediments may remove sorbed contaminants near the river faster than would be predicted assuming steady-state groundwater flow.

Groundwater models were also used to assess the performance of groundwater pump-and-treat systems in the 200-UP-1 and 200-ZP-1 Operable Units in the 200-West Area. In these systems, contaminated water is removed by means of extraction wells, treated, and either disposed of to the State-Approved Land Disposal Site (200-UP-1) or returned to the aquifer through injection wells (200-ZP-1) (BHI-01126). The models were used to predict system performance, assuming different extraction and injection well configurations, capture zones, and zones of hydraulic influence for the extraction and injection wells. Modeling was conducted using the Micro-FEM© finite-element code (Hemker-vanElburg, Amsterdam, The Netherlands). Groundwater modeling for the 200-UP-1 plume indicated that most of the targeted plume will be captured under the current well configuration. Modeling of the 200-ZP-1 pump-and-treat operation predicted that the high concentration area of the plume will be captured. During 1997, measurable progress was made toward hydraulic containment at each of these pump-and-treat operations (Section 5.9.4 in PNNL-11793).

## 6.1.5 Groundwater Monitoring

Groundwater monitoring at the Hanford Site is an integral part of the *Hanford Site Ground-Water Protection Management Plan* (DOE/RL-89-12, Rev. 2). 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 to assess the distribution and movement of existing groundwater contamination, to identify potential and emerging groundwater contamination problems, and to integrate 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 the annual groundwater monitoring report (e.g., PNNL-11793). Groundwater monitoring is also carried out during cleanup investigations under the Comprehensive Environmental Response, Compensation, and Liability Act as described in the 5-year plan (DOE/S-0078P). These investigations are managed by the environmental restoration contractor.

### 6.1.5.1 Groundwater Sampling and Analytes of Interest

Groundwater samples were collected from 726 wells for all monitoring programs during 1997. The locations of sampled wells are shown in Figures 6.1.10 and 6.1.11. Well names are indicated only for wells in the 600 and 400 Areas 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 6.1.12 shows the locations of facilities where groundwater monitoring was conducted to comply with the Resource Conservation and Recovery Act (Appendix A in PNNL-11793). 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 6.1.2. 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 726 wells sampled, 324 were sampled once, 184 twice, 54 three times, 81 four times, and 83 more than four times 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 1.5 million groundwater monitoring result records. After the data are verified and/or validated, they are made available to state and federal regulators for retrieval.

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 (a registered trademark of Instrumentation Northwest, Inc., Redmond, Washington), though some wells are sampled with bailers or airlift systems.

Samples were collected for all programs following documented sampling procedures (PNL-6894, Rev. 1; WHC-CM-7-4) based on U.S. Environmental Protection Agency (EPA) guidelines (OSWER 9950-1). Analytical techniques used are listed in DOE/RL-91-50, Rev. 2; PNL-10698 (Section 4.1.7); and Comprehensive Environmental Response, Compensation, and Liability Act work plans. The radionuclides and chemicals for which analyses were conducted are listed in Table 6.1.3.

Most groundwater samples collected onsite in 1997 were analyzed for tritium. Selected samples were analyzed for other radionuclides. Sample results for radionuclides are generally presented in picocuries per liter; however, the results for total uranium, which is usually measured by laser fluorescence, are given in micrograms per liter (µg/L).

Nitrate analyses were performed on many samples collected during 1997 because of the extensive areas with elevated nitrate concentrations originating from onsite and offsite sources. However, nitrate concentrations were below the EPA 45-mg/L 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 chemical contaminants.

### 6.1.5.2 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

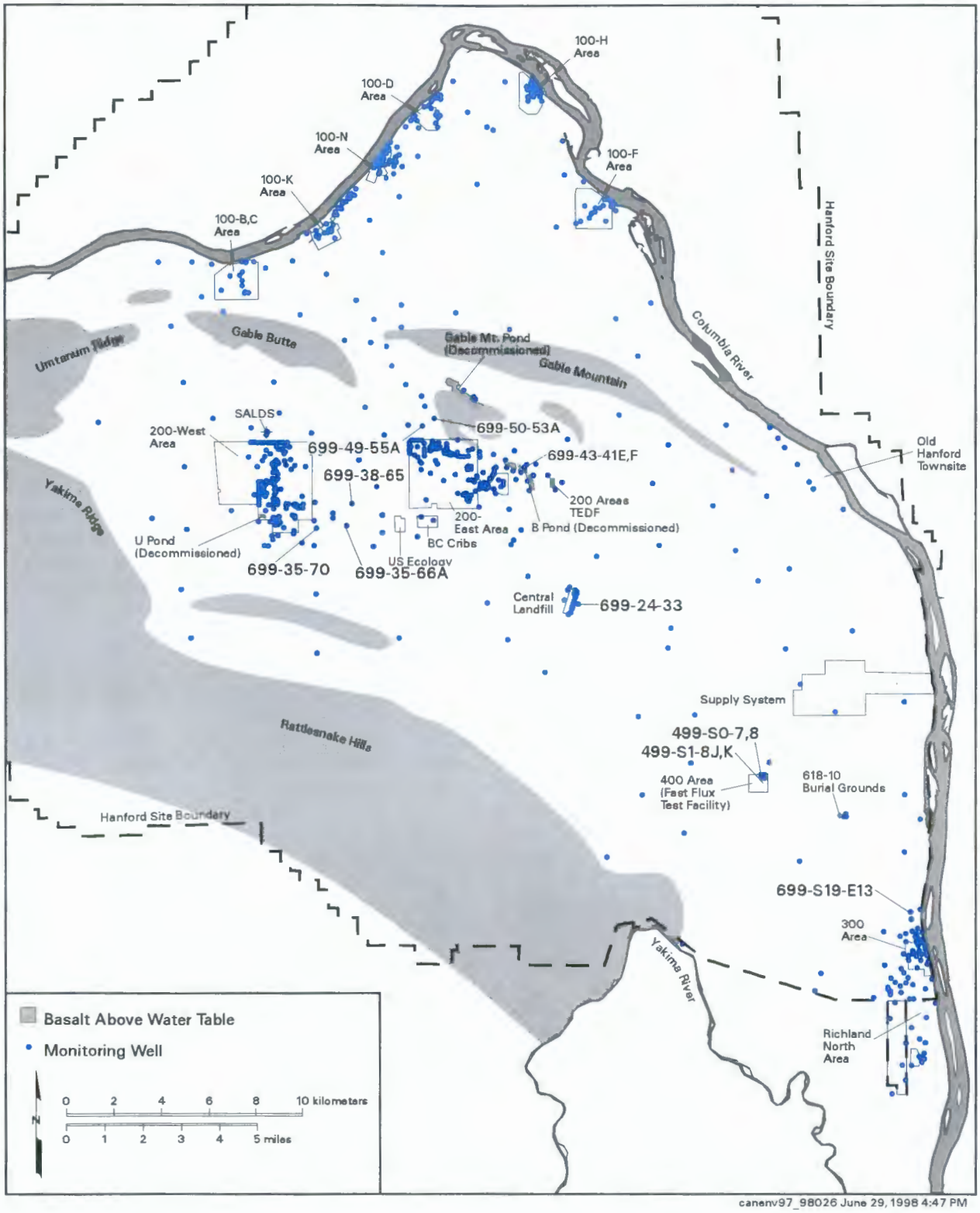



**Figure 6.1.10**. Unconfined Aquifer Monitoring Well Locations, 1997

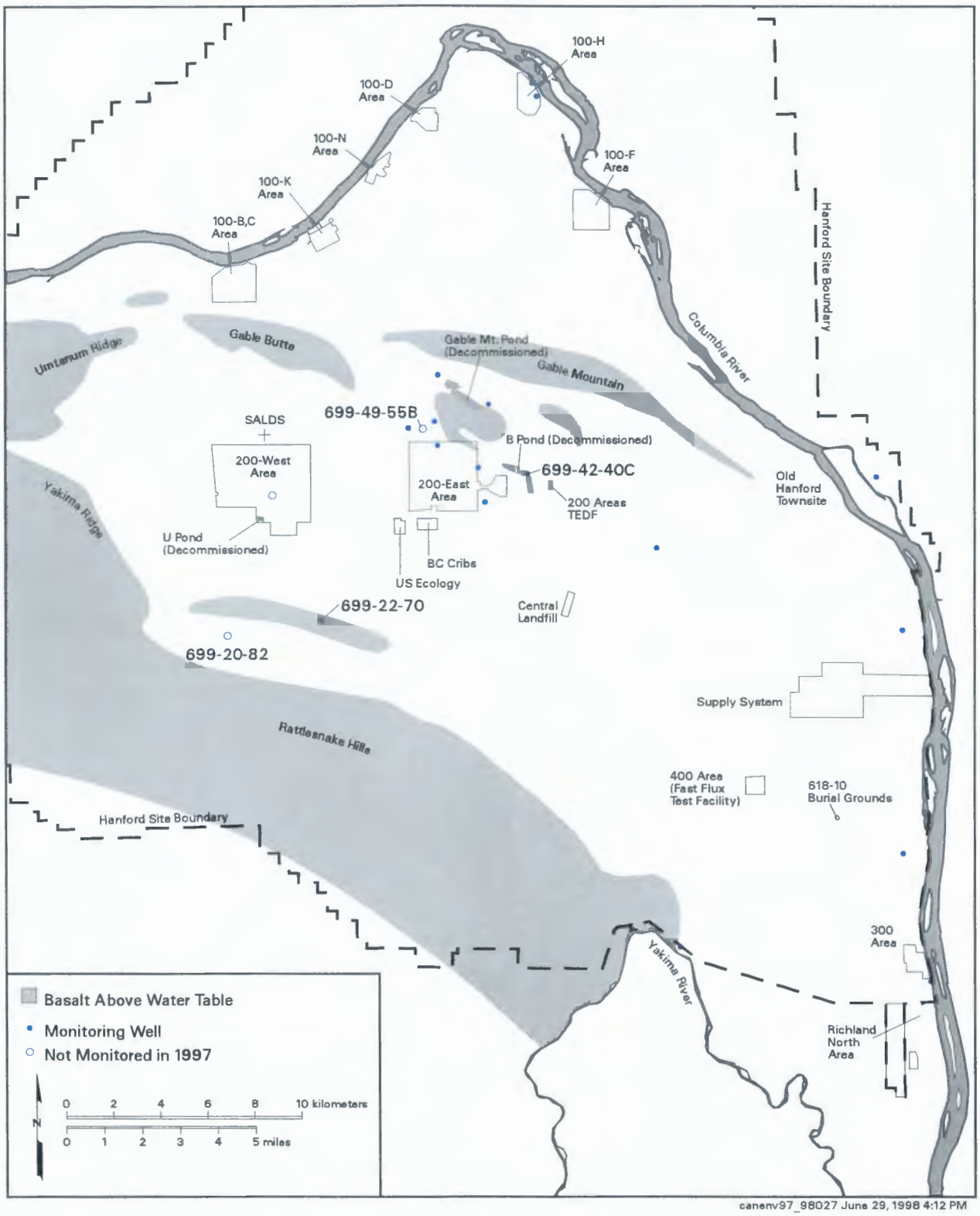
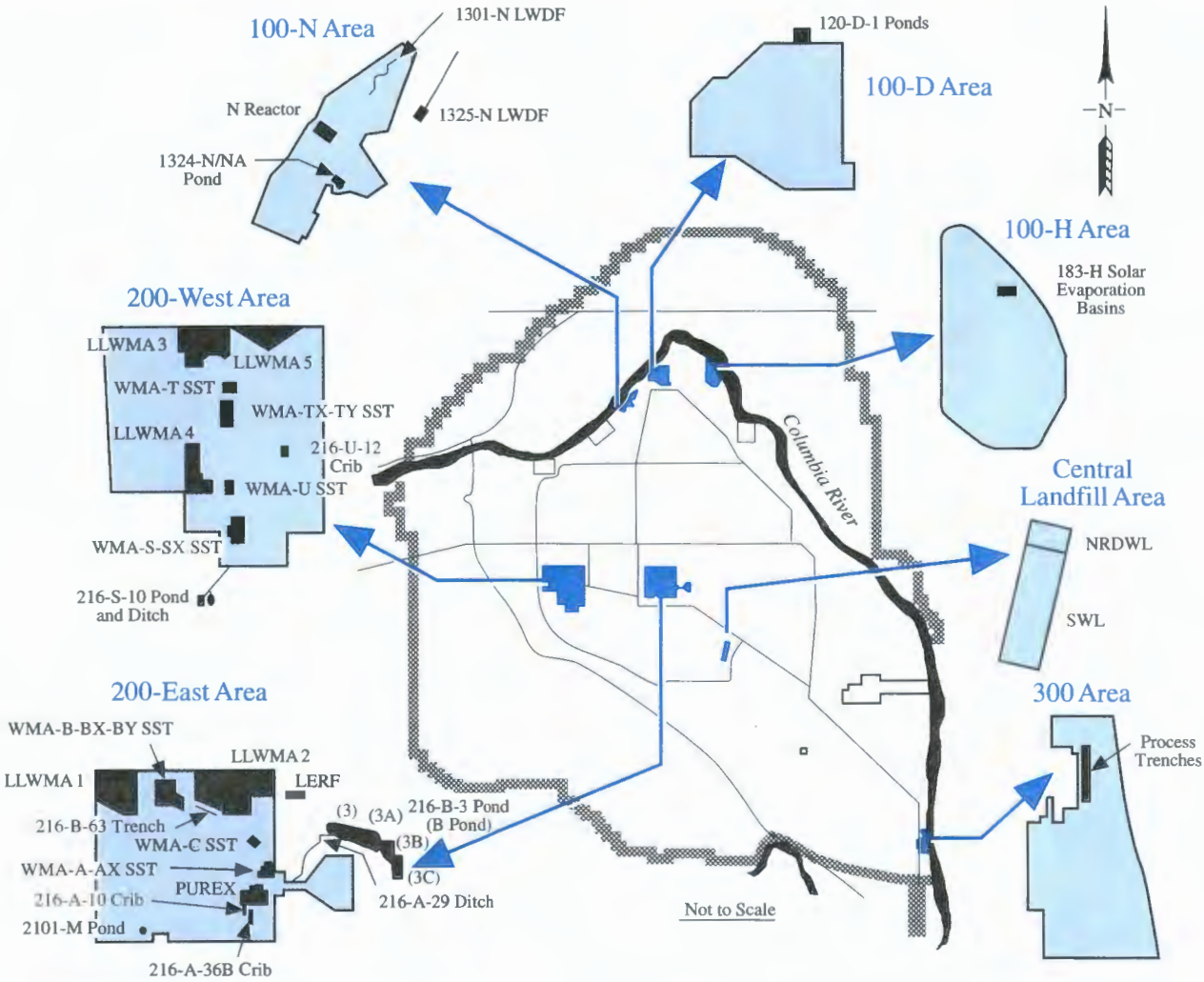



**Figure 6.1.11.** Confined Aquifer Monitoring Well Locations, 1997




| | | | |
|---|---|---|---|
| LERF | Liquid Effluent Retention Facility | PUREX | Plutonium-Uranium Extraction (Plant) |
| LLWMA | Low-Level Waste Management Area | SST | Single-Shell Tank |
| LWDF | Liquid Waste Disposal Facility | SWL | Solid Waste Landfill |
| NRDWL | Nonradioactive Dangerous Waste Landfill | WMA | Waste Management Area |

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**Figure 6.1.12.** Locations of Resource Conservation and Recovery Act Groundwater Monitoring Projects

**Table 6.1.2.** 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.

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, field equipment problems, 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.

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 less-than-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 analytical laboratories participate in interlaboratory comparisons in which many laboratories analyze blind samples prepared by the EPA (Section 8.0, "Quality Assurance").

In 1997, double-blind samples for specific constituents were analyzed (Section 8.0, "Quality Assurance," discusses double-blind results). Several wells were also cosampled with the Washington State Department of Health for comparison, and the results are available from that agency.

The chemical composition of groundwater may fluctuate from differences in the contaminant source, recharge, or 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.

**Table 6.1.3.** Radionuclides and Chemicals Analyzed for in Groundwater, 1997

| Radiological Parameters | Chemical Parameters |
|---|---|
| Tritium | pH (field and laboratory) |
| Carbon-14 | Conductance (field) |
| Cobalt-60 | Alkalinity |
| Strontium-90 | Total carbon |
| Technetium-99 | Total organic carbon |
| Ruthenium-106 | Total organic halogens |
| Antimony-125 | B, Be, Na, Mg, Al, K, Co, Si, As, Se |
| Iodine-129 | Ca, V, Cr, Mn, Fe, Ni, Pb, Li, Mo, Hg |
| Cesium-137 | Cu, Zn, Sr, Ag, Cd, Sb, Ba, Sn, Tl |
| Americium-241 | $F^-$, $Cl^-$, $NO_3^-$, $PO_4^{-3}$, $SO_4^{-2}$, $NO_2^-$, $Br^-$ |
| Gross alpha | $CN^-$ |
| Gross beta | $NH_4^+$ |
| Plutonium isotopes | Volatile organic compounds |
| Radium isotopes | Semivolatile organic constituents |
| Uranium isotopes | Polychlorinated biphenyls |
| Uranium (total) | Dioxins/furans |
| | Pesticides/herbicides |
| | Biological oxygen demand/chemical oxygen demand |
| | Dissolved oxygen |
| | Total petroleum hydrocarbons |
| | Oil and grease |

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 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.

## 6.1.6 Groundwater Monitoring Results

The following sections summarize the distribution of radioactive and chemical contaminants detected in Hanford Site groundwater during 1997. 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 PNNL-11793. However, because PNNL-11793 (the annual groundwater report) covers the fiscal year, it does not include results from the last 3 months of 1997.

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 DOE Order 5400.5; see Appendix C, Tables C.2 and C.5). The drinking water standards are for protecting public drinking water supplies. The derived concentration guides are for protecting the public from radionuclides resulting from DOE activities. 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.

## 6.1.6.1 Radiological Monitoring Results for the Unconfined Aquifer

The radionuclides for which analyses were conducted on Hanford Site groundwater were listed in Table 6.1.3. The distribution of tritium, iodine-129, technetium-99, uranium, strontium-90, cesium-137, cobalt-60, and plutonium are discussed in the following sections. Gross alpha and gross 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, including ruthenium-103, antimony-125, and americium-241, are associated with wastes from Hanford Site operations. Because of their very low concentrations in groundwater, they are not discussed in this section.

**Tritium**. 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/EIS-0119F, WHC-SD-EN-RPT-004). In the late 1960s, tritium production took place in N Reactor (WHC-MR-0388).

Tritium was present in many historical waste streams at the Hanford Site 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. Figure 6.1.13 shows the 1997 distribution of tritium in the unconfined aquifer. Tritium is one of the most widespread contaminants in groundwater across the Hanford Site and exceeds the EPA 20,000-pCi/L drinking water standard in the 100-B,C, 100-D, 100-K, 100-N, 200, 400, and 600 Areas. It is assumed that the 20,000-pCi/L concentration yields an annual dose of 4 mrem/yr, as explained in the introduction to this section. Tritium exceeded the DOE 2,000,000-pCi/L derived concentration guide at one location in the 200-East Area.

In 1997, the only tritium bearing liquid effluent discharged to the soil column on the Hanford Site occurred at the State-Approved Land Disposal Site, which began operation in 1995 and located just north of the 200-West Area.

***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-K, and 100-N Areas. The highest tritium concentrations were detected in the 100-K Area. The largest tritium plume in the 100 Areas with concentrations above the drinking water standard occurs near the Columbia River from the 100-N Area to the 100-D Area.

Samples from two wells in the 100-B,C Area showed tritium concentrations that exceeded the 20,000-pCi/L drinking water standard in 1997. The concentrations downgradient of B Reactor waste disposal cribs showed an increasing trend between approximately 1994 and 1997, reaching a maximum of 420,000 pCi/L in 1997. The tritium concentration adjacent to the Columbia River slightly exceeded the drinking water standard in 1997.

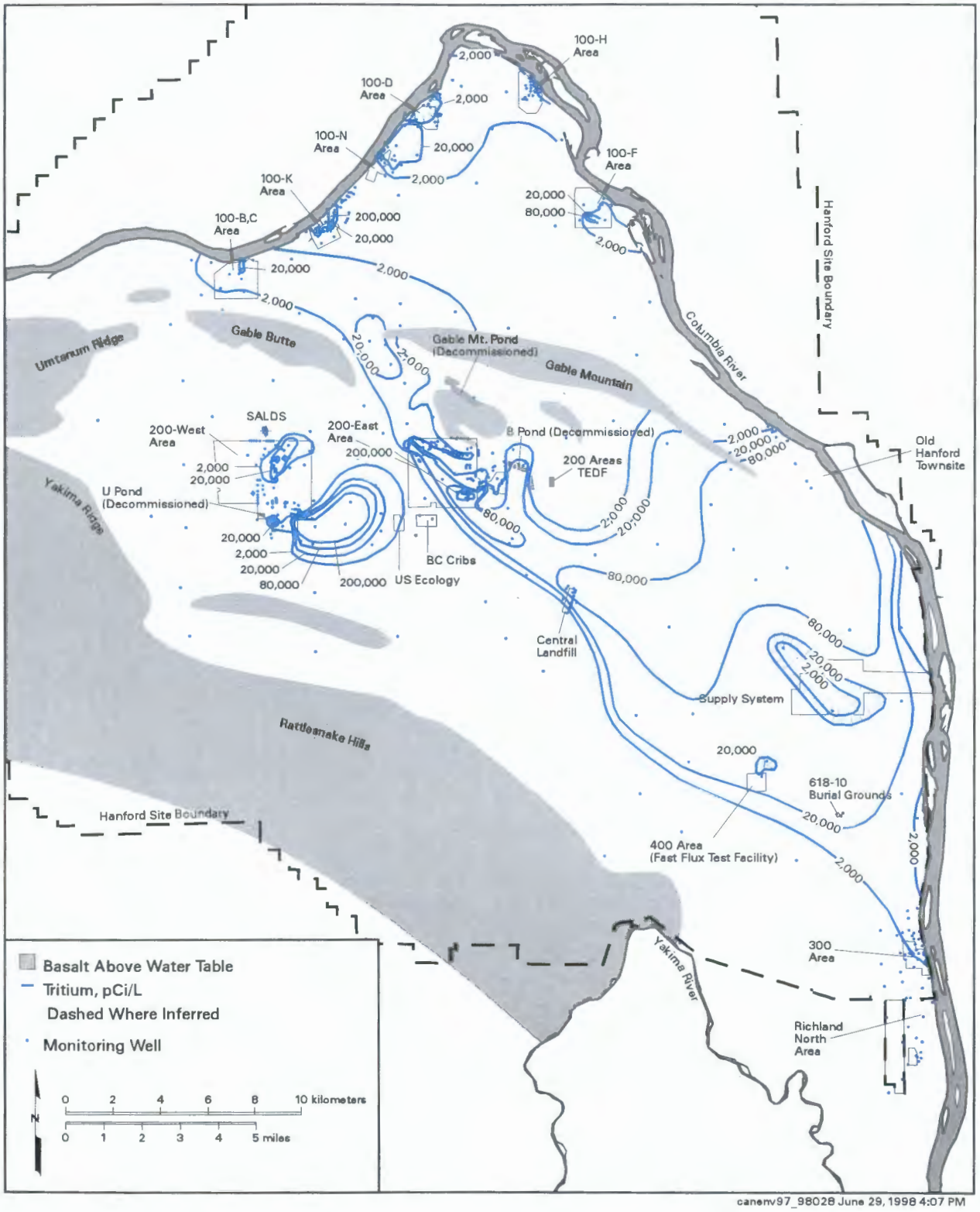


**Figure 6.1.13.** Tritium Distribution in the Unconfined Aquifer, 1997

In the 100-D Area, tritium concentrations were greater than the 20,000-pCi/L drinking water standard in two wells located in the southwestern corner of the area. The maximum tritium level reported during 1997 was 47,600 pCi/L. These concentrations are associated with the tritium plume that extends southwest to the 100-N Area.

In the 100-K Area, the highest tritium concentrations in groundwater occur in the vicinity of the KE and KW Reactors. Well 199-K-30, located near the KE Reactor, continued to contain the highest tritium level within the 100 Areas, with a maximum concentration of 536,000 pCi/L in 1997. The tritium trend for well 199-K-30 is shown in Figure 6.1.14. Previously, in April and May 1993, this well contained tritium in excess of the 2,000,000-pCi/L derived concentration guide. The tritium concentrations declined after reaching a lower peak in mid-1995 but began to increase in 1997. The probable source is past disposal to a french drain east of the reactor building (DOE/EIS-0119F). A well located at the northwestern corner of the KE Reactor showed the most abrupt increase in tritium concentrations in 1997, reaching a maximum of 420,000 pCi/L. Additional investigation is planned for 1998 to assess the cause of this increase. A well located adjacent to a french drain near the KW Reactor showed a maximum concentration of 52,300 pCi/L in 1997. This was almost an order of magnitude lower than the maximum (499,000 pCi/L) in 1996.

Tritium in the northern part of the 100-N Area is found in concentrations greater than the 20,000-pCi/L drinking water standard. The tritium plume in this area extends northeast to the 600 and 100-D Areas. This plume is associated with the 1301-N and 1325-N Liquid Waste Disposal Facilities. The most significant concentrations were reported in two wells near these facilities. The maximum tritium level reported in the 100-N Area in 1997 was 95,600 pCi/L near the 1325-N facility. A well located between the 1301-N facility and the Columbia River showed a maximum of 60,200 pCi/L in 1997.

***Tritium in the 200-East and 600 Areas.*** The highest tritium concentrations in the 200-East Area continued to be measured in wells near cribs that received effluent from the Plutonium-Uranium Extraction Plant. However, tritium concentrations are generally decreasing slowly in this area. Concentrations greater than the 2,000,000-pCi/L derived concentration guide were detected in only one well (299-E17-9) in 1997 in the 200-East Area. The maximum tritium level detected in this well, which monitors the 216-A-36B Crib, was 3,070,000 pCi/L. This was the highest tritium concentration detected in any well onsite. Tritium concentrations in the plume extending from the southeastern portion of the 200-East Area were generally lower in 1997 than in previous years as a result of dissipation and radioactive decay. Downgradient of the Plutonium-Uranium Extraction Plant, the area of contaminated groundwater with tritium concentrations above 200,000 pCi/L extended southeast of the 200-East Area boundary up until 1996. These high concentrations have extended at least as far southeast as the Central Landfill area in the recent past (PNL-8073). In 1997, the plume area above the 200,000-pCi/L concentration contour was considerably smaller and did not extend beyond the 200-East Area boundary.

The movement of the widespread tritium plume (see Figure 6.1.13), extending from the southeastern portion of the 200-East Area to the Columbia River, was consistent with patterns noted in recent monitoring reports (Section 4.8 in PNNL-11472, Section 5.10.3.2 in PNNL-11793). 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 pulse is clearly observable near the Central Landfill (Figure 6.1.15), which shows arrival in early 1987. Tritium concentrations from the first pulse were much higher than from the second. The effects of the second operational period have not been detected near the Columbia River. A trend plot (Figure 6.1.16) of the tritium concentrations in well 699-40-1 near the shore of the Columbia River shows the arrival of the first pulse in the mid-1970s, but shows 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 6.1.17 shows the distribution of tritium in selected years from 1964 through 1988. This figure was created from maps in BNWL-90, BNWL-1970, PNL-5041, and PNL-6825 (Section 5.0). The contours in the original references were recalculated and interpreted to provide uniform contour intervals. Figure 6.1.17 shows that tritium at concentrations greater than the 20,000-pCi/L drinking water standard reached the Columbia River in approximately the mid-1970s.

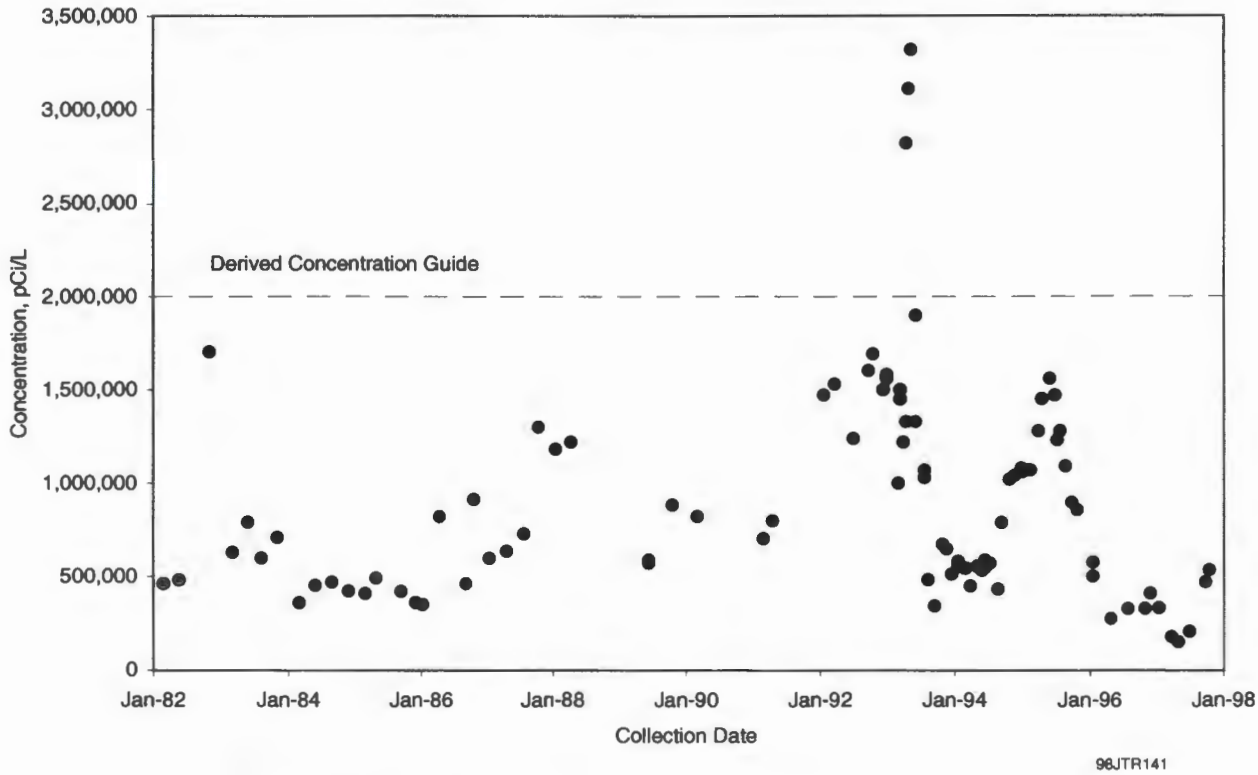


**Figure 6.1.14**. Tritium Concentrations in Well 199-K-30, 1982 Through 1997

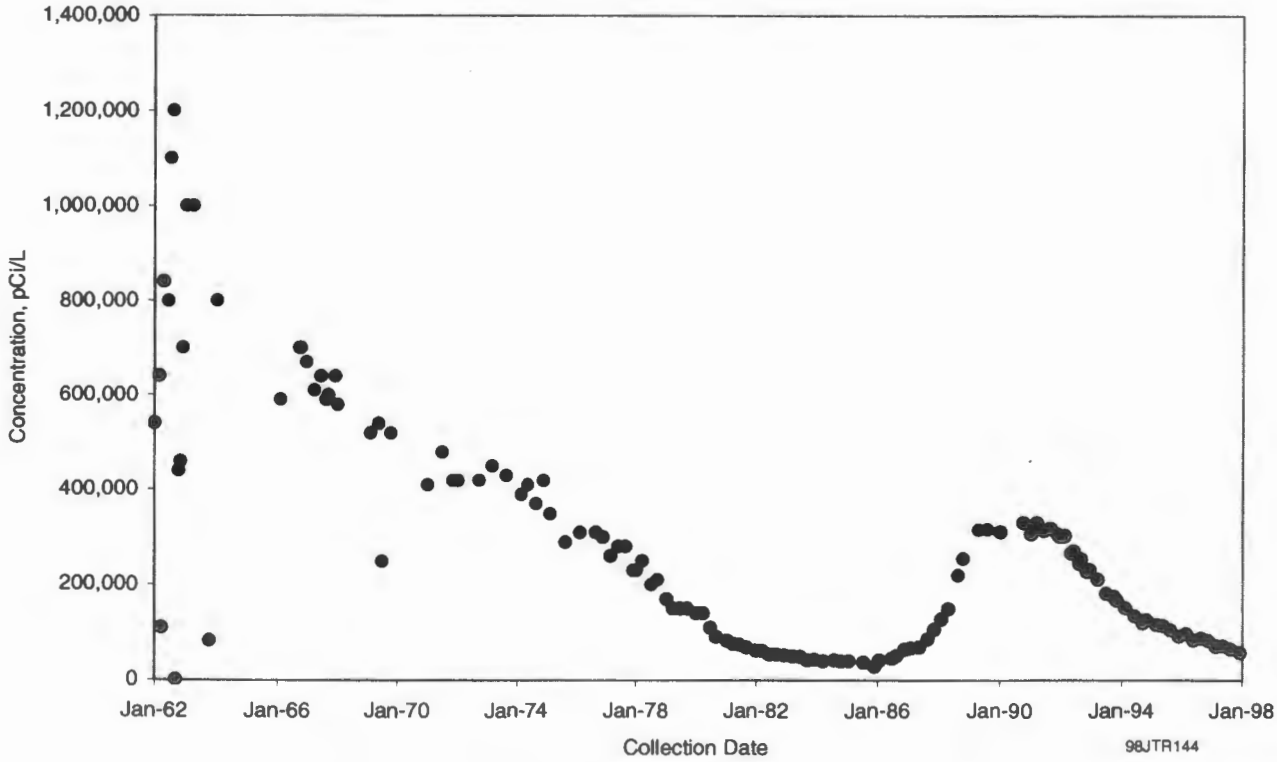


**Figure 6.1.15**. Tritium Concentrations in Well 699-24-33 Near the Central Landfill, 1962 Through 1997

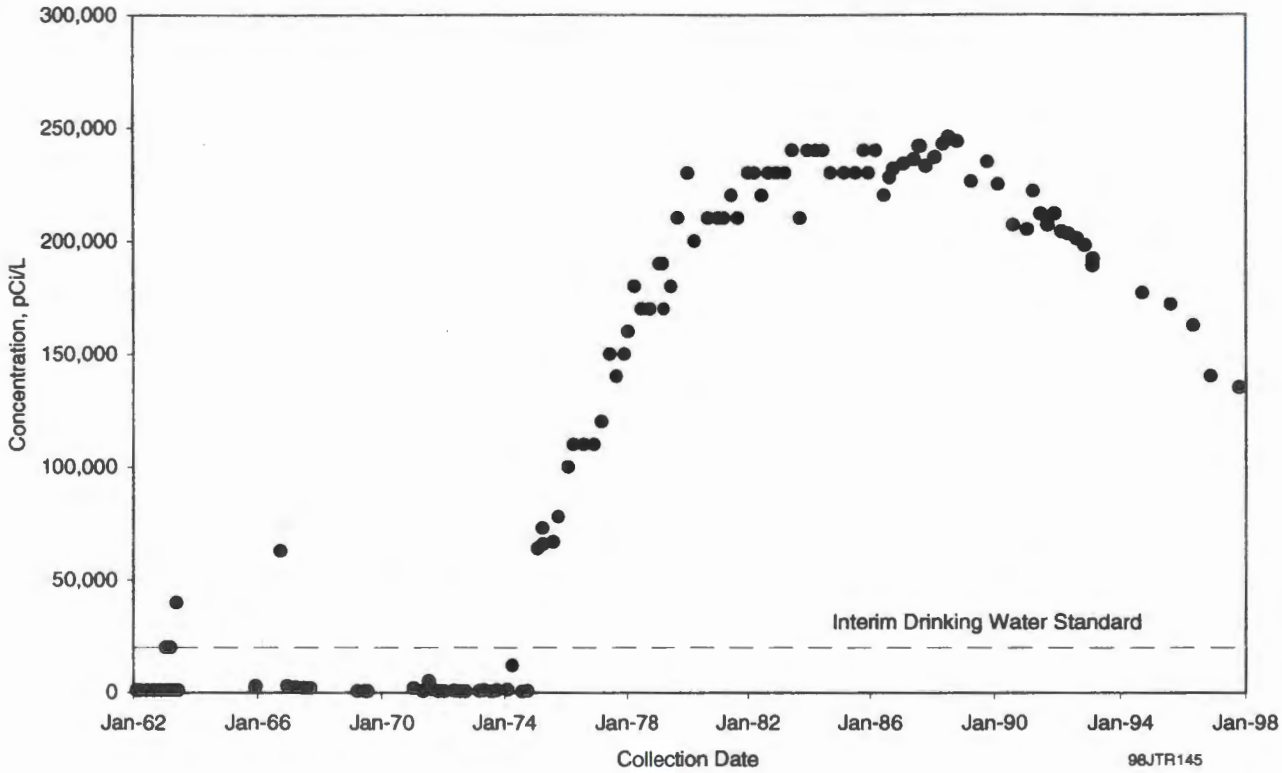


**Figure 6.1.16**. Tritium Concentrations in Well 699-40-1 Near the Columbia River, 1962 Through 1997

The configuration of the western portion of the tritium plume shown in Figure 6.1.13 closely matches previous predictions of the direction of contaminant movement from the 200-East Area (PNL-6328). Movement is forced to the south by the flow originating at the groundwater mound beneath the former 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 (PNL-7144).

The tritium concentration distribution near the former B Pond shows an area of concentration above the drinking water standard that extends from the former B Pond south to the main tritium plume. B Pond produced a radial flow pattern of groundwater that mostly had low contaminant concentrations. The mound under the former B Pond has begun to dissipate since wastewater flow was diverted to the 200 Areas Treated Effluent Disposal Facility in August 1997. A new mound will presumably form under this facility, as long as it is used for disposal of site effluent.

Tritium is also found at levels above the drinking water standard in the northwestern part of the 200-East Area. This plume appears to extend to the northwest through the gap between Gable Mountain and Gable Butte. The distribution of tritium concentrations to the northwest and southeast of the 200-East Area indicates a divide in groundwater flow direction across the 200-East Area. A pulse of tritium levels above the standard also occurred between Gable Mountain and Gable Butte.

***Tritium in the 200-West 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 1997. 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 in 1996. However, this well was not sampled in 1997 because of declining water levels. The declining concentrations in this well are shown in Figure 4.8.21 of PNNL-11472. In the 600 Area east of the 200-West Area, tritium concentrations exceeded

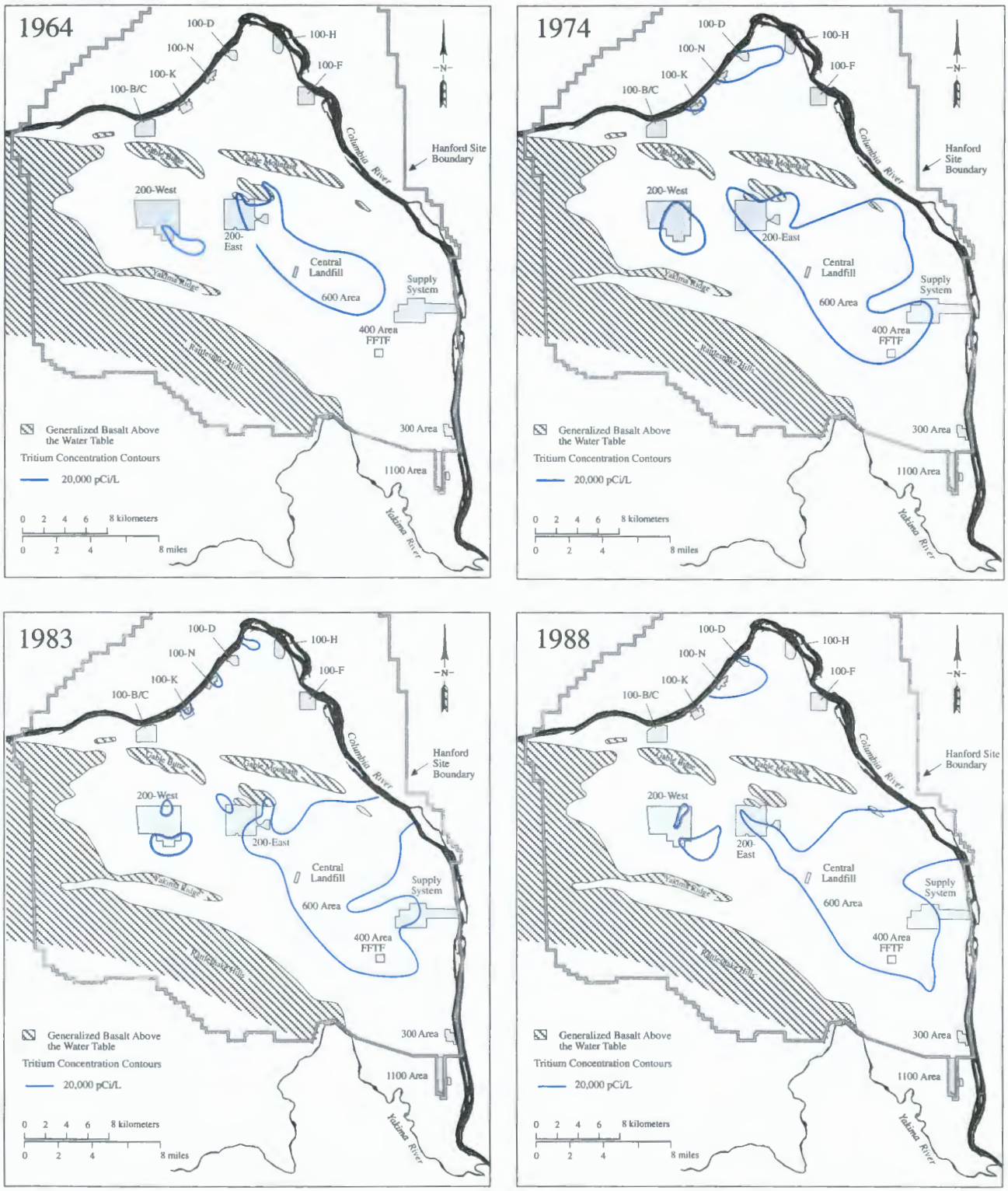


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**Figure 6.1.17.** Historical Tritium Concentrations on the Hanford Site

200,000 pCi/L in three wells, with a maximum of 491,000 pCi/L in well 699-35-66A. Tritium levels have generally been declining, as illustrated by trend plots in Figure 6.1.18, however the highest levels in 1997 continue to be well above the 20,000-pCi/L drinking water standard by more than an order of magnitude. Only one well (299-W23-14) near the 216-S-25 Crib upgradient of the Reduction-Oxidation Plant in the 200-West Area showed concentrations that exceeded 200,000 pCi/L in 1997. 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 hydraulic 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 tank farms (see Figures 6.1.12 and 6.1.13) and T Plant disposal facilities, which received liquid waste from T Plant operations. The highest concentrations were detected near the TX-TY Tank Farms. The area where concentrations exceeded the drinking water standard extends northeast past the northern boundary of the 200-West Area.

Two wells monitoring the State-Approved Land Disposal Site just north of the 200-West Area showed tritium concentrations that exceeded the drinking water standard, with one of the wells showing a maximum value equal to that of the 2,000,000-pCi/L derived concentration guide in 1997. These concentrations are associated with the disposal site, which receives treated effluent containing tritium. This disposal site has been in operation since 1995.

***Tritium in the 300 Area.*** The eastern portion of the tritium plume that emanates from the 200-East Area continues to move to the east-southeast and discharge into the Columbia River (see Figure 6.1.13). The southern edge of the tritium plume extends into the 300 Area, as shown in Figure 6.1.19. Figure 6.1.20 shows the trend of tritium concentrations in well 699-S19-E13 just north of the 300 Area. Tritium concentrations in this well, which have shown increased levels since 1985, reached a maximum of 14,500 pCi/L in 1997. Even though tritium concentrations in the 300 Area are below the 20,000-pCi/L drinking water standard, a concern has been the potential migration of the tritium plume to an offsite municipal water supply to the south. The municipal water supply consists of the city of Richland's well field and recharge basins (see Figure 6.1.19).

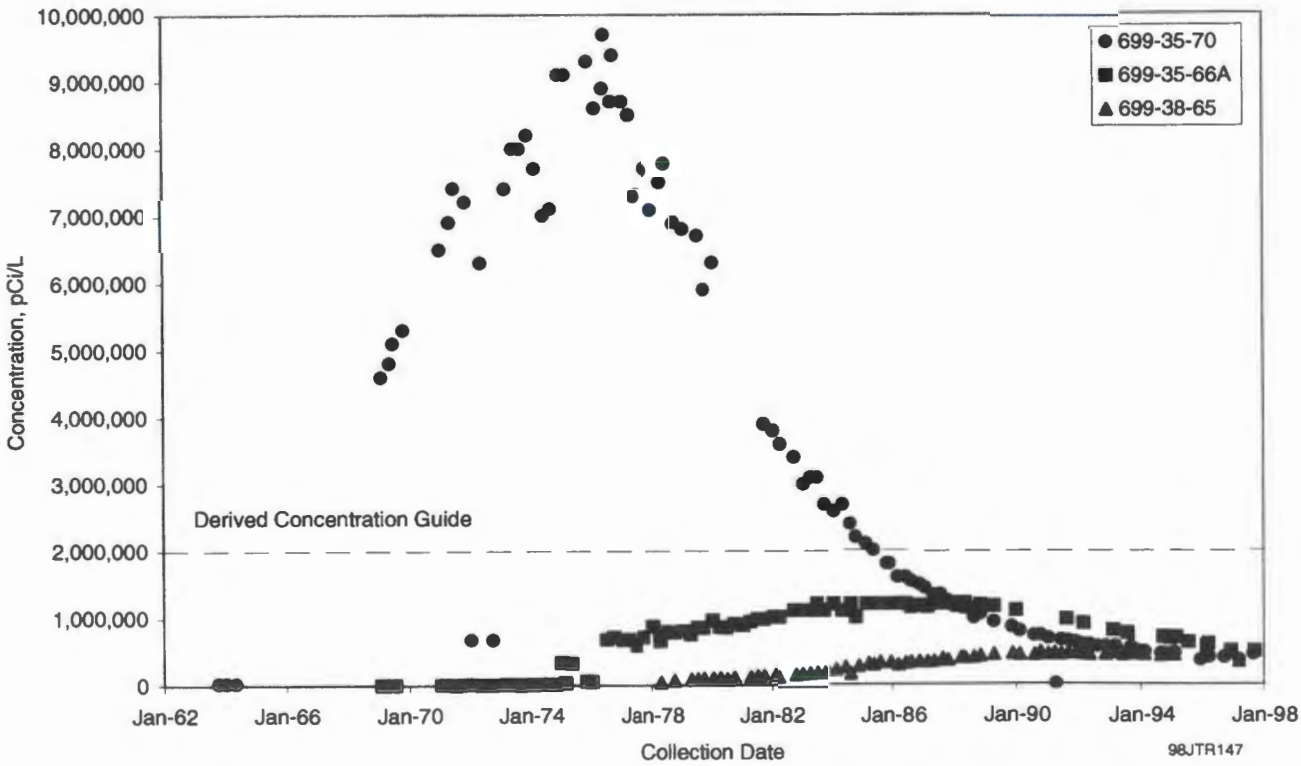


**Figure 6.1.18.** Tritium Concentrations in Wells 699-35-70, 699-35-66A, and 699-38-65, 1962 Through 1997

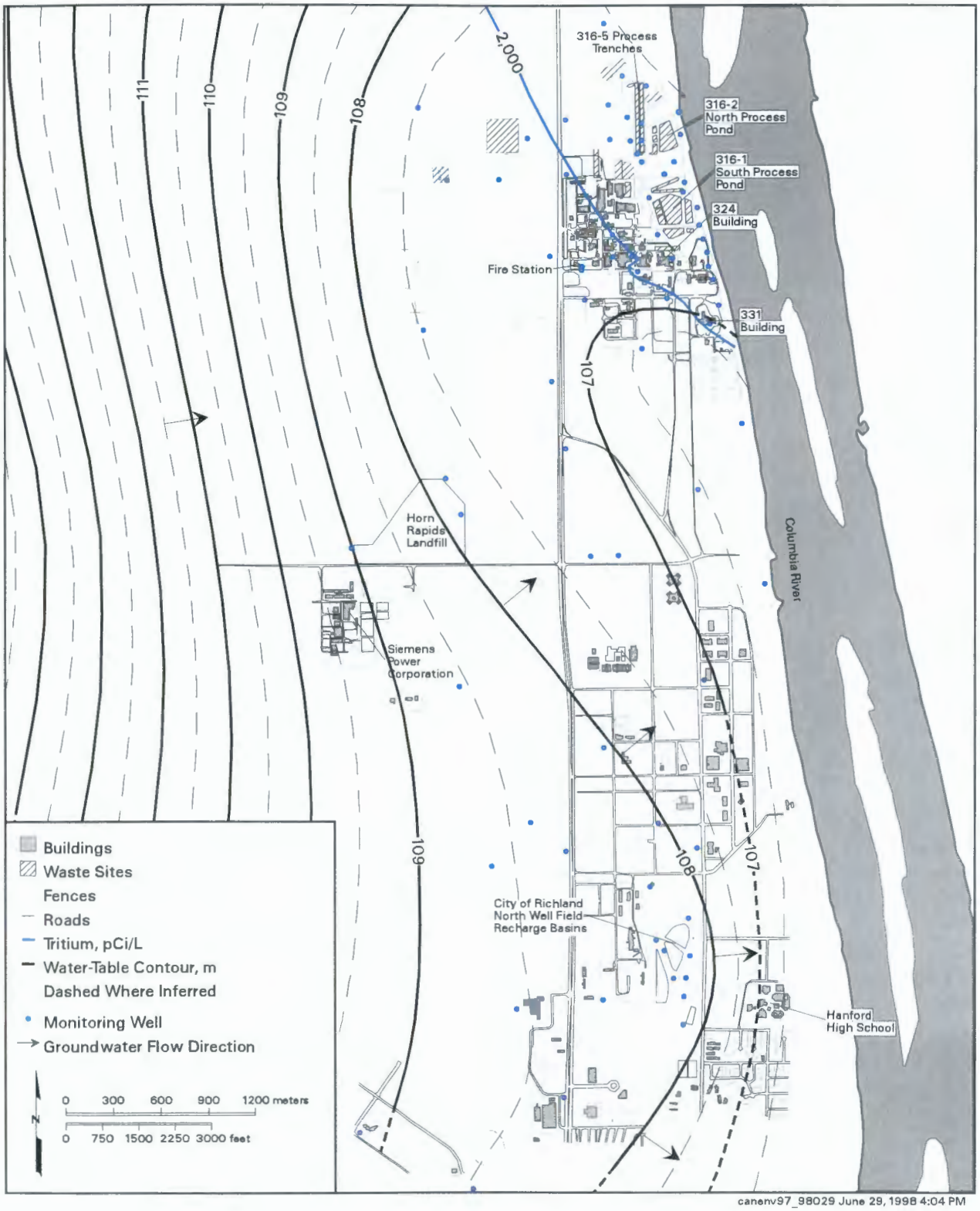


**Figure 6.1.19.** Tritium Distribution and Groundwater Flow Near the 300 Area, 1997

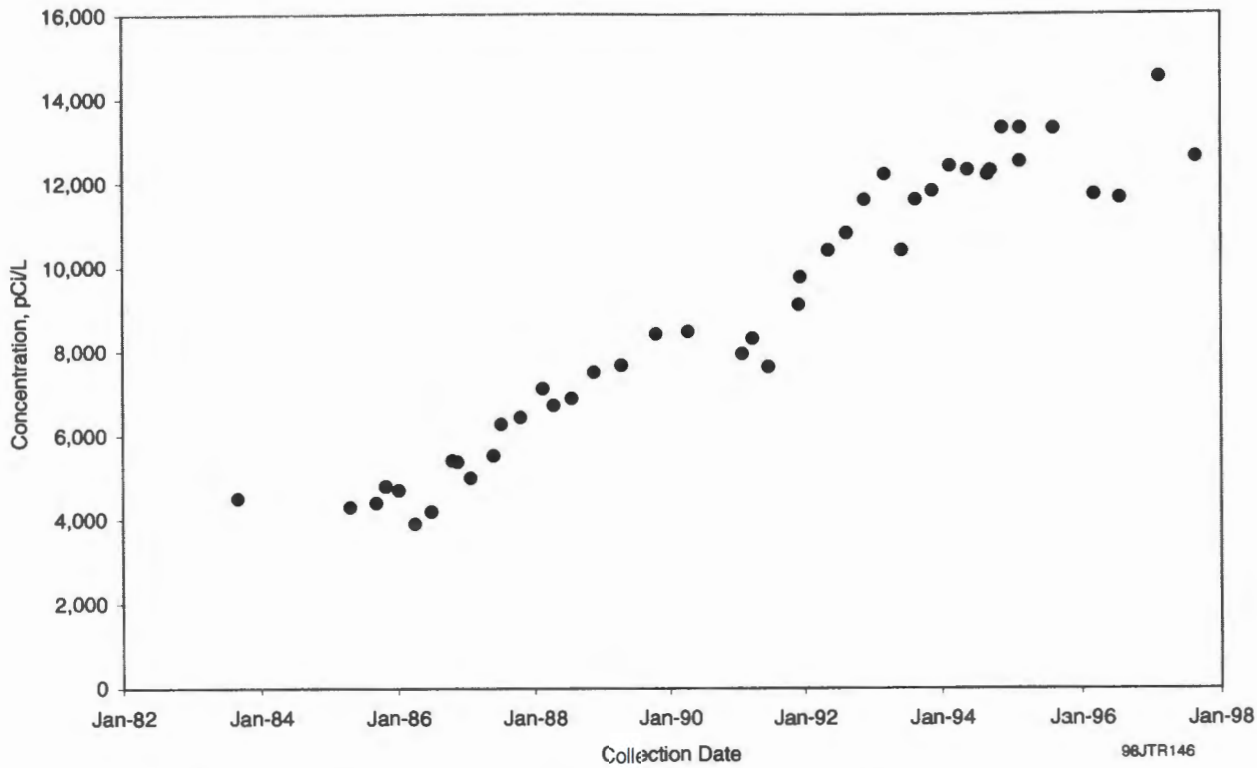


**Figure 6.1.20**. Tritium Concentrations in Well 699-S19-E13, 1982 Through 1997

The tritium plume is not expected to impact the well field and recharge basin because of the influence on groundwater flow from the Yakima River and recharge from infiltration ponds at the well field (see Figure 6.1.19). The Yakima River is at a higher elevation and recharges the groundwater in this area. As a result, groundwater flows from west to east (see Figure 6.1.19), minimizing the southward movement of the contaminant plume. The recharge basin is 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.

***Tritium in the 400 Area***. The tritium plume that originated in the 200-East Area extends under the 400 Area. The maximum concentration observed in this area during 1997 was 38,500 pCi/L at well 499-S1-8K. 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 5,550 pCi/L during 1997. Concentrations at wells used for backup water supply (499-S0-7 and 499-S0-8) 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."

**Iodine-129**. Iodine-129 has a relatively low drinking water standard (1 pCi/L), has the potential for accumulation in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and has a long half-life (16,000,000 years). The relatively low fission yield for production of iodine-129 combined with its long half-life limits its specific activity in Hanford wastes. Iodine-129 may be released as a vapor during fuel dissolution and other elevated temperature processes and, thus, may be associated with process condensate wastes. At the Hanford Site, the main contributor of iodine-129 to 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. No iodine-129 samples showed concentrations above the 500-pCi/L derived concentration guide in 1997.

The distribution of iodine-129 in groundwater in the 200-West Area is shown in Figure 6.1.21. The highest iodine-129 concentration observed in 1997 in Hanford

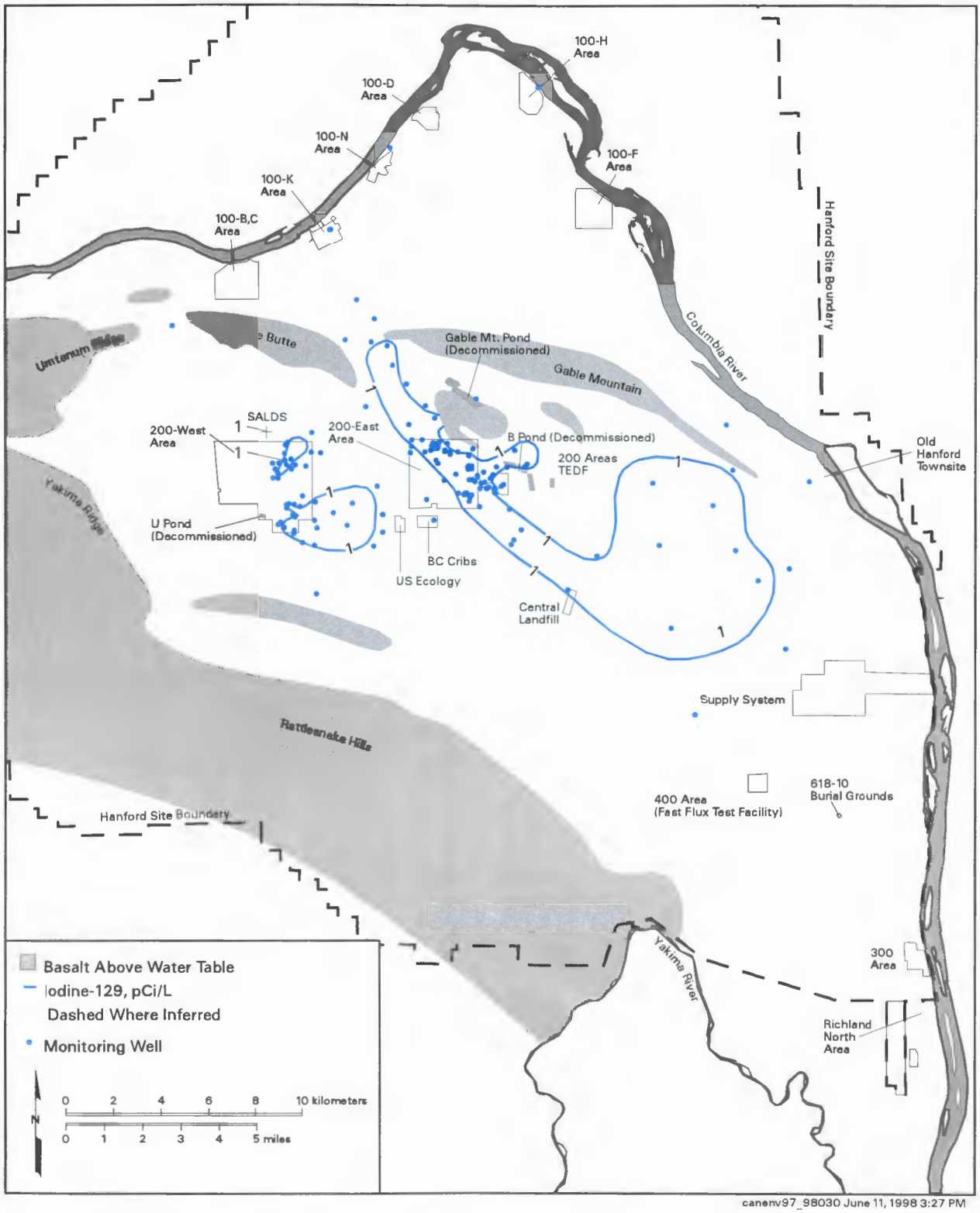


**Figure 6.1.21.** Iodine-129 Distribution in the Unconfined Aquifer, 1997

Site groundwater was 30.6 pCi/L in an area southeast of the 200-West Area and east of 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. In the northern part of the 200-West Area, a second iodine-129 plume originates near the T Tank Farm and nearby disposal facilities and extends northeast toward T Plant. This plume is coincident with the technetium-99 and tritium plumes in this area.

The distribution of iodine-129 in groundwater in the 200-East Area is shown in Figure 6.1.21. 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 1997 in the 200-East Area was 18.1 pCi/L south of the Plutonium-Uranium Extraction Plant near the 216-A-10 Crib. The plume extends from the Plutonium-Uranium Extraction Plant area southeast into the 600 Area and appears coincident with the nitrate and tritium plumes (see Figure 6.1.13). The plume appears smaller than the tritium plume because of the lower initial concentration of iodine-129. The iodine-129 contamination can be detected as far east as the Columbia River but at levels below the 1-pCi/L drinking water standard. Current data indicate that iodine-129 at levels above the drinking water standard is approaching the Columbia River (see Figure 6.1.21). The 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; however, a definite source for this plume has not been determined. This plume extends northwest into the gap between Gable Mountain and Gable Butte.

**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 Site 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 interim drinking water standard in the 100-H, 200-East, and 200-West Areas. The highest concentrations were measured in the 200-West Area.

***Technetium-99 in the 100-H Area***. Technetium-99 concentrations exceeded the 900-pCi/L interim drinking water standard in a localized area downgradient of the former 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 maximum concentration of technetium-99 detected in this area in 1997 was 2,080 pCi/L. The plume, which coincides with the uranium plume, was displaced slightly to the south because of the effects of the unusually high river stage in 1996 and 1997 and by the influence from a pump-and-treat system in the area.

***Technetium-99 in the 200-East Area***. Groundwater in the northwestern part of the 200-East Area and a part of the 600 Area north of the 200-East Area contains technetium-99 at concentrations above the 900-pCi/L interim drinking water standard (see Figure 6.1.22). The source of these technetium plumes was apparently the BY Cribs (Section 5.8.2 in PNL-10698). The technetium-99 plume is associated with cobalt-60, cyanide, and tritium contamination in groundwater. Near the BY Cribs, the maximum concentration observed was 3,000 pCi/L. The maximum technetium-99 concentration north of the 200-East Area in 1997 was 2,490 pCi/L. This plume appears to be moving through the gap between Gable Mountain and Gable Butte. Completion of a treatability test in 1997 showed technetium-99 concentrations falling below the interim drinking water standard in an extraction well (699-50-53A) north of the 200-East Area.

In 1997, high concentrations of technetium-99 were identified at isolated locations near B-BX-BY Tank Farms. The concentrations varied widely in monitoring well 299-E33-41 on the east side of the BX Tank Farm, ranging from 523 pCi/L to a maximum of 12,000 pCi/L in 1997 (Figure 6.1.23). This well had the highest technetium-99 concentration in the 200-East Area in 1997. On the northwestern side of the B-BX-BY Tank Farms, technetium-99 concentrations continued to rise in 1997 (maximum of 760 pCi/L in well 299-E33-42) after increasing sharply in 1996. Some of this contamination is believed to originate from the B-BX-BY Tank Farms (PNNL-11826).

***Technetium-99 in the 200-West Area***. Technetium-99 is also detected at levels greater than the 900-pCi/L interim drinking water standard in the 200-West Area and the adjacent 600 Area (Figure 6.1.24). The largest technetium-99 plume in the 200-West Area originates in the cribs that received effluent from U Plant and extends

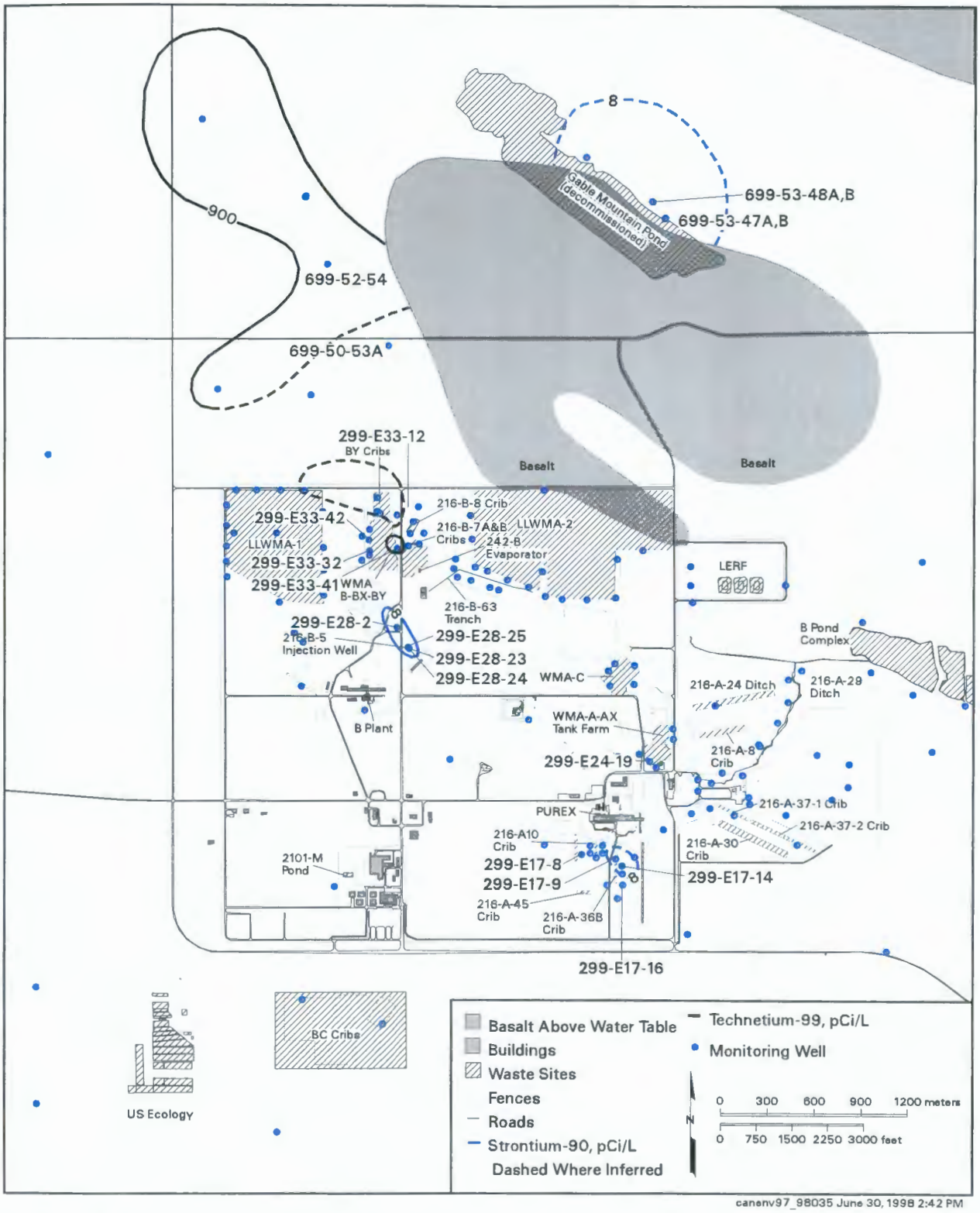


**Figure 6.1.22.** Technetium-99 and Strontium-90 Concentrations in the Unconfined Aquifer Near the 200-East Area, 1997

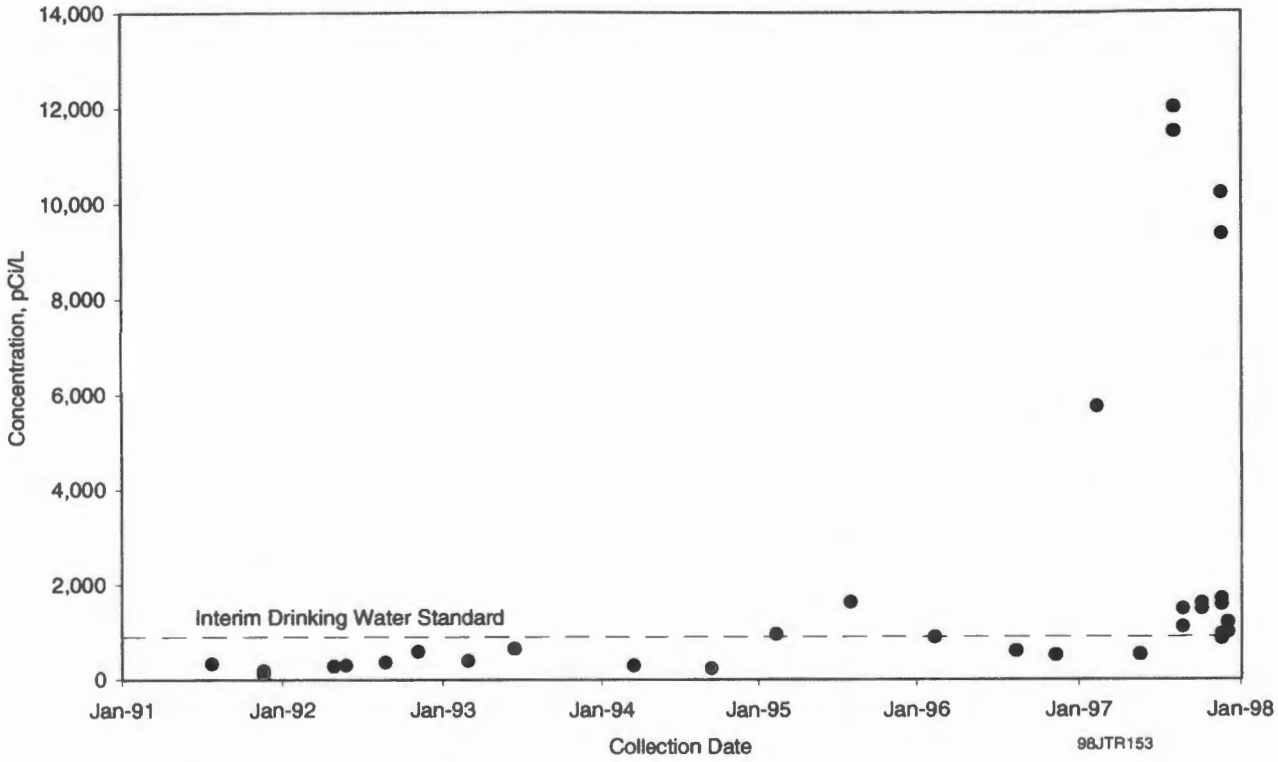


**Figure 6.1.23**. Technetium-99 Concentrations in Well 299-E33-41, 1991 Through 1997

into the 600 Area to the east. The highest concentrations in this plume in 1997 were measured in several wells in the vicinity of the 216-U-17 Crib, where remediation by the pump-and-treat method is occurring. Concentrations in these wells are increasing, indicating that the core of the plume is moving toward the extraction center (well 299-W19-39). The maximum concentration was detected in well 299-W19-28 at a level of 25,500 pCi/L, the highest observed in the 200-West Area in 1997 (Figure 6.1.25).

A pump-and-treat system was implemented near the 216-U-17 Crib to contain and reduce the highest concentrations in the technetium-99 and uranium plumes (Record of Decision 1997). Extracted groundwater was treated using ion exchange and granular, activated carbon (to filter carbon tetrachloride) and returned to the aquifer using an upgradient injection well. Between March 1994 and February 1997, greater than 131,500,000 L of groundwater had been treated and 37.8 g of technetium-99 had been removed. In February 1997, the pump-and-treat system was shut down to modify the treatment operation. Between April and September 1997, greater than 49,400,000 L of groundwater had been transported to the 200 Areas Effluent Treatment Facility, where 5.6 g of technetium-99 had been removed (BHI-01126). The upgradient injection well is no longer used.

A technetium-99 plume in the vicinity of the T and TX-TY Tank Farms extends to the north. Two wells that monitor these tank farms consistently showed technetium-99 concentrations above the interim drinking water standard in 1997. Near the TX-TY Tank Farms, well 299-W14-12 consistently showed technetium-99 concentrations at steady levels just above the interim drinking water standard in 1997 after showing a sharp decline in 1995 and 1996. In the northeastern corner of T Tank Farm at well 299-W11-27, technetium-99 levels increased sharply in 1996, reached a maximum of 21,700 pCi/L in early 1997, and then fell to a level just above the interim drinking water standard in late 1997, as shown in Figure 6.1.26. The source of this technetium-99 pulse was assessed, and it was concluded that the T and TX-TY Tank Farms were the sources (PNNL-11809)

The small plume in the southern part of the 200-West Area originates near the S-SX Tank Farms and the 216-S-13 Crib. The maximum concentration detected in this area was approximately 5,000 pCi/L near the southeastern corner of the SX Tank Farm. The concentrations

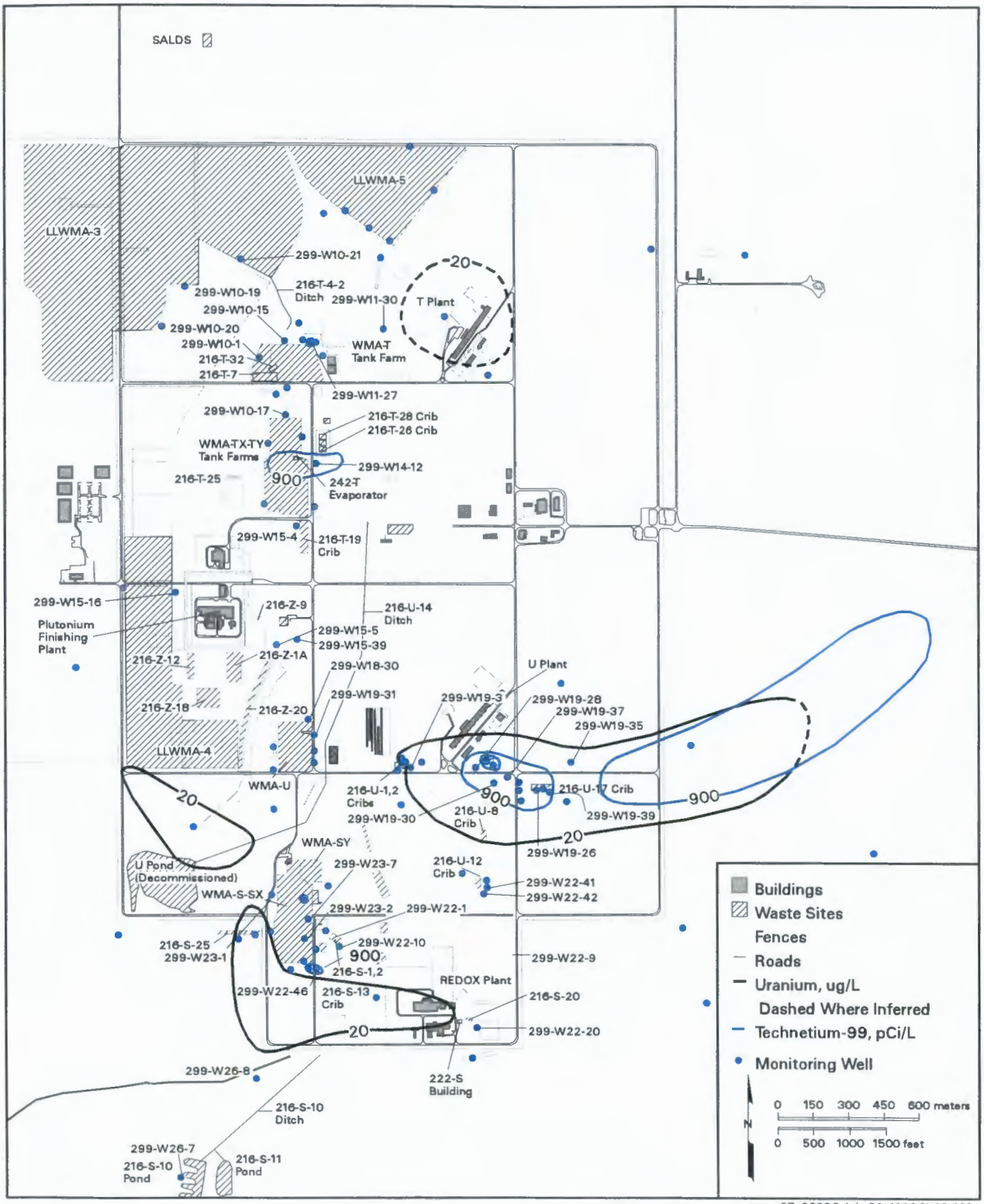


**Figure 6.1.24.** Technetium-99 and Uranium Concentrations in the Unconfined Aquifer in the 200-West Area, 1997

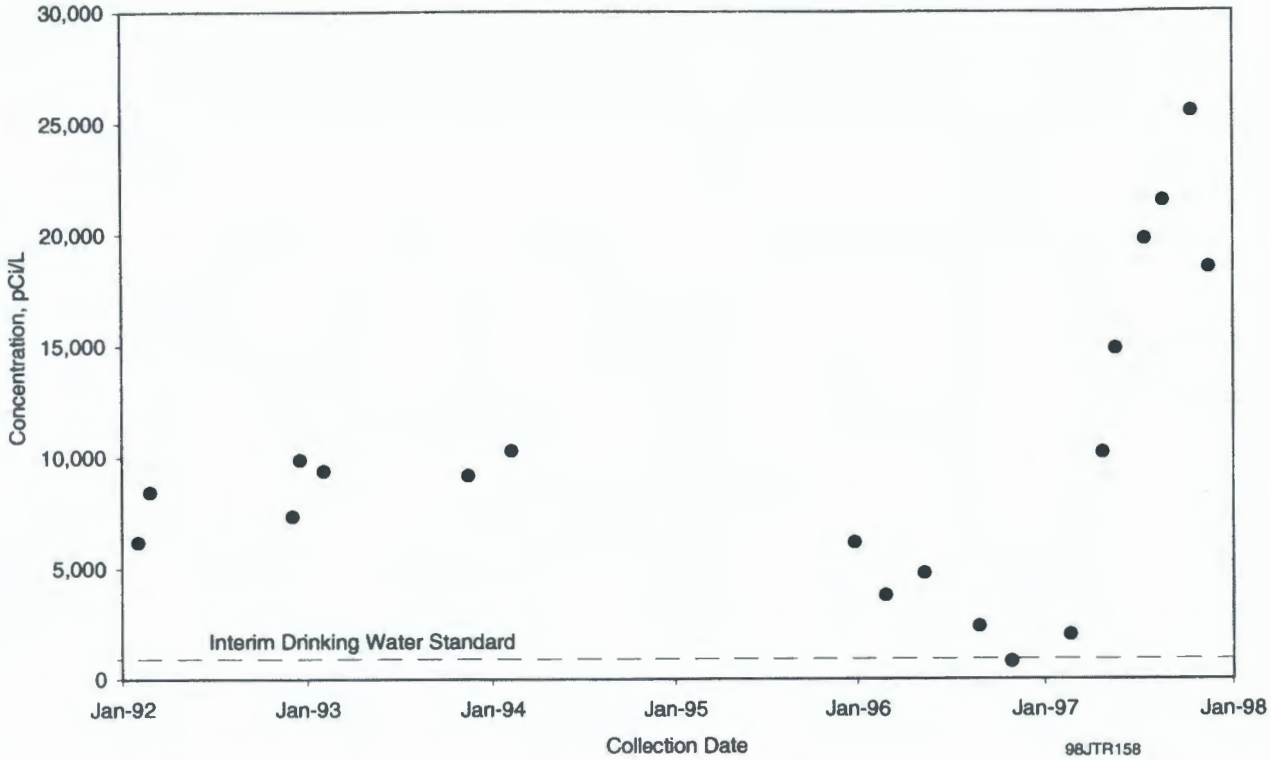


**Figure 6.1.25**. Technetium-99 Concentrations in Well 299-W19-28, 1992 Through 1997

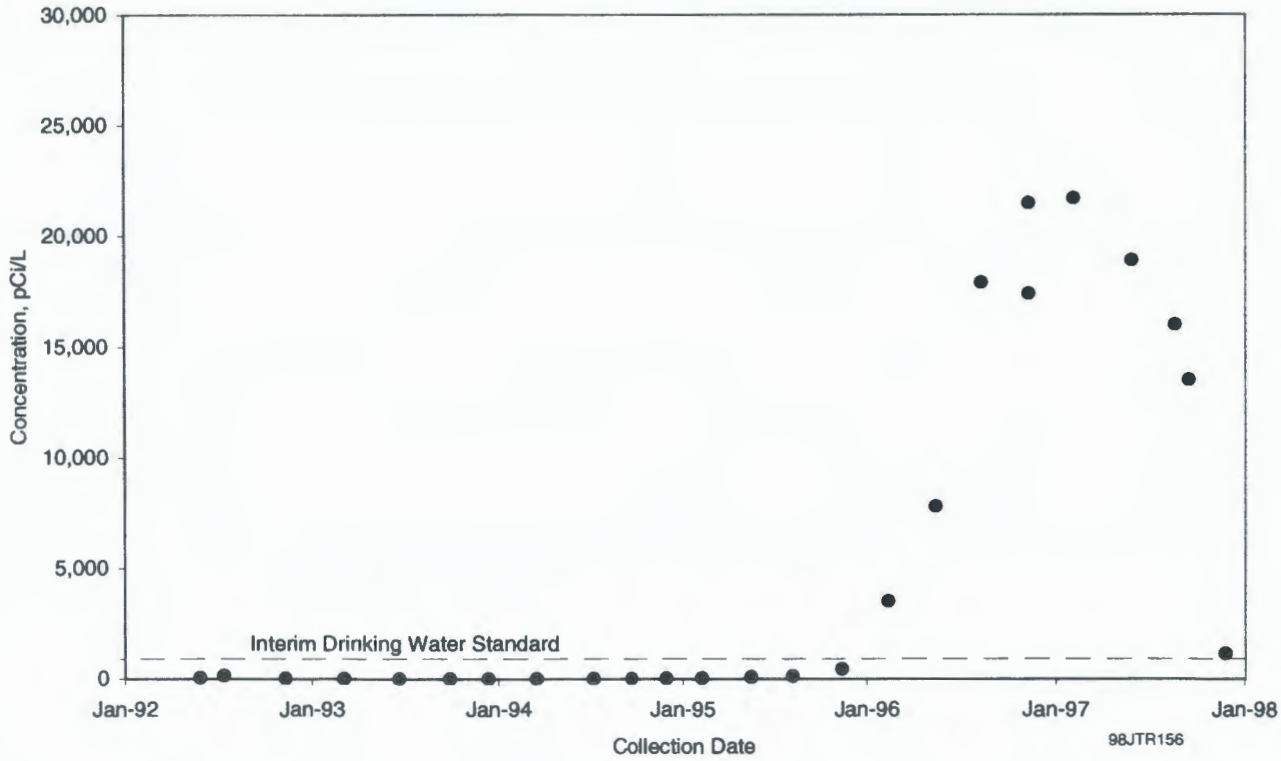


**Figure 6.1.26**. Technetium-99 Concentrations in Well 299-W11-27, 1992 Through 1997

in this well increased significantly in late 1996 and early 1997. Leakage from the single-shell tanks is believed to be a source of the technetium-99 in this vicinity (PNNL-11810).

**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 Site 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. The derived concentration guide that represents the 100-mrem/yr dose equivalent for uranium is 790 µg/L.

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 the Hanford Site in 1997 were near U Plant in the 200-West Area and were above the derived concentration guide.

***Uranium in the 100 Areas***. In 1997, uranium was detected at a concentration greater than the 20-µg/L proposed drinking water standard in one well near F Reactor in the 100-F Area (Figure 6.1.27). The maximum concentration detected was 47.6 µg/L.

Uranium was detected at levels higher than the proposed drinking water standard in several wells in the 100-H Area (Figure 6.1.28). The maximum concentration detected in 1997 was 159 µg/L near the 183-H Solar Evaporation Basins. Past leakage from these basins is considered to be the source of the 100-H Area uranium contamination. These basins were remediated in 1996.

***Uranium in the 200 Areas***. In 1997, several wells in the northwestern part of the 200-East Area contained uranium at concentrations greater than the 20-µg/L proposed drinking water standard. The distribution of uranium in this area suggests that contamination is of limited extent with the highest concentrations in the vicinity of the B-BX-BY Tank Farms, BY Cribs, and 216-B-5 Injection Well that has been inactive since 1947. However, the magnitude and extent of uranium contamination has increased since 1991 north and east of the B-BX-BY Tank Farms. The highest concentration detected was 203 µg/L northeast of the B-BX-BY Tank Farms (and east of the BY Cribs). The source of the uranium contamination in this area is unclear. Near the inactive 216-B-5 Injection Well, two wells showed uranium concentrations greater than the proposed drinking water standard. The highest concentration was 52 µg/L.

The highest uranium concentrations in Hanford Site groundwater occurred near U Plant in the 200-West Area, at wells adjacent to the inactive 216-U-1, 216-U-2, and 216-U-17 cribs (see Figure 6.1.24). These concentrations exceeded the 790-µg/L derived concentration guide for uranium. The maximum uranium concentration detected in this area in 1997 was 2,870 µg/L west of the 216-U-17 Crib. Uranium concentrations in this area have been increasing as a result of a pump-and-treat operation of an extraction well (299-W19-39) located near the 216-U-17 Crib. These increasing concentrations indicate that the core of the uranium plume is moving toward the extraction center. This uranium plume extends east into the 600 Area along with the technetium-99 plume discussed above.

The pump-and-treat system removed 45.8 kg of uranium between March 1994 and February 1997. Between April and September 1997, 11 kg of uranium had been removed from extracted groundwater (BHI-01126).

Other areas within the 200-West Area with uranium contamination are also shown in Figure 6.1.24, 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. The maximum uranium concentration in these areas is 154 µg/L immediately downgradient of the 216-S-13 Crib (just west of the Reduction-Oxidation Plant). In the northern part of the 200-West Area, a localized area of uranium contamination, where a single sample showed a concentration above the proposed drinking water standard in 1997, was found near T 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 6.1.29). The major source of the contamination is the inactive 316-5 Process Trenches, as indicated by the distribution of the uranium concentrations downgradient from these trenches (see Section 5.13.3.1 in

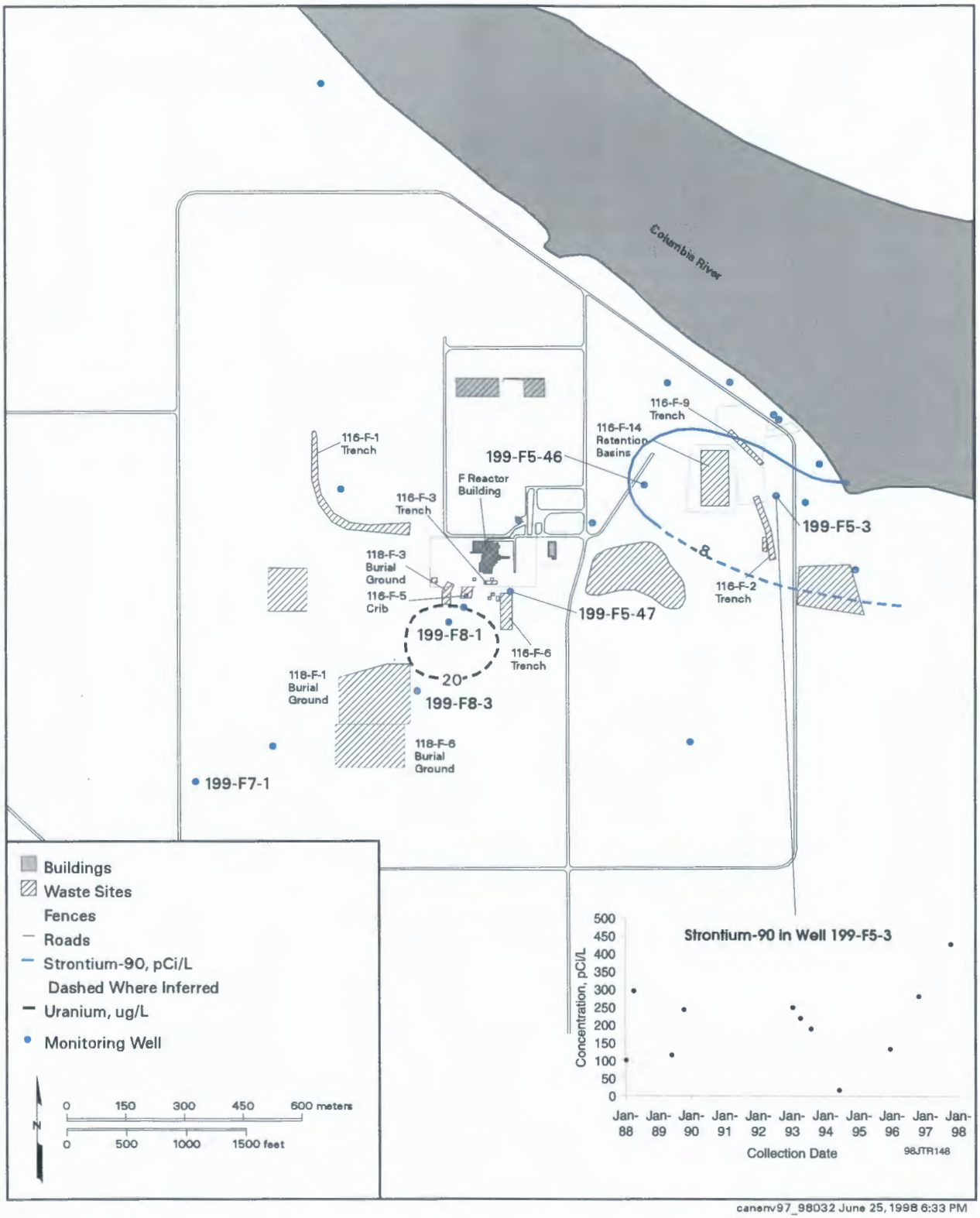


**Figure 6.1.27.** Uranium and Strontium-90 Concentrations in the Unconfined Aquifer in the 100-F Area, 1997, and Concentration Trends in Well 199-F5-3

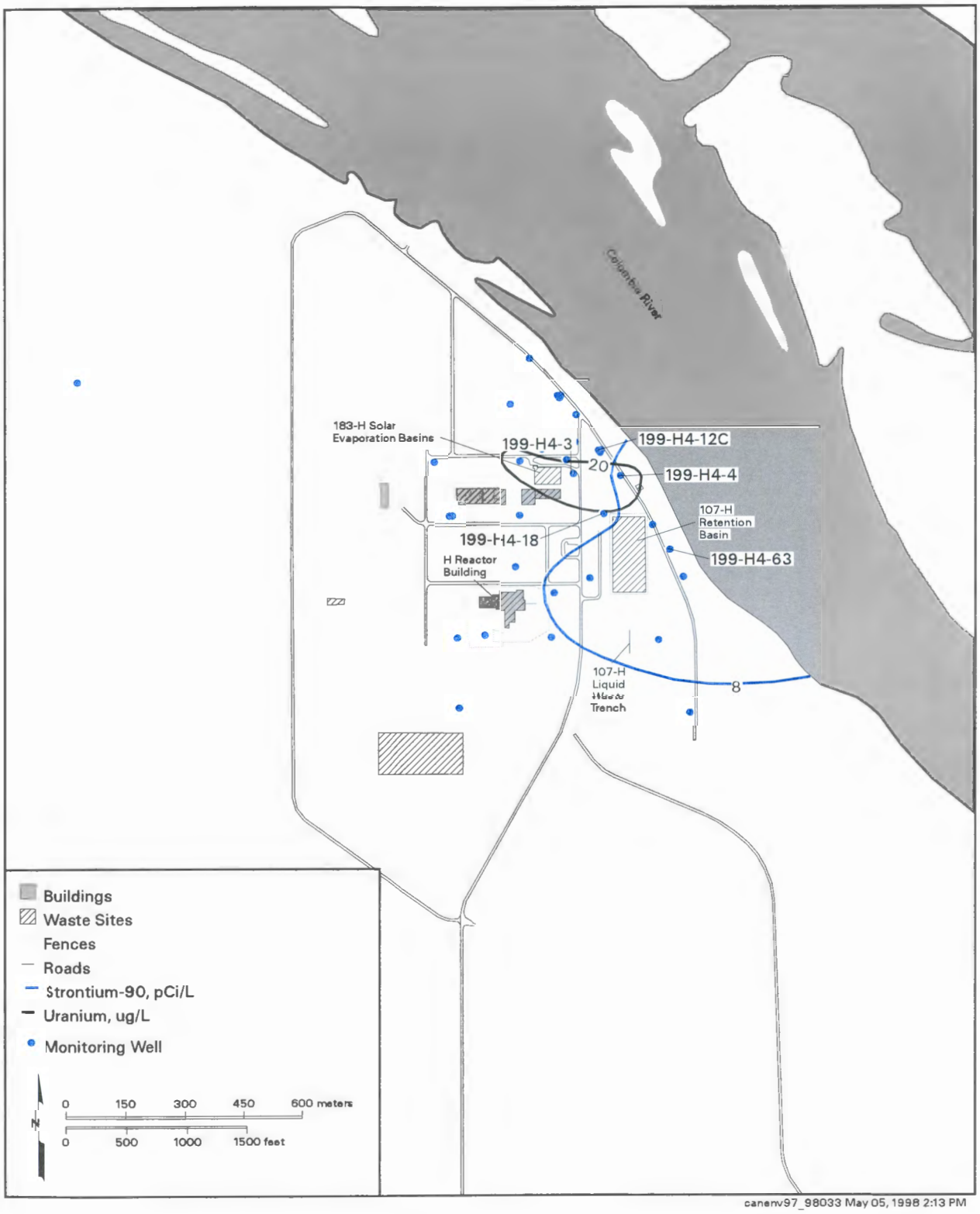


**Figure 6.1.28**. Uranium and Strontium-90 Concentrations in the Unconfined Aquifer in the 100-H Area, 1997

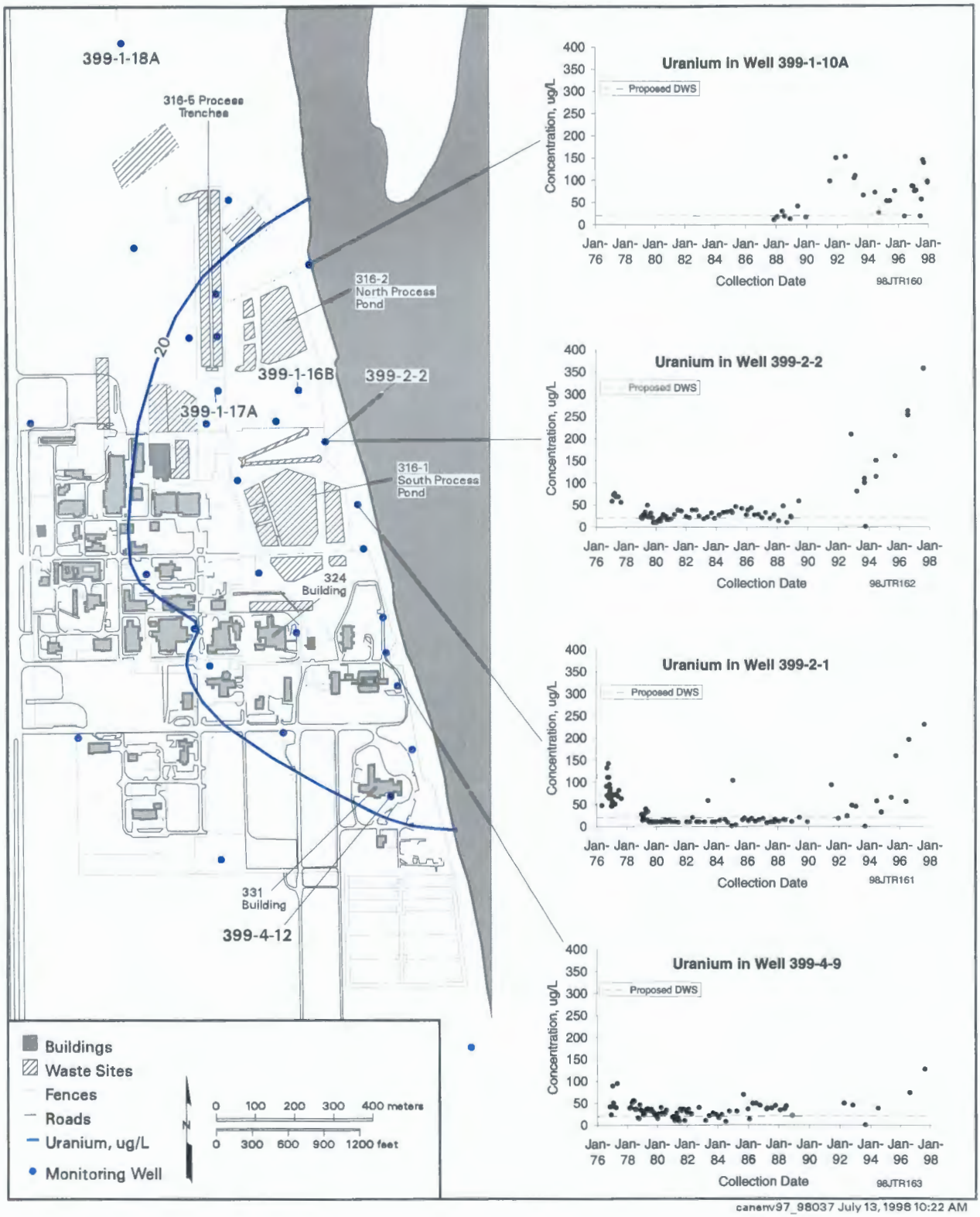


**Figure 6.1.29.** Uranium Concentrations in the Unconfined Aquifer in the 300 Area, 1997, and Concentration Trends for Selected Wells

PNNL-11793). Movement of the uranium plume toward the Columbia River has resulted in increased uranium concentrations near the Columbia River in recent years, as shown by the trend plots for wells 399-2-1 and 399-2-2 or Figure 6.1.29. The maximum concentration of uranium detected in 1997 was 358 µg/L.

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 was resumed following completion of the remedial action; however discharge to the trenches was much lower than before the expedited response action. As a result, uranium levels in well 399-1-17A, located closest to the inflow portion of the trenches, dropped to approximately the 20-µg/L proposed drinking water standard following the remedial action (Figure 6.1.30). In late 1994 and early 1995, uranium levels increased sharply in response to a complete cessation of discharge to the trenches in December 1994. The increased uranium concentrations since the discharges were terminated indicate that the soil column is contributing uranium contamination to the groundwater.

Between 1996 and 1997, a localized area of high uranium concentrations (maximum of 130 µg/L) near the 324 Building moved downgradient toward the Columbia River (see trend plot in Figure 6.1.29).

***Uranium in the 600 Area.*** The measured uranium concentration in groundwater southeast of the 400 Area dropped from 768 µg/L in 1995 to 108 µg/L in 1996, following renovation of the well. However, the concentration increased to a maximum of 225 µg/L in 1997. The contamination at this well is attributed to the nearby inactive 316-4 Crib (Section 6.12.2.4 in PNNL-11470, Section 5.12.3.3 in PNNL-11793). The retired 618-10 Burial Grounds are also located near this well.

**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 Site groundwater is reduced by adsorption onto sediment particles. However, strontium-90 is moderately mobile in groundwater because its adsorption is much weaker than for other isotopes such as cesium-137 and plutonium. Because of sorption, a large proportion of the strontium-90 in the subsurface is not present in solution.

In 1997, concentrations of strontium-90 greater than the 8-pCi/L interim drinking water standard were found in one or more wells in each of the following areas: 100, 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, 200-East, and 600 Areas. Maximum concentrations were detected in the 100-N Area during 1997. The strontium-90 concentrations in the 100-K Area were first detected above the derived concentration guide in 1996.

***Strontium-90 in the 100 Areas.*** Strontium-90 is found at levels greater than the 8-pCi/L interim drinking water standard in the northeastern part of the 100-B,C Area between the B Reactor and the Columbia River. The maximum concentration detected in this area in 1997 was 68 pCi/L at monitoring well 199-B3-1. The extent of strontium-90 contamination greater than the standard in the 100-B,C Area is shown in Figure 6.1.31. 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/EIS-0119F).

In the 100-D Area, two wells showed strontium-90 concentrations greater than the 8-pCi/L interim drinking water standard. The maximum level (35.2 pCi/L) was reported in well 199-D8-68, located in the northern part of the 100-D Area near the Columbia River. This is the first time that elevated strontium-90 has been observed in this part of the 100-D Area. Well 199-D8-68 will be sampled for strontium-90 in 1998 to confirm this elevated result. Strontium-90 continues to be detected at levels greater than the interim drinking water standard near the D Reactor fuel storage basin trench.

The 100-F Area strontium-90 plume is shown in Figure 6.1.27. In a small area near the Columbia River, groundwater has strontium-90 concentrations greater than the 8-pCi/L interim drinking water standard. The maximum concentration detected in 1997 was 429 pCi/L. This concentration is an increase from 282 pCi/L measured in 1996, as shown by the trend plot in Figure 6.1.27.

In the 100-H Area, strontium-90 contamination levels greater than the 8-pCi/L interim drinking water standard were present in an area adjacent to the Columbia River near the 107-H Retention Basin, as shown in Figure 6.1.28. The maximum concentration detected in the 100-H Area in 1997 was 51.2 pCi/L between the 107-H Retention Basin and the Columbia River.

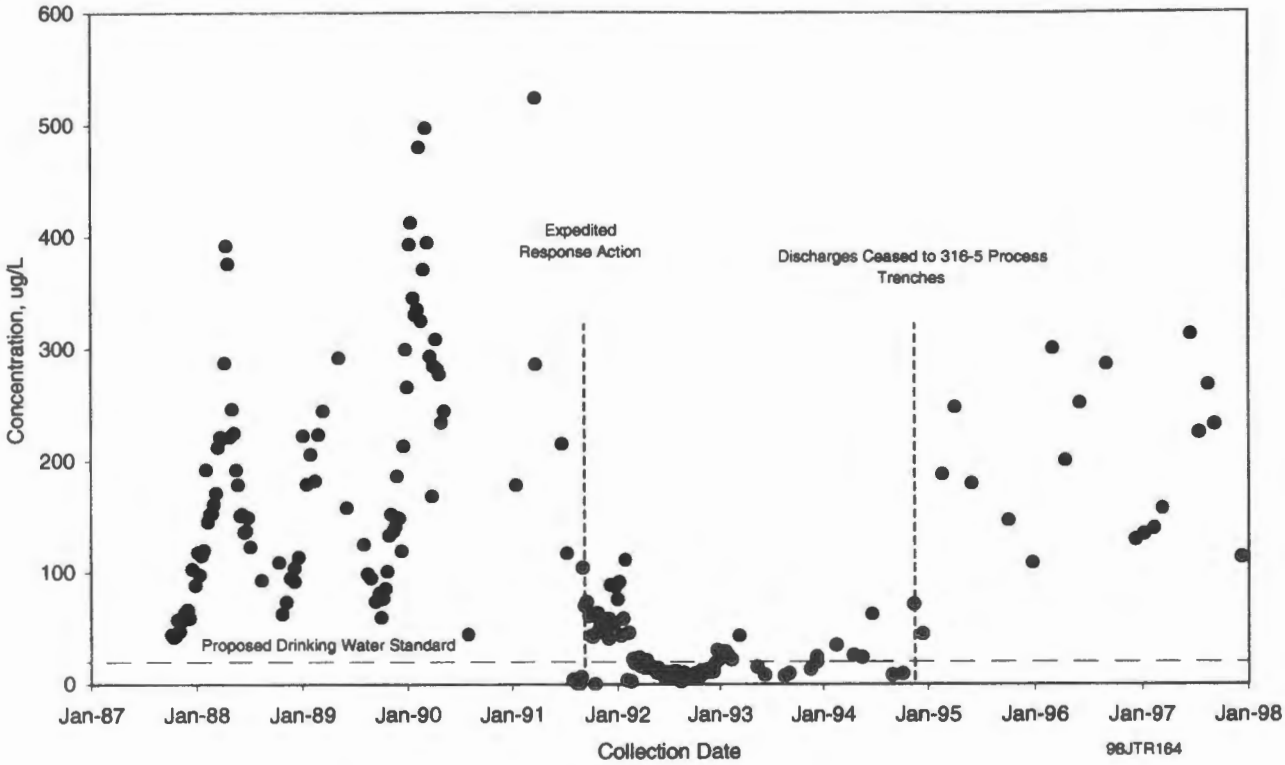


**Figure 6.1.30**. Uranium Concentrations in Well 399-1-17A, 1987 Through 1997

The extent of strontium-90 at levels greater than the 8-pCi/L interim drinking water standard in the 100-K Area is shown in Figure 6.1.32. Localized plumes occur in the vicinity of the KE and KW Reactors and between the 116-K-2 Liquid Waste Disposal Trench and the Columbia River. The maximum concentration detected in 1997 was 18,600 pCi/L at well 199-K-109A, the only well in the 100-K Area where concentrations were above the 1,000-pCi/L derived concentration guide. Maximum strontium-90 concentrations near the KW Reactor and the disposal trench were significantly lower than those near KE Reactor by approximately three orders of magnitude.

In the 100-N Area, strontium-90 was detected at concentrations greater than the 1,000-pCi/L derived concentration guide in approximately 10 wells in 1997. Most of these wells are located between the 1301-N Liquid Waste Disposal Facility, a source of the strontium-90, and the Columbia River. The 1325-N Liquid Waste Disposal Facility is also a source of strontium-90 in groundwater. The average concentrations were generally higher in 1997 than during previous years because of the unusually high river stage during 1997. As the river stage rises, the water table near the river rises into the vadose zone, causing strontium-90 to desorb from the saturated sediments and to increase the concentrations in groundwater. As water levels fall, strontium-90 adsorbs to sediments that become unsaturated. This is illustrated by Figure 6.1.33, which shows a comparison of the strontium-90 concentrations and water-table elevation at well 199-N-2. The maximum level detected in 1997 was 25,000 pCi/L near the head end of the 1301-N Liquid Waste Disposal Facility (well 199-N-67).

The movement of the strontium-90 plume northward in the 1980s is illustrated by the trend plot for well 199-N-14 in Figure 6.1.32. 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," discuss the results of riverbank springs water sampling.

Remediation of strontium-90 in the 100-N Area by the pump-and-treat method began in 1995 (BHI-01126). The objective is to pump from the extraction wells to create a hydraulic barrier between the river and the 1301-N facility, thus reducing the groundwater discharge rate and strontium-90 flux to the river. The unusually high river stage also contributed to this hydraulic barrier. The

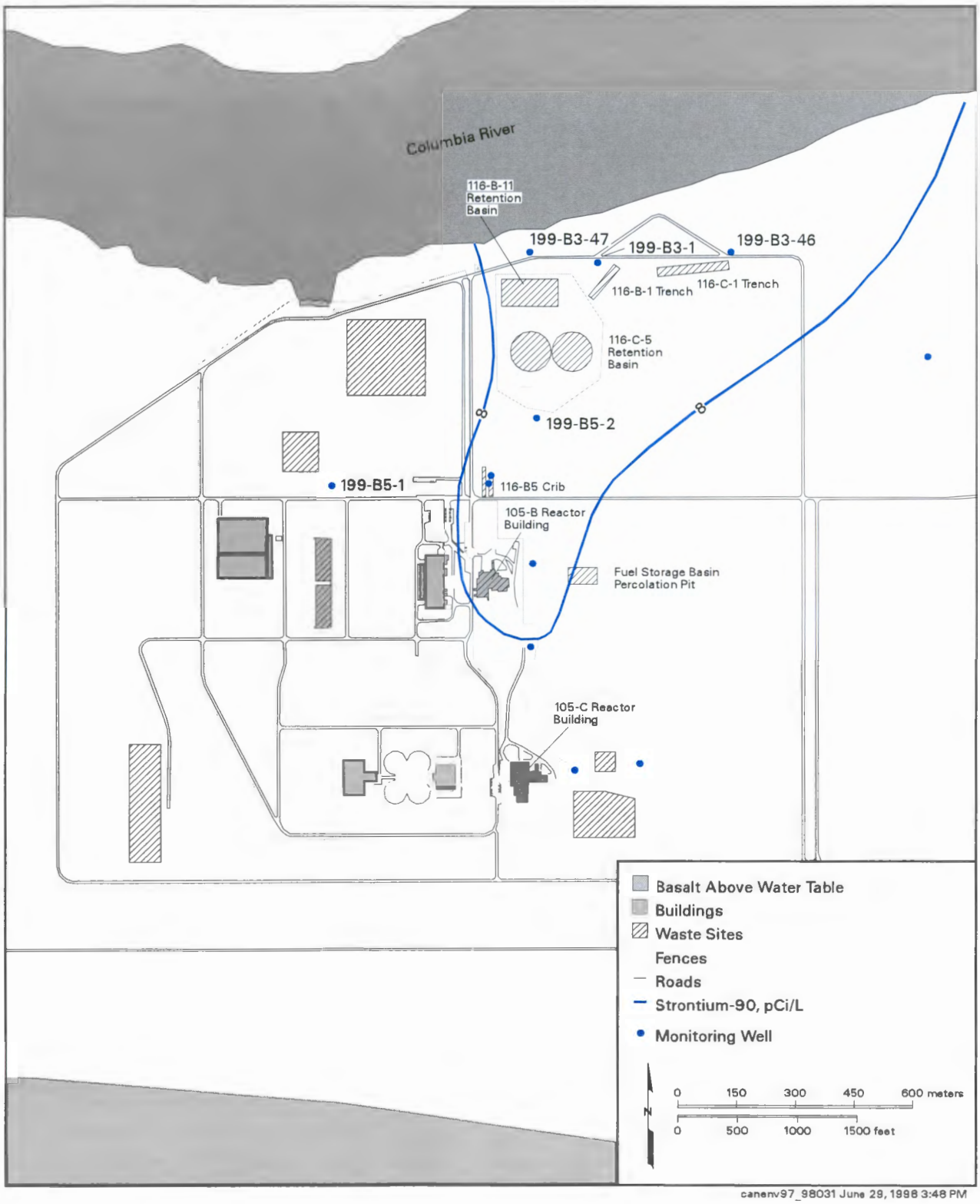


**Figure 6.1.31**. Strontium-90 Concentrations in the Unconfined Aquifer in the 100-B,C Area, 1997

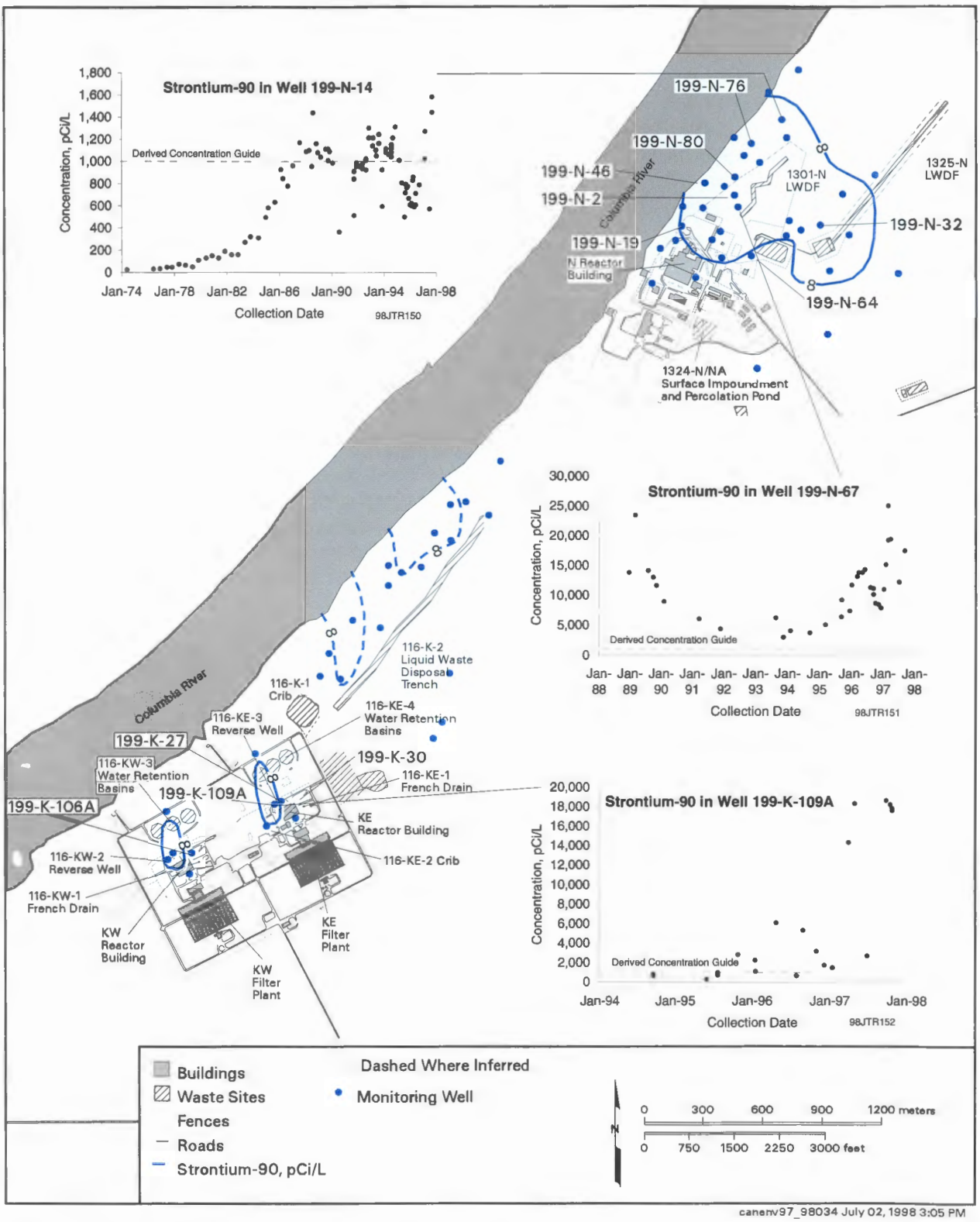


**Figure 6.1.32.** Strontium-90 Concentrations in the Unconfined Aquifer in the 100-K and 100-N Areas, 1997, and Concentration Trends in Selected Wells

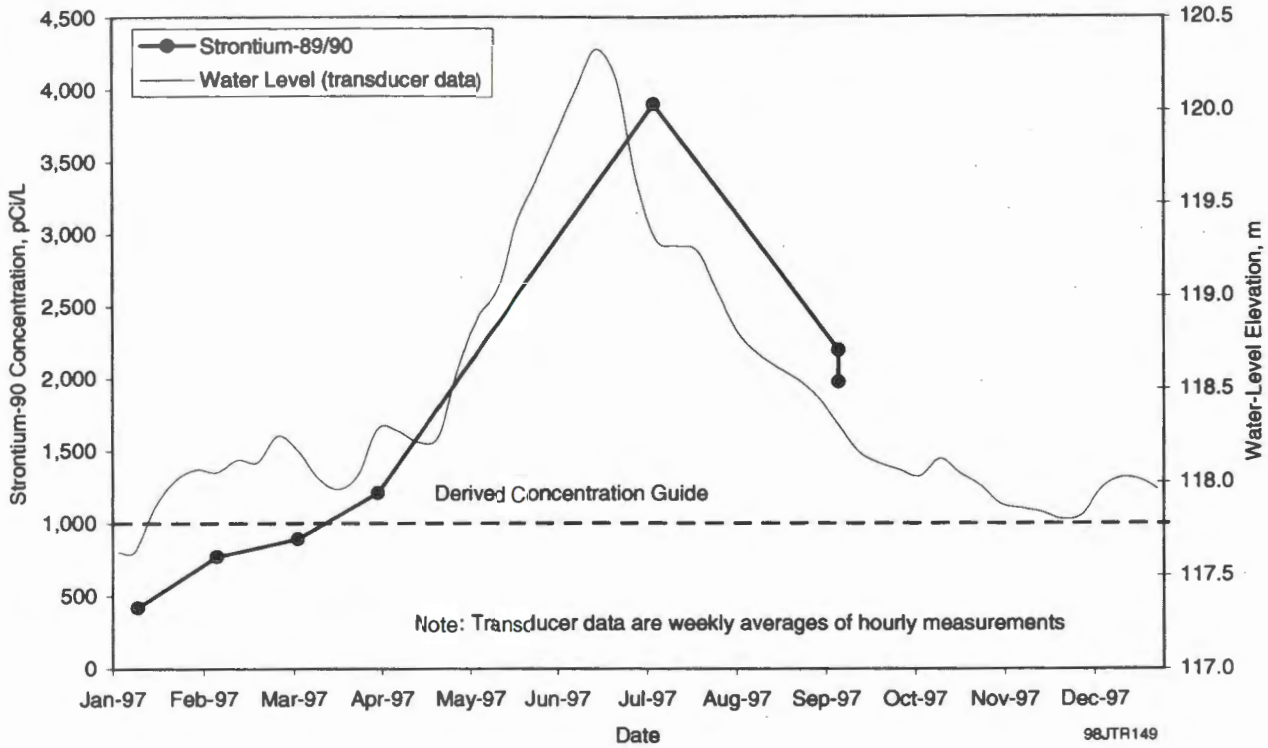


**Figure 6.1.33**. Strontium-90 Concentrations and Water-Table Elevations in Well 199-N-2, 1997

pump-and-treat system uses ion exchange technology to remove strontium-90 from the extracted groundwater and has performed as planned. During 1997, approximately 0.17 Ci of strontium-90 was removed from groundwater (BHI-01126).

***Strontium-90 in the 200 Areas***. Strontium-90 distribution in the 200-East Area is shown in Figure 6.1.22. Concentrations of strontium-90 in the 200-East Area were above the 1,000-pCi/L derived concentration guide in two wells near the 216-B-5 Injection Well. The maximum concentration was 9,630 pCi/L in well 299-E28-23. Strontium-90 increased to 145 pCi/L in one well located approximately 150 m (490 ft) from the inactive 216-B-5 Injection Well. Strontium-90 continued to be detected at a level above the 8-pCi/L interim drinking water standard in one well near the Plutonium-Uranium Extraction Plant cribs.

***Strontium-90 in the 600 Area***. In the 600 Area, the highest concentrations of strontium-90 were detected in four wells in the former Gable Mountain Pond area (see Figure 6.1.22). These concentrations were near or exceeded the 1,000-pCi/L derived concentration guide and reached a maximum of 1,320 pCi/L in 1997. Strontium-90 contamination in this area resulted from the discharge of radioactive waste to the former Gable Mountain Pond during its early use.

**Cesium-137**. Cesium-137 is produced as a high yield fission product and is present in waste streams associated with fuel processing. Former reactor operations may have also resulted 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 Site groundwater. The interim drinking water standard for cesium-137 is 200 pCi/L; the derived concentration guide is 3,000 pCi/L.

Cesium-137 was detected in three wells located near the inactive 216-B-5 Injection Well in the 200-East Area. The injection well received cesium-137 bearing wastes from 1945 to 1947. The maximum cesium-137 concentration in 1997 was above the 200-pCi/L interim drinking water standard at a level of 2,250 pCi/L. This is an increase from a concentration of 1,470 pCi/L last measured in 1995. Cesium-137 appears to be restricted to the immediate vicinity of the former injection well because of its extremely low mobility in groundwater.

**Cobalt-60**. Cobalt-60 is 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. All groundwater samples analyzed for cobalt-60 in 1997 were below the 100-pCi/L interim drinking water standard. The derived concentration guide for cobalt-60 is 5,000 pCi/L.

Cobalt-60 concentrations were less than half the interim drinking water standard in the northwestern part of the 200-East Area and the adjacent 600 Area north of the 200-East Area, which are the same areas where the technetium-99 contamination associated with the BY Cribs is found. Apparently, cobalt in this plume is mobilized by reaction with cyanide or ferrocyanide in the waste stream, forming a dissolved cobalt species. The maximum concentration measured in 1997 was 34 pCi/L. Cobalt-60 was last detected in this area in 1995 at 166 pCi/L, which is above the 100-pCi/L interim drinking water standard (Section 4.8 in PNNL-11139). Because of its relatively short half-life (5.3 years), much of the cobalt-60 in groundwater in this area has decayed.

**Plutonium**. Plutonium has been released to the soil column in several locations in both the 200-East and 200-West Areas. Plutonium is generally considered to sorb strongly on sediments and, thus, has limited mobility in the aquifer. The derived concentration guide for both plutonium-239 and plutonium-240 is 30 pCi/L. Analytical detection is incapable of distinguishing between plutonium-239 and plutonium-240. Thus, the results are expressed as a concentration of plutonium-239,240. There is no explicit drinking water standard for plutonium-239,240; however, the gross 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.

The only location where plutonium isotopes were detected in groundwater was near the inactive 216-B-5 Injection Well in the 200-East Area. Groundwater sampled during 1997 at wells located near this injection well ranged up to 67 pCi/L of plutonium-239,240. These values are lower than those measured in 1996. Because plutonium is strongly sorbed on 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. The injection well received an estimated 244 Ci of plutonium-239,240 during its operation from 1945 to 1947 (PNL-6456).

## 6.1.7 Chemical Monitoring Results for the Unconfined Aquifer

In recent years, chemical analyses performed by various monitoring programs at the Hanford Site have identified several hazardous chemicals in groundwater at concentrations greater than their respective drinking water standards. Nitrate, chromium, and carbon tetrachloride are the most widely distributed of these hazardous chemicals and have the highest concentrations in groundwater at the Hanford Site. Chemicals that are less widely distributed and have lower concentrations in groundwater include chloroform, cis-1,2-dichloroethylene, cyanide, fluoride, and trichloroethylene.

A number of parameters such as pH, specific conductance, total carbon, total organic carbon, and total organic halides are used as indicators of contamination. These are mainly discussed in Section 6.1.9, "Resource Conservation and Recovery Act Summary." Other chemicals and parameters listed in Table 6.1.3 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 occur naturally 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 a summary of the chemical constituents occurring in groundwater at concentrations greater than existing or proposed drinking water standards (40 CFR 141 and EPA 822-R-96-001; see Appendix C). Although cyanide concentrations are less than the drinking water standard and have stabilized, a brief discussion of cyanide occurrence in groundwater is presented because of its implications for cobalt-60 mobility.

### 6.1.7.1 Nitrate

Many groundwater samples collected in 1997 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,C 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 6.1.34; 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 small. The widespread distribution of nitrate below the drinking water standard is shown in Figure 5.2-2 of PNNL-11793.

**Nitrate in the 100 Areas**. Nitrate is found at levels greater than the 45-mg/L drinking water standard in much of the 100-D Area. The highest nitrate concentration found in the 100-D Area in 1997 was 103 mg/L in the southwestern part of the area. Slightly lower concentrations were found in the northeastern part of the 100-D Area.

The central and southern portions of the 100-F Area contain nitrate in groundwater at levels greater than the drinking water standard. This plume appears to extend to the south and southeast into the 600 Area from upgradient sources near F Reactor. In the vicinity of the reactor, groundwater flow was to the southeast in 1997. The maximum nitrate detected in the 100-F Area in 1997 was 287 mg/L in the southwestern part of the 100-F Area.

Nitrate above the drinking water standard in the 100-H Area is restricted to a small area downgradient of the former 183-H Solar Evaporation Basins; however, the concentrations are some of the highest onsite. In this small area, the maximum nitrate concentration was detected at a level of 730 mg/L, which was the maximum concentration reported onsite in 1997. These high levels of nitrate exhibit trends related to groundwater levels and Columbia River stage.

Nitrate at levels greater than the drinking water standard in the 100-K Area is found downgradient of both the KE and KW Reactors. The maximum concentration detected in 1997 was 218 mg/L in a well adjacent to the 116-K-2 Liquid Waste Disposal Trench.

Although detected over most of the 100-N Area, nitrate contamination above the 45-mg/L drinking water standard occurs at isolated locations in the 100-N Area. The 367 mg/L maximum was detected in a 1997 sample from between the 1301-N Liquid Waste Disposal Facility and the Columbia River. Another elevated concentration was 280 mg/L along the Columbia River downgradient of the 1324-N/NA Surface Impoundment and Percolation Pond.

**Nitrate in the 200-East Area**. The nitrate plume in the 200-East Area covers a nearly identical area to that of the tritium plume. However, the area with nitrate exceeding the 45-mg/L drinking water standard is smaller than the area with tritium exceeding its drinking water standard. Nitrate exceeds the drinking water standard near the Plutonium-Uranium Extraction Plant and near cribs in the northern part of the 200-East Area. In 1997, the highest concentrations were reported in several wells near the 216-B-8 and BY Cribs. The maximum concentration in the 200-East Area was 357 mg/L adjacent to the 216-B-8 Crib. High nitrate concentrations in the 600 Area north of the 200-East Area, ranging up to 120 mg/L, are apparently related to past disposal practices at the BY Cribs.

High nitrate concentrations 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 was 145 mg/L adjacent to the 216-A-10 Crib.

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 in 1997 was 147 mg/L.

**Nitrate in the 200-West Area**. Nitrate concentrations greater than the 45-mg/L 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. Some of the highest nitrate concentrations across the site continued to be found in wells southeast of U Plant, where the maximum concentration detected in 1997 was 673 mg/L. Near the 216-U-17 Crib, one well showed a concentration of 1,100 mg/L in 1996, but was not sampled during 1997. This 1,100 mg/L concentration was consistent

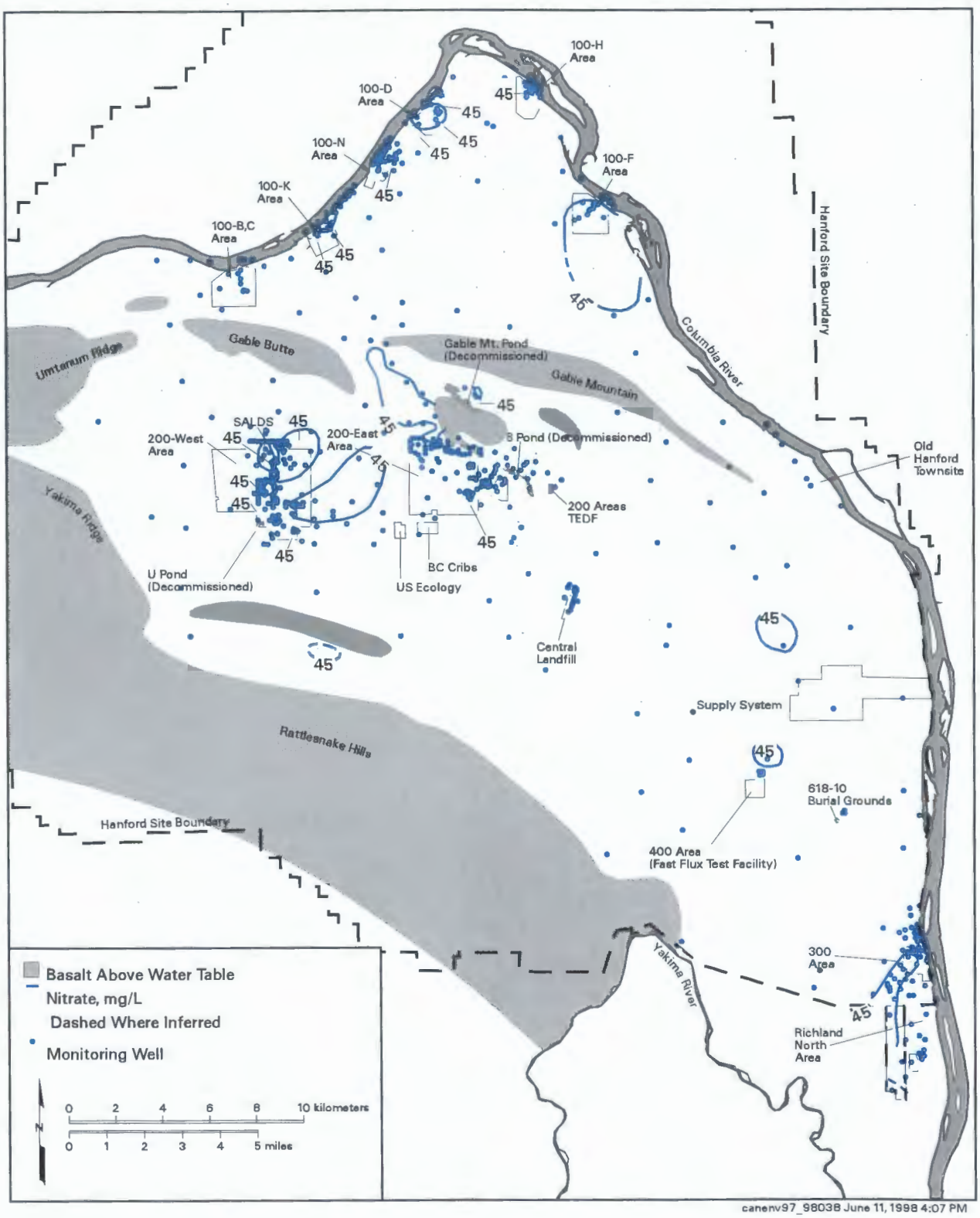


**Figure 6.1.34.** Nitrate Distribution in the Unconfined Aquifer, 1997

with previous data from this well. 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 southwest of U Plant. These cribs received over 1,000,000 kg (2,200,000 lb) of nitrate bearing chemicals during their operation from 1951 to 1967 (PNL-6456). 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. Between April and September 1997, a pump-and-treat system near the 216-U-17 crib removed 2,260 kg (4,980 lb) of nitrate from extracted groundwater (BHI-01126).

Nitrate concentrations (maximum of 303 mg/L) continued to be above the drinking water standard near other cribs to the south that are associated with the U Plant and Reduction-Oxidation Plant. These elevated levels represent nitrate plumes that coalesce with the plume emanating from the U Plant area. A small, isolated plume of elevated nitrate occurs west of the Reduction-Oxidation Plant near the 216-S-25 Crib and S-SX Tank Farm, where the maximum concentration was 130 mg/L.

A large area, encompassing the northern half of the 200-West Area, continued to contain nitrate in groundwater at concentrations much greater than the 45-mg/L drinking water standard. Wells showing the highest concentrations are located near several inactive liquid waste disposal facilities that received waste from early T Plant operations. A large amount of nitrate was disposed to these cribs (e.g., approximately 2,300,000 kg [5,100,000 lb] of nitrate bearing chemicals to the 216-T-7 Crib). Maximum concentrations in these wells in 1997 ranged up to 437 mg/L west of T Plant near T Tank Farm. High concentrations of nitrate were also found at the northeastern boundary of the 200-West Area at a level of 317 mg/L in 1997.

A smaller area of elevated nitrate concentrations above the drinking water standard is located in the vicinity of the Plutonium Finishing Plant in the central part of the 200-West Area. The highest reported concentration was 478 mg/L near a Plutonium Finishing Plant crib (216-Z-9). This crib had received an estimated 1,300,000 kg (2,900,000 lb) of nitrate bearing chemicals during its operation in the past.

**Nitrate in Other Areas**. Nitrate concentrations near the city of Richland and in the 1100 Area, Richland North 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, south of the Horn Rapids Landfill, to the 300 Area to the northeast. The maximum nitrate concentration in 1997 was 166 mg/L on the northeastern edge of the Horn Rapids Landfill.

Although most nitrate observed onsite is the result of Hanford Site operations, elevated nitrate concentrations in wells in the western part of the site appear to be the result of increasing agricultural activity in offsite areas (e.g., Cold Creek Valley). There is no known source of nitrate in these areas associated with site operations, and the groundwater flow is from the west toward the Hanford Site facilities to the east. Nitrate levels have fluctuated considerably in wells upgradient of the 200 Areas over the past 30 years. In Cold Creek Valley, nitrate levels have been near or greater than the 45-mg/L drinking water standard in one well since 1985. The concentration was 43 mg/L in 1997. A maximum nitrate concentration of 54 mg/L was found in a well located just north of the Rattlesnake Hills.

High nitrate concentrations have been reported offsite in parts of Adams, Franklin, and Grant Counties to the north and east of the Hanford Site. Ryker and Jones (1995) reported 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 northern part of the Hanford Site north of the Columbia River.

### 6.1.7.2 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. Chromium was used for decontamination in the 100, 200, and 300 Area and was used also 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 drinking water standard for chromium is 100 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, which are considered to be representative of dissolved hexavalent chromium, will be used to describe the level of contamination in the discussion below.

**Chromium in the 100 Areas**. Chromium has been detected above the 100-mg/L drinking water standard in the 100-D, 100-H, and 100-K Areas. Groundwater pump-and-treat systems were implemented in each of these areas in 1997 to reduce hexavalent chromium entering the Columbia River.

The chromium distribution in the 100-D Area is shown in Figure 6.1.35. An area of chromium concentrations greater than the 100-µg/L drinking water standard extends from northeast to southwest across the 100-D Area near the Columbia River. The source of chromium in groundwater is sodium dichromate released to the ground at facilities near D Reactor. In 1997, the maximum chromium concentration from filtered samples was 2,260 µg/L in a well in the vicinity of a chromium hot spot in the southwestern portion of the 100-D Area. In situ redox manipulation technology is currently being demonstrated in the hot spot area to address hexavalent chromium contamination in groundwater. In the area near the former 120-D-1 Ponds, chromium concentrations increased in response to ceased discharges of noncontaminated water to the ponds in 1994, as shown by the trend plot for well 199-D5-13 in Figure 6.1.35. Chromium concentrations began to decrease in late 1997. A pump-and-treat system began operating in July 1997 in the northern part of the 100-D Area downgradient of the retention basins. Groundwater is extracted and piped to the 100-H Area, where chromium is removed using ion exchange technology. A performance evaluation of the pump-and-treat system is planned for 1998.

Many samples from 100-H Area wells contained chromium at levels greater than the drinking water standard (see Figure 6.1.35). In 1997, the maximum chromium concentration from 100-H Area filtered samples collected from the shallow parts of the unconfined aquifer was 196 µg/L near the former 183-H Solar Evaporation Basins. Chromium was also found at levels above the drinking water standard in one well monitoring the deeper part of the unconfined aquifer in the 100-H Area. Samples from this well, located near the former 183-H Basins, contained up to 256 µg/L of chromium (in filtered samples) in 1997. Potential sources in the 100-H Area include past disposal of sodium dichromate near H Reactor, disposal to the 107-H Liquid Waste Disposal Trench, and chromium in acid wastes stored in the former 183-H 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.

A groundwater remediation pump-and-treat system to reduce hexavalent chromium entering the Columbia River from the aquifer was implemented in 1997. Groundwater extracted from 100-H Area wells located in the chromium plume is treated using ion exchange technology and then reinjected into the aquifer in the southwestern part of the 100-H Area. Pumping was stopped in one of the 100-H extraction wells because of a slight buildup of technetium-99 in the treatment system. A performance evaluation of the interim action to pump and treat is planned for 1998 (DOE/RL-96-90, Draft A).

Chromium in the 100-K Area occurs in groundwater near or at levels greater than the 100-µg/L drinking water standard (Figure 6.1.36). Two localized areas of chromium contamination occur near the KW Reactor and the former water treatment basins southeast of the KE Reactor. The maximum concentration in 1997 was 191 µg/L near the KW Reactor. A much wider area of chromium contamination is found in the vicinity of the former 116-K-2 Liquid Waste Disposal Trench to the northeast. A pump-and-treat system for treating chromium in groundwater between the trench and the Columbia River began operating in October 1997. Groundwater extracted from a network of wells is treated using ion exchange technology and then returned to the aquifer upgradient of the 116-K-2 trench. An evaluation of performance monitoring data collected from the pump-and-treat system is planned for 1998 (DOE/RL-96-90, Draft A).

**Chromium in the 200 Areas**. Chromium at concentrations greater than the 100-µg/L drinking water standard in the 200-East Area was found in one well on the southern

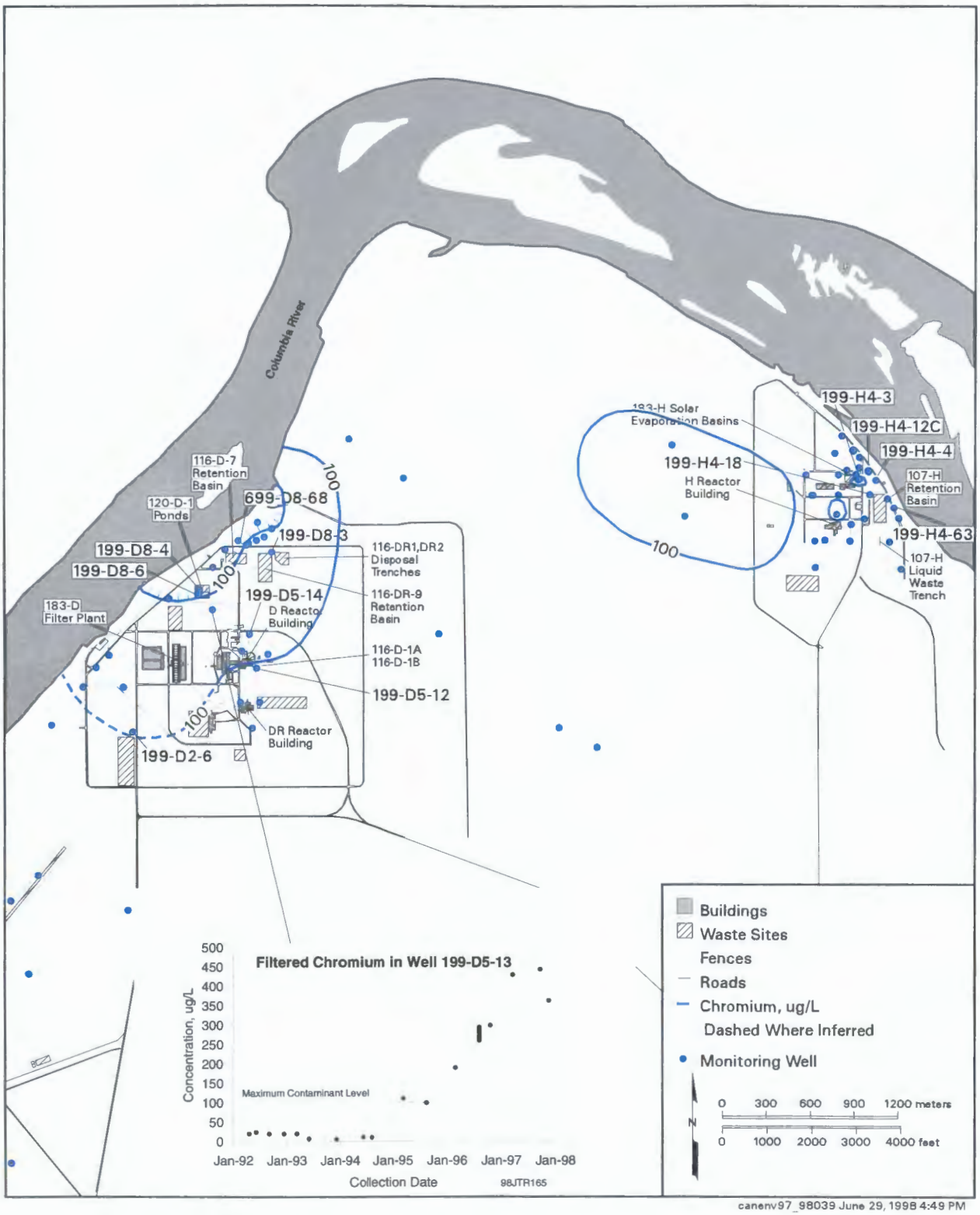


**Figure 6.1.35**. Filtered Chromium Distribution in the 100-D and 100-H Areas, 1997, and Concentration Trends in Well 199-D5-13

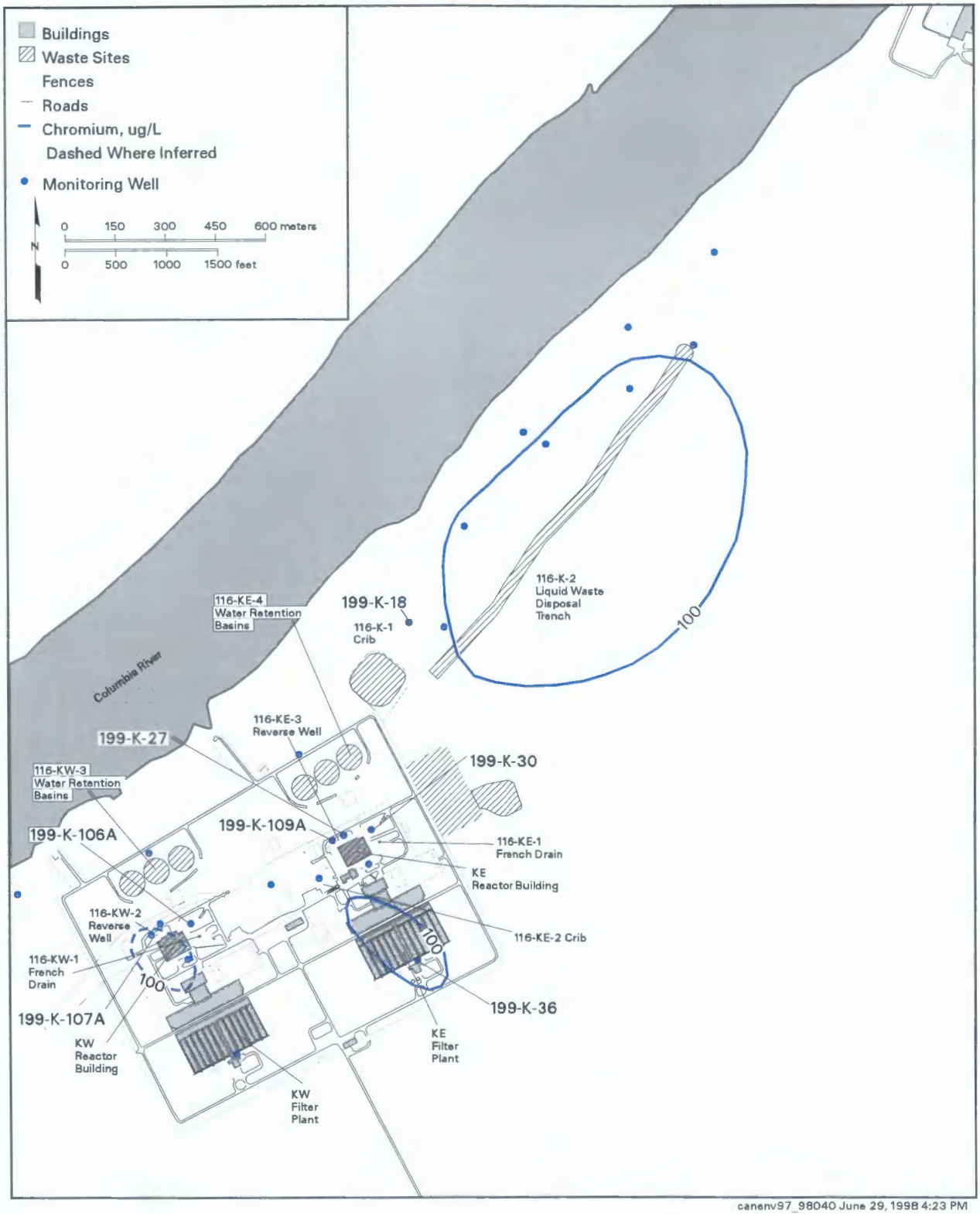


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**Figure 6.1.36**. Filtered Chromium Distribution in the 100-K Area, 1997

boundary of the A-AX Tank Farms. The maximum concentration detected in the sample was 1,660 µg/L. Chromium concentrations in this well decreased between 1992 and 1996 but increased to 1,660 µg/L in 1997 (Figure 6.1.37). Releases from the A-AX Tank Farms are a potential source of this chromium contamination.

Chromium contamination in groundwater has been found at several locations in the 200-West Area. Areas where concentrations exceeded the 100-µg/L drinking water standard in 1997 include the retired 216-S-10 Pond and T-TX-TY Tank Farms. The highest filtered chromium concentration observed in the 200-West Area in 1997 was 576 µg/L adjacent to the 216-S-10 Pond. The highest concentration found in the vicinity of T Tank Farm in 1997 was 155 µg/L. Filtered samples from wells monitoring the TX-TY Tank Farms showed a maximum concentration of 306 µg/L, which is much higher than in previous years.

**Chromium in the 300 Area**. Chromium is occasionally detected at concentrations greater than the 100-µg/L drinking water standard in unfiltered samples from the 300 Area. In 1997, filtered and unfiltered samples from the 300 Area showed chromium concentrations below the standard. High chromium concentrations found in unfiltered samples 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**. Filtered chromium was detected in several wells located downgradient (east) of the southern part of the 200-West Area in 1997. The maximum concentration detected in filtered samples in this area during 1997 was 226 µg/L. The extent of chromium contamination in this area is poorly defined, and the source has not been determined.

### 6.1.7.3 Carbon Tetrachloride and Chloroform

Carbon tetrachloride contamination above the 5-µg/L drinking water standard was found in the unconfined aquifer beneath much of the 200-West Area. The bulk of the contamination is believed to be from waste disposal operations associated with the Plutonium Finishing Plant in the west-central part of the 200-West Area. 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

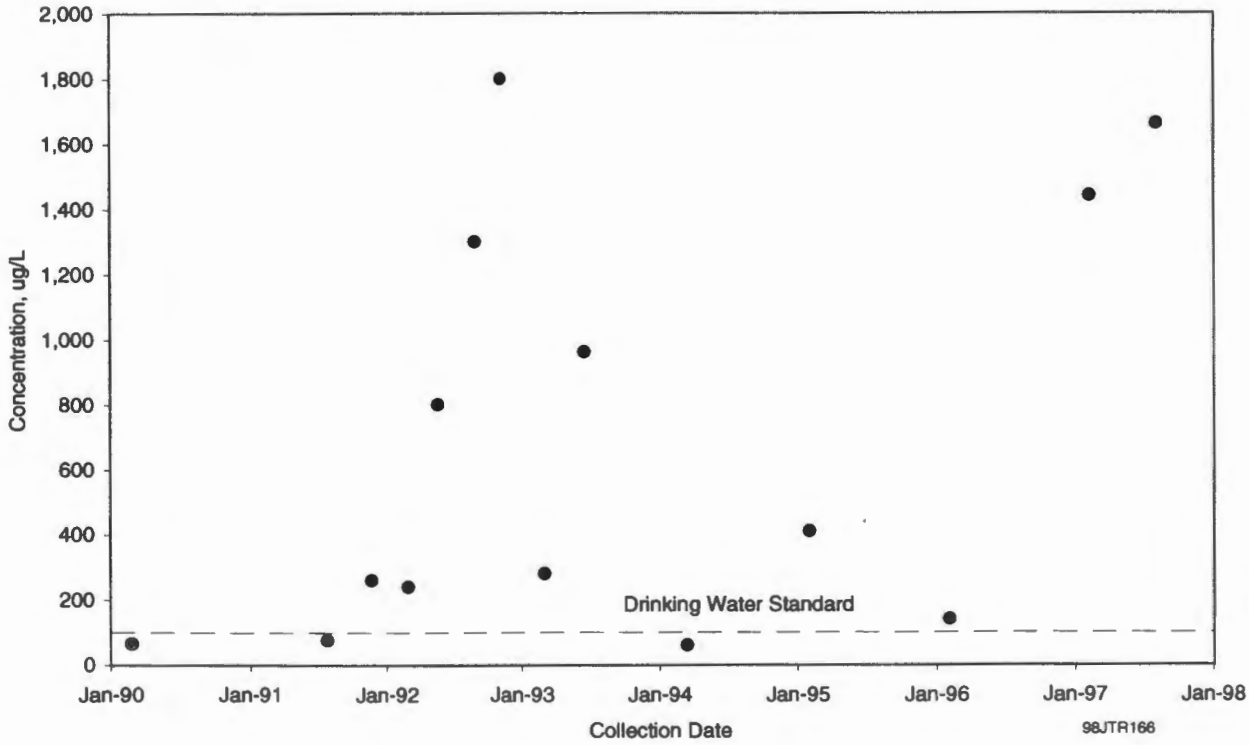


**Figure 6.1.37**. Filtered Chromium Concentrations in Well 299-E24-19, 1990 Through 1997

nonflammable thinning agent while machining plutonium. A minor source of carbon tetratchloride is a waste disposal crib near T Plant. 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 carbon tetratchloride plume in the 200-West Area covers a large area that is over 10 $km^2$ (4 $mi^2$). However, the overall carbon tetrachloride distribution in the groundwater (Figure 6.1.38) has changed slowly since the presence of the contaminant plume was first noted in 1987. This slow change is illustrated in Figure 6.1.38 by the trends in carbon tetrachloride concentrations through time for wells at various locations within the plume.

Wells in the vicinity of the Plutonium Finishing Plant showed the highest concentrations in the carbon tetrachloride plume, with levels exceeding the 5-µg/L drinking water standard by more than 3 orders of magnitude. The maximum concentration was 8,200 µg/L in one pump-and-treat extraction well east of the Plutonium Finishing Plant near the 216-Z-9 Crib. Carbon tetrachloride concentrations have increased in several of the extraction wells since the pump-and-treat operation began in 1994. Carbon tetrachloride concentrations in the injection wells southwest of the Plutonium Finishing Plant continued to decline in 1997 as a result of injection of the treated water in these wells. As of September 1997, greater than 259,000,000 L (68,400,000 gal) of extracted groundwater have been treated, resulting in the removal of approximately 860 kg (1,900 lb) of carbon tetrachloride.

The pump-and-treat system near the 216-U-17 Crib in the southeastern part of the 200-West Area removed 10.6 kg (23.3 lb) of carbon tetrachloride from the extracted groundwater between March 1994 and February 1997. Between April and September 1997, 0.89 kg (2.0 lb) of carbon tetrachloride had been removed (BHI-01126).

The extent of carbon tetrachloride contamination, as defined by the 5-mg/L contour is poorly defined in the east-central part of the 200-West Area because of the lack of monitoring wells (see Figure 6.1.38). There is considerable uncertainty regarding the extent of contamination in deeper parts of the aquifer because of the limited amount of carbon tetrachloride concentration data from depths below the water table.

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 aqueous or vapor phase. Although free-phase liquid carbon tetrachloride above and possibly below the water table has not been observed, the carbon tetrachloride concentrations in the aqueous and vapor phases and the conceptual understanding of contaminant behavior suggest that a continuing source of contamination exists. Therefore, lateral expansion of the carbon tetrachloride plume is expected to continue.

In addition to carbon tetrachloride, lesser amounts of chloroform were found in 200-West Area groundwater. The chloroform plume appears to be associated with, but not exactly coincident with, the carbon tetrachloride plume, as shown by Figure 5.3.6 in PNL-10698. The highest chloroform concentrations appear to be located in the vicinity of the Plutonium Finishing Plant. The highest chloroform level recorded in 1996 was 250 µg/L; however, in 1997, the distribution of chloroform in this area could not be defined because high carbon tetrachloride concentrations interfered with the analyses. The drinking water standard for chloroform is 100 µg/L (total trihalomethanes), which is 20 times higher than that for carbon tetrachloride. The origin of the chloroform is unknown but is suspected to be a degradation product of carbon tetrachloride.

### 6.1.7.4 Trichloroethylene

Trichloroethylene, which is a commonly used organic solvent, has a drinking water standard of 5 µg/L. In 1997, 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 1997 at levels greater than the 5-µg/L drinking water standard in the southwestern corner of the 100-F Area and in the adjacent 600 Area. The maximum concentration detected in this area was 20 µg/L in 1997. No specific sources of this contamination have been identified.

In the 100-K Area, two wells sampled in 1997 contained trichloroethylene at levels above the drinking water standard, with a maximum concentration of 18 µg/L. This trichloroethylene level represents a localized area of contamination near the KW Reactor.

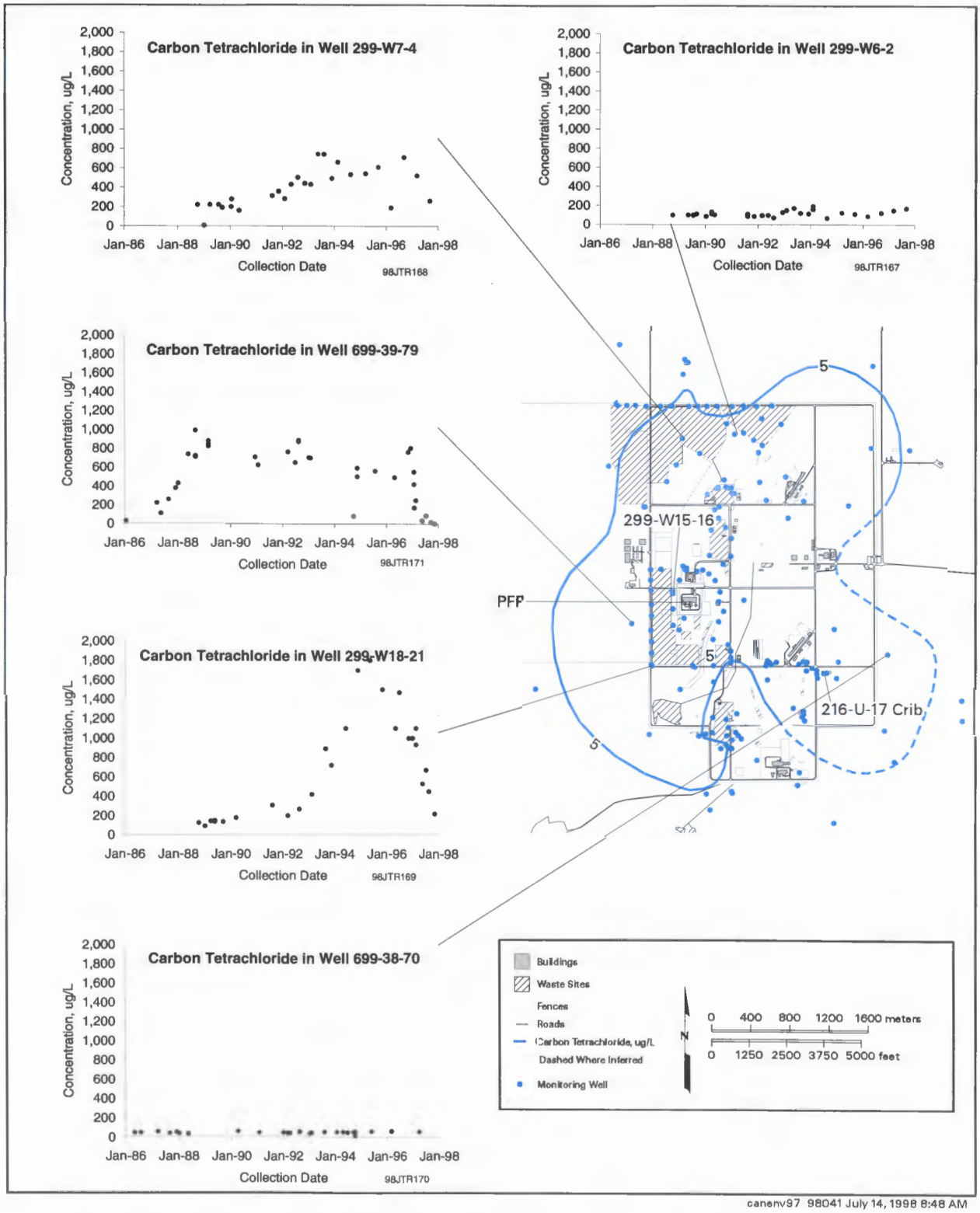


**Figure 6.1.38**. Carbon Tetrachloride Distribution in the Unconfined Aquifer in the 200-West Area, 1997, and Concentration Trends for Several Wells Within the 200-West Area

**Trichloroethylene in the 200 Areas**. Trichloroethylene is known to occur at levels greater than the 5-µg/L drinking water standard in several areas of the 200-West Area, as shown by 1996 data (Section 6.9.3.1 in PNNL-11470). The first area extends from the Plutonium Finishing Plant, west of T Plant, and past the northern boundary of the 200-West Area. Two smaller areas of trichloroethylene contamination occur east of U Plant and east of the Reduction-Oxidation Plant. In 1996, trichloroethylene concentrations in these areas ranged up to 26 µg/L. In 1997, samples were collected and analyzed for trichloroethylene in these areas. However, high carbon tetrachloride concentrations in many of the samples interfered with the analyses of low levels of trichloroethylene. Thus, the 1997 analytical data cannot be used to contour the trichloroethylene concentrations in these areas.

**Trichloroethylene in the 300 Area**. Trichloroethylene was detected in one well in 1997 in the 300 Area at concentrations above the 5-µg/L drinking water standard. The maximum concentration was 10 µg/L in well 399-1-16B. This well monitors the base of the unconfined aquifer downgradient of the former 316-5 Process Trenches.

**Trichloroethylene in the 600 Area**. Trichloroethylene was found at levels above the drinking water standard in a number of wells in the vicinity of the former Horn Rapids Landfill in the southern part of the site (Richland North Area). This contamination forms an elongated plume that extends from an area just south of the former landfill to the 300 Area and appears to have an origin off the Hanford Site (Figure 6.1.39). The trichloroethylene plume as defined by the 5-µg/L contour extended into the southwestern part of the 300 Area between 1996 and 1997. Trend plots in Figure 6.1.39 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 1997 was 12 µg/L on the northeastern side of the former Horn Rapids Landfill.

### 6.1.7.5 cis-1,2-Dichloroethylene

Concentrations of cis-1,2-dichloroethylene biodegradation product of trichloroethylene are increasing in well 399-1-16B located near former process trenches and ponds. 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 above the 70-µg/L drinking water standard. In 1997, a maximum of 190 µg/L of cis-1,2-dichloroethylene was detected in well 399-1-16B.

### 6.1.7.6 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 (Section 4.1 in PNL-6886 and Section 3.2.2 in PNL-7120). The drinking water standard for cyanide is 200 µg/L.

The highest cyanide levels were 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. However, no samples collected in 1997 contained cyanide at levels above the drinking water standard. The highest cyanide concentration in groundwater was 130 µg/L in the 600 Area north of the 200-East Area. The highest cyanide concentration in the 200-East Area was 113 µg/L near the BY Cribs. 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.

### 6.1.7.7 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 a maximum level equal to the primary drinking water standard at one well near T Tank Farm in the 200-West Area in 1997. This well showed a maximum fluoride concentration of 4.0 mg/L. This is a decrease from the maximum level of 7.8 mg/L that was above the primary standard in 1996. Aluminum fluoride nitrate used in the 200-West Area processes is the probable source of the fluoride contamination.

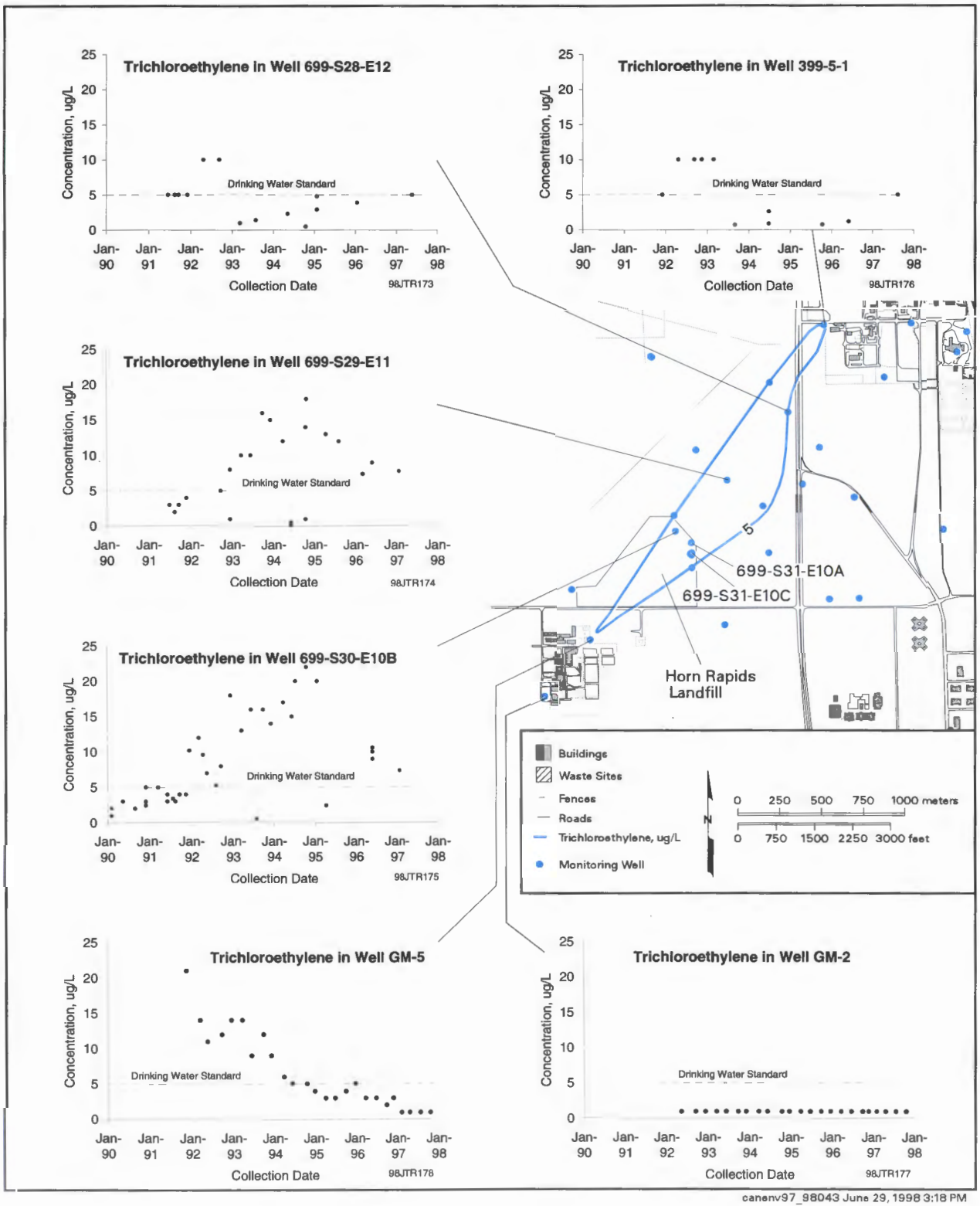


**Figure 6.1.39**. Trichloroethylene Distribution in the Vicinity of the Former Horn Rapids Landfill and Richland North Area, 1997, and Concentration Trends for Selected Wells

## 6.1.8 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 concentration distribution of tritium and other detected contaminants in the upper basalt-confined aquifer are shown in Figure 6.1.40.

Intercommunication between the unconfined and basalt-confined aquifers in the vicinity of the northern part of the 200-East Area was identified in RHO-BWI-ST-5 and RHO-RE-ST-12 P. The hydrochemical and hydrogeologic conditions within the upper basalt-confined aquifer system and the potential for offsite migration of contaminants through confined aquifer pathways were evaluated in PNL-10817.

Several confined aquifer wells north and east of the 200-East Area that show evidence of intercommunication with the overlying unconfined aquifer were identified in PNL-10817. 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 1997 was reduced to include only those with groundwater contamination or those downgradient from areas with historical indications of contamination. Prominent analytical results and trends arising from 1997 sampling are discussed below. The locations of wells used for monitoring confined aquifer groundwater chemistry were given in Figure 6.1.11.

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 (RHO-RE-ST-12 P). During 1997, technetium-99 was detected in well 299-E33-12 at a concentration of 1,290 pCi/L, which is above the 900-pCi/L drinking water standard. Cobalt-60 was detected in this well at a concentration of 12.9 pCi/L in 1997. In 1995, cobalt-60 was detected at a concentration of 154 pCi/L in the confined aquifer at well 699-49-55B north of the 200-East Area. However, this well was not sampled for cobalt-60 in 1996 and 1997. The cobalt-60 contamination at this well may be related to the use of neighboring well 699-49-55A, which was 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 the former B Pond. Tritium at this well declined from 8,284 pCi/L in 1996 to 6,680 pCi/L in 1997. Iodine-129, which showed a high of 0.36 pCi/L in 1996, was not detected in well 699-42-40C in 1997. The drinking water standard for iodine-129 is 1 pCi/L.

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 (PNL-10817). Samples from well 699-22-70 contained up to 9.4 mg/L of nitrate in 1997, 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

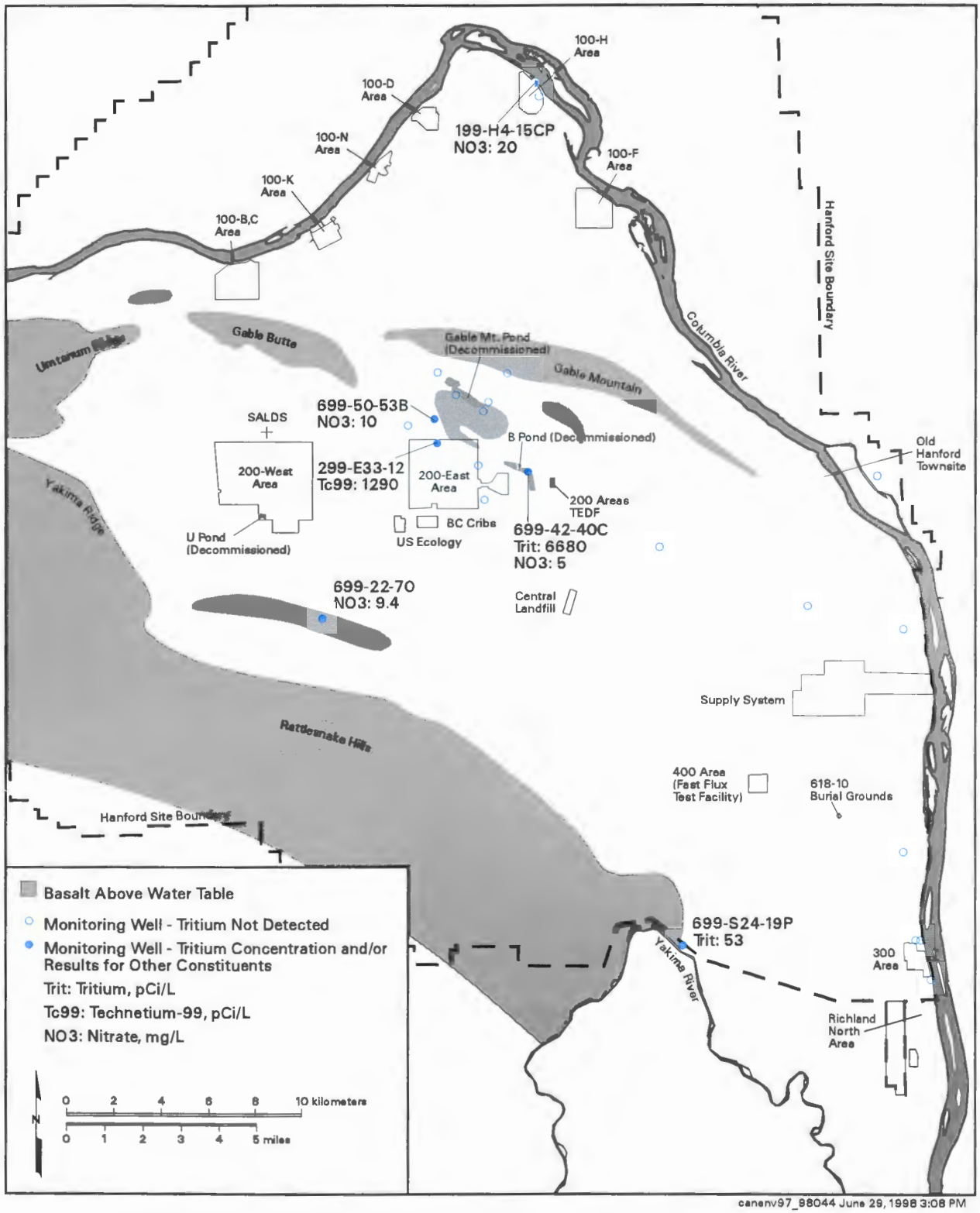


**Figure 6.1.40.** Tritium and Other Contaminants Detected in Confined Aquifer Wells, 1997

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.

## 6.1.9 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, 25 required groundwater monitoring during 1997. Locations of these groundwater monitoring sites were given in Figure 6.1.12. 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 1996 through September 1997, is available in PNNL-11793. Any significant changes in Resource Conservation and Recovery Act groundwater monitoring results that occurred from October through December 1997 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 (or pH decrease) 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 Appendix B in PNNL-11793. If a statistically significant increase (or pH decrease) from the "critical mean" 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 2.2.3 listed the phase pertaining to each of the Resource Conservation and Recovery Act groundwater monitoring projects at the end of 1997.

### 6.1.9.1 100 Areas Facilities

**1301-N and 1325-N Liquid Waste Disposal Facilities.** 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, lead, morpholine, phosphoric acid, and sodium dichromate. The 1301-N facility consists of a concrete basin with an unlined, zigzagging extension trench, covered with concrete panels.

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 halide measured in downgradient wells remained below the critical mean values at both facilities during 1997. Groundwater at these facilities is also analyzed for other constituents that were discharged to them, including cadmium, chromium, lead, nitrate, and phosphate. Cadmium, lead, and phosphate (in filtered samples) were not detected in groundwater at these facilities in significant concentrations. Nitrate was detected at levels greater than the EPA maximum contaminant level in 1997 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 for neutralizing high and low pH waste from a demineralization plant. The 1324-NA Pond is unlined and was used for treating waste from August 1977 to May 1986 and for disposing of treated waste from May 1986 to August 1990. The effluent to both facilities

contained sulfuric acid and sodium hydroxide, and the pH was occasionally high or low enough to classify the effluent as a dangerous waste.

Specific conductance measured in 1997 in wells downgradient from these ponds was higher than the background critical mean value. The increase in this indicator parameter was expected because the 1324-NA Pond introduced nondangerous constituents (e.g., sodium, sulfate) to groundwater. Total organic carbon was detected above the background critical mean value in one downgradient well in 1997. This exceedance was part of an increasing trend and was confirmed by resampling in January 1998. As a result, a groundwater quality assessment was initiated in 1998. Downgradient measurements of pH and total organic halide were below critical mean values.

**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 (5 lb) of mercury to have been discharged to the ponds. Between 1986 and 1994, the effluent discharged to the ponds included chlorine and flocculating agents such as aluminum sulfate. Effluent discharge to the ponds ceased in 1994. Contaminated soils were removed from the ponds in 1996.

In 1997, specific conductance, pH, total organic carbon, and total organic halide in wells downgradient from the 120-D-1 Ponds continued to be below the background critical mean values. Mercury is the only listed waste that may have been discharged to these ponds but it was not detected in any of the downgradient monitoring wells in 1997. The site remains in indicator parameter monitoring.

**183-H Solar Evaporation Basins**. This facility, which is now remediated, consisted of four separate concrete basins surrounded by an earthen berm. Between 1973 and 1985, the basins were used to store liquid waste in the 100-H Area, 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 (WHC-SD-EN-EV-027) 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 immediately downgradient of the basins. Although the concentrations decreased several orders of magnitude in this area since the basins ceased operation, they remained above their respective drinking water standards for most of 1997.

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 Facility Resource Conservation and Recovery Act permit in September 1994 and became subject to final-status monitoring.

Results of the September through December 1996 and March through June 1997 sampling events indicated that concentration limits for chromium, nitrate, technetium-99, and uranium were exceeded in one or more downgradient wells and that concentrations continue to follow previously observed trends. The Washington State Department of Ecology was notified of the exceedances in 1996 and in May 1997, a corrective action groundwater monitoring plan was released. The monitoring plan was implemented in early 1998 after the 183-H corrective action plan was incorporated into a revision of the Hanford Facility Resource Conservation and Recovery Act permit. The new monitoring plan takes into account the effects of a pump-and-treat system that began operation in 1997.

### 6.1.9.2 200 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, which have been designated as part of Resource Conservation and Recovery Act Waste Management Areas A-AX, B-BX-BY, C,

S-SX, T, TX-TY, and U, respectively. Waste Management Areas A-AX, B-BX-BY, and C are located in the 200-East Area; Waste Management Areas S-SX, T, TX-TY, and U are in the 200-West Area. Each waste management area includes tanks and associated ancillary systems (e.g., pipelines). The single-shell tanks store a mixture of dangerous chemical and radioactive wastes generated by reprocessing fuel irradiated in Hanford Site 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 combined waste streams from different processes. In many tanks, wastes have been concentrated by removing water vapor.

**Waste Management Area A-AX**. Critical mean values of the indicator parameters specific conductance, pH, total organic carbon, and total organic halide were not exceeded during 1997. Iodine-129 showed concentration values above the 1-pCi/L interim drinking water standard in the monitoring wells because of a plume extending through this area from other sources. Tritium levels, though considerably less than the drinking water standard, have been historically greater in one upgradient well versus downgradient wells at Waste Management Area A-AX. Chromium and nickel exceedances continue to be observed in one of the network wells.

In one downgradient well, the technetium-99 concentration rose sharply in February 1997, reached a maximum of 374 pCi/L in August 1997, and then dropped to 112 pCi/L in December 1997. The increase in technetium-99 concentration may be associated with a rise in the nitrate concentration that began in 1994. The nitrate concentration peaked at approximately 13 mg/L in February 1997, then fell with the technetium-99 concentration between August and December 1997. These concentrations are below their respective drinking water standards.

**Waste Management Area B-BX-BY**. A Phase I groundwater quality assessment was conducted between June 1996 and August 1997 after elevated specific conductance was observed in a downgradient well (PNNL-11826, WHC-SD-EN-AP-002). The indicator parameter specific conductance has been increasing in downgradient wells since monitoring began in 1990 and exceeded the critical mean value in several wells in 1997. The rise in specific conductance appears to be related to an increase in chloride, nitrate, sodium, and sulfate. Several other downgradient wells have displayed trends of increasing chloride and nitrate with corresponding increases in specific conductance since 1992. Also, specific conductance periodically fluctuates above and below the critical mean value. There were no exceedances of critical means for the indicator parameters pH, total organic carbon, or total organic halide during 1997.

Technetium-99 is a long-lived, mobile fission product that was first identified in an old well inside the S Tank Farm in 1985. The concentrations in this well showed an upward trend and exceeded the interim drinking water standard, reaching a maximum of 1,500 pCi/L in 1997. Since 1986, concentration transients of 1 to 2 years in duration have occurred in 4 other wells within the boundary of Waste Management Area S-SX. The most recent transient occurred in the southeastern corner of the SX Tank Farm, where the peak concentration was 5,000 pCi/L in 1997. Chromium reached a maximum of 39 µg/L in the southeastern corner of the SX Tank Farm. Cesium-137 was not detected in any of the Resource Conservation and Recovery Act wells monitoring Waste Management Area S-SX in 1997.

Technetium-99 concentrations continued to rise in several of the monitoring wells in 1997. In one well (299-E33-41) technetium-99 levels increased sharply in February 1997 and again in August 1997. Results of the Phase I groundwater quality assessment in PNNL-11826 showed that Waste Management Area B-BX-BY was a likely source of the high technetium-99 concentrations observed. A sharp uranium spike of 81 mg/L measured in one monitoring well in November 1997 will be investigated during the Phase II assessment, planned for 1998 to further investigate the rate of groundwater movement and the source(s), nature, and extent of groundwater contamination attributed to Waste Management Area B-BX-BY.

**Waste Management Area C**. Critical mean values of the indicator parameters specific conductance, pH, total organic carbon, and total organic halide were not exceeded during 1997. Iodine-129 showed concentrations above the 1-pCi/L drinking water standard in the monitoring wells because of a plume extending through this area from other sources.

**Waste Management Area S-SX**. A groundwater quality assessment program was initiated in 1996 in response to a directive from the Washington State Department of Ecology. This directive cited anomalous trends in technetium-99 and elevated specific conductance in groundwater. In response to the directive, a groundwater quality assessment plan (WHC-SD-EN-AP-191) was prepared

and submitted to the Washington State Department of Ecology. The first phase of this assessment was conducted in 1996 and 1997. The findings of the first phase assessment showed that the S and SX Tank Farms contributed to groundwater contamination (PNNL-11810). However, multiple source locations are needed to explain the data. A second phase assessment will be conducted to determine the nature, extent, and source(s) of groundwater contamination attributed to Waste Management Area S-SX.

**Waste Management Areas T and TX-TY**. In November 1992, the critical mean for specific conductance was exceeded in downgradient wells 299-10-15 (at Waste Management Area T) and 299-W10-17 and 299-W14-12 (at Waste Management Area TX-TY). Verification sampling placed these waste management areas 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 6.1.34) because of the discharge of large amounts of nitrate bearing chemicals to nearby trenches and cribs in the mid-1950s.

A number of other constituents exceeded regulatory limits in the vicinity of these waste management areas. These included carbon tetrachloride, filtered chromium, filtered iron, fluoride, iodine-129, nickel, technetium-99, and tritium. Some of these contaminants follow the same historical trend as nitrate, indicating a source more extensive than the tank farms. At Waste Management Area T, well 299-W11-27 showed large increases in several chemical species in late 1995 and 1996, including specific chromium, cobalt-60, nitrate, conductance, technetium-99, and tritium. In 1997, levels of these chemical species decreased slightly. Based on an assessment study in 1993 to 1997, contaminants in well 299-W11-27 are most likely the result of sources within the T Tank Farm (PNNL-11809). Therefore, a second phase of assessment, which is being planned in 1998, will be performed. Well 299-W11-27 is going dry as the water table continues to decline and is planned to be replaced by a new monitoring well. The assessment study also showed that contaminants in well 299-W10-15 are a result of sources external to the T Tank Farm. Wells 299-W10-15 and 299-W11-27 are located north and northeast, respectively, of Waste Management Area T.

At Waste Management Area TX-TY, well 299-W14-12 showed elevated concentrations of cobalt-60, iodine-129, technetium-99, and tritium. Based on an assessment study in 1993 to 1997, these contaminants are consistent with a source within the TX-TY Tank Farm (PNNL-11809); therefore, a second phase of assessment will be conducted. However, upgradient sources may also be contributing to the contamination. The assessment study also indicated that contaminants in well 299-W10-17 are a result of sources external to the TX-TY Tank Farm. Wells 299-W14-12 and 299-W10-17 are located north and east, respectively, of Waste Management Area TX-TY.

**Waste Management Area U**. This waste management area, located southeast of the Plutonium Finishing Plant in the south-central part of the 200-West Area, is currently under a detection-level monitoring program. There was a general increase in total organic halide concentrations across Waste Management Area U, resulting in several critical mean exceedances for this contamination indicator parameter. The exceedances are a result of a carbon tetrachloride plume that originated in the area of the Plutonium Finishing Plant and are not related to the U Tank Farm (Section 5.9.3.4 in PNNL-11793).

### 6.1.9.3 200 Areas Liquid Effluent Disposal Facilities

**216-A-10, 216-A-36B, and 216-A-37-1 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 cobalt-60, strontium-90, ruthenium-106, iodine-129, cesium-137, tritium, and uranium. The 216-A-37-1 Crib received process condensate from the 242-A Evaporator. The process condensate contained radionuclides, spent halogenated and nonhalogenated solvents, and ammonia. The radionuclides included cobalt-60, strontium-90, ruthenium-106, cesium-137, plutonium, and uranium.

The 216-A-10 and 216-A-36B Cribs were in indicator parameter evaluation status through the end of June 1997.

Beginning in July 1997, these cribs and the 216-A-37-1 Crib were combined into one groundwater quality assessment program (PNNL-11523). Prior to July, the 216-A-37-1 Crib was monitored under the operational monitoring program. Groundwater monitoring changed from indicator parameter evaluation status to groundwater quality assessment because of known groundwater contamination and the high probability that a new indicator parameters program for the cribs would show that critical means are exceeded. Constituents, including strontium-90, iodine-129, nitrate, and tritium are detected at levels that exceed their respective drinking water standards. However, the source of these groundwater contaminants is uncertain because they are present within large plumes in this area.

**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 declined steadily in both upgradient and downgradient wells at the site. However, in 1997, specific conductance increased in nearly all network wells. During the fourth quarter of 1997, total organic carbon exceeded the critical mean in one downgradient well. However, this exceedance was not consistent with the total organic carbon trend observed in this well. Resampling in early 1998 confirmed that the exceedance was an error.

**216-B-3 Pond**. The former 216-B-3 Pond (B Pond) was located immediately east of the 200-East Area and consisted of a main pond and three expansion ponds (216-B-3A, 216B-3B, and 216-B-3C). The main pond began operating in 1945 and the expansions were built in the 1980s. In 1994, the main pond ceased operating and the waste streams were rerouted to the 216-B-3C Expansion Pond and the 200 Areas Treated Effluent Disposal Facility. In August 1997, waste streams received by the expansion pond were diverted to the 200 Areas Treated Effluent Disposal Facility, thus ending operation of the B Pond system. In the past, B Pond received liquid waste from B Plant and the Plutonium-Uranium Extraction Plant, consisting of chemical sewer waste, cooling water, and steam condensate. These waste streams contained aluminum nitrate, nitric acid, potassium hydroxide, sulfuric acid, tritium, and other acids. More recently, B Pond received nondangerous, nonradioactive effluent primarily from the Plutonium-Uranium Extraction Plant and B Plant.

In 1990, groundwater monitoring at the B Pond system was changed to assessment level because of elevated total organic carbon and total organic halide concentrations in downgradient wells 699-43-41E and 699-43-41F. In 1997, the assessment findings indicated that these elevated levels were isolated and were not attributed to groundwater contamination by hazardous waste (PNNL-11604). Thus, the assessment program was discontinued in October 1997, and a detection-level program was restored.

The only contaminants consistently detected in groundwater that could be attributed to B Pond operations were nitrate and tritium; however, these constituents have shown downward trends since monitoring began at B Pond.

**216-B-63 Trench**. This trench, in the north-central part of the 200-East Area, received liquid effluent from the B Plant chemical sewer from March 1970 to February 1992. The liquid effluent consisted of a mixture of steam condensate and water. Past releases to the trench also 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 show no evidence that dangerous nonradioactive constituents from the site entered the groundwater from this trench. There were no exceedances in the indicator parameters pH, specific conductance, total organic carbon, or total organic halide in 1997.

**216-U-12 Crib**. This crib, south of U Plant in the 200-West Area, received wastewater containing both dangerous chemical wastes and radionuclides from April 1960 until February 1988. This facility has been in the groundwater quality assessment phase of monitoring

since 1993. Site-specific waste indicators include technetium-99, iodine-129, gross alpha, gross beta, nitrate, and tritium. Technetium-99, iodine-129, nitrate, and tritium are detected repeatedly in groundwater. The findings of the first two phases of the assessment monitoring program indicate that the 216-U-12 Crib is a source of nitrate and technetium-99 detected in the downgradient wells (PNNL-11574). Because of these findings, the crib must continue in groundwater quality assessment monitoring. The sources of the iodine-129 and tritium are upgradient locations near the Reduction-Oxidation Plant. Of the waste indicator parameters specific conductance, total organic halide, total organic carbon, pH, gross alpha, and gross beta monitored at the crib, only specific conductance exceeded the 458-mS/cm critical mean in the downgradient wells in 1997. 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 former facility was 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 southwestern end of the ditch. The pond and ditch 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 wastewater after 1985.

The indicator parameters for this facility are specific conductance, pH, total organic carbon, and total organic halide. All indicator parameters were below their respective critical mean values in 1997.

## 6.1.9.4 200 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 (see Figure 5.1.12).

**Low-Level Waste Management Area-1**. This waste management area consists of the 218-E-10 Burial Ground in the northwestern corner of the 200-East Area. Disposal activities began in 1960 and continue today. Materials placed in this facility are primarily failed equipment and mixed industrial waste from the Plutonium-Uranium Extraction Plant, B Plant, and N Reactor.

Critical means for the contamination indicator parameters established for this area were not exceeded during 1997. Although there is no evidence of any contaminant contribution from this area, contaminant plumes from other sources affect groundwater quality.

**Low-Level Waste Management Area-2**. This waste management area is located in the northeastern corner of the 200-East Area and includes all of the 218-E-12B Burial Ground, 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.

In 1997, specific conductance was the only contamination indicator parameter that exceeded the critical mean established for this area. This exceedance was primarily the result of an increase in sulfate, which is not a regulated constituent in groundwater. Because the increase occurred in an upgradient well, assessment monitoring will not be required. Values for iodine-129 were above the 1-pCi/L interim drinking water standard in several wells along the southern boundary of this area. However, this is related to the widespread iodine-129 plume beneath the 200-East Area, and there is no evidence of groundwater contamination from this waste management area.

**Low-Level Waste Management Area-3**. The 218-W-3A, 218-W-3AE, and 218-W-5 burial grounds make up this area in the north-central portion of the 200-West Area. These facilities cover 74.3 ha (181.4 acres). The 218-W-3A Burial Ground began accepting waste in 1970 and received primarily ion exchange resins and failed equipment (e.g., tanks, pumps, ovens, agitators, heaters, hoods, vehicles, accessories). The 218-W-3AE Burial Ground began operation in 1981 and contains low-level and mixed waste, including rags, paper, rubber gloves, tools, and industrial waste. The 218-W-5 Burial Ground 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 their respective drinking water standards of 5 µg/L and 45 mg/L in monitoring wells in this waste management area. However, the elevated values can be attributed to contaminant plumes originating to the south of the area. There appears to be no groundwater contamination directly attributable to this waste management area, and

there were no exceedances of the critical mean values for indicator parameters in 1997.

**Low-Level Waste Management Area-4**. This area consists of the 218-W-4B and 218-W-4C Burial Grounds, which cover 24.4 ha (60 acres) in the south-central portion of the 200-West Area. The 218-W-4B Burial Ground 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. Wastes were first deposited in the 218-W-4C Burial Ground in 1978 and were classified as transuranic, mixed, or low-level and included contaminated soil, decommissioned equipment, and remote-handled transuranic waste.

There appears to be no groundwater contamination directly attributable to this waste management area. Samples from downgradient wells did not exceed the critical means established for indicator parameters in 1997. Concentrations of carbon tetrachloride above the 5-µg/L drinking water standard were found in most wells in 1997. However, the source of the carbon tetrachloride is past disposal of liquid waste near the Plutonium Finishing Plant. Nitrate also exceeded the 45-mg/L 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**. Located in the northern part of the 200-West Area, this waste management area was eliminated from further groundwater monitoring because no waste has been disposed to this facility and there are no plans for its use.

### 6.1.9.5 200 Areas Liquid Effluent Retention Facility

This facility consists of three lined surface impoundments (basins) located east 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, strontium-90, ruthenium-106, cesium-137, 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 halide. There were no exceedances of the critical mean values for these parameters, which indicates that no dangerous nonradioactive constituents have been released by the facility to groundwater.

### 6.1.9.6 300 Area Process Trenches

The site of the 316-5 Process Trenches in the northern part of the 300 Area was under groundwater quality assessment between June 1995 and December 1996. Since December 1996, the process trenches have been under final-status compliance 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 20-µg/L proposed drinking water standard at several wells near this facility in 1997.

One downgradient well showed concentrations that exceeded the required limits of 70 mg/L and 5 mg/L for cis-1,2-dichloroethylene and trichloroethylene, respectively. In 1997, these exceedances were confirmed by additional sampling. As required, the groundwater monitoring plan (WHC-SD-EN-AP-185) was modified for corrective action, which is scheduled for late 1998 after the permit modification becomes effective.

### 6.1.9.7 Nonradioactive Dangerous Waste Landfill

The former Nonradioactive Dangerous Waste Landfill (Central Landfill) in the 600 Area southeast of the 200-East Area is in the indicator parameter phase of groundwater monitoring. None of the indicator parameters specific conductance, pH, total organic carbon, or total organic halide exceeded critical mean values during 1997. Chlorinated hydrocarbons were detected in a few wells at concentrations below their respective drinking water standards.

# 6.2 Vadose Zone Characterization and Monitoring

## 6.2.1 Tank Farms Vadose Zone Baseline Characterization Project

*J. R. Brodeur*

Contamination was released to the near-surface and subsurface sediment at Hanford Site single-shell tank farms as the result of tank leaks, spills of radioactive effluent on the ground surface, pipeline leaks, and airborne releases of particulate matter through tank ventilation and access ports. Airborne releases and surface spills created contamination plumes in the vadose zone that are generally confined to the near surface but, in some cases, surface contamination is known to have migrated deeper into the vadose zone. Pipeline leaks have also occurred either near the surface or at a maximum depth of 6.1 m (20 ft). In some cases, contamination from pipeline leaks has also migrated deeper into the vadose zone; however, tank leaks created the deepest contamination plumes. Tank leaks occurred most often at the base of the tank or at the footing, where the base and sidewall are joined.

The Resource Conservation and Recovery Act specifies requirements to identify sources of contamination and to determine the nature and extent of the contamination that has leaked from the single-shell tanks. In 1994, the tank farms vadose zone baseline characterization project was begun to perform an initial baseline characterization of the vadose zone gamma-emitting contamination at Hanford Site tank farms and to satisfy Resource Conservation and Recovery Act requirements in a limited way. The technical plan for this baseline characterization is documented in P-GJPO-1786.

Under the baseline characterization project, approximately 800 preexisting monitoring boreholes surrounding the single-shell tanks are being logged with passive spectral gamma-ray logging methods. Passive spectral gamma-ray logging methods were developed at the Hanford Site in the late 1980s and early 1990s to identify specific gamma-emitting radionuclides in the subsurface and to determine their concentrations.

Borehole logging is used for the initial characterization because it is an economical means of obtaining information about conditions in the subsurface using existing boreholes and it helps to identify the locations and sizes of the contamination plumes. For comprehensive characterizations or special investigations, follow-up drilling and sampling must be conducted to identify specific contaminants and to collect geologic samples as needed.

Once a baseline is established for a particular tank, that tank can be monitored over time for either short-term or long-term changes. Long-term monitoring over a 5- to 10-year period can provide information on migration rates of gamma emitters that can be used to verify models used for predictive risk assessments. Short-term monitoring is useful for identifying recent changes in the vadose zone that result from current operations or tank leaks.

A plan view of a typical tank farm is presented in Figure 6.2.1. Each tank farm consists of a collection of between 2 and 18 underground waste storage tanks. Most of the tanks are surrounded by monitoring boreholes that 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.

The baseline characterization project involves logging the boreholes surrounding the single-shell tanks and analyzing the data to produce logs of the radionuclide concentrations. Figure 6.2.2 presents an example of a radionuclide concentration log. The logs for all of the boreholes surrounding a tank are interpreted and reported in a tank summary data report for each tank. The reports also provide summaries of the tank histories and any other tank-specific information.

After completion of a tank summary data report for each tank, a more comprehensive tank farm report is prepared. Each tank farm report provides a correlation of the

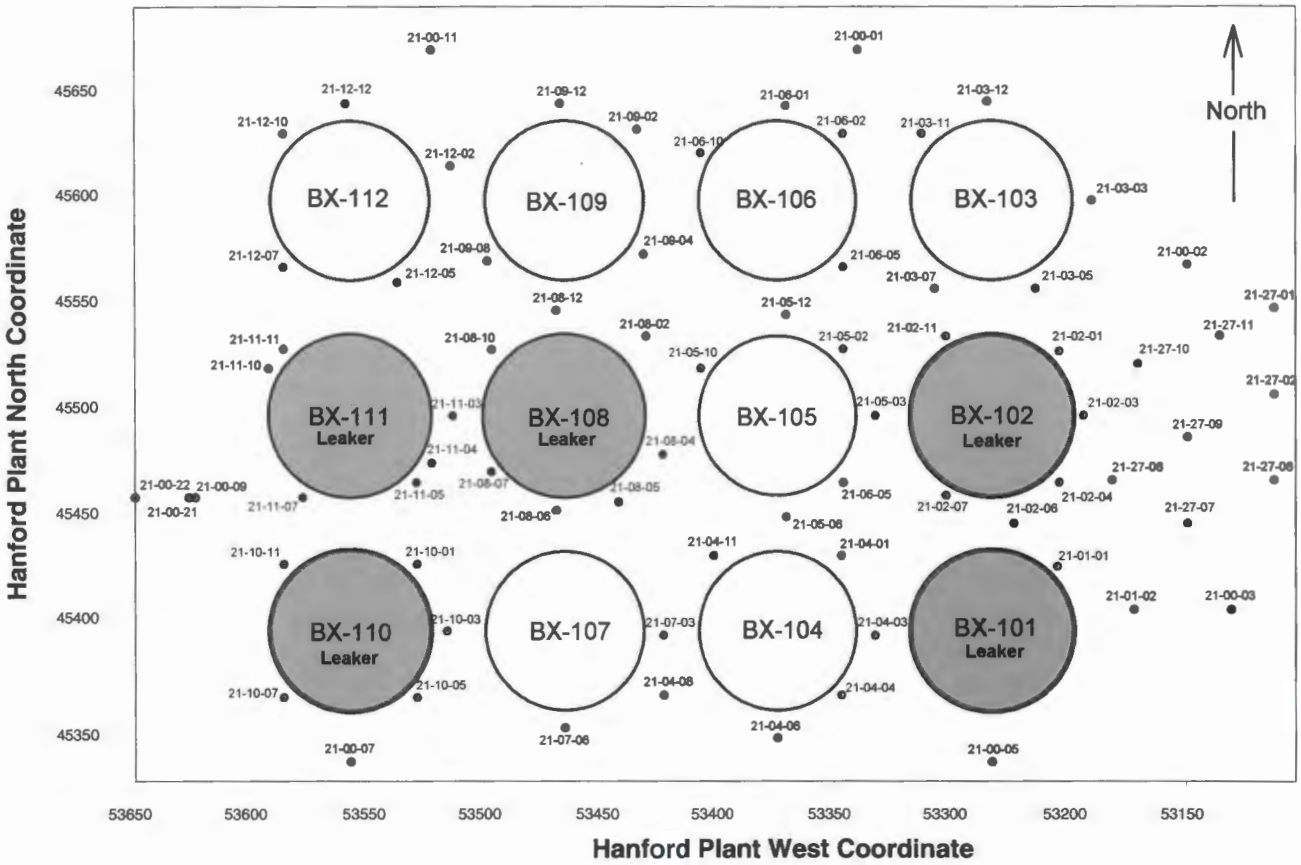


**Figure 6.2.1**. Plan View of BX Tank Farm with Monitoring Boreholes

contamination across the farm and includes computer-generated visualizations of the contamination. Correlations between boreholes help to determine contamination sources and define the three-dimensional contamination distributions. The visualizations are based strictly on an empirical geostatistical correlation of the data and are used to help identify the general location and distribution of the contamination so that more complete analyses can be completed to develop more realistic and quantitative contamination distribution models.

## 6.2.2 Data Collection and Analysis

All data acquisition is accomplished with spectral gamma-ray logging systems that are automated and configured to deliver a germanium detector down a borehole. Data acquisition operations are specified by logging procedures provided in MAC-VZCP-1.7.10-1, Rev. 2 and governed by quality assurance procedures specified in a project management plan MAC-VZCP-1.7.2, Rev. 1. All data are managed as quality records governed by the current revision of the Hanford Tank Farms Vadose Zone Working File Index, which is used in conjunction with Section 3.0, "Records Management," of *General Administrative Procedures Manual* MAC-1000.

The spectral gamma-ray logging system equipment was calibrated by conducting a comprehensive base calibration and biannual field calibrations as specified in a calibration plan (MAC-VZCP-1.7.3, Rev. 1). The base calibration was conducted using borehole model standards constructed at the DOE Grand Junction Office specifically for borehole logging. The results of the base calibration are reported in GJPO-HAN-1. Biannual field calibrations were conducted using borehole calibration models installed at the Hanford Site, and the results were reported in biannual calibration reports. The results of the third biannual recalibration are documented in GJO-HAN-13.

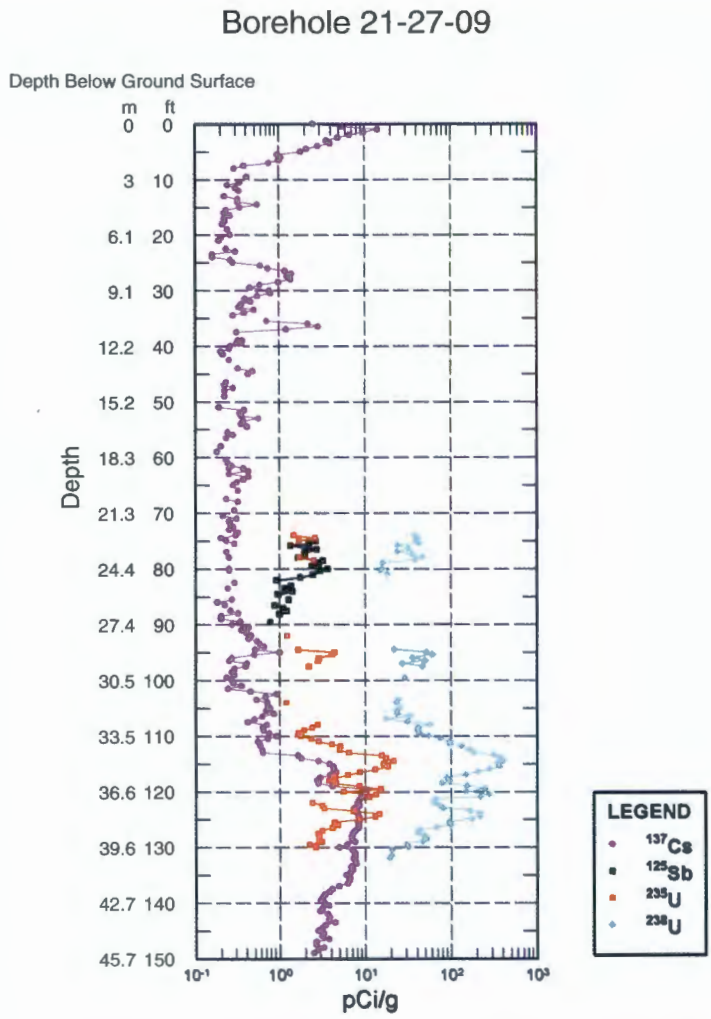


**Figure 6.2.2.** Example of a Radionuclide Concentration Log

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 isotope-specific logs of the radionuclide concentration versus depth, and the data are plotted as logs. Logs of man-made and naturally occurring radionuclides are produced routinely. Details of the data analysis process are documented in a data analysis manual (MAC-VZCP-1.7.9, Rev. 1).

Data are interpreted by reviewing all of the spectral gamma logs from a single borehole and correlating the data with information on the geology, tank history, and historical gross gamma-ray logs. The intent of the individual borehole interpretations is to quantify contamination plumes, identify potential contamination sources, and relate contamination distribution patterns to the geology or tanks.

## 6.2.3 Activities for 1997

### 6.2.3.1 Baseline Logging, Tank Summary Data Reports, and Tank Farm Reports

Logging data acquisition was completed for 211 boreholes surrounding tanks at the A, B, BX, and C Tank Farms during 1997.

In addition, tank summary data reports were prepared for tanks AX-102, AX-103, and AX-104; tank BX-102; tanks C-101 through C-110; all 12 of the tanks in the S Tank Farm; tanks TX-106 and TX-108 through TX-118; and all 6 of the tanks in the TY Tank Farm. The individual borehole logs are reported in individual tank summary data reports (GJ-HAN-47 and GJ-HAN-49 through GJ-HAN-92).

Tank farm reports were prepared for the AX, BY, TX, TY, and U Tank Farms in 1997. For the AX Tank Farm, a preliminary farm report (GJO-HAN-10) was prepared to support a tank characterization project being conducted by the Hanford Tanks Initiative Program. The final AX Tank Farm report (GJ-HAN-12) followed a few months later. The bulk of the work on the BY Tank Farm report was completed in 1996, and the report was published in January 1997 (GJO-HAN-6). Because the results of the logging in the BY Tank Farm are discussed in PNNL-11472 (Section 3.3), they will not be discussed here. Preparation of the tank farm reports for the C and S Tank Farms was begun in 1997 but they will not be published until 1998 so they will be discussed in next year's environmental report.

The TY farm report (GJ-HAN-16) was prepared in 1997 and was published in January 1998. It is discussed in the following sections.

### 6.2.3.2 Improvements Made to Contamination Visualizations

During 1996 and 1997, a significant effort went into developing the spectrum analysis technique called shape factor analysis. This method allows a log analyst to interpret the gamma-ray spectra within vertically continuous zones of contamination to assess the radial distribution of contamination at a depth location in a borehole. The shape factor analysis method can help an analyst differentiate between the following contamination distributions: contamination located on the inside of a borehole casing, contamination located on the outside of a borehole casing, contamination distributed uniformly in the formation in the radial direction, and contamination that is located remote to the borehole. The details regarding spectral shape factor analyses are provided in GJO-HAN-7 and GJO-HAN-15.

The primary utility of the shape factor analysis method is that it often identifies conditions where contamination was carried down during the drilling of a borehole and is not distributed in the formation. If there has been borehole contamination, this condition needs to be recognized and eliminated from the visualization database, so that false contamination plumes are not generated and a false interpretation of the contaminant distribution is not presented.

Shape factor analysis provides a useful interpretation tool but does not provide an unequivocal interpretation. Quite often, the contamination of interest is not found in a vertically continuous region. In this instance, a unique solution to the shape factor results does not exist and there is no way to differentiate vertically remote source effects from horizontally remote source effects. In addition, shape factor analysis can only be applied over a limited dynamic range of radionuclide concentrations. If the cesium-137 concentration is below approximately 1.5 pCi/g, the counting uncertainty is too high to yield valid results; if the cesium-137 concentration is above approximately 3,000 pCi/g, the spectra become distorted and shape factor analysis results are invalid. However, more often than not, the shape factor analysis provides relatively conclusive information about the distribution of contamination around the boreholes.

Shape factor analysis was implemented in 1997 as a routine analytical method. The results of the shape factor analyses were used to help justify the elimination of regions of borehole contamination from the visualization databases.

Along with the shape factor analysis, the log data were reviewed to identify areas of very low concentrations of discontinuous contamination. Regions with this type of contamination distribution can often be attributed to contamination that was carried down during the borehole drilling operations or particulate matter that fell down into the boreholes. Unless the contamination data can be correlated between several boreholes or the contamination can be otherwise demonstrated to exist within the formation, it is removed from the visualization database.

### 6.2.3.3 Activities Related to Vadose Zone Characterization at the AX Tank Farm

Thirty boreholes surrounding the four tanks in the AX Tank Farm in the 200-East Area were logged with the spectral gamma logging systems in August and September 1996, with the data reported in GJ-HAN-49 through GJ-HAN-52. A preliminary AX Tank Farm report

(GJO-HAN-10) was published in April 1997; the final (GJ-HAN-12) was published in August 1997.

Cesium-137 was the main gamma-emitting radionuclide detected in the vadose zone at the AX Tank Farm. The highest cesium-137 concentrations (<8,000 pCi/g) and most extensive vertical distributions were detected on the north side of the AX Tank Farm in 2 boreholes that are adjacent to tanks AX-101 and AX-103. Those tanks are designated as sound tanks, whereas tanks AX-102 and AX-104 are designated as leakers. The contamination between tanks AX-101 and AX-103 (shown in Figure 6.2.3) was attributed to a surface source that migrated to depths of more than 30.5 m (100 ft). The historical gross gamma log record shows contamination was present when the borehole was drilled, and there is a high probability that some contamination was carried down during drilling and is not actually present in the formation.

Evaluation of the spectral gamma log data indicates there has been significant near-surface contamination at the AX Tank Farm. Data acquired from virtually all of the boreholes show near-surface contamination is present. Sources of this contamination include surface spills, airborne releases, and pipeline leaks. Other gamma-emitting radionuclides such as cobalt-60, antimony-125, and europium-154 were detected in several boreholes near the ground surface. Occurrences of these radionuclides were associated with the near-surface cesium-137 contamination.

Some small, isolated occurrences of cesium were identified in several boreholes. These boreholes did not show significant contamination above the deeper isolated zones of contamination other than at the ground surface; therefore, it is unlikely that contamination was carried down during drilling.

Borehole log plots of concentrations of the naturally occurring radionuclides potassium-40, thorium-232, and uranium-238 were prepared and evaluated to determine if lithologic features may have contributed to the distribution of cesium-137 contamination in the AX Tank Farm. Interpretations of three-dimensional visualizations of the potassium-40 concentration data indicate an extensive region of coarse and more permeable sediments may be

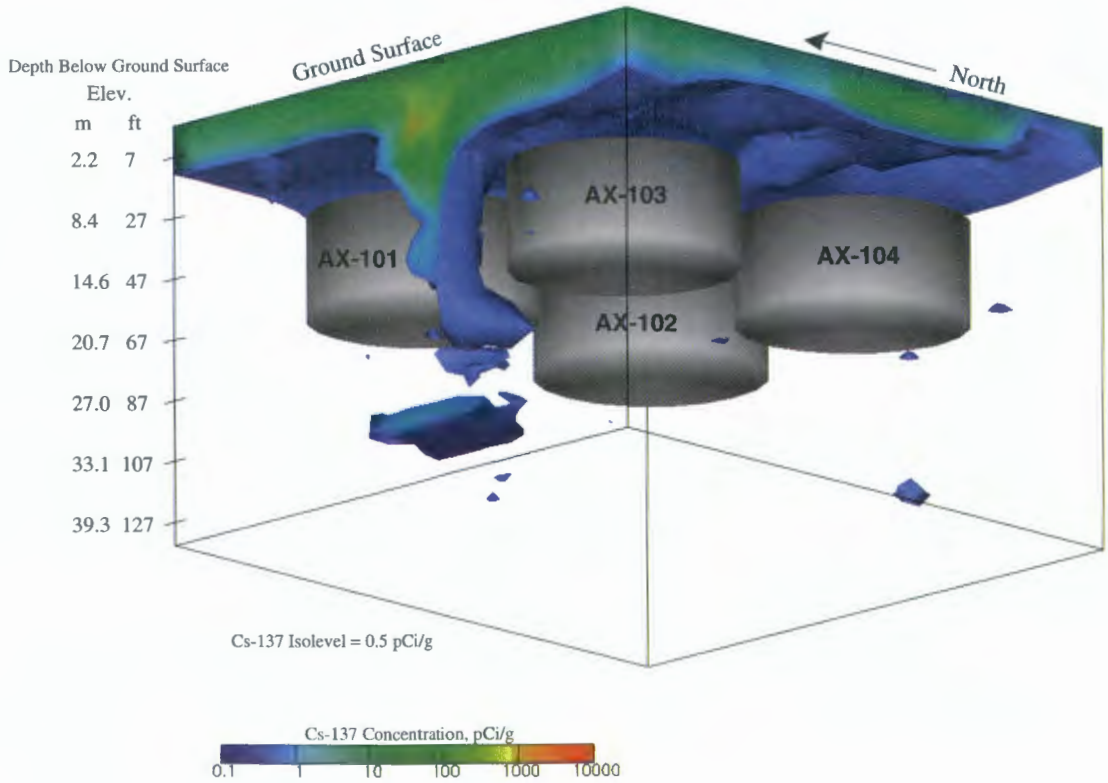


**Figure 6.2.3**. Vadose Zone Contamination at the AX Tank Farm

present in the north and northeast portions of this tank farm. These sediments may have provided a vertical pathway that enhanced cesium-137 migration in this region of the tank farm.

### 6.2.3.4 Activities Related to Vadose Zone Characterization at the BX Tank Farm

Seventy-six boreholes surrounding the 12 tanks in the BX Tank Farm in the 200-East Area were logged with the spectral gamma logging systems from May to August 1997. The tank summary data report for tank BX-102 (GJ-HAN-89) was the only report issued for the BX Tank Farm in 1997. The BX Tank Farm report is planned for completion in mid-1998.

Because tank BX-102 was the source of an extensive, well-documented, contamination plume (Figure 6.2.4), the tank summary data report contained visualizations and was more comprehensive than other such reports.

Spectral gamma log data acquired from the BX-102 boreholes showed significant and deep contamination east and northeast of the tank that resulted from leakage of tanks BX-101 and BX-102. Contamination from these tanks created deep and laterally extensive plumes of cobalt-60, antimony-125, cesium-137, europium-154, uranium-235, and uranium-238.

Cesium-137 contamination was detected throughout the length of borehole 21-02-04, which is located adjacent to the southeast side of tank BX-102. This borehole, which was 77.7 m (255 ft) deep when the borehole was first drilled, was the deepest borehole in the BX Tank Farm. Contamination was detected from ground surface to the groundwater at approximately 73.2 m (240 ft), but it is probable that some contamination was carried down the borehole when it was drilled. The highest concentration of cesium from this borehole is located at the base of the tank, implicating this region as the source of the contamination. If borehole contamination occurred, it is probable that cesium-137 is present in the formation at a depth of 65.8 m (150 ft) because cesium that cannot be explained as borehole contamination was detected in several adjacent boreholes at the 65.8-m (150-ft) depth region.

An extensive uranium plume with concentrations approaching 1,000 pCi/g was also detected in the region

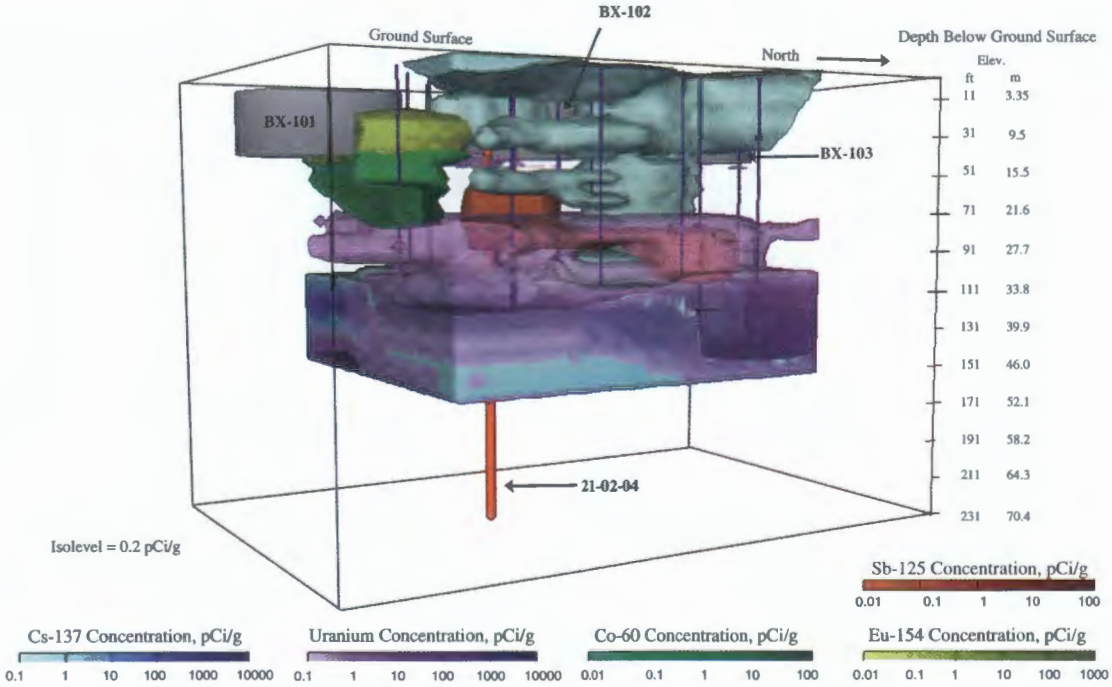


**Figure 6.2.4.** Vadose Zone Contamination at the BX Tank Farm

of this cesium plume from depths of 30.7 to 65.8 m (70 to 150 ft). Because no uranium was detected near the ground surface, it is not probable that the uranium was carried down during drilling. The total depth extent of the uranium is not known because it was detected as continuous plumes at the bottoms of several 65.8-m (150-ft) boreholes. Uranium was also identified in the sediment at the depths of the groundwater and the capillary fringe in well 299-E33-41, a groundwater monitoring well drilled in 1991 just northwest of tank BX-102. The strong correlation with the uranium plume from tank BX-102 makes it highly probable that uranium from the tank migrated down and into the groundwater. Slightly anomalous levels of uranium have been detected in the groundwater from well 299-E33-41.

Cobalt-60 and europium-154 contamination plumes were detected as relatively isolated plumes next to tank BX-101 (see Figure 6.2.4). These plumes appear to have originated from a leak from tank BX-101. A separate antimony-125 contamination plume was also identified and is associated with the leak from tank BX-102.

## 6.2.3.5 Activities Related to Vadose Zone Characterization at the TX Tank Farm

Ninety-four boreholes surrounding the 18 tanks in the TX Tank Farm in the 200-West Area were logged with the spectral gamma logging systems, and the logging was completed in May 1996. The last tank summary data report (GJ-HAN-63) was issued in April 1997; the TX Tank Farm report (GJ-HAN-11) was issued in September 1997.

Cesium-137 is the most abundant and highest concentration man-made gamma-emitting radionuclide that was detected, and concentrations >8,000 pCi/g were identified. Other gamma-emitting radionuclides detected were cobalt-60, europium-154, uranium-235, uranium-238 from processed uranium, and minor amounts of antimony-125. Visualizations of the spectral log data showing the distribution of these contaminants (with the exception of antimony, which occurred as a minor, isolated occurrence) in the vadose zone surrounding the TX tanks were prepared. Figure 6.2.5 is an example of the visualizations that were

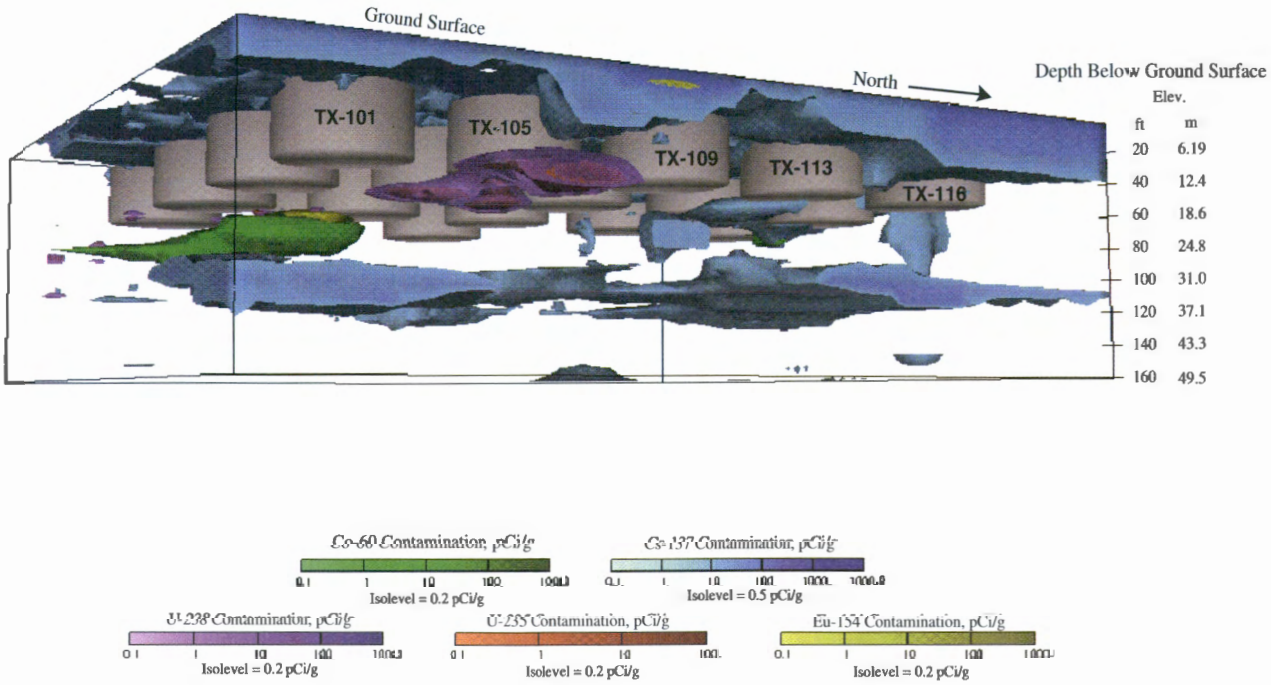


**Figure 6.2.5.** Vadose Zone Contamination at the TX Tank Farm

prepared to show the distribution of these contaminants in the vadose zone at the TX Tank Farm.

Cesium-137 contamination was detected in all of the boreholes. Plumes originating from tank leaks were detected between tanks TX-103 and TX-107, near tanks TX-113 and TX-114, and between tanks TX-117 and TX-118. Other areas showed low levels of contamination that could not be spatially correlated, and it is suspected that drilling may be responsible for much of this low-level contamination. Because the TX Tank Farm log data were not analyzed with the shape factor analysis method, the influence of contamination carried down during drilling was not evaluated. A future priority task will be to perform shape factor analysis on the data from farms that were logged before shape factor analysis was developed.

The contamination shown in Figure 6.2.5 as a widespread cesium plume near an elevation of 175.3 m (575 ft) may not actually exist within the vadose zone and may be caused by contamination that has fallen down the inside of the borehole casings.

Spatially continuous cobalt-60 contamination identified in the vicinity of tanks TX-103 and TX-107 is shown in Figure 6.2.5 as a green contamination plume below the tanks on the south side of the farm. This contamination most likely resulted from leakage of tank TX-107 that migrated laterally to the region beneath tank TX-103 and reached a depth of 30.5 m (100 ft); however, the maximum depth of the cobalt-60 plume could not be determined because it was detected at the bottoms of the boreholes. The cobalt migrated laterally at least 36.6 m (120 ft), and was tracked over time with gross gamma monitoring of the boreholes. The monitoring data show that cobalt did not migrate down along the outside of the borehole casings after the boreholes were drilled.

A plume of processed uranium, containing the isotopes uranium-235 and uranium-238, was identified in the region around tanks TX-101 and TX-105. This contamination is shown in Figure 6.2.5 as a violet contamination plume next to tank TX-105. This plume originated from tank TX-105 and was present when the boreholes were drilled.

Most of the monitoring boreholes in the TX Tank Farm extend to depths of approximately 30.5 m (100 ft); only 7 extended to depths of approximately 76.2 m (250 ft). Therefore, the maximum depth of the contamination plumes in this tank farm is not known.

## 6.2.3.6 Activities Related to Vadose Zone Characterization at the TY Tank Farm

The TY Tank Farm in the 200-West Area consists of six single-shell tanks, five of which are designated as leakers. Twenty-two monitoring boreholes surrounding the six TY tanks were logged with the spectral gamma logging systems. The logging was completed in May 1996, and the last tank summary data report (GJ-HAN-69) was issued in May 1997. The TY Tank Farm report (GJ-HAN-16) was issued in early 1998.

Cobalt-60 and cesium-137 were the major gamma-emitting contaminants detected in the TY Tank Farm. Borehole log data from this farm were subjected to shape factor analysis, and regions of known borehole contamination as well as isolated or discontinuous regions of low-level cesium contamination were removed from the visualization database prior to developing three-dimensional visualizations. The resulting "interpreted data set" was used to create visualization of the cesium and cobalt plumes, as shown in Figure 6.2.6.

Figure 6.2.6 shows the most extensive contamination in the southern region of the tank farm below the bases of tanks TY-105 and TY-106. Both tanks are presently designated as leakers; the deep contamination beneath these tanks is primarily cobalt-60. Cobalt plumes are as much as 15.2 m (50 ft) thick, and because cobalt was detected at the bottom of several boreholes, with a pattern of increasing concentration with depth, the maximum depth of the cobalt is not known.

Some of the cobalt-60 contamination was detected below the Early Palouse/Plio-Pleistocene interval (see Section 6.1.1, "Geologic Setting"), which has often been considered a barrier between downwardly migrating fluids and groundwater. A zone of cobalt-60 contamination was also detected in one borehole at a depth of 64.9 m (213 ft), immediately above the water table and within the capillary fringe. This contamination, which has probably reached groundwater, is shown on the visualization as an isolated pod down deep in the southwest corner of the farm. It is not confirmed that the deep cobalt plumes in the vadose zone from the tanks are the source of the groundwater contamination, but this is highly likely. Cobalt was released into nearby cribs and trenches, and it is probable that those cribs contributed cobalt to the groundwater.

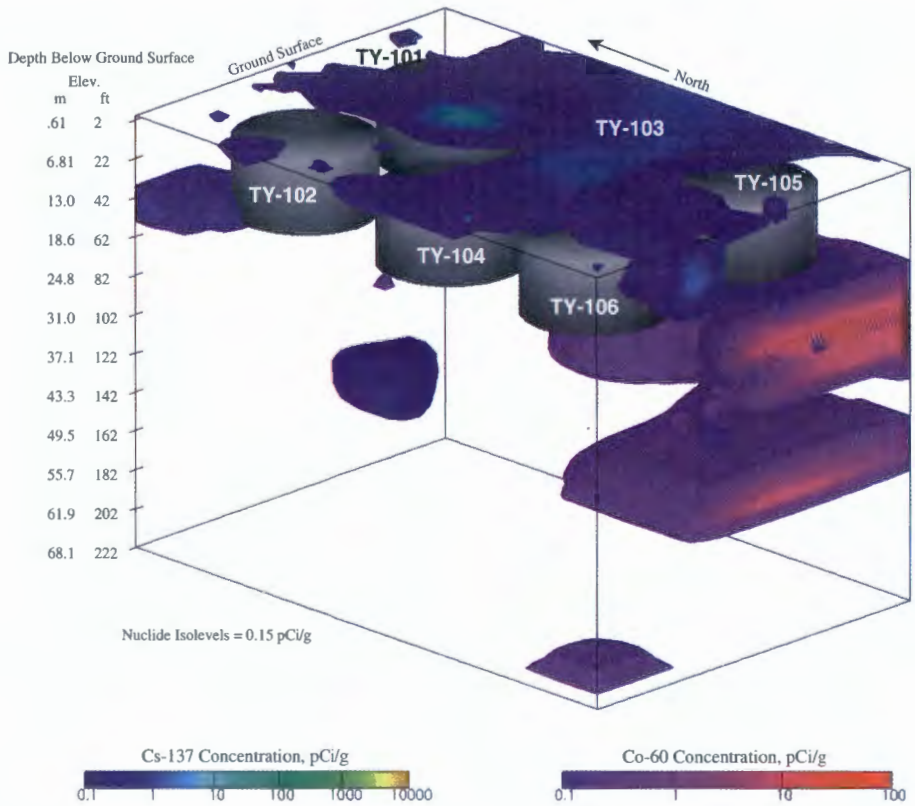


**Figure 6.2.6**. Vadose Zone Contamination at the TY Tank Farm

Cesium-137 detected near the ground surface over a widespread area of the TY Tank Farm resulted from surface spills and/or pipeline leaks. This contamination migrated as deep as 4.6 m (15 ft) in the southern portion of the tank farm.

An interval of cesium-137 contamination of approximately 100 pCi/g was also detected near the base of tank TY-102, indicating that this tank may have leaked, though the tank is presently designated as sound. This contamination was detected in a borehole outside the northwest quarter of the tank that is isolated from tanks that are known to have leaked; therefore, it could not have originated from another tank. This contamination was shown in Figure 6.2.6 as a plume in the northwest corner of the farm at the base of tank TY-102. Historical gross gamma-ray log data acquired in the borehole indicated increased activity in 1980 at the depth cesium-137 was detected with the spectral gamma logging system. It is possible that this contamination originated from either a surface spill or a leak from the near-surface tank condenser tower (the above-ground portion of the tower was removed) and then migrated down the tank side. However, no contamination was detected in the upper portion of the borehole, which would be expected for this scenario.

### 6.2.3.7 Activities Related to Vadose Zone Characterization at the U Tank Farm

Fifty-nine boreholes surrounding the 12 tanks in the U Tank Farm in the 200-West Area were logged with the spectral gamma logging system from September to December 1995. The final tank summary data report for the U Tank Farm (GJ-HAN-41) was completed in September 1996. The U Tank Farm report (GJ-HAN-8) was issued in May 1997.

Cobalt-60, cesium-137, europium-154, uranium-235, and uranium-238 were detected in the U Tank Farm boreholes. Plots of the radionuclide concentrations as a function of depth are included in the individual tank summary data reports.

Three-dimensional visualizations of the contamination at the U Tank Farm were created directly from the borehole log data because shape factor analysis was not yet developed. In addition, isolated regions of low-level contamination that is thought to result from drilling were not removed from the visualization database. The cross-borehole correlation is, therefore, based on the empirical geostatistical correlation of data that is biased, in that suspected borehole contamination is not removed, and the visualizations may show contamination plumes in the vadose zone that may not actually be present. Figure 6.2.7 is a visualization showing the interpreted distribution of cesium-137 and uranium-238 in the vadose zone at the U Tank Farm.

The spectral gamma log data indicated cesium-137 is the most extensive contaminant in the U Tank Farm. The highest cesium-137 concentrations were detected north of tank U-112, which is designated an assumed leaker. This contamination is not shown in Figure 6.2.7. The contamination plume, which is defined by the log from a single borehole, is found at the base of the tank down to a depth of 38.1 m (125 ft). However, the amount of contamination carried down during borehole drilling is unknown, and data acquired from other nearby boreholes do not show similar high levels of contamination. As a result, shape factor analysis or additional drilling will be required to determine the total depth of this plume. Tasks are planned to do shape factor analysis on these logs.

A plume of cesium-137 contamination was also identified near the base of tank U-110, which is also designated an assumed leaker. This plume, which is shown in Figure 6.2.7, is defined by the log data from two boreholes.

Other high cesium-137 contamination is related to near-surface spills or leaks associated with equipment failures and operations. Cesium-137 contamination was detected throughout the lengths of several boreholes at concentrations of 1 pCi/g or less and is suspected to be the result of contamination carried down during drilling. The extensive and deep cesium plume shown in Figure 6.2.7 between elevations of 152.4 and 164.6 m (500 and 540 ft) is not as extensive as shown and is the result of borehole

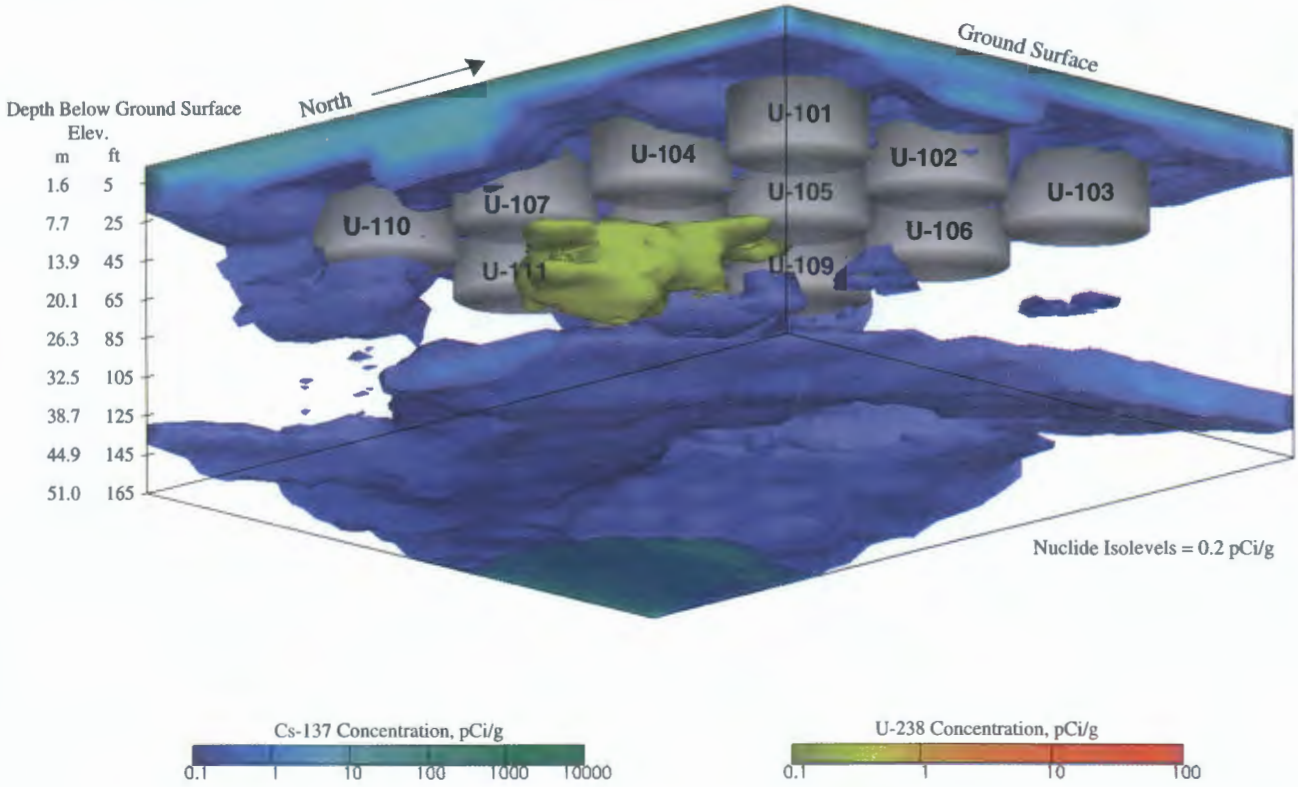


**Figure 6.2.7.** Vadose Zone Contamination at the U Tank Farm

contamination in some places. In some boreholes, however, the contamination was not carried down during drilling, as determined by the fact that little contamination was detected in the upper portion of the borehole, while the lower portion of the borehole showed relatively higher concentrations.

A processed uranium plume, consisting of the isotopes uranium-235 and uranium-238, was identified near tanks U-104 and U-108. This plume, located between tanks U-104, U-105, U-107, and U-108, is well defined in Figure 6.2.7. This plume was associated with leakage from tank U-104.

Only small amounts of cobalt-60 and europium-154 were detected at the U Tank Farm. These radionuclides, which were limited in distribution and detected as isolated occurrences near the ground surface, are clearly the result of surface spills.

No contamination plume was identified for the region around tank U-101, the only other assumed leaker in the U Tank Farm. It is probable that the leak from the tank was relatively small and that the boreholes around this tank did not intercept the contamination plume.

Concentrations of the naturally occurring radionuclides potassium-40, thorium-232, and uranium-238 were correlated with the lithologic information to determine if distinguishable features were present beneath the U Tank Farm and to determine how these features correlate with the distribution of contaminants. The potassium-40 concentration plots showed distinct increases at the interface between the backfill sediments and undisturbed Hanford formation fine-grained unit at the base of the tank farm excavation. Although few of the monitoring boreholes were deep enough to intercept the Plio-Pleistocene unit, those that did showed a very distinct low activity response on the potassium-40 log that is correlated to the caliche zone of the Plio-Pleistocene unit.

## 6.2.4 Vadose Zone Monitoring at Waste Disposal Facilities

*R. J. Serne, V. J. Rohay, and P. E. Dresel*

Radioactive and hazardous waste in the soil column from past intentional liquid waste disposals, accidental spills, and leachate from solid waste burial grounds at the Hanford Site are potential sources of current and future groundwater contamination. Subsurface source characterization and vadose zone monitoring, using spectral gamma logging and soil-gas monitoring were conducted during 1997. This section summarizes major findings from these efforts. The 1997 efforts focused primarily on vadose zone soil contamination associated with past liquid disposals to cribs, trenches, drain fields, and injection wells at the B-BX-BY Waste Management Area in the 200-East Area, the Plutonium Finishing Plant liquid waste disposal sites in the 200-West Area, and the Nonradioactive Dangerous Waste Landfill at the Central Landfill in the 600 Area. The interpretation of monitoring and characterization results is presented in the sections that follow.

### 6.2.4.1 In Situ Monitoring

The objectives of vadose zone monitoring are to document contamination location and to determine moisture and radionuclide movement in the soil column. Spectral gamma logging is an in situ (meaning in place) measurement of subsurface gamma-emitting radionuclides obtained through cased monitoring wells that are completed in the vadose zone or extend into the saturated zone. The detector or sensor is generally a crystal of germanium and associated electronics. Photons emitted from radionuclides in the formation interact with the detector material, resulting in electronic pulses transmitted to the surface via electrical cables to a digital data storage system. By periodically recording detector response at various depths, changes over time can be documented. This general type of logging (in particular gross gamma screening as opposed to spectral gamma) has been conducted at the Hanford Site for over 25 years by slowly raising and lowering the detector inside existing cased monitoring wells in the vicinity of disposal facilities and single-shell tanks. During 1997, in situ spectral gamma logging was performed by Waste Management Federal Services, Inc., Northwest Operations personnel in support of Pacific Northwest National Laboratory Resource Conservation and Recovery Act assessment (PNNL-11826) in selected groundwater monitoring wells outside the B-BX-BY Waste Management Area.

Sixteen wells were successfully surveyed from the ground surface to the water table. The well numbers and location description are given in Table 6.2.1 and can be seen on Figure 6.2.8. The technique is capable of probing the sediment around the well casing to a radius of a few to several tens of centimeters (0.5 to 2 ft), depending on the casing thickness and sediment bulk density. Corrections for varying well diameters and presence of sealants around

**Table 6.2.1**. Location of Spectral Gamma Logged Boreholes at the B-BX-BY Waste Management Area, 200-East Area

| Well Number | Closest Disposal Facility |
|---|---|
| 299-E33-04 | Just northwest of the 216-B-46 Crib in the BY Cribs |
| 299-E33-05 | Located just southwest of 216-B-47 cribs in the BY Cribs |
| 299-E33-13 | ~100 m east of the BY Cribs and northeast of the BY Tank Farm |
| 299-E33-15 | At the end of the last spur line of the 216-B-8TF Tile Field |
| 299-E33-16 | At the front end of the 216-B-8 Crib and 216-B-8TF Tile Field |
| 299-E33-17 | East of the 216-B-8TF Tile Field and north of the 216-B-11 Injection Wells |
| 299-E33-18 | Just north of the northwestern edge of the B Tank Farm and just southwest of the 216-B-7B Crib |
| 299-E33-19 | Just north of the 216-B-11B Injection Well |
| 299-E33-20 | Just south of the 216-B-11A Injection Well |
| 299-E33-21 | Near the eastern end of the 216-B-36 Trench and west of the BX Tank Farm |
| 299-E33-31 | West of the fence line surrounding the BX-BY Tank Farms |
| 299-E33-32 | Along the fence line of the BX-BY Tank Farms; 135 m directly south of well 299-E33-31 |
| 299-E33-38 | Midway between the 216-B-47 Crib and north fence line of BY Tank Farm; inside BY Cribs fence |
| 299-E33-41 | On east fence line of BX Tank Farm |
| 299-E33-42 | Approximately midway between wells 299-E33-31 and 299-E33-32 |
| 299-E33-43 | 30 m south of well 299-E33-31 |

the annulus of the casing should be taken into account prior to interpreting the raw counts obtained as a function of depth in monitoring wells. In addition, a concern with any well is the degree to which contaminants may have migrated down the inside or outside of the well casing. A technique called shape factor analysis discussed in Section 6.2.3.2, "Improvements Made to Contamination Visualizations," can help address this latter issue. Shape factor analysis was not used to aid the interpretation of the spectral gamma logging presented in the next section.

**Spectral Gamma Logging Results**. Four of the 16 gamma logs obtained outside the B-BX-BY Waste Management Area suggest that gamma-emitting radionuclides may have been redistributed in sediments surrounding 4 wells in the last 10 years (299-E33-05, 299-E33-18, 299-E33-38, and 299-E33-41). The evidence for redistribution is not above question for some of these wells, and the significance of redistribution varies. An attempt was made to capture the uncertainties and significance in the discussion that follows.

Movement of cobalt-60 at well 299-E33-05 between September 1991 and December 1994 was documented in a small zone between 33.2 and 34.7 m (109 and 114 ft) but the logging in September 1997 showed no measurable change since 1994. The 1994 logging showed apparent horizontal migration of cobalt-60 away from the well based on a slight decrease (above that expected from natural radioactive decay) in cobalt activity. Because there was no difference between the spectral gamma logs at shallower or deeper depths, one can speculate that the cobalt moved laterally. Geologic data from a nearby well suggested that there is a fine-grained sand lens at the 33.5-m (110-ft) level that is bounded above and below by coarser material that would act as a barrier that limits water flow to occur only in the fine-grained sand. See Hillel (1980) or Guymon (1994) for descriptions of unsaturated flow in vadose zone sediments and Richards-type barriers. Several Hanford scientists are concerned that the small change in cobalt-60 may be within the uncertainty in calibration of the detectors and slight procedural changes from one logging event to another. These logging activities found no change in the cobalt-60, antimony-125, or cesium-137 in the rest of the vadose zone profile.

Cobalt was found in the September 1997 log between 15.2 and 50.3 m (50 and 165 ft) and trace amounts were found close to the water table at 68.6 to 71.3 m (225 to 234 ft). The higher levels of cobalt-60 are between 25.9 and 38.1 m (85 and 125 ft). The maximum cobalt-60 activity is 50 pCi/g at 29.9 m (98 ft). Antimony-125 and cesium-137 and are also found in the gamma logs at well 299-E33-05. The cesium-137 was between the depths of 15.2 and 19.8 m (50 and 65 ft) with a trace amount (approximately 3 pCi/g) just above the water table. Groundwater taken from this well show cobalt-60 has been present since samples have been collected (October 1956), and the concentration has ranged between 10 to 30 pCi/L over the past 2 years. The groundwater data,

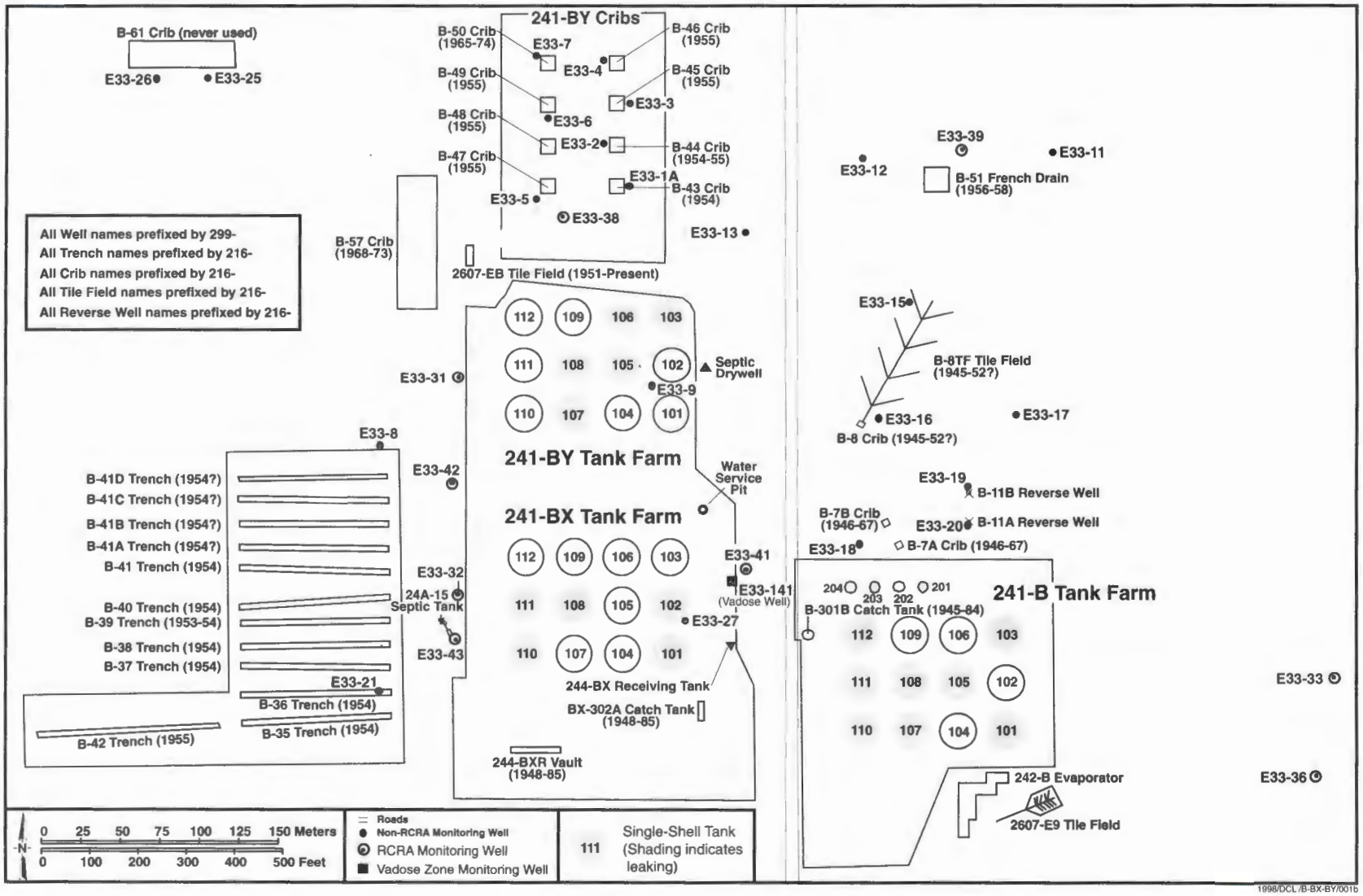


**Figure 6.2.8**. Diagram of Waste Management Area B-BX-BY

more so than the spectral gamma logging, suggest that the vadose zone sediments under the BY Cribs are slowly draining cobalt-60 into the water table.

The cesium-137 maximum concentration (900 pCi/g) was found at 16.2 m (53 ft). Antimony-125 was present from 15.2 to 29.9 m (50 to 98 ft), with the maximum (33 pCi/g) at 29 m (95 ft). Maximum activities of antimony-125 and cobalt-60 occur at nearly the same depth (29 to 29.9 m [95 to 98 ft]) and the remaining profiles are also similar.

These facts suggest that the antimony and cobalt migrate at approximately the same velocity through the sediment. A common measure of migration rate is the retardation factor that relies on measurement of a distribution coefficient for each contaminant (e.g., Serne and Muller 1987, Freeze and Cherry 1979). It is known that the distribution coefficient for antimony, which is generally present in groundwaters as an anion, is small; often as low as zero, yet the distribution coefficient for the free cobalt cation is generally quite large (see EPA 520/6-78-007 and NUREG/CR-1322, PNL-2901). In some chemical environments, cobalt is found to be complexed with ligands such that its adsorption tendencies are significantly reduced. Disposal at the BY Cribs included discharges of liquids that contained cyanide, a known strong complexant for cobalt. The cobalt-60 present in the vadose zone sediments and groundwater below BY Cribs probably has complexed with cyanide and has migrated to the groundwater.

Elevated uranium was identified by spectral gamma logging in wells 299-E33-18 and 299-E33-41 at much higher concentrations than natural background. At well 299-E33-18, the uranium concentration changed from not detected in September 1992 to 400 pCi/g when logged in September 1997. Uranium movement occurred just above the groundwater table between the depths of 70.7 to 75.9 m (232 to 249 ft). The groundwater at this well started showing rising uranium concentrations between February 1993 and April 1994 and ranged between 100 to 200 µg/L in the past 2 years. The significance of the uranium migration is under study (PNNL-11826).

At well 299-E33-18, there is a minor amount (maximum <2 pCi/g) of cesium-137 between the ground surface and 3.05-m (10-ft) depth. There is also some cobalt-60 deep in the formation between 70.1 and 81.4 m (230 and 267 ft), with a maximum activity of 3 pCi/g in a zone between 70.1 and 74.7 m (230 and 245 ft), just above the current water table. In the 1960s, groundwater at this well contained several thousand to a few tens of thousands of picocuries per liter of cobalt-60; by late 1977, the activity had dropped to a few tens of picocuries per liter; and by 1985, activities were at the detection limit.

Logging of well 299-E33-38 was done at the time of construction (in early 1991), in July 1995, and again in September 1997. Originally, very low levels of cobalt-60, antimony-125, and cesium-137 were observed at several depths. The current log shows cesium-137 at a maximum activity of 3 pCi/g in a thin lens between 15.8 and 17.7 m (52 and 58 ft). The previous logs show the cesium at the same depth. A quantitative comparison is complicated by changes in well "geometry" when the construction casing was removed and bentonite seals were placed in the void. In the current log, cobalt-60 was found from 17.4 to 61.9 m (57 to 203 ft). This recent logging shows very minor changes from the July 1995 log but significant changes from the January 1991 log. The change in the cobalt-60 profile between 1991 and 1995 was at 37.2 to 42.1 m (122 to 138 ft), showing that cobalt-60 moved deeper down the profile but the magnitude of the vertical migration was <1 pCi/g and could be solely an artifact of the changes in well geometry. If the small changes are real, they are not significant based on risk analyses. Because of its short half-life and because it has decayed away, antimony-125 was not detected in 1997.

In well 299-E33-41, uranium appears to have increased by a factor of 5 (from 200 to 1,000 pCi/g) between April 1991 and September 1997 in a deep zone between 67.1 to 73.2 m (220 to 240 ft). When this well was constructed in April 1991, there were 2 uranium-238 peaks between 65.2 and 71.6 m (214 and 235 ft), with activity maxima of 190 pCi/g at 66.4 m (218 ft) and 160 pCi/g at 71.3 m (234 ft). These values do not agree very well with gross alpha determinations on sediment samples obtained during construction of the well. The gross alpha activities are lower, by as much as a factor of 10. In September 1997, the log showed elevated uranium-238 in the sediment from 65.2 to 71.9 m (214 to 236 ft), with the maximum (1,000 pCi/g) at 72.5 m (238 ft). The peak activity and whole plume thus seems to have migrated 1.2 to 6.1 m (4 to 20 ft) deeper into the profile. It is noted that there were considerable changes in well geometry (changed casings and added seals) between the two logging events that could complicate interpretations. The well will be relogged in fiscal year 1998 and will be a candidate for future, more frequent monitoring. The overall uranium log for 1997 shows elevated activity from 22.9 to 73.2 m (75 to 240 ft), with numerous minor peaks all above the current water table at 75.1 m (246.5 ft). The spectral gamma log for this well also shows minor (2 pCi/g) cesium-137 surface contamination down to 1.5 m (5 ft).

The groundwater at well 299-E33-41 showed a small increase in uranium concentrations between June 1993 and March 1994. The uranium concentration in the groundwater has ranged from 8 to 81 µg/L. No water analyses for uranium were performed in 1995 to May 1997. A November 1997 analysis shows a significant increase from 1994 (81 versus 8 µg/L). The most recent uranium analysis (December 1997) was 23 µg/L. As discussed in Section 6.2.3.4, "Activities Related to Vadose Zone Characterization at the BX Tank Farm," single-shell tank BX-102 is the likely source of the uranium.

The following is a summary of the gamma logs for wells that do not show any signs that gamma-emitting radionuclides have moved in the sediments surrounding the casings over the last 20 years.

Well 299-E33-04 showed high levels of cesium-137 and some cobalt-60 in the profile. Significant cesium-137 activity is found between 6.1 and 21.3 m (20 and 70 ft), and the detector saturates between 6.1 and 8.2 m (20 and 27 ft) because of very high signal. Using a less sensitive detector, the region between 6.1 and 8.2 m (20 and 27 ft) shows the maximum activity is 1,400,000 pCi/g at 7.5 m (24.75 ft). Cesium-137 is not found in the log below 27.4 m (90 ft), suggesting that it is less mobile than cobalt-60. Cobalt-60 is observed from 16.8 m (55 ft) to the bottom of the well at 68.6 m (225 ft). There are 2 maxima, both 36 pCi/g at 27.4 and 70.4 m (90 and 231 ft). It is known that cobalt-60 has reached the groundwater under the BY Cribs, and the gamma logging seems to corroborate this finding. The water table in 1997 was at 69.3 m (227.4 ft) at this location but was higher in the past. In the 1950s to the mid 1960s, groundwater at this well contained 100,000 pCi/L cobalt-60 and, at present, there may be a small amount above the detection limit. There may also have been some cesium-137 in unfiltered groundwater in the late 1950s but because more accurate methods have been used, starting in the 1970s, there has been no detectable cesium-137 in groundwater.

Well 299-E33-13 shows cesium-137 in 2 zones: one very shallow (ground surface to 9.1 m [30 ft] deep), with a maximum of 16 pCi/g at 0.3 m (1 ft) and the second between 62.5 to 71.3 m (205 to 234 ft), with 16 pCi/g found 3 times between 62.5 and 67.1 m (212 and 220 ft). Cesium-137 has never been measured above detection limits in the groundwater in this well.

Cobalt-60 is also observed at this well at very low activities, from 30.5 to 67.1 m (100 to 220 ft), and at moderate levels between 67.1 and 73.2 m (220 and 234 ft), with a maximum of 8 pCi/g at the bottom (73.2 m [234 ft]) of the well. Cobalt-60 was present in the groundwater from 1956 to 1971. Sampling was restarted in 1991, and no cobalt-60 has been detected in the groundwater to the present time.

The log for well 299-E33-15 showed no cobalt-60 and cesium-137 in the profile until 67 m (220 ft) was reached. From 67.1 to 72.5 m (220 to 238 ft), cobalt-60 was found at a maximum of 30 pCi/g at the well bottom (72.5 m [238 ft]). Cobalt-60 was measured in the groundwater from 1956 through 1965, when the sampling ceased. Cesium-137 was present in the groundwater briefly in 1956. Starting in 1991, groundwater sampling resumed but no cobalt-60 or cesium-137 has been found above the detection limit.

The log for well 299-E33-16 showed very high cesium-137 activity between 8.5 and 10.1 m (28 and 33 ft) and high activity between 10.1 and 15.8 m (33 and 52 ft). There is also some cesium-137 at 0.3 m (1 ft) below the ground surface and between 6.7 and 50.3 m (22 and 165 ft). Using a less sensitive detector, the maximum cesium-137 was found to be 62,000 pCi/g at the 9.4-m (31-ft) level. The maximum cobalt-60 activity (20 pCi/g) was observed at 76.2 m (250 ft), with the overall zone found between 68.6 and 76.2 m (225 and 250 ft). The gamma log at the head end of the 216-B-8TF Tile Field shows much more radioactivity than the back end well (299-E33-15). Very little liquid waste may have reached the end of the tile field prior to percolating into the sediments. The brief occurrence of cesium-137 in the groundwater at well 299-E33-15 may have reached the water table closer to well 299-E33-16 and migrated toward well 299-E33-15.

Analyses of unfiltered water from well 299-E33-16 occurred from 1956 to 1962 and then resumed in late 1997. During the first period, cobalt-60 was readily detected in the water but the current sampling shows activity very near the detection limit. Early water analysis for cesium-137 ended in May 1959 and restarted in August 1997. It is not certain whether cesium-137 reached the water table at this location.

Well 299-E33-17 showed very low levels of cesium-137 near the surface and just above the water table (now at 67.8 m [229 ft]). The cesium-137 activity is always below 2 pCi/g. Cobalt-60 is observed deep in the profile between 68.6 and 73.5 m (225 and 241 ft), the bottom of the well. The cobalt-60 activity in this zone is 23 pCi/g. It would appear that the cobalt-60 reached this location via horizontal migration in the aquifer. Cobalt-60 was present in

the groundwater in the mid-1950s through the mid-1960s but currently, there is no detectable cobalt-60 in the groundwater. The very low cesium-137 activity near the ground surface and deep in the sediment at this location is difficult to explain. The well is approximately 100 m (328 ft) away from any disposal facility.

Well 299-E33-19 showed 3 zones of cesium-137 with decreasing activity with depth. The 216-B-11 Injection Wells were 10-cm (4-in.) dia. cased holes that extended 12.2 m (40 ft) below grade. The first zone was from the ground surface to 3.05 m (10 ft), with a maximum activity of 50 pCi/g. The second zone is a lens between 32 and 33.5 m (105 and 110 ft), with an activity of 10 pCi/g. The deepest zone is at 70.7 to 74.4 m (232 to 244 ft) at the bottom of the well, and the maximum cesium-137 concentration is <2 pCi/g. The two latter zones are well below the depth of the injection wells, suggesting cesium-137 migration through the vadose zone sediments. Cobalt-60 was detected between 69.2 and 71.3 m (227 and 234 ft) but the activities are rather low (<0.4 pCi/g). Groundwater at this well was monitored for a brief time (1957 to 1962) and never showed measurable cesium-137 but did show the presence of cobalt-60 at several thousand to a few tens of thousands of picocuries per liter.

The log for well 299-E33-20 was very similar to the log for well 299-33-19. Again, there are 3 zones of cesium-137 contamination: ground surface to 3.05 m (10 ft), 26.8 to 28.3 m (88 to 93 ft), and 57.3 to 60.4 (188 to 198 ft). The maximum cesium-137 activities in these zones are 40, 35, and 23 pCi/g, respectively. The values for the 2 deeper depths are higher than those at well 299-E33-19. This well also shows the deep (74.7- to 79.9-m [245- to 262-ft]) zone of very low cobalt-60 (<1 pCi/g). Groundwater from this well was analyzed from 1957 to 1963, briefly in 1987, and then again in 1997. Cesium-137 was never detected. Cobalt-60 was present through 1963 but had decayed away by 1987. In 1997, there were no gamma emitters present in the groundwater.

Well 299-E33-21 showed a significant cesium-137 plume, stretching from 3.7 m (12 ft) below ground surface (the depth of the trench bottom is 3.05 m [10 ft]) to the bottom of the well at 85.3 m (280 ft). Between 4.6 and 7.0 m (15 and 23 ft), the cesium-137 activity saturates the detector and also causes distortion in the detector readings down to 13.7 m (45 ft). A less sensitive detector was used to quantify the activity in this high-count-rate zone. The cesium-137 activity peaks at 5.5 m (18 ft) at a value of 120,000 pCi/g. The elevated cesium-137 at the bottom of the well (30 pCi/g) could be sediment adhering to the drive shoe that is the terminus of the casing. The 216-B-36 Trench received scavenged waste in 1954, the product of trying to reprocess bismuth phosphate waste to extract uranium. One would expect to see high activities of cesium-137 in the remaining fluid from extracting uranium. In the late 1970s, there may have been some (5 to 15 pCi/L) cesium-137 detected in unfiltered groundwater from this well but the quality assurance for these early results is difficult to ascertain. Since 1985, when better quality assurance documentation had been entered into the database, no cesium-137 was found above the detection limit in groundwater from this well. This trench appears to be a good candidate for more detailed study on cesium distribution and migration potential within the vadose zone.

There is also a very minor (<1-pCi/g) cobalt-60 signal at the very bottom of the casing in well 299-E33-21. In 1958, a few hundred picocuries per liter of cobalt-60 were observed in groundwater from this well. From 1975 through 1980, the cobalt-60 in the groundwater was between 10 and 20 pCi/L. By 1983, the cobalt-60 activity dropped to a few picocuries per liter, where it remains today.

Well 299-E33-31 showed no anthropogenic radionuclides at depth. There are minor amounts of cesium-137 from the surface to 3.05 m (10 ft). This undoubtedly reflects a surface spill in the past. Well 299-E33-32 has a spectral gamma log with no anthropogenic radionuclides measured. Well 299-E33-42 is approximately midway between wells 219-E33-31 and 299-E33-32. The spectral gamma log for well 299-E33-42 showed only minor cesium-137 contamination (<1 pCi/g) from the ground surface to 3.05 m (10 ft). Well 299-E33-43 showed no anthropogenic radionuclides at any depth. The logs for these four wells suggest that no man-made radionuclides have been transported from the 216-B-35 to 216-B-42 Trenches away in an easterly direction. Conversely, the data also suggest that no gamma-emitting radionuclides from tank leaks have traveled in a westerly direction. PNNL-11826, however, shows that concentrations of technetium-99, specific conductance, and nitrate have been increasing in groundwater well 299-E33-32 in the recent past such that there may be migration of some contaminants in the groundwater between the B Trenches and BX-BY Tank Farms.

In summary, the spectral gamma surveys in 16 wells within the B-BX-BY Waste Management Area found indications of small changes (a few picocuries per gram) in cobalt-60 concentrations in the sediment profiles in

two wells (299-E33-05 and 299-E33-38). The changes occurred between 1991 and 1994 in the first well and between 1991 and 1995 in the second well. As discussed, changes in casing construction, addition of sealants, and changes in logging procedures may have compromised the interpretation of whether the movement actually occurred. There has been little indication of further movement based on the September 1997 logs in these two wells. The cobalt-60 movement in well 299-E33-04 was horizontal (migration away from the casing) in a fine-grained zone between 33.2 and 34.7 m (109 and 114 ft). The cobalt-60 migration at well 299-E33-38 may have been down the profile between 37.2 and 42.1 m (122 and 138 ft), but amounts are insignificant (1 pCi/g). Uranium appears to have migrated deeper in wells 299-E33-18 and 299-E33-41, but the data for the latter well is being reevaluated. The zones in the two wells where the uranium may be migrating are near their respective water tables. There may not be a common source of uranium for these wells. The uranium activity increases in the gamma logs for these wells are 400 and 800 pCi/g, respectively. Groundwater in both wells has shown significant increases in uranium over the past 2 years such that the spectral gamma results corroborate the groundwater monitoring results. These 2 wells are approximately 100 m (328.1 ft) apart and are located to the east of the BX Tank Farm and just north of the B Tank Farm. The uranium concentration in the groundwater at well 299-E33-18 is higher than the uranium concentration in well 299-E33-41, perhaps suggesting that, if there is a common source, it is closer to well 299-E33-18. Spectral gamma logging from wells inside the BX Tank Farm suggest that a leak from tank BX-102 is the source of the uranium observed in well 299-E33-41. Thus, the higher uranium observed in groundwater at well 299-E33-18 may be from a different source. Well 299-E33-18 is 50 m (164 ft) north of tank B-112, a known leaker, and in the past, groundwater flow was in a north-northwesterly direction at this waste management area. The hydraulic gradient is almost level today; so it is difficult to be certain how the uranium reached well 299-E33-18. See PNNL-11826 for further discussion on the possible sources of recent elevated levels of uranium, technetium, specific conductance, and nitrates in groundwaters under this waste management area.

## 6.2.4.2 Soil-Gas Monitoring

Soil-vapor extraction is being used to remove the carbon tetrachloride source from the vadose zone as part of the 200-West Area carbon tetrachloride expedited response action being conducted by Bechtel Hanford, Inc. For descriptions of past work, see BHI-00720 (Rev. 1) and Section 4.2.2 in PNNL-11470. To track the effectiveness of the remediation effort, measurements of soil-gas concentrations of chlorinated hydrocarbons were made at individual, on-line, extraction wells; at soil-gas probes throughout the vadose zone; and at the inlets to three soil-vapor extraction systems during 1997. While the extraction systems were shut down from November 1996 through June 1997, a study was conducted to evaluate the magnitude and rate of chlorinated hydrocarbon concentration rebound by measuring soil-gas concentrations in samples collected from wells and probes throughout the extraction sites (BHI-01105). At the carbon tetrachloride extraction site (Figure 6.2.9), there are currently 46 drilled wells available for on-line extraction or monitoring (BHI-00720, Rev. 1; BHI-01105). Each of the soil-vapor extraction systems extracts simultaneously from multiple wells. The mix of on-line wells is adjusted periodically to optimize contaminant removal.

There are 125 subsurface monitoring probes at depths greater than 2 m (6.6 ft) as shown in Figure 6.2.10. The network was installed between 1991 and 1995. In 1997, a soil-gas study was also performed at the Nonradioactive Dangerous Waste Landfill, and results/observations are included in this section.

**Soil-Vapor Remediation and Monitoring Results**. The soil-vapor extraction systems were operated from October 1 through November 3, 1996 and from July 18 through September 30, 1997. From November 4, 1996 through July 17, 1997, the extraction systems were shut down and the rebound in carbon tetrachloride concentrations was monitored at 90 wells and soil-gas probes in the extraction well field sites.

During October and November 1996, carbon tetrachloride concentrations in extracted soil vapor continued to decline, as they have since operation of the extraction systems began in 1992 (BHI-00720, Rev. 1; BHI-01105). This is typical and represents removal of the readily available vapor phase of the contaminant in vadose zone sediment pore spaces. The most dramatic vapor-phase decrease was at the 216-Z-9 Well Field, where carbon tetrachloride concentrations measured at the system inlet declined from ~30,000 parts per million by volume (ppmv) in 1993 to 25 ppmv in early November 1996 (Figure 6.2.11). In comparison, carbon tetrachloride concentrations in soil vapor extracted from the 216-Z-1A Well Field declined from ~1,500 ppmv in 1992 to 16 ppmv in November 1996 (Figure 6.2.12) and in soil vapor extracted from the 216-Z-18 Well Field declined from ~275 ppmv in 1994 to 10 ppmv in November 1996 (Figure 6.2.13).

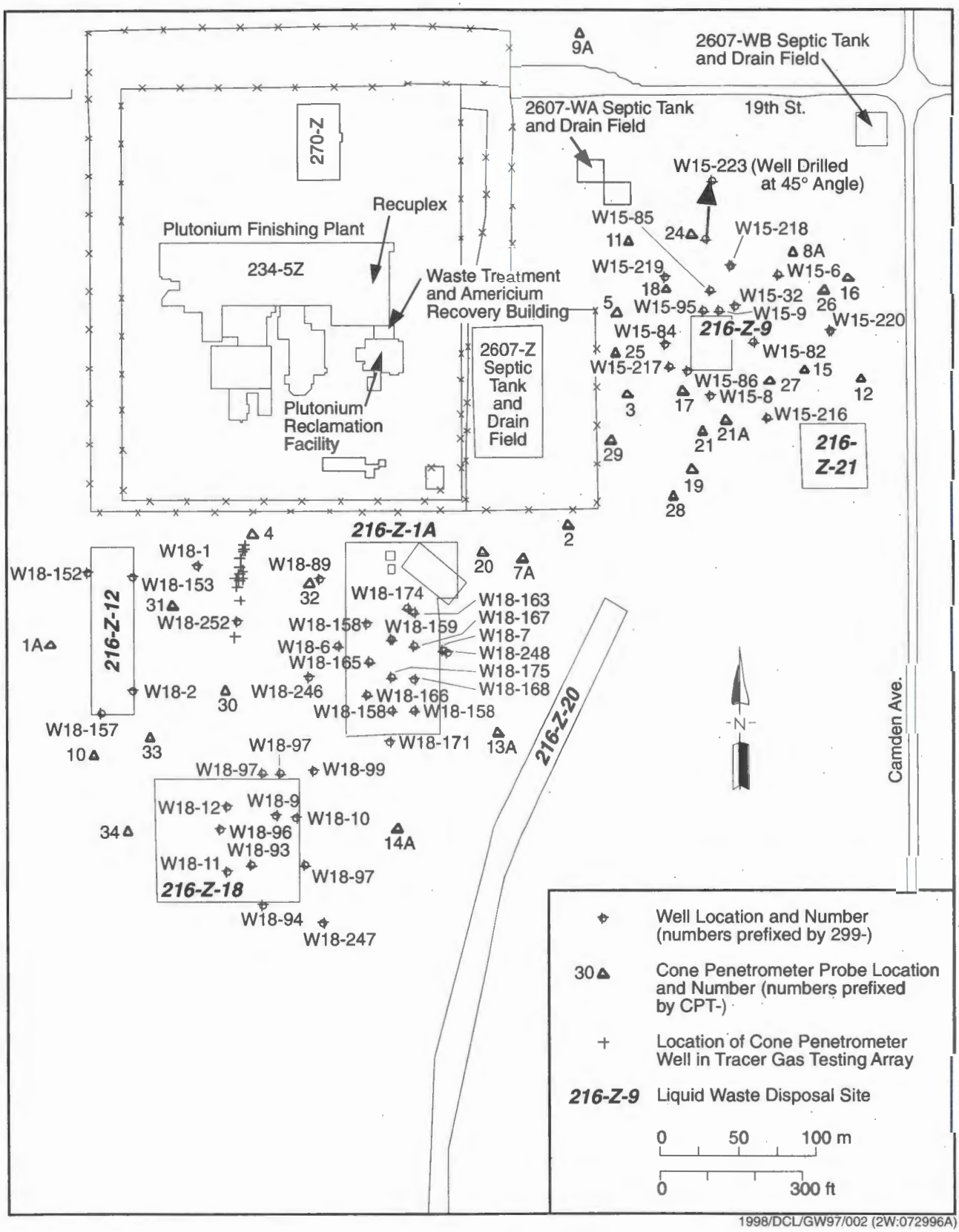


**Figure 6.2.9.** Wells and Deep Monitoring Probes at the Carbon Tetrachloride Vapor Extraction Site

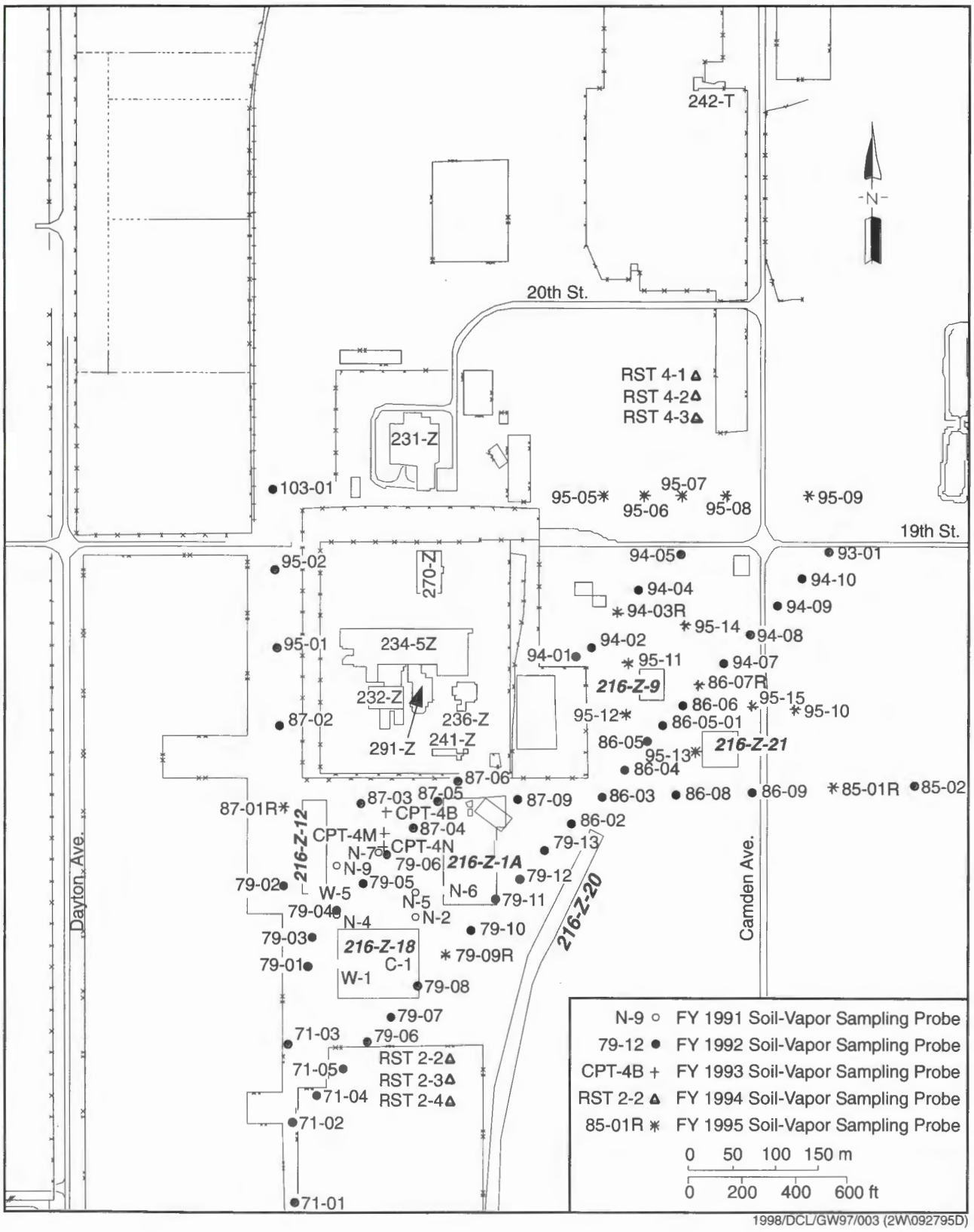


**Figure 6.2.10**. Shallow Soil-Vapor Monitoring Probes at the Carbon Tetrachloride Vapor Extraction Site

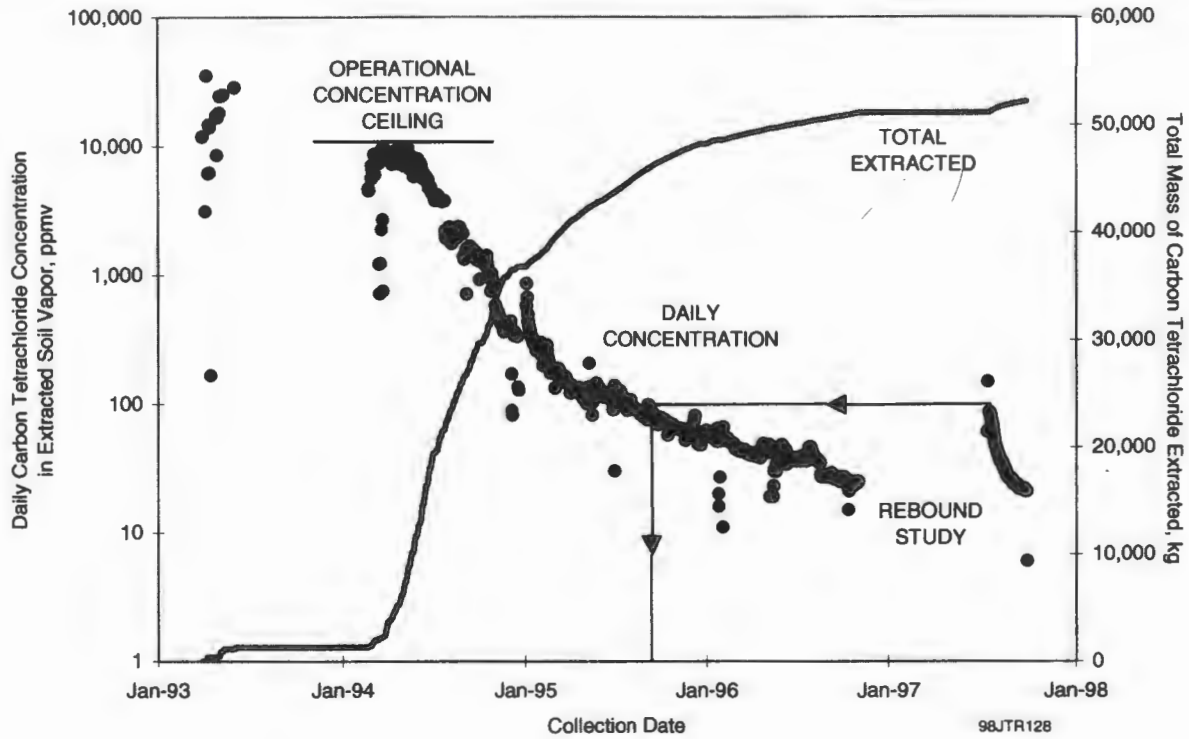


**Figure 6.2.11.** Daily Carbon Tetrachloride Concentrations in Soil Vapor Extracted from 216-Z-9 Well Field (after BHI-00720, Rev. 1)

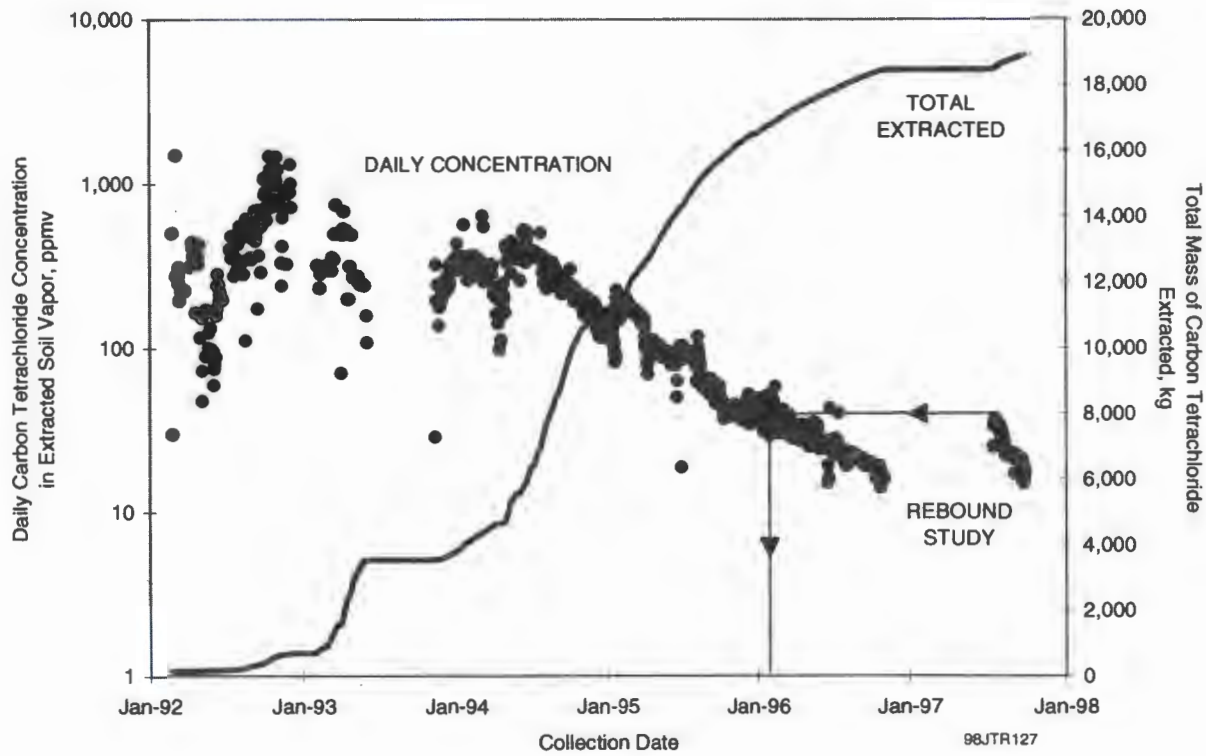


**Figure 6.2.12.** Daily Carbon Tetrachloride Concentrations in Soil Vapor Extracted from 216-Z-1A Well Field (after BHI-00720, Rev. 1)

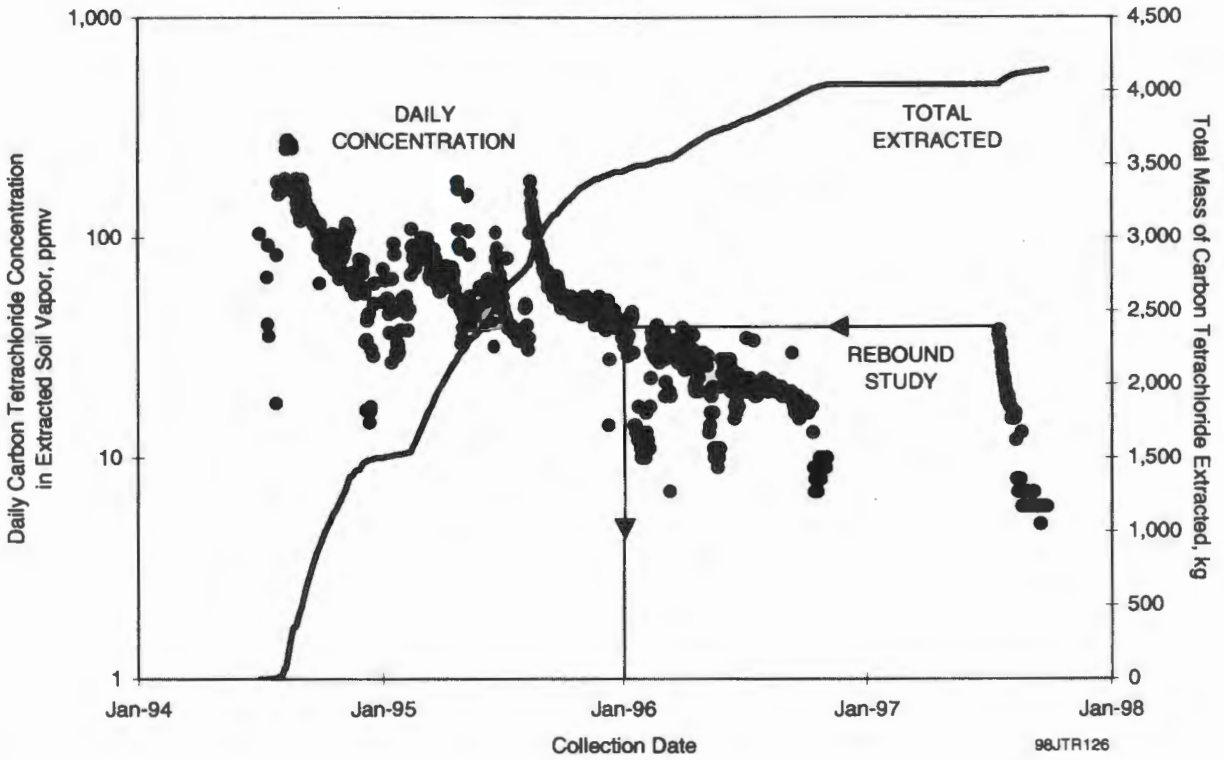


**Figure 6.2.13**. Daily Carbon Tetrachloride Concentrations in Soil Vapor Extracted from 216-Z-18 Well Field (after BHI-00720, Rev. 1)

Wells in the 216-Z-18 Well Field were included in the 216-Z-1A Well Field from 1992 to 1994.

When the extraction systems were restarted in July 1997 after the 8-month shutdown for the rebound study, carbon tetrachloride concentrations in the soil vapor had increased, as expected, at each of the three extraction systems (BHI-01105). After restart, daily concentrations at the three systems were equivalent to concentrations measured previously (at times ranging from September 1995 to February 1996) as indicated by arrows on Figures 6.2.11 to 6.2.13. However, the July 1997 concentrations decreased at a faster rate than the equivalent concentrations did in the past.

During the last 3 weeks of extraction operations (October-November 1996) before the 8-month shutdown for the rebound study, the 3 systems combined were extracting carbon tetrachloride at an average of 102 kg/wk (224.9 lb/wk). During the first 3 weeks of operations following the shutdown (July-August 1997), the 3 systems combined were extracting an average of 178 kg/wk (392 lb/wk) (BHI-01105). With continued operation in 1997, the mass removal rates continued to decline toward the October-November 1996 rates.

As of September 1997, ~75,000 kg (165,000 lb) of carbon tetrachloride had been removed from the subsurface since extraction operations started in 1992 (see Table 6.2.2 and BHI-01105 for additional details). Of this total, 1,824 kg (4,022 lb) were removed during 15 weeks of operation in 1997. Since its initiation in 1992, the extraction systems are estimated to have removed 6% of the residual carbon tetrachloride at the 216-Z-1A/216-Z-18 Well Fields and 21% of the residual carbon tetrachloride at the 216-Z-9 Well Field (BHI-00720, Rev. 1). This estimate assumes that all of the mass that has not been lost to the atmosphere (21% of the original inventory) or dissolved in groundwater (2% of the original inventory) is still available for extraction from the vadose zone (BHI-00720, Rev. 1; BHI-01105; WHC-SD-EN-TI-101).

**Rebound Study Results**. The rebound study was conducted at the 200-ZP-2 Operable Unit carbon tetrachloride soil-vapor extraction site from November 1996 through July 1997 (BHI-01105). The purpose of the study was to determine the increase in carbon tetrachloride vapor concentrations in vadose zone pores following shutdown of the extraction systems. During the time when the systems were off-line, carbon tetrachloride concentrations were

**Table 6.2.2.** Carbon Tetrachloride Inventory in Primary Disposal Sites, 200-West Area

| Well Field | Estimated Mass Discharged 1955 to 1973,[a] kg (lb) | Estimated Mass Lost to Atmosphere 1955 to 1990,[b] kg (lb) | Mass Removed Using Soil Vapor Extraction 1992 to 1997, [c] kg (lb) |
|---|---|---|---|
| 216-Z-1A | 270,000 (595,250) | 56,700 (125,000) | 22,729[d] (50,110) |
| 216-Z-18 | 170,000 (374,790) | 35,700 (78,700) | |
| 216-Z-9 | 130,000 to 480,000 (286,600 to 1,058,220) | 27,300 to 100,800 (60,190 to 222,230) | 51,984 (114,610) |
| Total | 570,000 to 920,000 (1,256,630 to 2,028,250) | 119,700 to 196,800 (263,890 to 433,870) | 74,713 (164,720) |

(a) Based on DOE/RL-91-32, Draft B.
(b) Based on WHC-SD-EN-TI-101.
(c) Based on BHI-01105.
(d) Includes mass removed from 216-Z-18; reported as a combined value because the well fields overlap.

monitored at 90 subsurface locations. The magnitude and rate of rebound can be used to indicate the distribution of remaining carbon tetrachloride sources and the transfer rate of additional carbon tetrachloride to the vapor phase that can be remediated using soil-vapor extraction.

The maximum carbon tetrachloride concentration measured at each sampling location is plotted with depth in Figure 6.2.14. This vertical profile indicates that the remaining carbon tetrachloride available for removal using soil-vapor extraction is primarily associated with the lower Hanford formation silt and underlying Plio-Pleistocene layers. The location of remaining carbon tetrachloride sources in the various strata is a result of its initial accumulation in the finer grained, lower permeability layers observed during characterization in 1991-1993 (WHC-SD-EN-TI-248) and the relative inability of the extraction system to induce airflow through this lower permeability zone to remove soil vapor effectively.

Additional carbon tetrachloride may be slowly migrating from the micropores of soil particles within the higher permeability zones also. Although rebound concentrations in these zones appear to be low, the large volume of high permeability soil represents a potentially significant mass of carbon tetrachloride. The continuing rebound at many locations indicates that the supply of additional carbon tetrachloride for soil-vapor extraction is limited by diffusion of the contaminant from the micropores and/or the lower permeability zones.

Carbon tetrachloride concentrations measured in soil vapor near the water table increased relatively slowly during the rebound study and remained relatively constant during restart in July 1997. These relatively slow changes during the rebound study suggest that the volatilization of dissolved carbon tetrachloride from groundwater into the unsaturated zone and/or the downward migration of carbon tetrachloride from the lower permeability zone toward the groundwater was occurring slowly relative to the 8-month-long rebound study.

The carbon tetrachloride vapor concentrations observed between the Plio-Pleistocene layers and the groundwater were similar at the 216-Z-1A and 216-Z-9 Well Fields despite the underlying groundwater plumes of different concentrations (3,000 µg/L in the water below 216-Z-1A and 6,000 µg/L in the water below 216-Z-9). The measured vapor concentrations are an order of magnitude lower than the equilibrium vapor concentrations predicted for these groundwater concentrations using Henry's Law (450 ppmv predicted at 216-Z-1A and 900 ppmv predicted at 216-Z-9). The vapor concentrations are also much lower than saturated vapor concentrations in equilibrium with a carbon tetrachloride nonaqueous-phase liquid (120,000 ppmv), suggesting that the continuous carbon

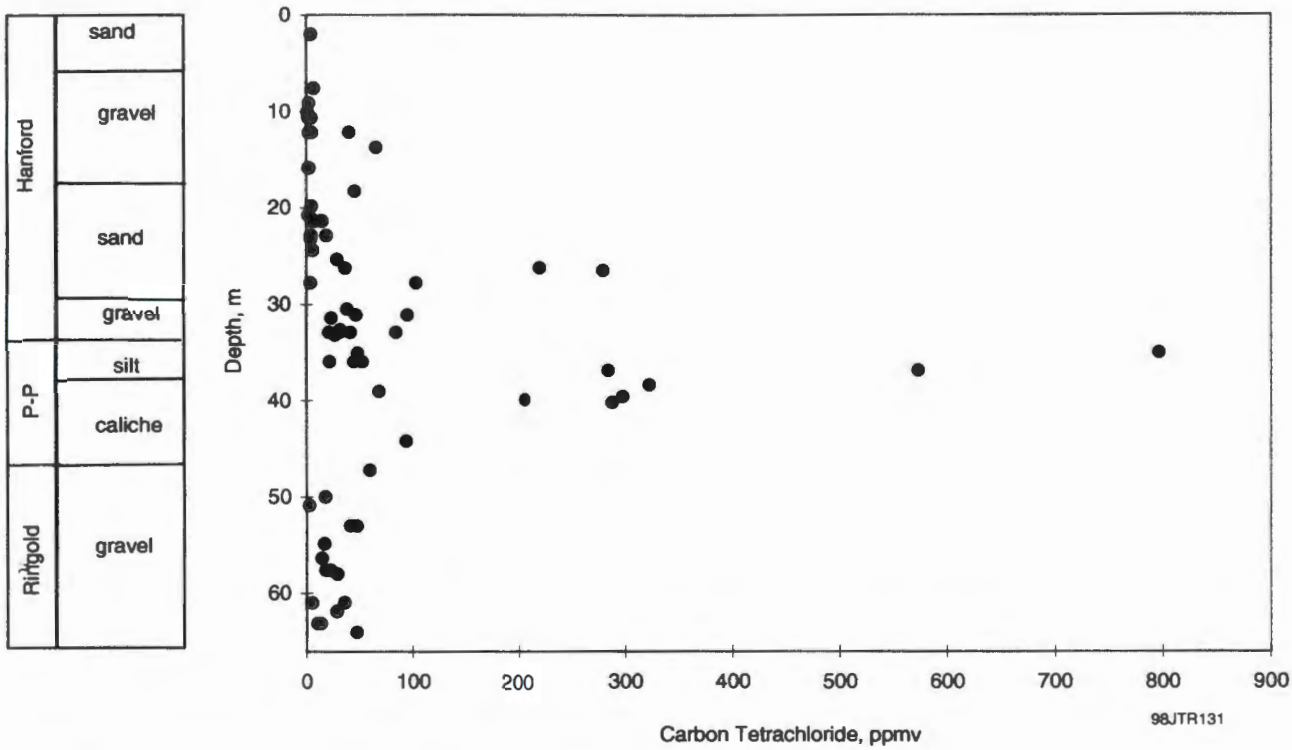


**Figure 6.2.14**. Vertical Profile of Maximum Carbon Tetrachloride Rebound Concentrations (after BHI-01105)

tetrachloride contamination source indicated for groundwater at the 216-Z-9 Well Field may be within the aquifer rather than draining from the vadose zone sediments (BHI-01105).

**Carbon Tetrachloride Migration**. Three major pathways for transport of carbon tetrachloride in the vadose zone to groundwater are possible: 1) sinking and lateral spreading of a heavier than air vapor phase down to the top of the aquifer; 2) transport of a liquid phase or dense nonaqueous-phase liquid down through the vadose zone over time, which eventually reaches the water column, dissolves, and settles through the saturated zone to an unknown depth; and 3) transport of carbon tetrachloride dissolved in the aqueous phase either through disposal of aqueous waste or by contact between infiltrating recharge and residual dense nonaqueous-phase liquid (WHC-SD-EN-TI-248). A schematic representation, or conceptual model, of the subsurface behavior of carbon tetrachloride beneath the 216-Z-9 Trench is shown in Figure 6.2.15.

The vapor phase results obtained to date suggest that vapor-phase transport is secondary to dense nonaqueous-phase liquid as a groundwater contamination pathway, but field measurements of carbon tetrachloride vapor concentrations are not completely consistent with numerical modeling results. If a major fraction of the carbon tetrachloride originally discharged to the 216-Z-9 Trench were still present in the soil column as a nonaqueous phase, a relatively high soil-vapor concentration would be expected. For example, vapor extraction concentrations >12,000 ppmv of carbon tetrachloride would indicate that the soil near the extraction well was saturated with nonaqueous carbon tetrachloride liquid.

During initial soil-vapor extraction operations at the 216-Z-9 Trench, soil-vapor concentrations extracted from wells open above the Plio-Pleistocene layer were in excess of 12,000 ppmv, suggesting the presence of a nonaqueous carbon tetrachloride phase (see Figure 6.2.11). Soil vapor extracted from wells open below the Plio-Pleistocene layer were an order of magnitude lower and, based on the rule of thumb, would not suggest the presence of a nonaqueous-phase liquid. However, the depths and locations of the extraction wells below the Plio-Pleistocene layer may not have been optimal to detect the presence of a nonuniformly distributed contaminant, and the presence of a nonaqueous-phase liquid cannot be ruled out.

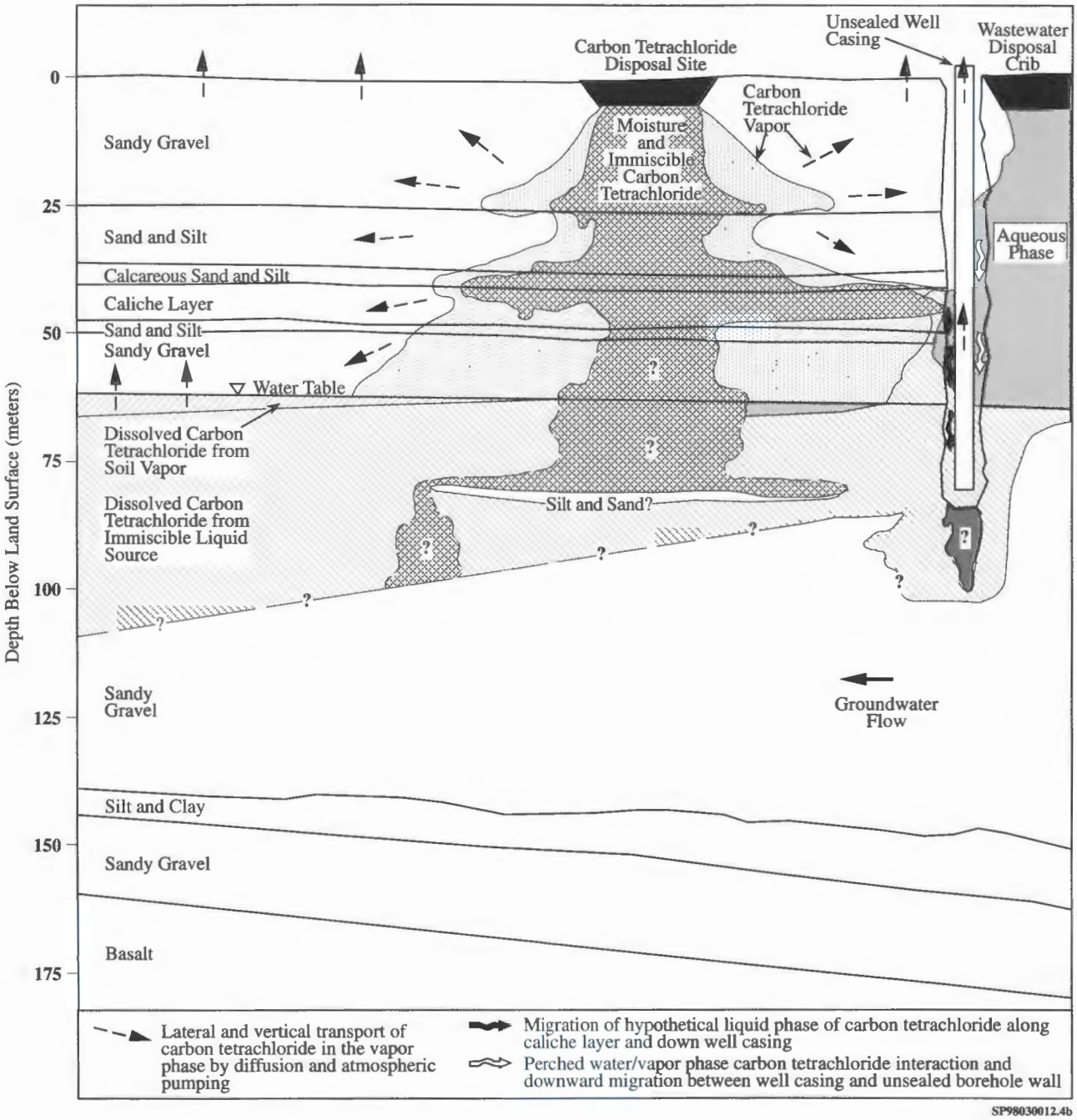


**Figure 6.2.15**. Conceptual Model of Carbon Tetrachloride and Wastewater Migration Beneath 216-Z-9 Trench

During the 1997 rebound study, the carbon tetrachloride vapor concentrations monitored deep within the vadose zone at the 216-Z-9 Trench did not exceed 60 ppmv. These low vapor concentrations do not indicate the presence of a nonaqueous-phase liquid remaining in the vadose zone below the Plio-Pleistocene layer; however, these measurements were not taken directly under the 216-Z-9 Trench. The data suggest that soil-vapor extraction may have removed much of the remaining deep vadose zone nonaqueous-phase liquid source in the 216-Z-9 area and that the continuing groundwater source may now be within the aquifer (BHI-01105).

The apparent discrepancy between the numerical modeling results and the field measurements may be a result of: 1) nonuniform discharge, migration, and distribution of the nonaqueous-phase carbon tetrachloride; 2) nonoptimal locations for monitoring; 3) nonequilibrium partitioning of carbon tetrachloride within the vadose zone; 4) discharge of carbon tetrachloride organic liquid mixtures rather than pure phase liquids; and/or 5) vadose zone geologic heterogeneities and structure.

In summary, groundwater monitoring below the carbon tetrachloride disposal units suggests there is a continuing groundwater source that produces somewhat uniform carbon tetrachloride concentrations with depth in the aquifer. A dense nonaqueous-phase liquid that has drained from the vadose zone into the aquifer and is slowly dissolving could produce such a pattern. The continuing presence of relatively high dissolved carbon tetrachloride concentrations in groundwater in the immediate vicinity of the 216-Z-9 Trench, 35 years after termination of disposal operations, suggests that a dense nonaqueous liquid phase of carbon tetrachloride is slowly dissolving within the aquifer. Although this liquid phase may be slowly draining from the vadose zone to groundwater, the soil-vapor concentrations monitored deep within the vadose zone during 1997 suggest that soil-vapor extraction remediation may have removed much of the vadose zone source and that the continuing groundwater source is now within the aquifer. Carbon tetrachloride concentrations in the soil vapor and underlying groundwater do not appear to be in equilibrium, and the expected direction of carbon tetrachloride migration is from the groundwater to the vadose zone (BHI-01105).

Carbon tetrachloride rebound concentrations indicate that, in many areas, much of the readily accessible mass has been removed during soil-vapor extraction operations and that the supply of additional carbon tetrachloride is limited by desorption and/or diffusion from contaminant sources (e.g., lower permeability zones such as the lower Hanford formation silt and Plio-Pleistocene layers). Under these conditions, the removal rate of the additional carbon tetrachloride using soil-vapor extraction is controlled by the desorption and diffusion rates of the contaminant.

**Nonradioactive Dangerous Waste Landfill**. The Nonradioactive Dangerous Waste Landfill is a Resource Conservation and Recovery Act land disposal unit located approximately 5.6 km (3.5 mi) southeast of the 200-East Area. This landfill was used to dispose of nonradioactive dangerous waste and asbestos waste from 1975 to 1985. Volatile organic compounds were detected primarily within and south of the eastern third of the landfill trenches during a 1993 shallow (1.5- to 1.8-m [4.9- to 5.9-ft] deep) soil-vapor survey and have been detected during groundwater monitoring of wells near the landfill since 1987 (WHC-SD-EN-TI-199).

A soil-vapor survey was conducted at the landfill during 1997 to 1) collect deep soil-vapor data to assess the vertical extent of volatile organic compound contamination and the potential impacts to groundwater and 2) resample selected shallow vapor probes to assess changes in contaminant distribution that may indicate contaminant movement. The strategy and methods used to sample and analyze the soil vapor within the subsurface at the landfill and a summary of the data quality objectives process are described in BHI-01073.

The sampling locations focused on the eastern half of the landfill based on the results of the 1993 soil-vapor survey (WHC-SD-EN-TI-199). A total of 35 probes were installed during August 1997. Soil-vapor samples were collected from six shallow probes (1.5 to 1.8 m [4.9 to 5.9 ft] deep) and 33 deep probes (8.8 to 29.7 m [28.9 to 97.4 ft] deep) (BHI-01115). The water table under the facility is 36.6 to 38.4 m (120 to 126 ft) below ground surface.

Six volatile organic compounds were detected during the 1997 survey: carbon tetrachloride, chloroform, 1,1-dichloroethane, tetrachloroethylene, 1,1,1-trichloroethane, and trichloroethylene (BHI-01115). Of these contaminants, 1,1,1-trichloroethane was the most widespread and was detected in all but one of the samples from the deep probes at concentrations <1 ppmv; however, 1,1,1-trichloroethane was not detected in the samples from the shallow probes. Carbon tetrachloride and chloroform were the only contaminants detected at concentrations exceeding 1 ppmv. In samples from 2 adjacent

locations (1 shallow and 2 deep probes within and beneath the chemical trenches), concentrations ranged from 20 to 46 ppmv. All of the same contaminants, except 1,1-dichloroethane, were detected in the 1993 survey.

Based on the 1997 results, the soil-vapor contaminants tend to be distributed at low concentration levels within or south of the landfill trenches. The volatile organic compound concentrations detected in deep samples suggest that vertical migration of carbon tetrachloride occurred directly beneath the chemical trenches within a narrow zone. Comparison of analytical results for 1993 and 1997 soil-vapor samples collected from shallow probes indicates that the maximum carbon tetrachloride concentrations are still within the chemical trenches at the landfill, suggesting that the contaminants have not migrated significantly (BHI-01115).

# 7.0 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 1997 to monitor the meteorology and climatology, to assess the status of the ecosystem, to monitor and manage cultural resources, and to actively involve the public in environmental surveillance activities near the Hanford Site.

# 7.1 Climate and Meteorology

*D. J. Hoitink*

Meteorological measurements are taken to support Hanford Site emergency preparedness and response, operations, and atmospheric dispersion calculations for dose assessments (Appendix D, Tables D.5 through D.9). 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.

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.

## 7.1.1 Historical Information

Daily and monthly averages and extremes of temperature, dew point temperature, and relative humidity for 1945 through 1997 are reported in PNNL-11794. From 1945 through 1997, 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 average 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 occurs during winter, with more than half of the annual amount occurring from November through February. The snowiest winter on record, 1992-1993, received 142.5 cm (56.1 in.) of snow.

## 7.1.2 Results of 1997 Monitoring

1997 was warmer than normal with nearly normal precipitation. The average temperature for 1997 was 12.7°C (54.8°F), which was 0.8°C (1.5°F) above normal (11.8°C [53.3°F]). Nine months during 1997 were warmer than normal, and three months were cooler than normal. May had the highest positive departure, 2.1°C (3.7°F); June, at 0.7°C (1.2°F) below normal, had the largest negative departure.

Precipitation for 1997 totaled 16.2 cm (6.39 in.), 102% of normal (15.9 cm [6.26 in.]), with 19.8 cm (7.8 in.) of snow (compared to an annual normal snowfall of 35.1 cm [13.8 in.]).

The average wind speed for 1997 was 12.7 km/h (7.9 mph), which was 0.3 km/h (0.2 mph) above normal. The peak gust for the year was 116 km/h (72 mph) on October 30. This was the highest gust ever recorded in October, and the fourth highest wind gust ever recorded at the Hanford Meteorology Station. Historically, the highest wind gust was 80 mph on January 11, 1972. Figure 7.1.1 shows the 1997 wind roses (diagrams showing direction and frequencies of wind) measured at a height of 10 m (32.8 ft) for the 29 meteorological monitoring stations on and around the Hanford Site.

Table 7.1.1 provides monthly climatological data from the Hanford Meteorology Station for 1997.

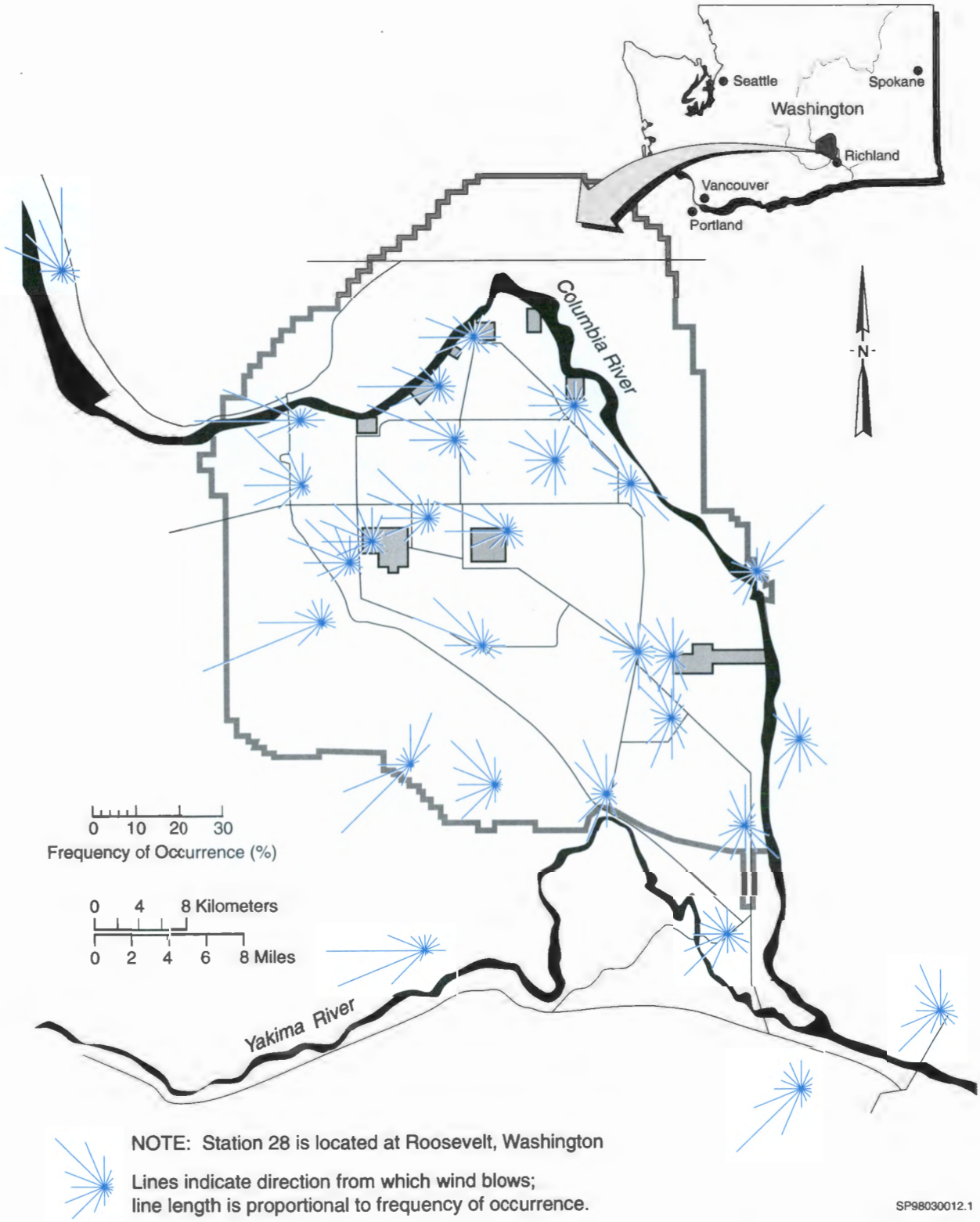


**Figure 7.1.1.** Hanford Meteorological Monitoring Network Wind Roses (measured at a height of 10 m [32.8 ft]), 1997. Individual lines indicate direction from which wind blows. Length of line is proportional to frequency of occurrences from a particular direction.

**Table 7.1.1.** Monthly Climatological Data from the Hanford Meteorology Station, 1997

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 | 5.2 | -3.4 | 0.9 | +1.3 | 13.9 | 2 | -13.3 | 14 | 3.8 | +1.8 | 4.6 | -5.3 | 74.7 | -1.7 | 10.6 | +0.2 | 79 | SSW | 1 |
| F | 9.8 | -0.7 | 4.6 | +1.2 | 17.8 | 15 | -6.7 | 5 | 0.6 | -0.9 | 6.8 | +1.7 | 67.5 | -2.8 | 11.9 | +0.3 | 68 | W | 19 |
| M | 14.7 | 2.4 | 8.6 | +1.1 | 24.4 | 25 | -2.2 | 14 | 1.8 | +0.6 | 3.8 | +3.0 | 55.2 | -0.7 | 15.5 | +2.1 | 95 | WSW | 30 |
| A | 18.2 | 3.9 | 11.0 | -0.5 | 23.9 | 26 | -3.9 | 6 | 0.8 | -0.2 | 0 | -T[c] | 46.0 | -1.2 | 14.6 | +0.2 | 87 | WSW | 20 |
| M | 26.2 | 10.6 | 18.3 | +2.1 | 34.4 | 13[d] | -1.1 | 2 | 0.8 | -0.5 | 0 | 0 | 41.5 | -1.2 | 13.2 | -1.4 | 58 | SW | 31 |
| J | 27.9 | 12.7 | 20.3 | -0.7 | 36.7 | 15 | 7.8 | 22[d] | 1.2 | +0.2 | 0 | 0 | 41.4 | +2.6 | 14.5 | -0.3 | 77 | W | 17 |
| J | 32.7 | 15.4 | 24.1 | -0.5 | 38.3 | 21[d] | 9.4 | 10 | 0.5 | 0 | 0 | 0 | 37.4 | +3.9 | 13.5 | -0.6 | 72 | SW | 9 |
| A | 34.2 | 16.9 | 25.6 | +1.6 | 41.1 | 14[d] | 11.1 | 29 | 0.2 | -0.5 | 0 | 0 | 35.8 | 0 | 12.9 | +0.2 | 89 | WSW | 26 |
| S | 26.8 | 11.9 | 19.3 | +0.6 | 35.0 | 1 | 6.7 | 21 | 0.8 | 0 | 0 | 0 | 51.9 | +9.2 | 13.0 | +1.1 | 77 | WSW | 26 |
| O | 18.6 | 5.0 | 11.8 | +0.2 | 25.0 | 17 | -1.7 | 25 | 2.3 | +1.4 | 0 | -T | 58.6 | +3.4 | 13.4 | +2.9 | 116 | SW | 30 |
| N | 11.1 | 1.3 | 6.2 | +1.7 | 17.2 | 1 | -5.0 | 13 | 2.6 | +0.3 | 0 | -4.6 | 77.8 | +4.4 | 10.0 | -0.3 | 53 | S | 28 |
| D | 5.4 | -2.5 | 1.5 | +1.8 | 15.6 | 16 | -7.2 | 22 | 0.8 | -1.8 | 4.6 | -9.9 | 81.0 | +0.7 | 8.9 | -0.6 | 66 | S | 16 |
| Y[e] | 19.3 | 6.2 | 12.7 | +0.8 | 41.1 | Aug 14[d] | -13.3 | Jan 14 | 16.2 | +0.3 | 19.8 | -15.1 | 55.6 | +1.3 | 12.7 | +0.3 | 116 | SW | Oct 30 |

NOTE: See Table H.2, Conversion Table in "Helpful Information" for unit conversion 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) Latest of several occurrences.
(e) Yearly averages, extremes, and totals.

# 7.2 Ecosystem Monitoring (Plants and Wildlife)

*L. L. Cadwell, D. D. Dauble, J. L. Downs, 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 (PNNL-6415, Rev. 9). Nearly 600 species of plants have been identified on the Hanford Site (WHC-EP-0054). Recent work by The Nature Conservancy of Washington 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, and Snively Springs. West Lake is 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 (PNNL-6415, Rev. 9), 44 species of fish (Gray and Dauble 1977; PNNL-6415, Rev. 9), 214 species of birds (Soll and Soper 1996), and 39 species of mammals (PNNL-6415, Rev. 9) 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 consumed by local Native American tribes.

Although no Hanford Site plant species have been identified from the federal list of threatened and endangered species (Title 50, Code of Federal Regulations, Part 17, Section 12 [50 CFR 17.12]), recent biodiversity inventory work conducted by The Nature Conservancy of Washington identified 82 populations of 17 rare plant taxa. In addition, The Nature Conservancy of Washington 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.

## 7.2.1 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 7.2.1). 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

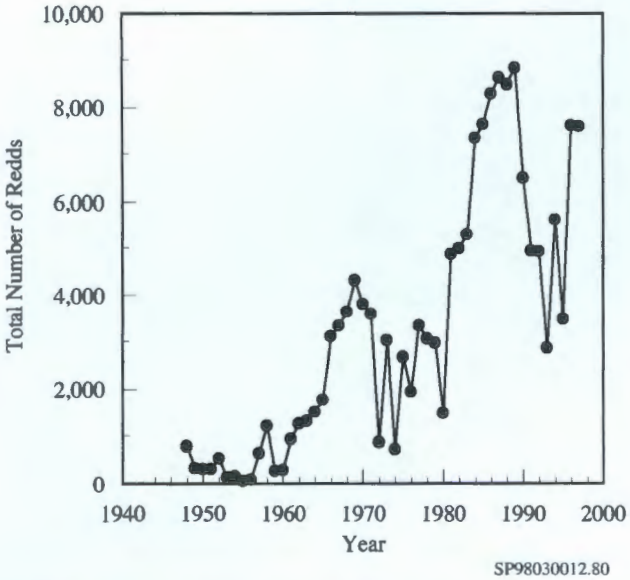


**Figure 7.2.1**. Chinook Salmon Spawning Redds in the Hanford Reach, 1948 Through 1997

**Figure 7.2.2**. Bald Eagles Observed Along the Hanford Reach, Fall and Winter Months, 1961 Through 1997

high in 1989 of nearly 9,000 (see Figure 7.2.1). In the early 1990s, redd counts declined to approximately one-third the 1989 peak, but they appear to have rebounded in recent years. In 1997, approximately 7,600 redds were observed, which represents no change from the 1996 count. 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 counted accurately. It has been noted, however, that redd survey data generally track adult escapement figures obtained by counting migrating adult fish at fish ladders on the Columbia River.

## 7.2.2 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 7.2.2). Following the passage of the Endangered Species Act in 1973, the number of wintering bald eagles increased. Possible reasons for the observed increase are 1) reduced persecution in Alaska, 2) protection of bald eagles at nesting locations off the Hanford Site, and 3) the nationwide elimination of dichlorodiphenyltrichloroethane (DDT) as an agricultural pesticide in 1972.

A single maximum count of 37 bald eagles was documented on the Hanford Reach in the winter of 1997. This number is similar to the 1996 count (41) and up from 25 birds 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 7.2.1 and 7.2.2 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* (DOE/RL-94-150) and coordinated with representatives of the U.S. Fish and Wildlife Service.

Several nest building attempts by bald eagles have been observed at the Hanford Site in recent years. The presence of two bald eagle pairs attending nest sites along the Hanford Reach triggered the closure of several roads and portions of the Hanford Site shoreline in 1997. Nest tending activities and territorial displays were documented as early as mid-November. However, the birds eventually left the area without successfully nesting.

The Hanford Reach is expected to continue providing wintering bald eagle habitat as long as critical resources

such as food, perches, and relative freedom from human activities are maintained.

## 7.2.3 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 or endangered (50 CFR 17.11) and also a Washington State endangered species (Washington State Department of Wildlife 1994). Approximately one quarter of the state's nesting territories are located on the Hanford Site.

In recent years, the number of ferruginous hawks nesting on the Hanford Site has remained stable (12 active nests in 1997). The site continues to provide hawk nesting habitats that are administratively protected from public intrusion. An evaluation of selected aspects of ferruginous hawk ecology on the Hanford Site and adjacent lands was completed in 1996 (Leary 1996). That work suggested that ferruginous hawks nesting on the Hanford Site were attracted to the area because of suitable, disturbance-free nesting habitat, but that much of the foraging for prey species occurred on adjacent privately owned agricultural fields. Male ferruginous hawks were observed to travel up to 15 km (9.3 mi) from their Hanford Site nests to hunt, making several trips each day to deliver prey to their mates and offspring. These results showed that medium-sized mammals such as northern pocket gophers, which can be serious agricultural pests, are the primary prey of ferruginous hawks. It is likely that the success and relative abundance of ferruginous hawks nesting at the Hanford Site depend on both site lands for quality nesting habitat and adjacent private agricultural lands for suitable foraging habitat.

## 7.2.4 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 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 591 animals prior to the 1997 hunting season (Figure 7.2.3). Although accurate counts of elk harvest on adjacent private lands are not available, the harvest appears to be small, with less than 5% of the herd being harvested and the majority of the harvest consisting of bulls. The 1997 harvest consisted of 16 adult bulls, 1 spike (yearling male), and 3 cows. Thus, growth of the herd is largely unconstrained, and increasing damage to natural plant communities on the Hanford Site and to crops on adjacent private land is likely. Several observations were made in 1996 and 1997 of elk having crossed to the north side of State Highway 240, making future sitings of elk near the 100 and 200 Areas probable. As the herd continues to grow, there are two safety-related concerns that will increase. The first is the potential for an increase in automobile-elk collisions on local highways, and the second is the possibility that elk will range into the recently enlarged radiation protection zone (BC Cribs) immediately south of the 200-East Area.

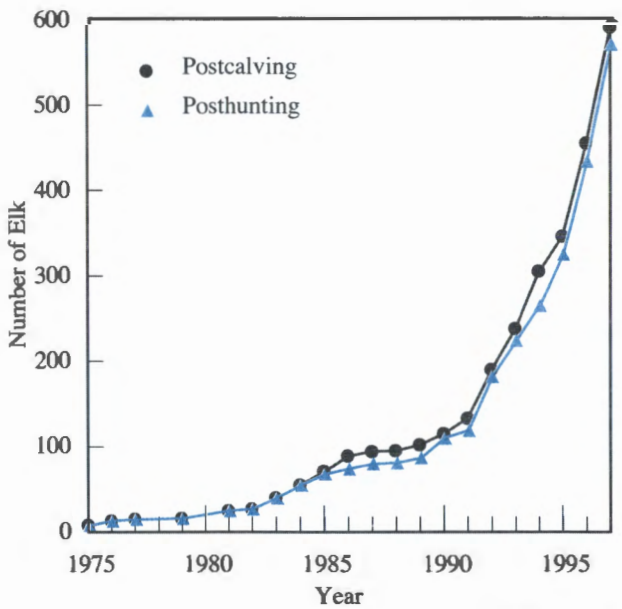


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**Figure 7.2.3.** Elk on the Hanford Site Counted by Aerial Surveillance During Postcalving (August through September) and Posthunting Periods (December through January), 1975 Through 1997

## 7.2.5 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.

Because mule deer are often hunted and eaten, they potentially can contribute to the radiation dose received by members of the public that consume game animals (PNL-7539, MacLellan et al. 1993). On the Hanford Site, deer are also of interest to environmental monitoring programs because they can provide useful information that can be used in contaminant cleanup efforts (Eberhardt and Cadwell 1983, PNL-10711, PNNL-11518).

The deer population onsite was estimated in 1996 by marking deer and counting the ratio of marked to unmarked animals along the south and west shorelines of the Columbia River. In addition, relative deer densities were determined for 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 along the Hanford Reach south of the Columbia River. The total Hanford Site mule deer population for the land area south of the Columbia River, including the central portion of the Hanford Site and the Fitzner/Eberhardt Arid Lands Ecology Reserve was estimated at 650.

Age and sex classes of deer that reside along the Columbia River of the Hanford Site have been monitored yearly since 1993. Roadside surveys have been conducted on an established route that is nearly 48 km (30 mi) long. The route is driven several times during the postfawning season (July-September) and the posthunting season (December-February) to get an estimate of the ratio of antlered deer (bucks) to antlerless deer (females) and the ratio of fawns to antlerless deer. The buck-to-doe ratios seen in this region have remained relatively stable since 1993. This ratio (22 antlered per 100 antlerless in 1997) is high compared to other more heavily hunted populations in the semiarid northwest. Fawn-to-doe ratios have begun to demonstrate a significant downward trend (Figure 7.2.4).

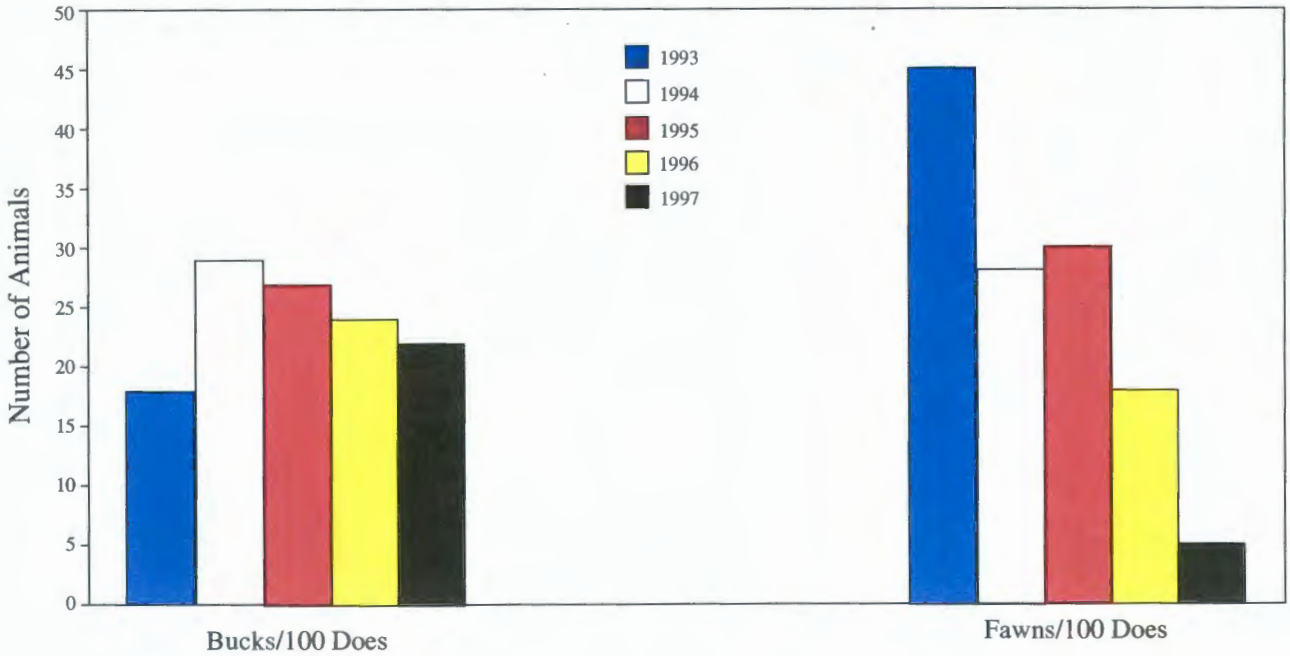


**Figure 7.2.4.** Age and Sex Ratios of Mule Deer Along the Hanford Reach, 1993 Through 1997

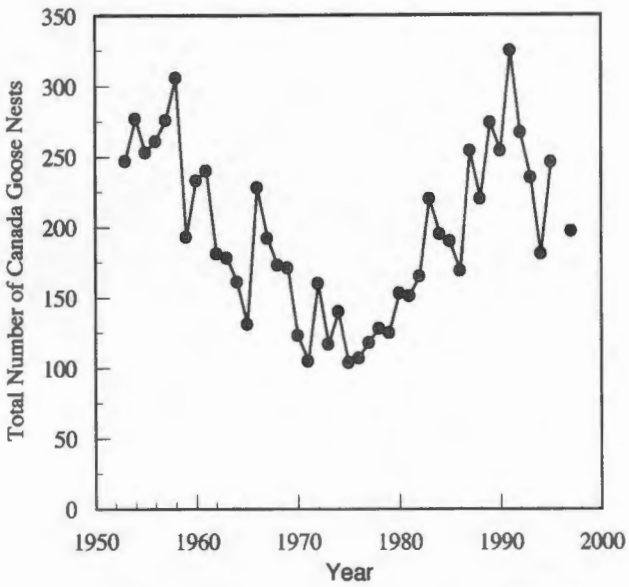


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**Figure 7.2.5.** Number of Canada Goose Nests and Successful Nests Along the Hanford Reach, 1954 Through 1997 (no survey conducted in 1996)

Typically, 30 to 40 fawns per 100 does are observed throughout the semiarid regions of the northwest. The cause of the decline in fawn recruitment on the Hanford Site is currently unknown.

## 7.2.6 Canada Geese

Nesting Canada geese are valuable recreational and aesthetic resources along the Snake and Columbia Rivers in eastern Washington. Goose nesting surveys began in the 1950s to monitor changes in response to reactor operations (Figure 7.2.5). The gradual decline observed in the late 1960s and early 1970s is attributed to persistent coyote predation, mostly on the Columbia River islands upstream from the Old Hanford Townsite. Since the 1970s, the majority of nesting geese have shifted from the upstream islands to the downstream islands near Richland, which in recent years have been relatively free from coyote predation. Nesting success was relatively low (61%) in 1995 as a result of predation and the increase in river flows during the nesting season. Surveys were conducted in 1997 to record the maximum number of nesting pairs found on each island and to determine nesting success for those nests. The results appear similar to past nesting seasons; 197 pairs were identified and 177 (90%) of those were considered successful hatches. Canada goose populations are successful on the Hanford Reach because the islands are restricted from human uses during the nesting period and because shoreline habitats provide adequate food and cover for successful brood rearing (Eberhardt et al. 1989).

## 7.2.7 Plant Biodiversity Inventories on the Hanford Site

Over the past years, The Nature Conservancy of Washington has conducted intensive surveys and mapping efforts to document the occurrence and extent of rare plant populations and plant community types on the Hanford Site (Soll and Soper 1996, Hall 1998). These data, along with existing data from the ecosystem monitoring project, provide information that supports the U.S. Department of Energy's (DOE's) land-use planning process, provides information on which to base responsible biological resource stewardship and management actions, and provides a technical basis for mitigation action planning associated with DOE's site cleanup mission.

Surveys for rare plants on the site were conducted through the growing seasons of 1994, 1995, and portions of 1997. Figure 7.2.6 delineates the known locations of more than 100 rare plant populations of 30 different taxa (Caplow and Beck 1996, Hall 1998). These populations include taxa listed by the Washington Natural Heritage Program (1977) as endangered, threatened, or sensitive within Washington State and the locations of populations of taxa that are listed as review group 1 (taxa in need of additional field work before status can be determined). Five of these 30 taxa, including the two new-to-science species, *Eriogonum codium* and *Lesquerella tuplashensis*, have been designated as species of concern in the Columbia River Basin ecoregion by the U. S. Fish and Wildlife Service.

In addition to the rare plant populations, several areas on the Hanford Site are designated as special habitat types with regard to potential occurrence of plant species of concern. These include areas that potentially support populations of rare annual species found in adjacent habitats. The inventory accomplished by The Nature Conservancy of Washington over the past several years documents a remarkable number of rare plant populations across the site. The degree of protection from disturbance afforded to the Hanford Site over the past 50 years has resulted in an "island of biodiversity" for plant resources

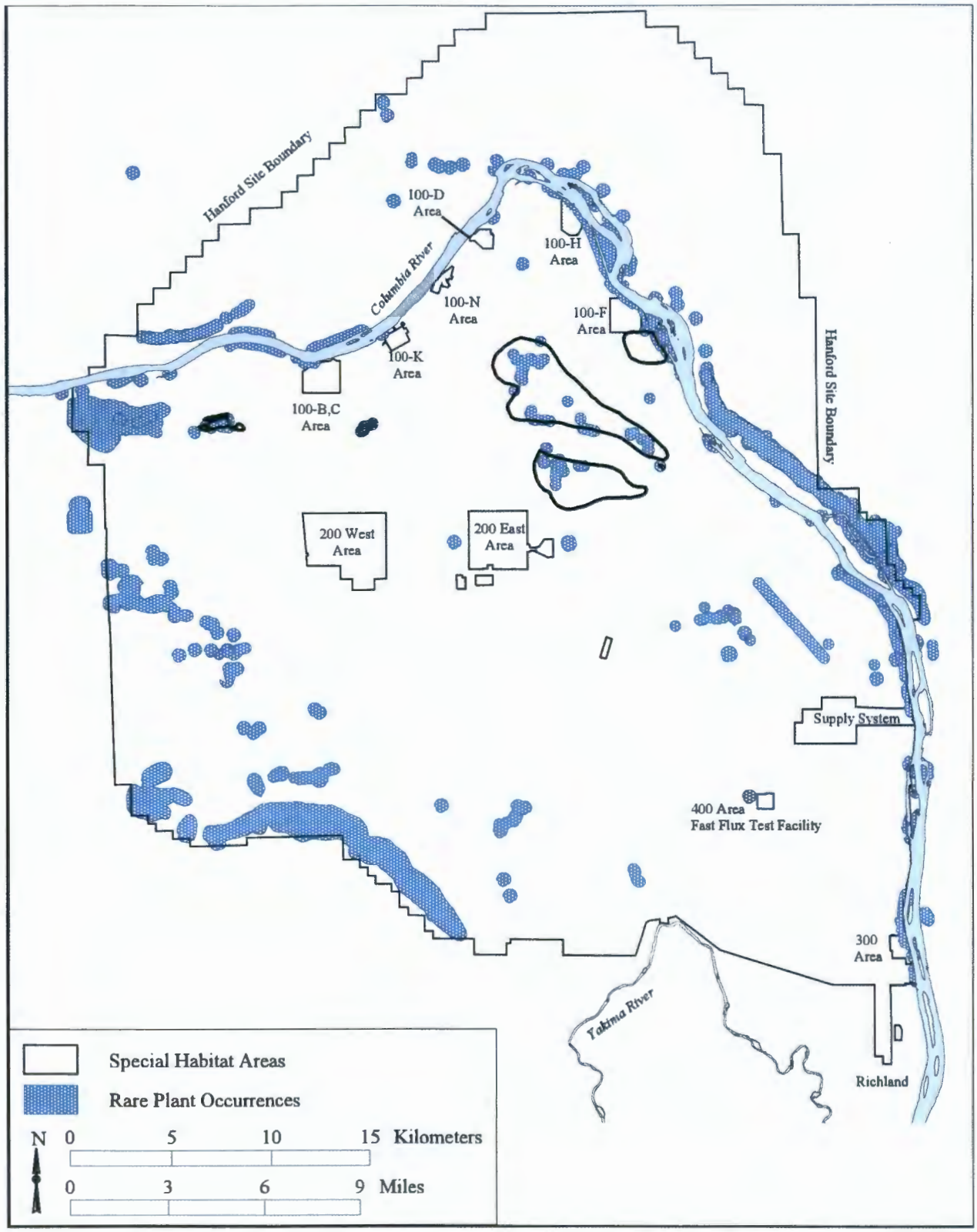


**Figure 7.2.6.** Rare Plant Locations on the Hanford Site Based on 1994, 1995, and 1997 Survey Conducted by The Nature Conservancy of Washington

(Caplow and Beck 1998). Some of the preliminary summary information on the site's rare plants was included in Appendix D of the *Draft, Hanford Site Biological Resources Management Plan* (DOE/RL-96-32). The draft plan currently serves as a guidance document for Hanford Site biological resources management, pending tribal input and comment and Hanford stakeholder review.

## 7.2.8 Sagebrush Die-Off

Big sagebrush (*Artemisia tridentata* subspecies *wyomingensis*) is the most common shrub component of shrub-steppe vegetation associations on the Hanford Site. Sagebrush stands represent an important resource for sagebrush-obligate wildlife species such as black-tailed jackrabbits, sage sparrows, sage thrashers, and loggerhead shrikes. Since 1993, site biologists have documented areas of sagebrush die-off in stands near the 100-D Area. The cause of the sagebrush die-off on the site is not known. Shrub die-offs are not uncommon in the intermountain west and such episodes have been reported from Nevada, Wyoming, Utah, Idaho, and British Columbia (Dobrowolski and Ewing 1990). Die-off of shrubs has been attributed to severe rootlet mortality, root rot, soil salinity and anaerobiosis, and vascular shoot wilt induced by fungal pathogens (Nelson et al. 1989, Weber et al. 1989).

The extent of the die-off on the Hanford Site was mapped and survey data were collected in 1996 and 1997 to establish a baseline for monitoring future expansion of the die-off (PNNL-11700). That report indicated that a total area of 1,776 ha (4,388 acres) showed evidence of sagebrush decline, with a central portion of 280 ha (692 acres) where shrub death was estimated to be approximately 80% or greater. Surveys in late 1997 and early 1998 of shrubs along transects established in late 1996 within the die-off areas indicate that sagebrush plants are continuing to decline. Shrub height and canopy volume decreased (Figure 7.2.7) and observations of shrub vigor (percent canopy defoliation) also indicate continuing declines in

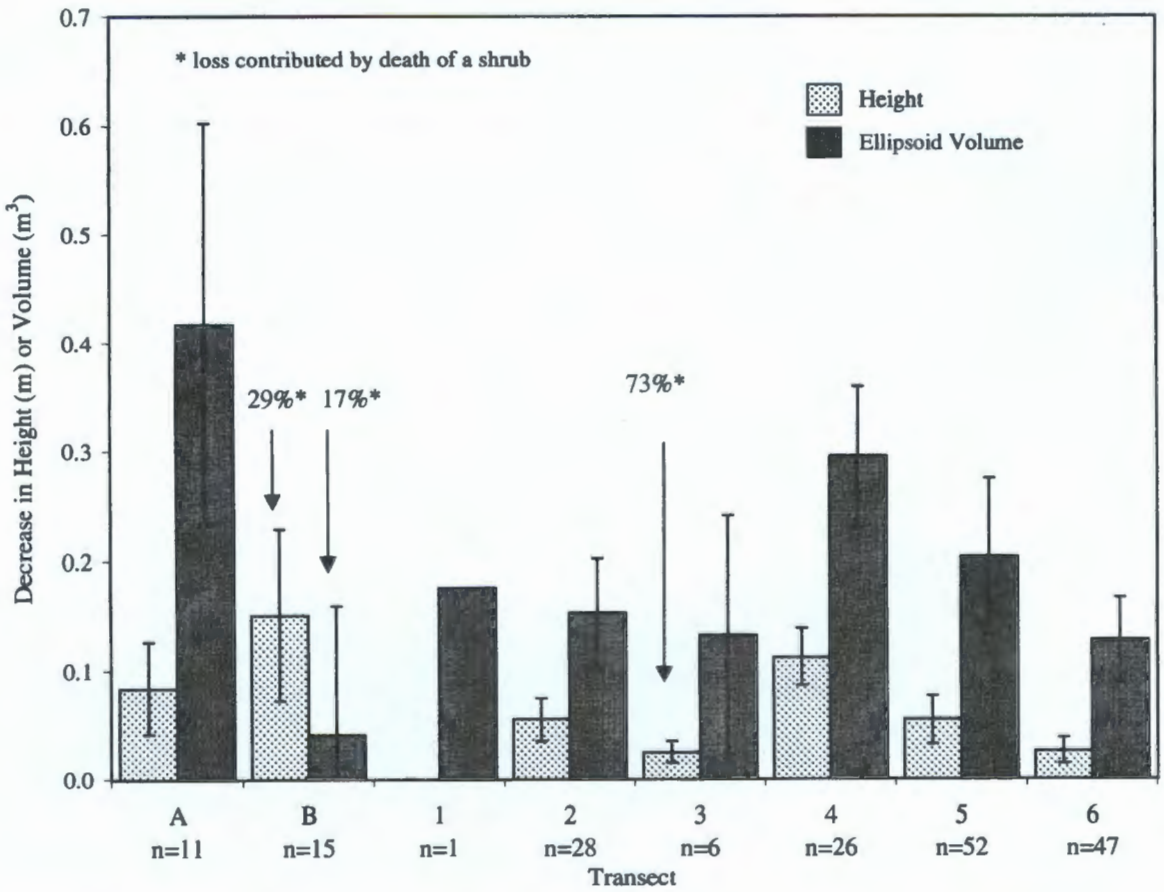


**Figure 7.2.7.** Average Decrease in Shrub Height and Volume Along Each Transect (bars are ±1 standard error of the mean)

shrub health in the die-off areas. No efforts have been made to compare the current extent of the die-off area with the area previously mapped in early 1997. Determining an exact boundary between healthy shrub stands and declining shrub stands is difficult because these boundaries are transitional with no clear edge.

Information was gathered regarding seedling recruitment and seedling growth in areas of shrub decline to understand whether and how sagebrush may reinvade the die-off areas. To examine how sagebrush seed germination and growth might be affected in die-off areas onsite, healthy seeds collected distant from the die-off areas were allowed to germinate in soils from areas inside and outside the die-off regions and growth of seedlings was measured over a 6-week period. No differences in germination rates were observed; however, 43 days after the seeds had been planted, seedling height and number of leaves were significantly less in die-off soils. No sagebrush seedling mortality was observed. The causes of reduced growth of seedlings in die-off soils are unknown, but might result from differences in soil nutrient and organic content where leaf fall and litter from healthy shrubs are reduced. These seedlings have been planted into the central die-off area and in a control plot away from the central die-off area. Sagebrush planted at the two sites will be monitored over the next year to determine seedling growth and vigor within and away from the die-off area.

# 7.3 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 (PNL-6942). Pacific Northwest National Laboratory, Bechtel Hanford, Inc., and CH2M Hill Hanford, Inc., provided support to DOE Richland Operations Office for the cultural resource program on the Hanford Site throughout 1997. Thus, management of archaeological, historical, and traditional cultural resources at the Hanford Site is provided in a manner consistent with the National Historic Preservation Act, Native American Graves Protection and Repatriation Act, Archaeological Resources Protection Act, and American Indian Religious Freedom Act.

## 7.3.1 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 1997. 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. Tribal staff and site contractors worked together during the completion of several field surveys and monitoring activities during the year. In addition, two Wanapum tribal members were hired by Pacific Northwest National Laboratory and trained to work as archaeological technicians and assist DOE Richland Operations Office with cultural resource management activities.

Other activities involving tribal expertise included 1) a tour of the Hanford Site, led by a Wanapum elder, to provide information to Wanapum families about the meaning and importance of locations, ranging from the shores of the Columbia River to the top of Rattlesnake Mountain and 2) a tribal and professional workshop to discuss the development of geophysical studies at the Hazardous Materials Management Emergency Response Training and Education Center.

## 7.3.2 Public Involvement

The cultural resources staff of the Pacific Northwest National Laboratory, Bechtel Hanford, Inc., and CH2M Hill Hanford, Inc., assisted DOE in organizing and conducting two public meetings for reviewing the implementation of DOE's building mitigation activities and the sitewide treatment plan (DOE/RL-97-56, Rev. 1), including a discussion of the future uses of historic buildings at the Hanford Site. Additional meetings focusing on the preservation of historic buildings for interpretive/museum purposes continued through 1997.

Two DOE-sponsored public meetings were held in 1997 for the purpose of identifying and evaluating buildings and structures in the 700 and 1100 Areas for listing consideration in the National Register of Historic Places (contained in the National Historic Preservation Act). A DOE-sponsored Hanford Curation Workshop of invited experts and a public meeting were held to develop a sitewide curation strategy for Manhattan Project and Cold War era artifacts.

## 7.3.3 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 can take place. Cultural resource reviews are required to identify properties that may be eligible for or listed in the National Register of Historic Places within the proposed project area and evaluate the effect the proposed project may have on any such property.

During 1997, 151 cultural resource reviews were requested. A majority of the reviews involved project areas that had been previously surveyed or were located in previously disturbed ground. Of the projects reviewed, 9 were also monitored during the construction phase, 12 required archaeological surveys, and 47 involved building modification or demolition (Figure 7.3.1). The surveys covered a total of 98 ha (242 acres) and resulted in the discovery of 1 isolated find and 5 archaeological sites (Figure 7.3.2).

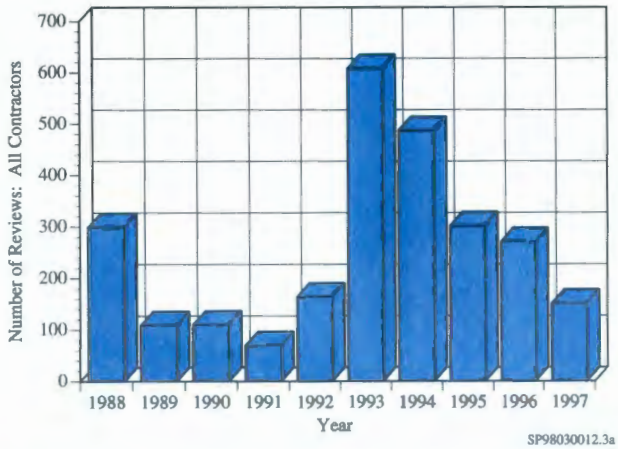


**Figure 7.3.1.** Cultural Resource Reviews Requested Each Calendar Year

**Figure 7.3.2.** Historic Sites are Commonly Found During Surveys Conducted at the Hanford Site

## 7.3.4 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 properties in a way that considers preservation of their values and ensures that preservation-related activities are completed in consultation with other agencies, tribes, and the general public.

In 1997, management activities conducted to fulfill Section 110 requirements included implementation of the programmatic agreement for the built environment (DOE/RL-96-77), development of a Hanford Site curation strategy for the purpose of identifying and preserving Manhattan Project and Cold War era artifacts (DOE/RL-97-71), and publication of a Multiple Property Documentation form (DOE/RL-97-02) to assist with the identification and evaluation of historic properties for listing in the National Register of Historic Places. Since the initiation of Section 110 activities, 465 buildings/structures have been documented on historic property inventory forms and are on file at the Hanford Cultural Resources Laboratory (Figure 7.3.3). National Register sites were also monitored to assess impacts caused by erosion associated with high water levels along the Columbia River.

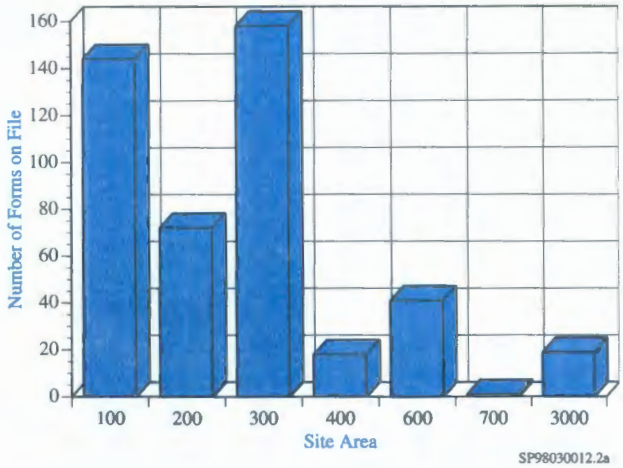


**Figure 7.3.3.** Hanford Buildings Documented with a Washington State Historic Property Inventory Form

### 7.3.4.1 Historic District

During 1997, the buildings mitigation project was implemented to carry out work under the programmatic agreement for the built environment (DOE/RL-96-77) and outlined in the Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan (DOE/RL-97-56, Rev. 1). The plan, required under Stipulation IV of the programmatic agreement, directs the production of a mitigation document chronicle the history of the Hanford Site during the Manhattan Project and Cold War era.

During 1996, the Hanford Site Manhattan Project and Cold War Era Historic District was established and approximately 185 buildings, structures, and complexes were identified as contributing properties within the district recommended for mitigation. Buildings in the 700 and 1100 Areas were not included in this evaluation. Two public meetings were held during 1997 to evaluate these buildings and as a result, 7 buildings were identified as contributing properties within the district recommended for mitigation (Figure 7.3.4). The Hanford railroad was also added to the list of properties recommended for mitigation. Of the 185 buildings, structures, and complexes selected as contributing properties within the historic district recommended for mitigation, 79 have been documented according to mitigation standards identified in the sitewide treatment plan (DOE/RL-97-56, Rev. 1). Three historic properties have been documented at the Historic American Engineering Record level, 18 have been documented with Expanded Historic Property Inventory Forms, while standard Historic Property Inventory Forms have been prepared for the remaining 58 buildings/structures.

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 (DOE/RL-97-56, Rev. 1), certain property types such as mobile trailers, modular buildings, storage tanks, towers, wells,

**Figure 7.3.4.** 105-C Reactor, One of Several Structures Included in the Hanford Site Manhattan Project and Cold War Era Historic District

and structures with minimal or no visible surface manifestations are exempt from the identification and evaluation requirement.

Hanford Site cultural resources staff provided a leadership role in developing a national initiative for management of DOE historic buildings based on concepts, methods, and themes developed for the Hanford Site Manhattan Project and Cold War Era Historic District. In addition, a curation strategy for artifacts associated with this time period was prepared and disseminated for public comment and review.

### 7.3.4.2 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, 5 historic contexts were completed in 1996 as part of the National Register Multiple Property Documentation process. These contexts were used during 1997 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).

### 7.3.4.3 Monitoring

An inventory of exposed and eroding cutbanks along all islands in, and both shorelines of, the Columbia River corridor located within the Hanford Site was initiated in response to the significant increased erosion of riverbanks as a result of abnormally high water flows. Approximately 20 km (12.4 miles) of shoreline were examined during 1997. The primary focus of the shoreline inventory was to record the nature and extent of exposed cultural features both at previously identified archaeological sites and at newly eroded cutbanks not previously available for examination. A total of 13 new archaeological sites were recorded as a result of this effort.

Locke Island, in the Hanford Reach of the Columbia River, 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 has been ongoing since 1995 to evaluate a complex fluvial erosion problem exhibited along its northeastern shoreline. Erosion along the northeastern shoreline of Locke Island and along the entire Hanford Reach was substantial as a result of sustained high waters during the spring floods of 1997. Monitoring continued during 1997 along a portion of the island's northeastern shoreline to investigate rates of erosion and associated impacts to archaeological features. During the year, approximately 0.7 ha (1.8 acres) of the island's surface land was lost and entered the river along the monitored section of shoreline. A multiagency group was formed to investigate possible solutions to this complex issue.

## 7.3.5 Education and Research

Educational activities associated with the cultural resources program in 1997 included presenting lectures to groups, ranging from public school classrooms to civic groups, colleges, and professional societies. Several symposia were organized throughout the Pacific Northwest region to present DOE Richland Operations Office's cultural resource management techniques to professional groups and societies. The 3rd Annual Aboriginal Lifeways, Prehistoric Artifact Recognition and Documentation Certification training sponsored by the Confederated Tribes of the Umatilla Reservation was attended by Bechtel Hanford, Inc. and CH2M Hill Hanford, Inc., staff. Pacific Northwest National Laboratory participated in the Associated Western Universities, Inc., Northwest program by hosting a student intern involved in field and laboratory work with Hanford Cultural Resources Laboratory staff.

Research activities continued as part of compliance work. Research in the field of archaeology and history focused on archaeological site preservation and protection, quantification and analysis of erosion and associated impacts to archaeological sites and features at Locke Island, use of plants significant to native American people in post-cleanup revegetation, and documentation of the built environment of the Manhattan Project and Cold War periods.

# 7.4 Community-Operated Environmental Surveillance Program

*R. W. Hanf*

Since 1991, citizens living near the Hanford Site have been actively participating in site environmental surveillance activities through the Community-Operated Environmental Surveillance Program. During 1997, nine radiological air sampling stations were operated by local teachers at selected locations around the site perimeter. These stations are located in Basin City, Richland, Pasco, Kennewick, north Franklin County, Othello, Mattawa, Toppenish, and Benton City, Washington (see Figure 4.1.1). Each station consists of equipment for collecting air samples and for monitoring ambient radiation levels. Four of the nine stations also include large, lighted informational displays that provide real-time meteorological and radiological information as well as general information on station equipment, sample types, and analyses (Figure 7.4.1). The station managers' names and telephone numbers are provided on the four displays for anyone desiring additional information about the purpose of the station, station equipment, or analytical results.

**Figure 7.4.1**. Community Members See Environmental Surveillance in Action at a Community-Operated Environmental Surveillance Station in Richland

Two teachers from schools located near the stations were selected to operate each station. Each pair of teachers is responsible for collecting a variety of air samples, preparing the samples and collection records for submission to the analytical laboratory, monitoring the performance of station equipment, performing minor station maintenance, and participating in scheduled training. They also serve as spokespersons for the Community-Operated Environmental Surveillance Program and are points of contact for local citizens. Pacific Northwest National Laboratory staff 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 1997 are discussed in Section 4.1, "Air Surveillance." Results of gamma radiation measurements are discussed briefly in Section 4.7, "External Radiation Surveillance."

# 8.0 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 crosscontamination.

This section discusses specific measures taken to ensure quality in project management, sample collection, and analytical results.

## 8.0.1 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 the U.S. Environmental Protection Agency (EPA) and/or the U.S. Department of Energy (DOE) for the project-specific requirements.

### 8.0.1.1 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 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.

### 8.0.1.2 Sample Collection Quality Assurance/Quality Control

Environmental surveillance samples are collected by staff trained to conduct sampling according to approved and documented procedures (PNL-MA-580, Rev. 2). 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 (Section 3.0, "Facility-Related Monitoring," and Section 4.0, "Environmental Surveillance Information").

Samples for the groundwater monitoring program are collected by trained staff according to approved and

documented procedures (WHC-CM-7-7). Chain-of-custody procedures are followed (SW-846) 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 are obtained during field operations. Summaries of the 1997 groundwater field quality control sample results are provided in Appendix D of PNNL-11793. The percentages of acceptable field blank and duplicate results in fiscal year 1997 were very high, 88% for blanks and 99% for field duplicates.

## 8.0.1.3 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 the Quanterra Laboratory, St. Louis, Missouri. Some routine analyses of hazardous and nonhazardous chemicals for the Comprehensive Environmental Response, Compensation, and Liability Act groundwater program were also performed by Recra Labnet, Exton, Pennsylvania and/or LAS, Las Vegas, Nevada. Each laboratory participates in the EPA Water Pollution and Water Supply Performance Evaluation Studies. Each laboratory maintains an internal quality control program that meets the requirements in SW-846 which is audited and reviewed internally and by Pacific Northwest National Laboratory. 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's Richland, Washington laboratory. Data from LAS, Las Vegas, Nevada and Thermo NUtech, Richmond, California were also used in the 1997 groundwater evaluations. Each laboratory participates in DOE's Quality Assessment Program, Environmental Measurements Laboratory, New York, and EPA's Laboratory Intercomparison Studies at the National Exposure Research Laboratory, Characterization Research Division, Las Vegas, Nevada. An additional quality control blind spiked sample program is conducted for each project. Each laboratory also maintains 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 sections.

## 8.0.1.4 DOE and EPA Comparison Studies

Standard water samples are distributed blind to participating laboratories. These samples contain specific organic and inorganic analytes with concentrations unknown to the analyzing laboratories. After analysis, the results are submitted to the EPA for comparison with known values and other participating laboratory concentrations. Summaries of the results for 1997 are provided in Table 8.0.1 for the primary laboratory, Quanterra, St. Louis, Missouri. The percentage of EPA-acceptable results is high for the laboratory, indicating acceptable 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

**Table 8.0.1**. Summary of Laboratory Performance on EPA Water Pollution and Water Supply Studies, 1997

| Laboratory | Water Supply Study March 1997 % Acceptable | Water Pollution Study May 1997 % Acceptable | Water Supply Study September 1997 % Acceptable | Water Pollution Study November 1997 % Acceptable |
|---|---|---|---|---|
| Quanterra Laboratory, St. Louis, Missouri | 89[a] | 96[b] | 95[c] | 81[d] |

(a) Unacceptable results were for 2,2-dichloropropane, molybdenum, orthophosphate, residual free chlorine, sulfate, 1,2,3-trichlorobenzene, and 1,2,3-trichloropropane.
(b) Unacceptable results were for arsenic, oil and grease, and orthophosphate.
(c) Unacceptable results were for 1,1-dichloroethylene, trans-1,2-dichloroethylene, and turbidity.
(d) Unacceptable results were for magnesium, total alkalinity (as $CaCO_3$), orthophosphate, Kjeldahl-nitrogen, nonfilterable residue. Possible errors in reporting of silver, titanium, carbonaceous biological oxygen demand, heptachlor epoxide, benzene, and toluene.

laboratory. After analysis, the results are forwarded to DOE or EPA for comparison with known values and results from other laboratories. Both DOE and EPA have established criteria for evaluating the accuracy of results (EPA-600/4-81-004, EML-591, EML-594). Summaries of the 1997 results for the programs are provided in Tables 8.0.2 and 8.0.3.

## 8.0.1.5 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 Quanterra. In 1997, blind spiked samples were submitted for air filters, vegetation, soil, water, and groundwater. Overall, 74% of nonradiochemistry blind spiked determinations were within control limits, and 86% of Quanterra's radiochemistry blind spiked determinations were within control limits (Tables 8.0.4 and 8.0.5). Overall, this indicates acceptable results.

The groundwater monitoring project also submitted blind spiked samples to Recra Labnet for evaluation during the year. The discussion and summary of data can be found in Appendix D of PNNL-11793.

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. However, no samples were designated by the Quality Assurance Task Force for analysis in 1997.

## 8.0.1.6 Laboratory Internal Quality Assurance Programs

The analyzing laboratories are required to maintain an internal quality assurance and control program. Periodically, the laboratories are internally audited for compliance to the quality assurance and control programs. At Quanterra St. Louis, the quality control programs meet the quality assurance and control criteria in SW-846. 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 at Quanterra 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 are used for radiochemical calibrations. 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/005/80).

Periodically, inspections of services are performed, which document conformance with contractual requirements of the analytical facility and provide the framework for identifying and resolving potential performance problems. Responses to assessment and inspection findings are documented by written communication, and corrective actions are verified by follow-up audits and inspections. An assessment of Quanterra St. Louis was conducted in 1997 by the Hanford Site's Integrated Contractor Assessment Team, consisting of representatives from Bechtel Hanford, Inc., Pacific Northwest National Laboratory, and Waste Management Federal Services of Hanford, Inc. An inspection of services was also performed at Quanterra Richland in 1997. The purpose of the assessment and inspection of services was to evaluate the continued capability of the laboratories to analyze and process samples for the Hanford Site as specified in the statement of work between the DOE contractors and the laboratories.

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.

## 8.0.1.7 Media Audits and Comparisons

Additional audits and comparisons are conducted on several specific types of samples. The Washington State

**Table 8.0.2.** Summary of Laboratory Performance on DOE Quality Assessment Program Samples, 1997

| Medium | Radionuclides | Number of Results Reported for Each Analyte | Number Within Acceptable Control Limits[a] |
|---|---|---|---|
| **Quanterra Environmental Services, Richland, Washington** | | | |
| Air filter particulate | $^{54}$Mn, $^{57}$Co, $^{60}$Co, $^{90}$Sr, $^{134}$Cs, $^{137}$Cs, $^{144}$Ce, $^{234}$U, $^{238}$Pu, $^{238}$U, $^{239}$Pu, $^{241}$Am, gross alpha, gross beta, U total | 2 | 2 |
| | $^{125}$Sb | 2 | 1 |
| Soil | $^{40}$K, $^{60}$Co, $^{90}$Sr, $^{137}$Cs, $^{234}$U, $^{238}$Pu, $^{238}$U, $^{239}$Pu, $^{241}$Am, $^{244}$Cm, U total | 2 | 2 |
| Vegetation | $^{40}$K, $^{60}$Co, $^{90}$Sr, $^{134}$Cs, $^{239}$Pu, $^{241}$Am, $^{244}$Cm | 2 | 2 |
| Water | $^{3}$H, $^{90}$Sr, $^{137}$Cs, $^{234}$U, $^{238}$Pu, $^{238}$U, $^{239}$Pu, $^{241}$Am, gross alpha, gross beta, U total | 2 | 2 |
| | $^{60}$Co, $^{54}$Mn | 2 | 1 |
| | $^{134}$Cs | 1 | 1 |
| **LAS, Las Vegas, Nevada** | | | |
| Water | $^{3}$H, $^{54}$Mn, $^{60}$Co, $^{90}$Sr, $^{137}$Cs, $^{238}$Pu, $^{238}$U, $^{239}$Pu, $^{241}$Am, gross alpha, gross beta, U total | 2 | 2 |
| | $^{234}$U | 2 | 1 |
| | $^{134}$Cs | 1 | 1 |
| **Thermo NUtech, Richmond, California** | | | |
| Water | $^{3}$H, $^{54}$Mn, $^{60}$Co, $^{90}$Sr, $^{137}$Cs, $^{238}$Pu, $^{238}$U, $^{239}$Pu, $^{241}$Am, gross alpha, gross beta, U total | 2 | 2 |
| | U total | 2 | 1 |
| | $^{134}$Cs | 1 | 1 |

(a) Control limits are from EML-591 and EML-594.

**Table 8.0.3**. Summary of Laboratory Performance on EPA Intercomparison Program Samples, 1997

| Medium | Radionuclides | Number of Results Reported for Each Analyte | Number Within Control Limits for Each Analyte[a] |
|---|---|---|---|
| **Quanterra Environmental Services, Richland, Washington** | | | |
| Water | $^{3}H$, $^{65}Zn$, $^{131}I$, $^{133}Ba$ | 2 | 2 |
| | $^{89}Sr$, $^{90}Sr$ | 4 | 4 |
| | $^{60}Co$, $^{134}Cs$, $^{137}Cs$ | 4 | 3 |
| | Gross alpha, gross beta, U total, $^{226}Ra$, $^{228}Ra$ | 5 | 5 |
| **LAS, Las Vegas, Nevada** | | | |
| Water | $^{131}I$ | 1 | 1 |
| | $^{65}Zn$, $^{133}Ba$ | 2 | 2 |
| | $^{3}H$ | 2 | 1 |
| | $^{60}Co$, $^{89}Sr$, $^{90}Sr$, $^{137}Cs$ | 4 | 4 |
| | $^{134}Cs$ | 4 | 3 |
| | Gross alpha, gross beta, U total, $^{228}Ra$ | 5 | 5 |
| | $^{226}Ra$ | 5 | 4 |
| **Thermo NUtech, Richmond, California** | | | |
| Water | $^{3}H$, $^{65}Zn$, $^{131}I$, $^{133}Ba$ | 2 | 2 |
| | $^{60}Co$, $^{89}Sr$, $^{90}Sr$, $^{134}Cs$, $^{137}Cs$ | 4 | 4 |
| | Gross alpha, gross beta, U total, $^{226}Ra$, $^{228}Ra$ | 5 | 5 |

(a) Control limits are from EPA-600/4-81-004.

Department of Health routinely cosampled various environmental media and measured external radiation levels at multiple locations during 1997. Media that were cosampled included groundwater from 23 wells, water from 4 Columbia River locations along the river, water from 3 riverbank springs, water from 2 onsite drinking water locations, sediment from 4 Columbia River sites, surface soil samples from 4 locations, samples from 3 air monitoring stations, and thermoluminescent dosimeters from 14 sites. Also cosampled were upwind and downwind samples of leafy vegetables, fruit, perennial vegetation, alfalfa, and wine. Results will be published in the Washington State Department of Health 1997 annual report.

The Food and Drug Administration also cosampled fruit, leafy vegetables, and potatoes from upwind and downwind sampling locations. The data are presented in Table 8.0.6.

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 1997 results is shown in Table 8.0.7. On average, the thermoluminescent dosimeter measurements were biased 1% higher than the known values.

**Table 8.0.4.** Summary of Groundwater Monitoring Project Double-Blind Spike Determinations, 1997[a]

| Constituent | Number of Results Reported[b,c] | Number Within Control Limits | Control Limits, % |
|---|---|---|---|
| Tritium | 12 | 12 | 60 to 140 |
| Cobalt-60 | 12 | 12 | 60 to 140 |
| Strontium-90 | 12 | 12 | 60 to 140 |
| Technetium-99 | 12 | 11 | 60 to 140 |
| Iodine-129 | 6[d] | 5 | 60 to 140 |
| Cesium-137 | 12 | 12 | 60 to 140 |
| Plutonium-239,240 | 12 | 10 | 60 to 140 |
| U total | 12 | 12 | 60 to 140 |
| Chloroform | 12 | 12 | Determined each quarter |
| Carbon tetrachloride | 12 | 12 | Determined each quarter |
| Trichloroethene | 12 | 12 | Determined each quarter |
| Chromium | 12 | 12 | ±20 |
| Cyanide | 12 | 5 | ±25 |
| Fluoride | 12 | 5 | ±25 |
| Nitrate | 12 | 12 | ±25 |
| Total organic halides (spiked with 2,4,6-trichlorophenol) | 7 | 2 | ±25 |
| Total organic halides (spiked with chloroform, carbon tetrachloride, and trichloroethene) | 7 | 2 | ±25 |
| Total organic carbon (spiked with potassium phthalate) | 6 | 3 | ±25 |
| Gross alpha (spiked with $^{239}Pu$) | 6 | 4 | ±10 |
| Gross beta (spiked with $^{90}Sr$) | 6 | 0 | ±10 |

(a) The Groundwater Monitoring Project reporting requirements are by fiscal year (October 1 through September 30).
(b) Blind samples were submitted in triplicate each quarter and compared to actual spike values.
(c) Total organic halides, total organic carbon, gross alpha, and gross beta samples were submitted in triplicate during the second and third quarters of fiscal year 1997 only.
(d) Twelve samples were forwarded to the laboratory during the year: 3 were not analyzed because of a laboratory error; 3 were not analyzed because sample volumes did not meet required detection limits.

**Table 8.0.5**. Summary of Surface Environmental Surveillance Project Blind Spiked Determinations, 1997

| Medium | Radionuclides | Number of Results Reported | Number Within Control Limits[a] |
|---|---|---|---|
| Air filters | $^{7}Be$, $^{54}Mn$, $^{57}Co$, $^{60}Co$, $^{90}Sr$, $^{134}Cs$, $^{137}Cs$, $^{144}Ce$, $^{238}Pu$, $^{239}Pu$ | 15 | 11 |
| Soil | $^{40}K$, $^{90}Sr$, $^{137}Cs$, $^{234}U$, $^{238}U$, $^{238}Pu$, $^{239}Pu$ | 20 | 14[b] |
| Water | $^{3}H$, $^{54}Mn$, $^{57}Co$, $^{60}Co$, $^{90}Sr$, $^{134}Cs$, $^{137}Cs$, $^{144}Ce$, $^{234}U$, $^{238}U$, $^{238}Pu$, $^{239}Pu$ | 25 | 22 |
| Vegetation | $^{40}K$, $^{90}Sr$, $^{137}Cs$, $^{238}Pu$, $^{239}Pu$ | 15 | 15 |

(a) Control limit of ±30%.
(b) Uranium isotopic results were determined using a different preparation method than was used to determine the standard value.

**Table 8.0.6**. Comparison of Food and Drug Administration Cosampling, 1997

| Medium | Area[a] | Organization | Potassium-40, pCi/g[b] | Strontium-90, pCi/g[b,c] | Cesium-137, pCi/g[c] | Ruthenium-106, pCi/g[c] |
|---|---|---|---|---|---|---|
| Apples | Riverview | FDA[d] | 2.6 ± 0.9 | NA[e] | <0.01 | <0.01 |
| | | PNNL[f] | 0.528 ± 0.289 | <0.0018 | <0.0098 | <0.069 |
| | Sagemoor | FDA | 1.7 ± 0.9 | NA | <0.01 | <0.01 |
| | | PNNL | 1.28 ± 0.323 | <0.0021 | <0.0087 | <0.064 |
| Leafy vegetables | Riverview | FDA | 4.7 ± 1.1 | NA | <0.01 | <0.01 |
| | | PNNL | 3.01 ± 0.465 | 0.034 ± 0.0083 | <0.0081 | <0.075 |
| | Sunnyside | FDA | 3.4 ± 0.9 | NA | <0.01 | <0.01 |
| | | PNNL | 2.4 ± 0.41 | <0.0042 | <0.0089 | <0.079 |
| Potatoes | Horn Rapids | FDA | 5.5 ± 0.8 | NA | <0.01 | <0.01 |
| | | PNNL | 3.8 ± 0.48 | <0.0050 | <0.0066 | <0.055 |
| | Sagemoor | FDA | 4.0 ± 0.8 | NA | <0.01 | <0.01 |
| | | PNNL | 3.45 ± 0.47 | 0.0042 ± 0.0037 | <0.0079 | <0.059 |
| | Sunnyside | FDA | 4.4 ± 0.7 | NA | <0.01 | <0.01 |
| | | PNNL | 3.44 ± 0.50 | <0.0037 | <0.0073 | <0.073 |

(a) Locations are identified in Figure 4.4.1.
(b) ±2-sigma total propagated analytical uncertainty.
(c) < values are ±2-sigma total propagated analytical uncertainties.
(d) FDA = Food and Drug Administration.
(e) NA = Not analyzed.
(f) PNNL = Pacific Northwest National Laboratory.

**Table 8.0.7.** Comparison of Thermoluminescent Dosimeter Results with Known Exposure, 1997

| Quarter/ Exposure | | Known Exposure, mR[a] | Determined Exposure, mR[b] | Known Exposure, % |
|---|---|---|---|---|
| 1st | February 7, 1997 | 17 ± 0.63 | 16.83 ± 0.15 | 99 |
| | February 7, 1997 | 19 ± 0.70 | 18.87 ± 0.00 | 99 |
| | February 7, 1997 | 26 ± 0.96 | 25.98 ± 1.09 | 100 |
| 2nd | May 13, 1997 | 19 ± 0.70 | 17.97 ± 0.57 | 95 |
| | May 13, 1997 | 25 ± 0.93 | 24.04 ± 0.22 | 96 |
| | May 13, 1997 | 28 ± 1.04 | 27.00 ± 1.13 | 96 |
| 3rd | August 14, 1997 | 18 ± 0.67 | 17.92 ± 0.91 | 100 |
| | August 14, 1997 | 20 ± 0.74 | 20.82 ± 0.46 | 104 |
| | August 14, 1997 | 27 ± 1.00 | 27.54 ± 0.57 | 102 |
| 4th | December 5, 1997 | 18 ± 0.67 | 17.83 ± 1.47 | 99 |
| | December 5, 1997 | 21 ± 0.78 | 20.55 ± 1.13 | 98 |
| | December 5, 1997 | 28 ± 1.04 | 27.65 ± 0.30 | 99 |

(a) ±2 sigma total propagated analytical uncertainty.
(b) ±2 times the standard deviation.

## 8.0.2 Effluent Monitoring and Near-Facility Environmental Monitoring

The site effluent monitoring and near-facility environmental monitoring programs are subject to the quality assurance requirements specified in the Hanford Analytical Services Quality Assurance Requirements Document (DOE/RL-96-68). These quality assurance programs comply with DOE Order 5700.6C, using standards from the American Society of Mechanical Engineers (ASME NQA-1-1989 Edition) as their basis. The programs also adhere to the guidelines and objectives in EPA/005/80 and EPA/540/G-87/003.

The 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.

### 8.0.2.1 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/RL-91-50, Rev. 2.

### 8.0.2.2 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 8.0.8 provides a summary of Hanford's analytical laboratory utilization for effluent monitoring and near-facility monitoring samples grouped by contractor and sample media.

The quality of the analytical data is ensured by several means. Counting room instruments, for instance, are

**Table 8.0.8**. Laboratories Utilized by Contractor and Sample Type, 1997

| Analytical Laboratory | Effluent Monitoring Samples | | | | | Near-Facility Environmental Monitoring Samples | | |
|---|---|---|---|---|---|---|---|---|
| | Fluor Daniel Hanford, Inc. | | Pacific Northwest National Laboratory | Bechtel Hanford, Inc. | | Fluor Daniel Hanford, Inc. | | |
| | Air | Water | Air | Air | Water | Air | Water | Other |
| Waste Sampling and Characterization Facility[a] | X | X | | X | | X | X | X |
| 222-S Analytical Laboratory[a] | | | | | | | X | X |
| Quanterra Environmental Services, Richland | X | X | X | X | X | X | | |
| PNNL[b] Analytical Chemistry Laboratory | X | X | X | | | | | |

(a) Onsite laboratory operated by Waste Management Federal Services of Hanford, Inc.
(b) Pacific Northwest National Laboratory.

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 are reported and tracked. Formal, written laboratory procedures are used in analyzing samples. Analytical procedural control is ensured through administrative procedures. Chemical technologists at the laboratory qualify to perform analyses through formal classroom and on-the-job training.

The participation of the analytical laboratories in DOE and EPA laboratory intercomparison programs also serves to ensure the quality of the data produced. Laboratory intercomparison program results for 1997 can be found in Tables 8.0.9 through 8.0.14 for the Waste Sampling and Characterization Facility, the 222-S Analytical Laboratory, and the Pacific Northwest National Laboratory Analytical Chemistry Laboratory. Laboratory intercomparison results for Quanterra were previously provided in Tables 8.0.2 and 8.0.3. In 1996, the EPA intercomparison program deleted some of the analysis categories (e.g., air filters) from the program because of budget reductions.

**Table 8.0.9**. Waste Sampling and Characterization Facility[a] Performance on DOE Quality Assessment Program Samples, 1997

| Medium | Radionuclide | Number of Results Reported | Number Within Control Limits | Number Outside Control Limits |
|---|---|---|---|---|
| Air filters | Gross alpha, gross beta, $^{54}Mn$, $^{57}Co$, $^{60}Co$, $^{90}Sr$, $^{106}Ru$, $^{125}Sb$, $^{134}Cs$, $^{137}Cs$, $^{144}Ce$, $^{234}U$, $^{238}U$, $^{238}Pu$, $^{239}Pu$, $^{241}Am$, U total | 42 | 33 | 9[a] |
| Soil | $^{40}K$, $^{60}Co$, $^{90}Sr$, $^{137}Cs$, $^{238}U$, $^{239}Pu$, $^{241}Am$ | 18 | 18 | 0 |
| Vegetation | $^{40}K$, $^{60}Co$, $^{90}Sr$, $^{137}Cs$, $^{239}Pu$, $^{241}Am$, $^{244}Cm$ | 17 | 17 | 0 |
| Water | Gross alpha, gross beta, $^{3}H$, $^{54}Mn$, $^{60}Co$, $^{90}Sr$, $^{137}Cs$, $^{234}U$, $^{238}U$, $^{238}Pu$, $^{239}Pu$, $^{241}Am$, U total | 36 | 36 | 0 |

(a) Onsite laboratory operated by Waste Management Federal Services of Hanford, Inc.
(b) One gross alpha, one $^{54}Mn$, one $^{57}Co$, one $^{60}Co$, one $^{90}Sr$, one $^{137}Cs$, and three $^{125}Sb$ results were not within control limits.

**Table 8.0.10**. 222-S Analytical Laboratory[a] Performance on DOE Quality Assessment Program Samples, 1997

| Medium | Radionuclide | Number of Results Reported | Number Within Control Limits | Number Outside Control Limits |
|---|---|---|---|---|
| Soil | $^{40}K$, $^{90}Sr$, $^{137}Cs$ | 8 | 8 | 0 |
| Vegetation | $^{40}K$, $^{60}Co$, $^{90}Sr$, $^{137}Cs$, $^{239}Pu$, $^{241}Am$, $^{244}Cm$ | 15 | 13 | 2[b] |
| Water | $^{3}H$, $^{54}Mn$, $^{60}Co$, $^{90}Sr$, $^{134}Cs$, $^{137}Cs$, $^{238}Pu$, $^{239}Pu$, $^{241}Am$, U total | 28 | 26 | 2[c] |

(a) Onsite laboratory operated by Waste Management Federal Services of Hanford, Inc.
(b) One $^{137}Cs$ and one $^{241}Am$ result were not within control limits.
(c) One $^{134}Cs$ and one U total result were not within control limits.

**Table 8.0.11**. Pacific Northwest National Laboratory Analytical Chemistry Laboratory Performance on DOE Quality Assessment Program Samples, 1997

| Medium | Radionuclide | Number of Results Reported | Number Within Control Limits | Number Outside Control Limits |
|---|---|---|---|---|
| Air filters | Gross alpha, gross beta, $^{54}Mn$, $^{57}Co$, $^{60}Co$, $^{90}Sr$, $^{106}Ru$, $^{125}Sb$, $^{134}Cs$, $^{137}Cs$, $^{144}Ce$, $^{238}U$, $^{238}Pu$, $^{239}Pu$, $^{241}Am$, U total | 40 | 39 | 1[a] |
| Water | Gross alpha, gross beta, $^{3}H$, $^{54}Mn$, $^{55}Fe$, $^{60}Co$, $^{90}Sr$, $^{134}Cs$, $^{137}Cs$, $^{238}U$, $^{238}Pu$, $^{239}Pu$, $^{241}Am$, U total | 33 | 32 | 1[b] |

(a) One $^{125}Sb$ result was not within control limits.
(b) One $^{238}U$ result was not within control limits.

**Table 8.0.12**. Waste Sampling and Characterization Facility[a] Performance on EPA Intercomparison Program Samples, 1997

| Category | Radionuclide | Number of Results Reported | Number Within Control Limits | Number Outside Control Limits |
|---|---|---|---|---|
| Gross alpha-beta in water | Gross alpha, gross beta | 6 | 5 | 1[b] |
| Gamma in water | $^{60}Co$, $^{65}Zn$, $^{134}Cs$, $^{137}Cs$, $^{133}Ba$ | 10 | 10 | 0 |
| 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 | $^{3}H$ | 2 | 2 | 0 |
| Blind A[c] | Gross alpha, uranium (natural), $^{226}Ra$, $^{228}Ra$ | 8 | 8 | 0 |
| Blind B[d] | Gross beta, $^{60}Co$, $^{89}Sr$, $^{90}Sr$, $^{134}Cs$, $^{137}Cs$ | 12 | 10 | 2[e] |

(a) Onsite laboratory operated by Waste Management Federal Services of Hanford, Inc.
(b) One gross beta result was not within control limits.
(c) Blind A samples are liquid samples with unknown quantities of alpha emitters analyzed for gross alpha and each radionuclide component.
(d) Blind B samples are liquid samples with unknown quantities of beta emitters analyzed for gross beta and each radionuclide component.
(e) One $^{89}Sr$ result and one $^{90}Sr$ result were not within control limits.

**Table 8.0.13.** 222-S Analytical Laboratory[a] Performance on EPA Intercomparison Program Samples, 1997

| Category | Radionuclide | Number of Results Reported | Number Within Control Limits | Number Outside Control Limits |
|---|---|---|---|---|
| Gamma in water | $^{60}Co$, $^{65}Zn$, $^{134}Cs$, $^{137}Cs$, $^{133}Ba$ | 10 | 10 | 0 |
| Uranium-radium in water | Uranium (natural) | 1 | 0 | 1 |
| Tritium in water | $^{3}H$ | 2 | 0 | 2 |
| Blind A[b] | Gross alpha, uranium (natural) | 4 | 3 | 1[c] |
| Blind B[d] | Gross beta, $^{60}Co$, $^{134}Cs$, $^{137}Cs$ | 8 | 7 | 1[e] |

(a) Onsite laboratory operated by Waste Management Federal Services of Hanford, Inc.
(b) Blind A samples are liquid samples with unknown quantities of alpha emitters analyzed for gross alpha and each radionuclide component.
(c) One uranium (natural) result was not within control limits.
(d) Blind B samples are liquid samples with unknown quantities of beta emitters analyzed for gross beta and each radionuclide component.
(e) One gross beta result was not within control limits.

**Table 8.0.14.** Pacific Northwest National Laboratory Performance on EPA Intercomparison Program Samples, 1997

| Category | Radionuclide | Number of Results Reported | Number Within Control Limits | Number Outside Control Limits |
|---|---|---|---|---|
| Uranium-radium in water | Uranium (natural), $^{226}Ra$, $^{228}Ra$ | 3 | 3 | 0 |
| Tritium in water | $^{3}H$ | 1 | 1 | 0 |

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# Appendix A

## Additional Monitoring Results for 1997

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# Appendix A

## Additional Monitoring Results for 1997

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This appendix contains additional information on 1997 monitoring results, supplementing the data summarized in the main body of the report. More detailed information is available in PNNL-11796.

**Table A.1.** Radionuclide Concentrations in Columbia River Water at Priest Rapids Dam, 1997 Compared to Previous 5 Years

| Radionuclide[a] | | 1997 No. of Samples | 1997 Concentration,[b] pCi/L Maximum | 1997 Concentration,[b] pCi/L Average | 1992-1996 No. of Samples | 1992-1996 Concentration,[b] pCi/L Maximum | 1992-1996 Concentration,[b] pCi/L Average | Ambient Surface Water Quality Standard, pCi/L |
|---|---|---|---|---|---|---|---|---|
| **Composite System** | | | | | | | | |
| Alpha (gross) | | 12 | 0.82 ± 0.55 | 0.35 ± 0.076 | 60 | 1.2 ± 0.90 | 0.41 ± 0.046 | 15[c,d] |
| Beryllium-7 | | 12 | 11 ± 26 | 2.8 ± 1.9 | 60 | 18 ± 15 | 2.2 ± 1.0 | 6,000[e] |
| Beta (gross) | | 12 | 3.2 ± 1.8 | 0.36 ± 0.40 | 60 | 3.5 ± 2.4 | 1.0 ± 0.15 | 50[c,d] |
| Cobalt-60 | | 12 | 1.5 ± 1.3 | 0.11 ± 0.26 | 60 | 1.6 ± 0.99 | -0.024 ± 0.12 | 100[e] |
| Cesium-134 | | 12 | 2.8 ± 2.4 | 0.50 ± 0.39 | 60 | 1.4 ± 1.0 | -0.00099 ± 0.084 | 20,000[e] |
| Cesium-137 | | 12 | 2.0 ± 2.3 | 0.38 ± 0.35 | 60 | 1.2 ± 1.7 | 0.13 ± 0.066 | 200[e] |
| Europium-154 | | 12 | 4.6 ± 3.3 | -1.2 ± 1.0 | 60 | 5.2 ± 2.9 | 0.42 ± 0.26 | 200[e] |
| Europium-155 | | 12 | 5.8 ± 4.7 | 0.56 ± 0.78 | 60 | 3.5 ± 5.1 | -0.012 ± 0.18 | 600[e] |
| Potassium-40 | | 12 | 190 ± 52 | 59 ± 15 | 60 | 280 ± 54 | 44 ± 5.5 | --[f] |
| Ruthenium-106 | | 12 | 12 ± 22 | 2.4 ± 1.8 | 43 | 9.7 ± 8.8 | -2.2 ± 1.1 | 30[e] |
| Antimony-125 | | 12 | 6.4 ± 5.6 | -0.81 ± 0.91 | 43 | 3.2 ± 2.2 | -0.44 ± 0.26 | 300[e] |
| Strontium-90 | | 12 | 0.13 ± 0.062 | 0.090 ± 0.0074 | 60 | 0.14 ± 0.0049 | 0.085 ± 0.0029 | 8[c,d] |
| Technetium-99 | | 12 | 1.6 ± 0.69 | 0.17 ± 0.14 | 60 | 0.65 ± 0.55 | 0.012 ± 0.026 | 900[e] |
| Tritium | | 12 | 42 ± 9.4 | 28 ± 2.3 | 60 | 110 ± 16 | 38 ± 1.5 | 20,000[e] |
| Uranium-234 | | 12 | 0.36 ± 0.065 | 0.26 ± 0.012 | 60 | 0.44 ± 0.13 | 0.23 ± 0.0068 | -- |
| Uranium-235 | | 12 | 0.015 ± 0.012 | 0.0075 ± 0.0012 | 60 | 0.032 ± 0.039 | 0.0093 ± 0.0010 | -- |
| Uranium-238 | | 12 | 0.28 ± 0.054 | 0.22 ± 0.011 | 60 | 0.35 ± 0.11 | 0.18 ± 0.0055 | -- |
| Uranium (total) | | 12 | 0.64 ± 0.12 | 0.48 ± 0.022 | 60 | 0.83 ± 0.28 | 0.42 ± 0.012 | -- |
| Iodine-129[g] | | 4 | 0.000010 ± 0.0000012 | 0.0000072 ± 0.0000012 | 20 | 0.00013 ± 0.000013 | 0.000017 ± 0.0000065 | 1[e] |
| **Continuous System** | | | | | | | | |
| Plutonium-230,240 | P | 4 | 0.00015 ± 0.000098 | 0.000079 ± 0.000048 | 20 | 0.000097 ± 0.000040 | 0.000025 ± 0.0000058 | -- |
| | D | 4 | 0.000056 ± 0.00010 | 0.000018 ± 0.000030 | 20 | 0.00063 ± 0.00021 | 0.000063 ± 0.000033 | -- |

(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-570/9-76-003.
(f) Dashes indicate no concentration guides available.
(g) From 1992 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, 1997 Compared to Previous 5 Years

| Radionuclide[a] | | 1997 No. of Samples | 1997 Concentration,[b] pCi/L Maximum | 1997 Concentration,[b] pCi/L Average | 1992-1996 No. of Samples | 1992-1996 Concentration,[b] pCi/L Maximum | 1992-1996 Concentration,[b] pCi/L Average | Ambient Surface Water Quality Standard,[c] pCi/L |
|---|---|---|---|---|---|---|---|---|
| **Composite System** | | | | | | | | |
| Alpha (gross) | | 12 | 2.2 ± 1.1 | 0.58 ± 0.16 | 60 | 1.7 ± 1.1 | 0.57 ± 0.057 | 15[c,d] |
| Beryllium-7 | | 12 | 18 ± 23 | 1.4 ± 2.5 | 60 | 20 ± 12 | 1.7 ± 1.1 | 6,000[e] |
| Beta (gross) | | 12 | 2.6 ± 1.6 | 1.2 ± 0.21 | 60 | 3.4 ± 1.7 | 0.98 ± 0.13 | 50[c,d] |
| Cobalt-60 | | 12 | 1.7 ± 2.1 | 0.16 ± 0.41 | 60 | 2.0 ± 1.1 | 0.018 ± 0.096 | 100[e] |
| Cesium-134 | | 12 | 1.1 ± 1.2 | -0.00026 ± 0.23 | 60 | 1.2 ± 0.89 | -0.10 ± 0.091 | 20,000[e] |
| Cesium-137 | | 12 | 3.7 ± 2.1 | 0.77 ± 0.35 | 60 | 1.6 ± 1.5 | 0.22 ± 0.083 | 200[e] |
| Europium-154 | | 12 | 4.1 ± 3.4 | -0.19 ± 0.75 | 60 | 4.3 ± 2.6 | -0.052 ± 0.23 | 200[e] |
| Europium-155 | | 12 | 3.4 ± 4.6 | 0.15 ± 0.76 | 60 | 3.5 ± 2.8 | 0.034 ± 0.16 | 600[e] |
| Potassium-40 | | 12 | 240 ± 61 | 65 ± 19 | 60 | 100 ± 28 | 43 ± 2.9 | --[f] |
| Ruthenium-106 | | 12 | 13 ± 18 | 0.86 ± 2.6 | 43 | 18 ± 12 | 1.0 ± 0.96 | 30[e] |
| Antimony-125 | | 12 | 6.0 ± 4.7 | 0.36 ± 0.66 | 43 | 3.9 ± 2.5 | -0.032 ± 0.26 | 300[e] |
| Strontium-90 | | 12 | 0.13 ± 0.048 | 0.082 ± 0.0057 | 60 | 0.30 ± 0.081 | 0.090 ± 0.0046 | 8[c,d] |
| Technetium-99 | | 12 | 0.31 ± 0.56 | 0.094 ± 0.030 | 60 | 1.4 ± 0.71 | 0.042 ± 0.032 | 900[e] |
| Tritium | | 12 | 88 ± 13 | 61 ± 6.0 | 60 | 160 ± 20 | 87 ± 3.9 | 20,000[d] |
| Uranium-234 | | 12 | 0.40 ± 0.075 | 0.29 ± 0.021 | 60 | 0.50 ± 0.13 | 0.27 ± 0.010 | -- |
| Uranium-235 | | 12 | 0.017 ± 0.014 | 0.0088 ± 0.0016 | 60 | 0.048 ± 0.022 | 0.010 ± 0.0012 | -- |
| Uranium-238 | | 12 | 0.29 ± 0.057 | 0.24 ± 0.011 | 60 | 0.53 ± 0.14 | 0.21 ± 0.0083 | -- |
| Uranium (total) | | 12 | 0.70 ± 0.014 | 0.54 ± 0.030 | 60 | 1.0 ± 0.30 | 0.48 ± 0.018 | -- |
| Iodine-129[g] | | 4 | 0.00016 ± 0.000013 | 0.00012 ± 0.000028 | 17 | 0.00017 ± 0.000020 | 0.00010 ± 0.000010 | 1[e] |
| **Continuous System** | | | | | | | | |
| Plutonium-239,240 | P | 4 | 0.00015 ± 0.000051 | 0.000081 ± 0.000048 | 17 | 0.000056 ± 0.000026 | 0.000019 ± 0.0000035 | -- |
| | D | 4 | 0.000097 ± 0.00011 | 0.000039 ± 0.000041 | 17 | 0.00020 ± 0.00012 | 0.000050 ± 0.000013 | -- |

(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-570/9-76-003.
(f) Dashes indicate no concentration guides available.
(g) From 1992 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, 1997

| Transect/Radionuclide | No. of Samples | Concentration,[a] pCi/L Maximum | Minimum | Mean |
|---|---|---|---|---|
| **Vernita Bridge** | | | | |
| Tritium | 12 | 37 ± 9.1 | 23 ± 7.8 | 28 ± 1.1 |
| Strontium-90 | 12 | 0.11 ± 0.038 | 0.057 ± 0.032 | 0.083 ± 0.0041 |
| Uranium (total) | 12 | 0.54 ± 0.14 | 0.42 ± 0.10 | 0.48 ± 0.010 |
| **100-N Area** | | | | |
| Tritium | 5 | 32 ± 8.3 | 28 ± 8.1 | 30 ± 0.56 |
| Strontium-90 | 5 | 0.16 ± 0.047 | 0.092 ± 0.038 | 0.12 ± 0.015 |
| Uranium (total) | 5 | 0.49 ± 0.12 | 0.40 ± 0.10 | 0.46 ± 0.017 |
| **100-F Area** | | | | |
| Tritium | 10 | 30 ± 8.3 | 24 ± 8.1 | 27 ± 8.6 |
| Strontium-90 | 10 | 0.10 ± 0.038 | 0.079 ± 0.034 | 0.088 ± 0.028 |
| Uranium (total) | 10 | 0.62 ± 0.13 | 0.36 ± 0.091 | 0.45 ± 0.14 |
| **Old Hanford Townsite** | | | | |
| Tritium | 10 | 1,600 ± 140 | 25 ± 8.2 | 180 ± 150 |
| Strontium-90 | 10 | 0.12 ± 0.041 | 0.067 ± 0.033 | 0.091 ± 0.0058 |
| Uranium (total) | 10 | 0.49 ± 0.12 | 0.38 ± 0.098 | 0.42 ± 0.011 |
| **300 Area** | | | | |
| Tritium | 10 | 63 ± 11 | 27 ± 8.0 | 34 ± 3.5 |
| Strontium-90 | 10 | 0.12 ± 0.043 | 0.084 ± 0.036 | 0.098 ± 0.0037 |
| Uranium (total) | 10 | 0.89 ± 0.16 | 0.42 ± 0.10 | 0.51 ± 0.044 |
| **Richland Pumphouse** | | | | |
| Tritium | 31 | 71 ± 11 | 26 ± 8.3 | 35 ± 1.4 |
| Strontium-90 | 31 | 0.12 ± 0.043 | 0.049 ± 0.029 | 0.085 ± 0.0026 |
| Uranium (total) | 31 | 0.73 ± 0.14 | 0.36 ± 0.090 | 0.50 ± 0.014 |

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2-sigma). Mean values are ±2 standard error of the mean.

**Table A.4**. Selected U.S. Geological Survey Columbia River Water Quality Data,[a] 1997

| 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 | 11 | 19 | 12 | 3.0 | 4 | 20 | 11 | 4.5 | 20 (maximum) |
| Dissolved oxygen | mg/L | 11 | 14 | 13 | 10 | 4 | 13 | 12 | 10 | 8 (minimum) |
| Turbidity | NTU[c] | 11 | 4.7 | 1.9 | 0.30 | 4 | 3.5 | 1.0 | 0.30 | 5 + background |
| pH | pH units | 11 | 8.1 | 7.9 | 7.4 | 4 | 7.9 | 7.9 | 7.8 | 6.5 - 8.5 |
| Suspended solids, 105°C | mg/L | 11 | 12 | 4.0 | 0.0 | 4 | 13 | 5.5 | 3.0 | --[d] |
| Dissolved solids, 180°C | mg/L | 11 | 96 | 77 | 71 | 4 | 88 | 78 | 72 | -- |
| Specific conductance | µS/cm[e] | 11 | 160 | 130 | 110 | 4 | 150 | 130 | 120 | -- |
| Total hardness, as $CaCO_3$ | mg/L | 11 | 71 | 59 | 48 | 4 | 71 | 59 | 54 | -- |
| Phosphorus, total | mg/L | 11 | 0.04 | <0.01 | <0.01 | 4 | <0.01 | <0.01 | <0.01 | -- |
| Chromium, dissolved | µg/L | 0 | NR[f] | NR | NR | 4 | <1 | <1 | <1 | -- |
| Dissolved organic carbon | mg/L | 11 | 3.6 | 1.9 | 1.1 | 4 | 2.3 | 1.6 | 1.3 | -- |
| Iron, dissolved | µg/L | 11 | 66 | 13 | <3 | 4 | 12 | 8.0 | <3 | -- |
| Ammonia, dissolved, as N | mg/L | 11 | 0.008 | <0.002 | <0.002 | 4 | <0.02 | <0.01 | <0.01 | -- |
| Nitrogen, total Kjeldahl, as N | mg/L | 11 | 0.1 | <0.2 | <0.2 | 4 | <0.2 | <0.2 | <0.2 | -- |
| Nitrite + nitrate, dissolved, as N | mg/L | 11 | 0.26 | 0.093 | 0.040 | 4 | 0.22 | 0.11 | 0.090 | -- |

(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) Dashes indicate no standard available.
(e) µSiemens/cm.
(f) NR = not reported.

**Table A.5.** Radionuclide Concentrations in Columbia River and Riverbank Spring Sediment, 1997 Compared to Previous 5 Years

| Location | Radionuclide | 1997 No. of Samples | 1997 Concentration, pCi/g Maximum[a] | 1997 Concentration, pCi/g Median[b] | 1992-1996 No. of Samples | 1992-1996 Concentration, pCi/g Maximum[a] | 1992-1996 Concentration, pCi/g Median[b] |
|---|---|---|---|---|---|---|---|
| **River Sediment** | | | | | | | |
| 100-F Slough | Cobalt-60 | 1 | 0.024 ± 0.013 | | 6 | 0.033 ± 0.011 | 0.029 |
| | Cesium-137 | 1 | 0.28 ± 0.036 | | 6 | 0.76 ± 0.082 | 0.43 |
| | Europium-155 | 1 | 0.061 ± 0.033 | | 6 | 0.064 ± 0.048 | 0.028 |
| | Plutonium-239,240 | 1 | 0.0020 ± 0.00047 | | 6 | 0.0024 ± 0.00082 | 0.0015 |
| | Strontium-90 | 1 | 0.0032 ± 0.0029 | | 6 | 0.013 ± 0.0052 | 0.0033 |
| | Uranium-235 | 1 | 0.064 ± 0.068 | | 6 | 0.054 ± 0.068 | 0.0056 |
| | Uranium-238 | 1 | 0.99 ± 0.33 | | 6 | 1.4 ± 0.41 | 0.86 |
| Hanford Slough | Cobalt-60 | 1 | 0.18 ± 0.028 | | 6 | 0.32 ± 0.046 | 0.088 |
| | Cesium-137 | 1 | 0.25 ± 0.036 | | 6 | 0.59 ± 0.068 | 0.39 |
| | Europium-155 | 1 | 0.068 ± 0.029 | | 6 | 0.16 ± 0.077 | 0.080 |
| | Plutonium-239,240 | 1 | 0.0037 ± 0.00083 | | 6 | 0.0076 ± 0.0014 | 0.0040 |
| | Strontium-90 | 1 | 0.010 ± 0.0052 | | 6 | 0.017 ± 0.0052 | 0.0066 |
| | Uranium-235 | 1 | 0.040 ± 0.077 | | 6 | 0.24 ± 0.16 | 0.085 |
| | Uranium-238 | 1 | 1.4 ± 0.43 | | 6 | 2.4 ± 0.88 | 0.80 |
| McNary Dam | Cobalt-60 | 4 | 0.054 ± 0.017 | 0.030 | 24 | 0.27 ± 0.065 | 0.073 |
| | Cesium-137 | 4 | 0.34 ± 0.045 | 0.32 | 24 | 1.0 ± 0.11 | 0.48 |
| | Europium-155 | 4 | 0.078 ± 0.040 | 0.048 | 24 | 0.13 ± 0.069 | 0.064 |
| | Plutonium-239,240 | 4 | 0.0077 ± 0.0014 | 0.0068 | 24 | 0.014 ± 0.0026 | 0.0097 |
| | Strontium-90 | 4 | 0.024 ± 0.0074 | 0.017 | 24 | 0.061 ± 0.014 | 0.025 |
| | Uranium-235 | 4 | 0.21 ± 0.10 | 0.066 | 24 | 0.20 ± 0.16 | 0.066 |
| | Uranium-238 | 4 | 1.9 ± 0.49 | 1.7 | 24 | 2.3 ± 0.71 | 1.4 |
| Priest Rapids Dam | Cobalt-60 | 3 | 0.016 ± 0.010 | 0.0080 | 24 | 0.038 ± 0.049 | 0.0020 |
| | Cesium-137 | 3 | 0.52 ± 0.060 | 0.034 | 24 | 1.0 ± 0.14 | 0.42 |
| | Europium-155 | 3 | 0.057 ± 0.035 | 0.051 | 24 | 0.10 ± 0.050 | 0.049 |
| | Plutonium-239,240 | 3 | 0.017 ± 0.0030 | 0.013 | 24 | 0.018 ± 0.0032 | 0.0084 |
| | Strontium-90 | 3 | 0.015 ± 0.0072 | 0.0095 | 24 | 0.025 ± 0.0068 | 0.014 |
| | Uranium-235 | 3 | 0.14 ± 0.086 | 0.10 | 24 | 0.32 ± 0.17 | 0.073 |
| | Uranium-238 | 3 | 1.4 ± 0.50 | 1.2 | 24 | 2.2 ± 0.71 | 0.94 |

**Table A.5.** (contd)

| Location | Radionuclide | 1997 No. of Samples | 1997 Concentration, pCi/g Maximum[a] | 1997 Concentration, pCi/g Median[b] | 1992-1996 No. of Samples | 1992-1996 Concentration, pCi/g Maximum[a] | 1992-1996 Concentration, pCi/g Median[b] |
|---|---|---|---|---|---|---|---|
| Richland | Cobalt-60 | 1 | 0.035 ± 0.012 | | 5 | 0.074 ± 0.019 | 0.051 |
| | Cesium-137 | 1 | 0.22 ± 0.032 | | 5 | 0.36 ± 0.050 | 0.31 |
| | Europium-155 | 1 | 0.062 ± 0.030 | | 5 | 0.077 ± 0.045 | 0.059 |
| | Plutonium-239,240 | 1 | 0.0034 ± 0.00073 | | 5 | 0.0023 ± 0.00077 | 0.0020 |
| | Strontium-90 | 1 | 0.0043 ± 0.0029 | | 5 | 0.0050 ± 0.0035 | 0.0023 |
| | Uranium-235 | 1 | 0.053 ± 0.074 | | 5 | 0.14 ± 0.080 | 0.068 |
| | Uranium-238 | 1 | 0.83 ± 0.28 | | 5 | 2.1 ± 0.54 | 1.2 |
| White Bluffs Slough | Cobalt-60 | 1 | 0.029 ± 0.012 | | 6 | 0.20 ± 0.031 | 0.093 |
| | Cesium-137 | 1 | 0.53 ± 0.059 | | 6 | 0.97 ± 0.11 | 0.82 |
| | Europium-155 | 1 | 0.052 ± 0.031 | | 6 | 0.065 ± 0.034 | 0.049 |
| | Plutonium-239,240 | 1 | 0.0039 ± 0.00089 | | 6 | 0.0073 ± 0.0017 | 0.0041 |
| | Strontium-90 | 1 | 0.0050 ± 0.0035 | | 6 | 0.017 ± 0.0055 | 0.0072 |
| | Uranium-235 | 1 | -0.0034 ± 0.073 | | 6 | 0.15 ± 0.12 | 0.036 |
| | Uranium-238 | 1 | 1.0 ± 0.36 | | 6 | 1.9 ± 0.52 | 1.2 |
| **Riverbank Spring Sediment** | | | | | | | |
| 100-B Spring | Cobalt-60 | 1 | 0.051 ± 0.024 | | 2 | 0.029 ± 0.0097 | 0.020 |
| | Cesium-137 | 1 | 0.079 ± 0.032 | | 2 | 0.095 ± 0.015 | 0.060 |
| | Europium-155 | 1 | 0.043 ± 0.070 | | 2 | 0.074 ± 0.036 | 0.069 |
| | Strontium-90 | 1 | 0.0014 ± 0.0032 | | 2 | 0.0041 ± 0.0050 | 0.0034 |
| | Uranium-235 | 1 | 0.20 ± 0.10 | | 2 | 0.10 ± 0.080 | 0.042 |
| | Uranium-238 | 1 | 1.2 ± 0.40 | | 2 | 1.2 ± 0.38 | 1.2 |
| 100-F Spring | Cobalt-60 | 1 | 0.044 ± 0.024 | | 2 | 0.040 ± 0.015 | 0.022 |
| | Cesium-137 | 1 | 0.12 ± 0.040 | | 2 | 0.32 ± 0.040 | 0.26 |
| | Europium-155 | 1 | 0.030 ± 0.067 | | 2 | 0.055 ± 0.031 | 0.046 |
| | Strontium-90 | 1 | 0.0087 ± 0.0069 | | 2 | 0.0096 ± 0.010 | 0.0070 |
| | Uranium-235 | 1 | 0.083 ± 0.11 | | 2 | 0.17 ± 0.13 | 0.17 |
| | Uranium-238 | 1 | 0.97 ± 0.43 | | 2 | 1.4 ± 0.54 | 1.3 |

**Table A.5.** (contd)

| Location | Radionuclide | 1997 No. of Samples | 1997 Concentration, pCi/g Maximum[a] | 1997 Concentration, pCi/g Median[b] | 1992-1996 No. of Samples | 1992-1996 Concentration, pCi/g Maximum[a] | 1992-1996 Concentration, pCi/g Median[b] |
|---|---|---|---|---|---|---|---|
| 100-K Spring | Cobalt-60 | 1 | 0.015 ± 0.021 | | 1 | 0.0073 ± 0.020 | |
| | Cesium-137 | 1 | 0.19 ± 0.046 | | 1 | 0.15 ± 0.047 | |
| | Europium-155 | 1 | 0.039 ± 0.047 | | 1 | 0.13 ± 0.066 | |
| | Strontium-90 | 1 | 0.0085 ± 0.0048 | | 1 | 0.0012 ± 0.0046 | |
| | Uranium-235 | 1 | 0.14 ± 0.065 | | 1 | 0.20 ± 0.14 | |
| | Uranium-238 | 1 | 0.82 ± 0.24 | | 1 | 1.5 ± 0.54 | |
| 300 Area Spring | Cobalt-60 | 1 | 0.013 ± 0.019 | | 4 | 0.016 ± 0.0076 | 0.0093 |
| | Cesium-137 | 1 | 0.077 ± 0.042 | | 4 | 0.15 ± 0.026 | 0.072 |
| | Europium-155 | 1 | 0.034 ± 0.060 | | 4 | 0.13 ± 0.14 | 0.055 |
| | Strontium-90 | 1 | 0.0055 ± 0.0056 | | 4 | 0.012 ± 0.0060 | 0.0075 |
| | Uranium-235 | 1 | 0.19 ± 0.11 | | 4 | 0.41 ± 0.16 | 0.098 |
| | Uranium-238 | 1 | 2.0 ± 0.58 | | 4 | 5.2 ± 1.1 | 3.7 |
| Hanford Spring | Cobalt-60 | 1 | 0.049 ± 0.029 | | 4 | 0.090 ± 0.021 | 0.072 |
| | Cesium-137 | 1 | 0.25 ± 0.058 | | 4 | 0.29 ± 0.032 | 0.22 |
| | Europium-155 | 1 | 0.066 ± 0.063 | | 4 | 0.068 ± 0.034 | 0.061 |
| | Strontium-90 | 1 | 0.0057 ± 0.0039 | | 4 | 0.0086 ± 0.011 | 0.0074 |
| | Uranium-235 | 1 | 0.17 ± 0.11 | | 4 | 0.23 ± 0.14 | 0.024 |
| | Uranium-238 | 1 | 1.6 ± 0.56 | | 4 | 1.9 ± 0.54 | 1.1 |

(a) Values are ± total propagated analytical uncertainty (2-sigma).
(b) Median values are not provided when only one sample analyzed.

**Table A.6**. Median Metal Concentrations (mg/kg dry wt.) in Columbia River Sediment, 1997

| Metal | Priest Rapids Dam | Hanford Reach[a] | McNary Dam | Riverbank Springs[b] |
|---|---|---|---|---|
| Antimony | 0.80 | 0.70 | 0.85 | 0.63 |
| Arsenic | 6.9 | 5.3 | 8.1 | 5.1 |
| Beryllium | 1.1 | 1.2 | 1.4 | 1.4 |
| Cadmium | 4.3 | 0.99 | 1.9 | 0.92 |
| Chromium | 68 | 55 | 67 | 70 |
| Copper | 39 | 19 | 35 | 21 |
| Lead | 36 | 31 | 26 | 23 |
| Nickel | 36 | 19 | 30 | 21 |
| Selenium | 0.12 | <1.8 | 0.18 | <1.6 |
| Silver | 0.34 | 0.25 | 0.41 | 0.068 |
| Thalium | 1.5 | 0.73 | 0.76 | 0.58 |
| Zinc | 450 | 220 | 260 | 230 |

(a) 100-F Slough, Hanford Slough, Richland, and White Bluffs Slough.
(b) 100-B, 100-D, 100-F, 100-H, 100-K, 100-N, Old Hanford Townsite, and 300 Area.

**Table A.7.** Radionuclide Concentrations Measured in Riverbank Spring Water, 1997 Compared to Previous 5 Years

| Location/Radionuclide | 1997 No. of Samples | 1997 Concentration,[a] pCi/L Maximum | 1992-1996 No. of Samples | 1992-1996 Concentration,[a] pCi/L Maximum | 1992-1996 Concentration,[a] pCi/L Median | Washington State Ambient Surface Water Quality Standard,[b] pCi/L |
|---|---|---|---|---|---|---|
| **100-B Spring** | | | | | | |
| Alpha (gross) | 1 | 1.2 ± 0.89 | 6 | 3.5 ± 1.8 | 1.6 | 15 |
| Beta (gross) | 1 | 6.6 ± 1.9 | 6 | 38 ± 4.6 | 10 | 50 |
| Strontium-90 | 1 | 0.024 ± 0.030 | 6 | 0.072 ± 0.11 | 0.023 | 8 |
| Technetium-99 | 1 | 5.8 ± 1.1 | 6 | 25 ± 3.2 | 14 | 900[c] |
| Tritium | 1 | 11,000 ± 910 | 6 | 24,000 ± 1,800 | 14,000 | 20,000 |
| **100-D Spring** | | | | | | |
| Alpha (gross) | 1 | 0.86 ± 0.60 | 7 | 2.9 ± 1.9 | 1.3 | 15 |
| Beta (gross) | 1 | 2.1 ± 1.6 | 7 | 21 ± 3.3 | 9.3 | 50 |
| Strontium-90 | 1 | 1.7 ± 0.33 | 7 | 9.4 ± 1.8 | 4.3 | 8 |
| Tritium | 1 | 360 ± 160 | 7 | 12,000 ± 1,000 | 6,500 | 20,000 |
| **100-F Spring** | | | | | | |
| Alpha (gross) | 1 | 3.1 ± 1.3 | 3 | 41 ± 18 | 3.7 | 15 |
| Beta (gross) | 1 | 3.8 ± 1.8 | 3 | 65 ± 11 | 2.0 | 50 |
| Strontium-90 | 1 | 0.034 ± 0.033 | 3 | 0.099 ± 0.091 | 0.094 | 8 |
| Tritium | 1 | 1,100 ± 210 | 3 | 1,800 ± 240 | 1,600 | 20,000 |
| Uranium (total) | 1 | 4.6 ± 0.59 | 3 | 9.2 ± 1.2 | 4.6 | --[d] |
| **100-H Spring** | | | | | | |
| Alpha (gross) | 1 | 2.4 ± 1.0 | 5 | 4.6 ± 1.9 | 4.4 | 15 |
| Beta (gross) | 1 | 33 ± 4.2 | 5 | 69 ± 7.0 | 60 | 50 |
| Strontium-90 | 1 | 17 ± 3.1 | 5 | 25 ± 4.5 | 17 | 8 |
| Technetium-99 | 1 | 18 ± 2.4 | 5 | 140 ± 15 | 110 | 900 |
| Tritium | 1 | 430 ± 170 | 5 | 1,200 ± 240 | 1,100 | 20,000 |
| Uranium (total) | 1 | 1.7 ± 0.25 | 5 | 8.4 ± 1.2 | 6.6 | -- |
| **100-K Spring** | | | | | | |
| Alpha (gross) | 1 | 0.56 ± 0.51 | 3 | 1.6 ± 1.2 | 1.4 | 15 |
| Beta (gross) | 1 | 1.4 ± 1.4 | 3 | 3.6 ± 2.5 | 2.7 | 50 |
| Strontium-90 | 1 | 0.59 ± 0.13 | 3 | 0.11 ± 0.13 | -0.024 | 8 |
| Tritium | 1 | 110 ± 140 | 3 | 20,000 ± 1,500 | 18,000 | 20,000 |

**Table A.7.** (contd)

| Location/Radionuclide | 1997 No. of Samples | 1997 Concentration,[a] pCi/L Maximum | 1992-1996 No. of Samples | 1992-1996 Concentration,[a] pCi/L Maximum | 1992-1996 Concentration,[a] pCi/L Median | Washington State Ambient Surface Water Quality Standard,[b] pCi/L |
|---|---|---|---|---|---|---|
| **100-N Spring**[e] | | | | | | |
| Alpha (gross) | 2 | 2.8 ± 1.2 | 6 | 8.9 ± 14 | 1.6 | 15 |
| Beta (gross) | 2 | 16,000 ± 1,400 | 6 | 24,000 ± 1,700 | 4.5 | 50 |
| Strontium-90 | 2 | 9,900 ± 1,800 | 6 | 11,000 ± 2,000 | 0.066 | 8 |
| Tritium | 2 | 19,000 ± 1,500 | 6 | 31,000 ± 2,400 | 23,000 | 20,000 |
| **300 Area Spring** | | | | | | |
| Alpha (gross) | 1 | 45 ± 8.2 | 7 | 110 ± 21 | 54 | 15 |
| Beta (gross) | 1 | 7.6 ± 2.0 | 7 | 29 ± 4.7 | 16 | 50 |
| Iodine-129 | 1 | 0.0055 ± 0.00058 | 4 | 0.0049 ± 0.00063 | 0.0033 | 1 |
| Technetium-99 | 1 | 8.8 ± 1.4 | 6 | 14 ± 1.9 | 5.3 | 900[c] |
| Tritium | 1 | 7,900 ± 680 | 7 | 12,000 ± 940 | 9,800 | 20,000 |
| Uranium (total) | 1 | 53 ± 5.6 | 7 | 130 ± 12 | 87 | -- |
| **Old Hanford Townsite Spring** | | | | | | |
| Alpha (gross) | 1 | 0.10 ± 0.38 | 7 | 4.9 ± 2.2 | 3.0 | 15 |
| Beta (gross) | 1 | 18 ± 2.9 | 7 | 95 ± 140 | 18 | 50 |
| Iodine-129 | 1 | 0.14 ± 0.0081 | 5 | 0.22 ± 0.014 | 0.086 | 1 |
| Technetium-99 | 1 | 43 ± 5.1 | 7 | 130 ± 16 | 54 | 900[c] |
| Tritium | 1 | 56,000 ± 4,200 | 7 | 170,000 ± 13,000 | 120,000 | 20,000 |
| Uranium (total) | 1 | 2.0 ± 0.31 | 6 | 4.3 ± 0.52 | 2.6 | -- |

(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-570/9-76-003.
(d) Dashes indicate no concentration guides available.
(e) 1992 sample is from well 199-N-46, 1993-1997 samples are from shoreline spring. In 1997, two samples were collected; one below well 199-N-8T and one at the 1993-1996 spring location.

**Table A.8**. Average Metal Concentrations (µg/g dry wt.) in Livers of Hanford Reach Fish, 1997

| | 100 Areas | | | | Old Hanford Townsite | | | 300 Area | | | Vernita Bridge |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bass | Carp | Sculpin | Sucker | Bass | Carp | Sucker | Bass | Carp | Sucker | Sculpin |
| Antimony | 0.071 | 0.058 | 0.015 | 0.018 | 0.032 | 0.048 | 0.051 | 0.022 | 0.054 | 0.051 | 0.024 |
| Arsenic | 0.45 | 0.59 | 0.50 | 0.82 | 0.56 | 0.93 | 0.52 | 0.36 | 0.52 | 0.34 | 0.56 |
| Cadmium | 2.19 | 47. | 8.1 | 0.067 | 4.4 | 21. | 2.8 | 1.5 | 59. | 0.11 | 6.34 |
| Chromium | 0.21 | 0.30 | 0.29 | 0.23 | 0.21 | 0.38 | 0.23 | 0.20 | 0.35 | 0.20 | 0.37 |
| Copper | 8.8 | 110. | 20. | 5.6 | 17. | 87. | 14. | 6.2 | 116. | 4.6 | 14. |
| Mercury | 0.40 | 0.24 | 0.29 | 0.23 | 0.35 | 0.18 | 0.37 | 0.36 | 0.30 | 0.52 | 0.17 |
| Nickel | 0.055 | 0.14 | 0.26 | 0.370 | 0.050 | 0.26 | 0.26 | 0.030 | 0.13 | 0.15 | 0.14 |
| Lead | 0.44 | 0.83 | 0.20 | 0.048 | 0.037 | 0.37 | 0.14 | 0.036 | 0.67 | 0.036 | 0.20 |
| Selenium | 7.5 | 4.9 | 6.1 | 1.3 | 9.3 | 4.7 | 2.3 | 6.8 | 5.4 | 1.2 | 5.8 |
| Silver | 0.045 | 1.1 | 0.045 | 0.045 | 0.058 | 0.70 | 0.055 | 0.045 | 1.2 | 0.045 | 0.045 |
| Thallium | 0.27 | 0.12 | 0.23 | 0.098 | 0.38 | 0.165 | 0.078 | 0.33 | 0.13 | 0.081 | 0.35 |
| Zinc | 77. | 1000. | 146. | 30. | 81. | 790. | 41. | 62. | 980. | 19. | 150. |

**Table A.9**. Average Metal Concentrations (µg/g dry wt.) in Kidneys of Hanford Reach Fish, 1997

| | 100 Areas | | | Old Hanford Townsite | | | 300 Area | | |
|---|---|---|---|---|---|---|---|---|---|
| | Bass | Carp | Sucker | Bass | Carp | Sucker | Bass | Carp | Sucker |
| Antimony | 0.027 | 0.040 | 0.065 | 0.021 | 0.061 | 0.016 | 0.015 | 0.016 | 0.015 |
| Arsenic | 0.40 | 0.98 | 0.95 | 0.50 | 1.4 | 0.82 | 0.48 | 1.1 | 0.49 |
| Cadmium | 0.59 | 190. | 12. | 1.0 | 73. | 36. | 0.90 | 170. | 35. |
| Chromium | 0.25 | 0.31 | 0.280 | 0.22 | 0.31 | 0.43 | 0.40 | 0.42 | 0.64 |
| Copper | 4.54 | 11. | 4.0 | 5.4 | 8.8 | 5.4 | 6.6 | 12. | 6.1 |
| Mercury | 0.22 | 0.58 | 0.11 | 0.20 | 0.40 | 0.29 | 0.25 | 0.54 | 0.30 |
| Nickel | 0.21 | 0.95 | 1.2 | 0.16 | 1.0 | 3.2 | 0.18 | 1.72 | 4.1 |
| Lead | 0.36 | 2.7 | 0.25 | 0.11 | 1.1 | 0.25 | 0.089 | 1.5 | 0.34 |
| Selenium | 6.3 | 8.1 | 2.9 | 5.7 | 6.9 | 4.7 | 6.4 | 8.0 | 5.5 |
| Silver | 0.045 | 0.098 | 0.045 | 0.045 | 0.059 | 0.047 | 0.045 | 0.11 | 0.045 |
| Thallium | 0.19 | 0.54 | 0.072 | 0.16 | 0.46 | 0.067 | 0.19 | 0.48 | 0.081 |
| Zinc | 89. | 920. | 85. | 58. | 830. | 190. | 69. | 1100. | 130. |

## References

40 CFR 141, U.S. Environmental Protection Agency, "National Primary Drinking Water Regulations; Radionuclides; Proposed Rule." *Code of Federal Regulatons.*

PNNL-11796. 1998. *Hanford Site Environmental Data for Calendar Year 1997.* L. E. Bisping, Pacific Northwest National Laboratory, Richland, Washington.

EPA-570/9-76-003. 1976. *National Interim Primary Drinking Water Regulations.* Office of Water Supply, U.S. Environmental Protection Agency, Washington, D.C.

Washington Administrative Code (WAC) 246-290, *Group A Public Water Systems.*

Washington Administrative Code (WAC) 173-201A, *Water Quality Standards for Surface Waters of the State of Washington.*

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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.

**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). Another unit of activity, the curie, is related to the becquerel according to 1 Ci = $3.7 \times 10^{10}$ Bq.

**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."

**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 ($3.7 \times 10^{10}$) 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** - The splitting or breaking apart of a nucleus into at least two other nuclei, accompanied with a release of a relatively large amount 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.

**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.

**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.

**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** - A special unit of absorbed dose equal to 100 ergs/g or 0.01 J/kg.

**radiation** - The energy emitted in the form of photons or particles such as those thrown off by transforming (decaying) atoms. For this report, radiation refers to ionizing types of radiation; not radiowaves, microwaves, radiant light, or other types of nonionizing radiation.

**radioactivity** - Property possessed by some isotopes of elements of emitting radiation (such as alpha, beta, or gamma photons) 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."

**recruitment** - Survival from one life form or stage to the next or from one age class to the next.

**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.

**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 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.

**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 Site operations in 1997 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) and the State of Washington in Washington Administrative Code (WAC) 246-290 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. That 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 and 40 CFR 61. 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 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/yr. 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 Site radioactive air emissions. Permits for collecting wildlife for environmental sampling are issued by the Washington State Department of Fish and Wildlife and the U.S. Fish and Wildlife Service. Current permits are discussed in Table C.6.

**Table C.1.** Washington State Water Quality Standards for the Hanford Reach of the Columbia River

| Parameter | Permissible Levels |
|---|---|
| Fecal coliform | 1) Geometric mean value ≤100 colonies/100 mL<br>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<br>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<br>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<br>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-570-9-76-003 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) |

**Table C.2.** Selected Drinking Water Standards

| Radiological Constituent | Primary Maximum Contaminant Level | Interim Drinking Water Standard | Agency[a] | Status |
|---|---|---|---|---|
| Gross alpha[b] | 15 pCi/L | | DOH,[c] EPA[d] | Final |
| Radium-226 | | 3 pCi/L | DOH[c] | Final |
| Beta particle and photon activity | 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 | | 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)[j] | 100 µg/L | | DOH,[c] EPA[i] | Final |
| 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 gross 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-570/9-76-003.
(h) Equivalent to a nationwide EPA standard of 30 pCi/L and a sitewide standard of 13.4 pCi/L (see Section 6.1, "Groundwater Protection and Monitoring Program").
(i) EPA 822-R-96-001.
(j) Standard is for total trihalomethanes (THM).

**Table C.3.** Selected 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 | 1.7[c] | 0.64[d] | -- |
| Chromium(III)[e] | 950[f] | 110[g] | -- |
| Chromium(VI) | 16.0 | 11.0 | -- |
| Copper | 8.9[h] | 6.3[i] | -- |
| Lead | 32[j] | 1.2[k] | -- |
| Mercury | 2.4 | 0.012 | 0.14 |
| Nickel | 760[l] | 85[m] | 610 |
| Selenium | 20.0 | 5.0 | -- |
| Silver | 1.2[n] | -- | -- |
| Thallium | -- | -- | 1.7 |
| Zinc | 63[o] | 57[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 | -- | -- | 6,800 |
| 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 1992-1997 U.S. Geological Survey results is 48 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/d (10 mGy/d).

**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/yr (0.04 mSv/yr). 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) and sievert (or millisievert).
(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/yr 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 | Ingested Water, pCi/L | Inhaled Air, pCi/m$^3$ |
|---|---|---|
| Tritium | 2,000,000 | 100,000 |
| Carbon-14 | 700,000 | 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[e] |
| 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 | 30 | 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.

(e) Air immersion derived concentration guides.

**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-0098 and WM-0098b, issued by Washington State Department of Fish and Wildlife to Pacific Northwest National Laboratory for 1997; 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.

**National Pollutant Discharge Elimination System 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-002591-7 includes the outfall for the 300 Area Treated Effluent Disposal Facility.

Permit #'s WAR-00-000F and WAR-10-000F covering two storm water permits.

Copies of the regulations concerning these permits may be obtained from the following organizations:

| | | |
|---|---|---|
| State of Washington<br>Department of Ecology<br>P.O. Box 47600<br>Olympia, WA 92504-7600 | U.S. Environmental Protection Agency<br>Region 10<br>1200 Sixth Avenue<br>Seattle, WA 98101 | U.S. Department of Energy<br>Richland Operations Office<br>825 Jadwin Ave.<br>Richland, WA 99352 |

# 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*.

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."

EPA-570-9-76-003. 1976. *National Interim Primary Drinking Water Regulations*. Office of Water Supply, U.S. Environmental Protection Agency, Washington, D.C.

EPA 822-R-96-001. 1996. *Drinking Water Regulations and Health Advisories*. Office of Water, U.S. Environmental Protection Agency, 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."

# 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 1997 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, the air dose calculations were based on measurements made at the point of release (stacks and vents). The water pathway dose calculations were based on measurements of releases to the Columbia River (from the 100 Areas) or the difference in detectable radionuclide concentrations measured upstream and downstream of the site. Environmental concentrations were estimated from the 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 (PNL-6584), 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.

CRITRII 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 CRITRII (PNL-8150).

The computer program, CAP88-PC, was used to calculate dose to a maximally exposed individual as required by Title 40, Code of Federal Regulations, Part 61, Subpart H from airborne radionuclide effluents (other than radon) released at U.S. Department of Energy (DOE) facilities. Technical details of the CAP88-PC calculations are provided in detail in the 1997 air emissions report (DOE/RL-98-33).

## 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 (PNL-6584) and in PNL-3777, Rev. 2.

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 are based on either measured upstream/downstream differences or measured effluent releases and 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 PNNL-11796. These distributions are based on 1990 Bureau of the Census data (PNL-7803). 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 PNNL-11796. 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 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 panel were used to calculate the radiological doses (PNL-3777, Rev. 2). The calculations were then reviewed by the panel. Summaries of dose calculation technical details for this report are shown in Tables D.5 through D.9 and in PNNL-11796.

## 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 1997 are given in Table D.10.

**Table D.1**. Food Pathway Parameters Used in Dose Calculations, 1997

| Medium | Holdup, d[a] Maximally Exposed Individual | Holdup, d[a] Average Individual | Growing Period, d | Yield, kg/m² | Irrigation Rate, L/m²/mo |
|---|---|---|---|---|---|
| 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, 1997

| 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 | --[b] |
| Drinking water[a] | 730 | 440 |

(a) Units L/yr.
(b) Average individual consumption not identified; radiation doses were calculated based on estimated total annual catch of 15,000 kg (33,075 lb).

**Table D.3**. Residency Parameters Used in Dose Calculations, 1997

| 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, 1997

| 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, 1997

| | |
|---|---|
| Facility name | 100-N Area |
| Releases (Ci) | $^{90}Sr$ (2.1 x $10^{-5}$), $^{125}Sb$ (3.7 x $10^{-9}$), $^{137}Cs$ (5.5 x $10^{-5}$), $^{238}Pu$ (5.8 x $10^{-7}$), $^{239,240}Pu$ (3.9 x $10^{-6}$)[a], $^{241}Pu$ (4.0 x $10^{-5}$), $^{241}Am$ (2.5 x $10^{-6}$) |
| Meteorological conditions | 1997 annual average, calculated from data collected at the 100-N Area and the Hanford Meteorology Station from January 1997 through December 1997, using the computer code HANCHI |
| $\overline{X}/Q'$ | Maximally exposed individual at residence, 4.4 x $10^{-9}$ s/m$^3$ at 41 km (25.5 mi) SE; maximally exposed individual at food source, 2.1 x $10^{-9}$ s/m$^3$ at 53 km (33 mi) SSE; 80-km (50-mi) population, 1.0 x $10^{-3}$ s/m$^3$ person-s/m$^3$ |
| Release height | 10-m (33-ft) effective stack height |
| Population distribution | 375,000 (PNNL-11796, Table D-1) |
| Computer code | GENII, Version 1.485, December 3, 1990 (e.g., PNL-6584) |
| 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<br>Inhalation<br>Ingestion of locally produced foods |
| Files addressed | Radionuclide Library, Rev. 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>Internal Dose Factor Library, Rev. 12-3-90 |

(a) This value includes gross alpha release data. Gross 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, 1997

| | |
|---|---|
| Facility name | 100-N Area |
| Releases (Ci) | $^{3}H$ (1.3 x $10^{-1}$), $^{90}Sr$ (1.3 x $10^{-1}$), $^{241}Am$ (5.9 x $10^{-7}$) |
| Mean river flow | 4,784 $m^3/s$ (169,031 $ft^3/s$) |
| Shore-width factor | 0.2 |
| Population distribution | 70,000 for drinking water pathway<br>125,000 for aquatic recreation<br>2,000 for consumption of irrigated foodstuffs<br>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., PNL-6584) |
| 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<br>Ingestion of aquatic foods and irrigated farm products |
| Files addressed | Radionuclide Library, Rev. 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>Internal Dose Factor Library, Rev. 12-3-90<br>Bioaccumulation Factor Library, Rev. 10-26-92 |

**Table D.7.** Technical Details of 200 Areas Airborne Release Dose Calculations, 1997

| | |
|---|---|
| Facility name | 200 Areas |
| Releases (Ci) | 200-East Area |
| | $^{90}Sr$ (2.5 x $10^{-4}$)[a], $^{129}I$ (1.4 x $10^{-3}$), $^{137}Cs$ (9.1 x $10^{-4}$), $^{238}Pu$ (1.8 x $10^{-7}$), $^{239,240}Pu$ (6.3 x $10^{-6}$)[b], $^{241}Pu$ (6.4 x $10^{-6}$), $^{241}Am$ (4.8 x $10^{-6}$) |
| | 200-West Area |
| | $^{90}Sr$ (3.0 x $10^{-4}$)[a], $^{137}Cs$ (7.7 x $10^{-9}$), $^{238}Pu$ (2.2 x $10^{-6}$), $^{239,240}Pu$ (1.1 x $10^{-4}$)[b], $^{241}Pu$ (4.6 x $10^{-5}$), $^{241}Am$ (2.0 x $10^{-5}$) |
| Meteorological conditions | 1997 annual average, calculated from data collected at the Hanford Meteorology Station from January 1997 through December 1997, using the computer code HANCHI |
| $\overline{X}/Q'$ | Maximally exposed individual at residence, 1.0 x $10^{-8}$ s/m$^3$ at 34 km (21 mi) SE; maximally exposed individual at food source, 8.0 x $10^{-9}$ s/m$^3$ at 43 km (27 mi) SE; 80-km (50-mi) population, 1.4 x $10^{-3}$ person-s/m$^3$ |
| Release height | 89-m (292-ft) effective stack height |
| Population distribution | 376,000 (PNNL-11796, Table D-2) |
| Computer code | GENII, Version 1.485, December 3, 1990 (e.g., PNL-6584) |
| 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<br>Inhalation<br>Ingestion of locally produced foods |
| Files addressed | Radionuclide Library, Rev. 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>Internal Dose Factor Library, Rev. 12-3-90 |

(a) This value includes gross beta release data. Gross beta and unspecified beta results assumed to be $^{90}Sr$ for dose calculations.

(b) This value includes gross alpha release data. Gross 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, 1997

| | |
|---|---|
| Facility name | 300 Area |
| Releases (Ci) | $^{3}H$ (as HTO)[a] ($1.6 \times 10^{0}$), $^{3}H$ (as HT)[a] ($2.1 \times 10^{1}$), $^{60}Co$ ($8.3 \times 10^{-10}$), $^{90}Sr$ ($1.5 \times 10^{-5}$)[b], $^{137}Cs$ ($7.9 \times 10^{-7}$), $^{220}Rn$ ($5.0 \times 10^{1}$), $^{222}Rn$ ($1.6 \times 10^{0}$), $^{238}Pu$ ($9.5 \times 10^{-10}$), $^{239,240}Pu$ ($1.1 \times 10^{-6}$)[c], $^{241}Am$ ($6.5 \times 10^{-9}$) |
| Meteorological conditions | 1997 annual average, calculated from data collected at the 300 Area and the Hanford Meteorology Station from January 1997 through December 1997, using the computer code HANCHI |
| $\overline{X}/Q'$ | Maximally exposed individual at residence, $8.0 \times 10^{-7}$ s/m$^3$ at 1.5 km (1 mi) E; maximally exposed individual at food source, $7.9 \times 10^{-8}$ s/m$^3$ at 13 km (8 mi) SSE; 80-km (50-mi) population, $6.1 \times 10^{-3}$ person-s/m$^3$ |
| Release height | 10 m (33 ft) |
| Population distribution | 282,000 (PNNL-11796, Table D-3) |
| Computer code | GENII, Version 1.485, December 3, 1990 (e.g., PNL-6584) |
| 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<br>Inhalation<br>Ingestion of locally produced foods |
| Files addressed | Radionuclide Library, Rev 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>Internal Dose Factor Library, Rev. 12-3-90 |

(a) HTO = tritiated water vapor; HT = elemental tritium.
(b) This value includes gross beta release data. Gross beta and unspecified beta results assumed to be $^{90}Sr$ for dose calculations.
(c) This value includes gross alpha release data. Gross 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, 1997

| | |
|---|---|
| Facility name | 400 Area |
| Releases (Ci) | $^{3}H$ (as HTO)[a] ($7.9 \times 10^{0}$), $^{137}Cs$ ($4.6 \times 10^{-6}$)[b], $^{239,240}Pu$ ($3.8 \times 10^{-7}$)[c] |
| Meteorological conditions | 1997 annual average, calculated from data collected at the 400 Area and the Hanford Meteorology Station from January 1997 through December 1997, using the computer code HANCHI |
| $\overline{X}/Q'$ | Maximally exposed individual at residence, $8.7 \times 10^{-8}$ s/m$^3$ at 11 km (7 mi) SE; maximally exposed individual at food source, $3.0 \times 10^{-8}$ s/m$^3$ at 22 km (14 mi) SSE; 80-km (50-mi) population, $4.5 \times 10^{-3}$ person-s/m$^3$ |
| Release height | 10 m (33 ft) |
| Population distribution | 283,000 (PNNL-11796, Table D-4) |
| Computer code | GENII, Version 1.485, December 3, 1990 (e.g., PNL-6584) |
| 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<br>Inhalation<br>Ingestion of locally produced foods |
| Files addressed | Radionuclide Library, Rev 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>Internal Dose Factor Library, Rev. 12-3-90 |

(a) HTO = tritiated water vapor.
(b) $^{137}Cs$ value for the 400 Area is derived fully from gross beta measurements.
(c) This value includes gross alpha release data. Gross 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, pCi/yr[b] | Ingestion Dose Factor, rem/pCi[c] | Ingestion Dose, rem/yr (Sv/yr) |
|---|---|---|---|---|
| Gross alpha[d] | 0.450 ± 0.908 | 107 | $2.83 \times 10^{-7}$ | $3.0 \times 10^{-5}$ ($3.0 \times 10^{-7}$) |
| Gross beta[e] | 8.38 ± 2.86 | 2,000 | $5.00 \times 10^{-8}$ | $9.95 \times 10^{-5}$ ($9.95 \times 10^{-7}$) |
| Tritium | 6,033 ± 1,696 | $1.43 \times 10^{6}$ | $6.40 \times 10^{-11}$ | $9.2 \times 10^{-5}$ ($9.2 \times 10^{-7}$) |
| $^{90}Sr$ | 0.026 ± 0.128 | 6.19 | $1.42 \times 10^{-7}$ | $8.8 \times 10^{-7}$ ($8.8 \times 10^{-9}$) |
| Total | | | | $2.2 \times 10^{-4}$ ($2.2 \times 10^{-6}$) |

(a) Drinking water concentrations are annual average concentrations obtained from monthly samples taken during 1997.
(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).
(c) Ingestion intake-to-dose conversion factors are taken from EPA/520/1-88-020 and converted from System International (SI) units. Where the document lists dose factors for more than one chemical form of a radionuclide, the most soluble chemical form was assumed.
(d) Gross alpha concentrations were assumed to be $^{234}U$ for the purposes of this analysis.
(e) Gross 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 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 such as plutonium-239 or uranium-235. Some of 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*

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 (1997); 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 fish on the federal list of threatened and endangered species. Several species of both plants and animals are under consideration for formal listing as candidate species by Washington State (Table F.1). The National Marine Fisheries Service (1998) has the responsibility for the listing of anadromous fish. Mid-Columbia steelhead and upper Columbia River spring-run chinook salmon have been proposed for listing as threatened and endangered evolutionary significant units, respectively. There are 19 state-level candidate species of plants and animals (Table F.2) and 42 plant species of concern (Table F.3).

**Table F.1.** Federally or Washington State Listed Threatened (T) and Endangered (E) Species Occurring or Potentially Occurring on the Hanford Site

| Common Name | Scientific Name | Federal | State |
|---|---|---|---|
| **Plants** | | | |
| Columbia milkvetch | *Astragalus columbianus* | | T |
| Columbia yellowcress | *Rorippa columbiae* | | E |
| Dwarf evening primrose | *Camissonia (= Oenothera) pygmaea* | | T |
| Hoover's desert parsley | *Lomatium tuberosum* | | T |
| Loeflingia | *Loeflingia squarrosa var. squarrosa* | | T |
| Northern wormwood[a] | *Artemisia campestris borealis* var. *wormskioldii* | | E |
| Umtanum desert buckwheat | *Eriogonum codium* | | E |
| White Bluffs bladderpod | *Lesquerella tuplashensis* | | E |
| White eatonella | *Eatonella nivea* | | T |
| **Fish** | | | |
| Steelhead[b] | *Oncorhynchus mykiss* | | E |
| **Birds** | | | |
| Aleutian Canada goose[c] | *Branta canadensis leucopareia* | T | E |
| American white pelican | *Pelecanus erythrorhychos* | | E |
| Bald eagle | *Haliaeetus leucocephalus* | T | T |
| Ferruginous hawk | *Buteo regalis* | | T |
| Peregrine falcon[c] | *Falco peregrinus* | E | E |
| Sandhill crane[c] | *Grus canadensis* | | E |
| Western sage grouse[c] | *Centrocercus urophasianus phaios* | | T |
| **Mammals** | | | |
| Pygmy rabbit[a] | *Brachylagus idahoensis* | | E |

(a) Likely not currently occurring on the site.
(b) Upper Columbia River steelhead that migrate through the Hanford Reach.
(c) Incidental occurrence.

**Table F.2.** Washington 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* |
| Merlin | *Falco columbarius* |
| Northern goshawk[b] | *Accipter gentilis* |
| Sage sparrow | *Amphispiza belli* |
| Sage thrasher | *Oreoscoptes montanus* |
| **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 | State Listing[a] |
|---|---|---|
| Annual paintbrush | *Castilleja exilis* | R1 |
| Awned half chaff sedge | *Lipocarpha (= Hemicarpha) aristulata* | R1 |
| Basalt milk-vetch | *Astragalus conjunctus var. rickardii* | R1 |
| Bristly combseed | *Pectocarya setosa* | W |
| Brittle prickly-pear | *Opuntia fragilis* | R1 |
| Canadian St. John's wort | *Hypericum majus* | S |
| Chaffweed | *Centunculus minimus* | R1 |
| Columbia River mugwort | *Artemesia lindleyana* | W |
| Crouching milkvetch | *Astragalus succumbens* | W |
| Desert dodder | *Cuscuta denticulata* | S |
| Desert evening-primrose | *Oenothera cespitosa* | S |
| False pimpernel | *Lindernia dubia anagallidea* | R2 |
| Fuzzytongue penstemon | *Penstemon eriantherus whitedii* | R1 |
| Geyer's milkvetch | *Astragalus geyeri* | S |
| Grand redstem | *Ammannia robusta* | R1 |
| Gray cryptantha | *Cryptantha leucophaea* | S |
| Great Basin gilia | *Gilia leptomeria* | R1 |
| Hedge hog cactus | *Pediocactus simpsonii var. robustio nigrispinus* | R1 |
| Kittitas larkspur | *Delphinium multiplex* | W |
| Miner's candle | *Cryptantha scoparia* | R1 |
| Palouse thistle | *Cirsium brevifolium* | W |
| Piper's daisy | *Erigeron piperianus* | S |
| Robinson's onion | *Allium robinsonii* | W |
| Rosy balsamroot | *Balsamorhiza rosea* | W |
| Rosy pussypaws | *Calyptridium roseum* | S |
| Scilla onion | *Allium scilloides* | W |
| Shining flatsedge | *Cyperus bipartitus (rivularis)* | S |
| Small-flowered evening-primrose | *Camissonia (= Oenothera) minor* | R1 |
| Small-flowered nama | *Nama densum var. parviflorum* | R1 |
| Smooth cliffbrake | *Pellaea glabella simplex* | W |
| Snake River cryptantha | *Cryptantha spiculifera (= C. interrupta)* | S |
| Southern mudwort | *Limosella acaulis* | W |
| Stalked-pod milkvetch | *Astragalus sclerocarpus* | W |
| Suksdorf's monkey flower | *Mimulus suksdorfii* | S |
| Toothcup | *Rotala ramosior* | R1 |
| Winged combseed | *Pectocarya linearis* | R1 |

The following species have been reported as occurring on the Hanford Site, but the known collections are questionable in terms of location or identification, and have not been recently collected on the Hanford Site.

| | | |
|---|---|---|
| Coyote tobacco | *Nicotiana attenuata* | S |
| Dense sedge | *Carex densa* | S |
| Few-flowered collinsia | *Collinsia sparsiflora var. bruciae* | S |
| Medic milkvetch | *Astragalus speirocarpus* | W |
| Palouse milkvetch | *Astragalus arrectus* | S |
| Thompson's sandwort | *Arenaria franklinii thompsonii* | R2 |

(a) S = Sensitive (i.e., taxa vulnerable or declining) and could become endangered or threatened without active management or removal of threats.
R1 = Taxa for which there are insufficient data to support listing as threatened, endangered, or sensitive (formerly monitor group 1).
R2 = Taxa with unresolved taxanomic questions (formerly monitor group 2).
W = Taxa that are more abundant and/or less threatened than previously assumed (formerly monitor group 3).

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# Appendix G

## Errata

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# Appendix G

## Errata

Several errors were contained in the annual environmental reports for 1995 and 1996 (PNNL-11139 and PNNL-11472). Please make the following pen-and-ink changes.

*Hanford Site Environmental Report for Calendar Year 1995* – PNNL-11139:

Page 27, Table 2.2.1, line 3. Insert "(for CY95)" after the word Inventory.

Page 27, Table 2.2.1, line 4. Insert "(for CY94)" after the word Reporting and move the X from the "Yes" column to the "Not Required" column.

Page 27, Table 2.2.1, footnote (b). Substitute the following words "Extremely hazardous substance."

Page D.4. Table D.2, line 6. Change footnote at Milk from (a) to (b).

*Hanford Site Environmental Report for Calendar Year 1996* – PNNL-11472:

Page 29, Table 2.2.1, line 3. Insert "(for CY96)" after the word Inventory and move the X in the "Not Required" column to the "Yes" column.

Page 29, Table 2.2.1, line 4. Insert "(for CY95)" after the word Reporting.

Page 84, Figure 3.2.4. The cobalt-60 data are plotted inaccurately. See Figure 3.2.3 in this report (PNNL-11795) for a corrected representation.

Page D.4. Table D.2, line 6. Change footnote at Milk from (a) to (b).

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